IBM

Saturn Instrument Unit

INSTRUMENT UNIT PROGRAM REVIEW

JULY 26, 1966

XIII. 4

AGENDA

I.	INTRODUCTION	MR. GRACE
II.	MILESTONES - 201, 202, 203	MR. GRACE
III.	I. U. DESCRIPTION	MR. EHRHARDT
IV.	PROGRAM STATUS - PROBLEMS	MR. GRACE
V.	SOFTWARE	MR. MEADLOCK
VI.	CONTRACT MANAGEMENT	MR. LERNER
VII.	COST, MANPOWER, FOLLOW-ON CONSIDERATIONS	MR. GRACE
VIII.	FUTURE APPLICATIONS	DR. CASTRUCCIO
IX.	SUMMATION	MR. GRACE

MR H. F. SHIRES JR - 837- 4000 EXT - 2334, 2786

MR. J. M. HARROOD - 837- 4000 - EXT 3386

? Off of Track & Data Acquisition

Clarence P. Wilson

Dr. Raymond H. " ?

Walter W. " ?

INTRODUCTION

INTRODUCTION

Mr. GRACE. The Instrument Unit, as you are probably aware, is considered as one of the Uprated Saturn I and Saturn V stages. It is not a propulsion stage, obviously, but does contain the primary navigation, guidance and control, telemetry and measurements systems, et cetera, for the Saturn Vehicles. The Instrument Unit was designed specifically to have the flexibility that will be needed, from mission to mission, in the matter of incorporating technical changes. This flexibility is a significant point because it impacts the nature of our operation to a certain extent. In the propulsion stages, there is considerable commonality from mission to mission. Changes, when they do occur, are fairly significant and are well planned. They are implemented with considerable lead time and testing. On the other hand, the Instrument Unit is specifically designed to be very flexible, and last minute changes to the mission end up as last minute modifications in the Instrument Unit. We have to be geared to handle this kind of flexibility, to accept redirection momentarily, and be able to incorporate these changes into the program. I think we have some pretty good training in that regard, because, just getting into this program, we had considerable activity of that nature. As you know, the Instrument Unit is a Marshall Space Flight Center development. Along with a number of other contractors, we assisted them in terms of specific elements which were developed over a number of years. In February 1964, we were selected as the prime contractor for the Instrument Unit. At that time, we took over the completion of the design and development and the responsibility for building, testing, and shipping the Instrument Unit to the Cape.

Mr. GRACE (cont.).

Going back into the late 1950's, we had a background of producing equipment and developing new technology for the Marshall Center when it was the Army Ballistic Missile Agency. But prior to that, just by way of background, we at IBM had been involved in this kind of thing for quite sometime. In the early 1950's, we were on two big programs for the Air Force: one was the bombing navigation system for the B-52, which we developed, and the other was building the computers for the SAGE System (Semi-Automatic Ground Environment Program) for the North American Continental Air Defense Command. Both of those programs were big, and they were long lasting. As a matter of fact, we are still making parts for the B-52 System some 16 years later. The SAGE Program was about 8 to 10 years in duration and consisted of many similarities to what we are now doing on the Instrument Unit--mainly big system integration. In the middle and late 1950's, we had major responsibility on the B-70 Program, which, as you know, never really went operational. But we did develop a complete bombing-navigation missile guidance system for it--complete with in-flight testing and checking with totally integrated ground support systems. Again, this program was very similar to the kind of thing we are doing on the Instrument Unit. Also, by way of background, the TITAN guidance computer development, the guidance system for Gemini, and the primary processor and data storage system for the Orbiting Astronautical Observatory were all things that IBM was doing in the late 1950's and early 1960's.

Mr. EHRHARDT. We have the TITAN III, too.

Mr. GRACE. Yes, we have the TITAN III Computer. The TITAN III, of course, went through an iteration where they (USAF) were going to go for a new system. We did bid on that (TITAN III) but did not win. Then, by virtue of the economics that prevailed, they did not have as much money as they wanted and could not go for a brand new system. They went for an uprated TITAN II system, which we did have.

Mr. WILSON. Is there much commonality between subsystems in your Instrument Unit for the Uprated Saturn I and Saturn V and in the TITAN III, or is it very much different?

Mr. GRACE. Very different from the TITAN III. Yes, completely different, as you will see when we get into the mission and system description.

Mr. WILSON. Even in the subsystems?

Mr. GRACE. Even in the subsystems. There may be some similarity in some of the relatively smaller subsystems, such as the Azusa transponder. But basically, the type of programs that we were doing and that led to our being here, are those I mentioned. The most significant program, in terms of our relationship with Marshall, was on the Saturn I where we provided the guidance computer which was an Uprated TITAN II computer, called the ASC-15. It had a divide capability and a few other features that were not in the TITAN machine. But, basically, that same machine was used in the last six Saturn I's and actively guided the last five. That activity, of course, started back in the early 1960's. We also built the Guidance Signal Processor for Marshall which is the input-output part of the digital system on the Saturn I.

Mr. GRACE (cont.). We assisted them in some of the other Instrument Unit activities associated with the Saturn I Program.

As a result, we had people down here at Huntsville and were asked to provide some support on the Uprated Saturn I and Saturn V Instrument Unit activities. Additionally, we hoped to be considered, if and when a contract would be let, to develop the new computer required in Uprated Saturn I and Saturn V. We, in fact, were ultimately selected for that effort. Here in Huntsville, we have a situation where the guidance computer and data adapter, that we will describe a little bit later, are government-furnished equipment, even though the source of that equipment is IBM Owego, New York. As a result of that kind of background and internal Marshall review in terms of what should be done on the Instrument Unit, they asked us to take the responsibility for the Instrument Unit in the early part of 1964.

What I would like to do now is to get into the prepared presentation in terms of facilities, that we have here in Huntsville, to carry out this program. First of all, I would like to orient you with the particular area we are in--it is called the Research Park. This is a drawing of it. (Figure 1) You came in from University Drive down here, and down Sparkman Drive to our facilities. This blue-shaded area is the IBM property in the Research Park. We have three buildings that we will show you later in more detail. We also have a corner of this Brown Engineering property in which we have our Commercial Sales Branch Office. We also have about one-half of that building occupied with the activities we have here on the Instrument Unit Program.

RESEARCH PARK
Huntsville, Alabama

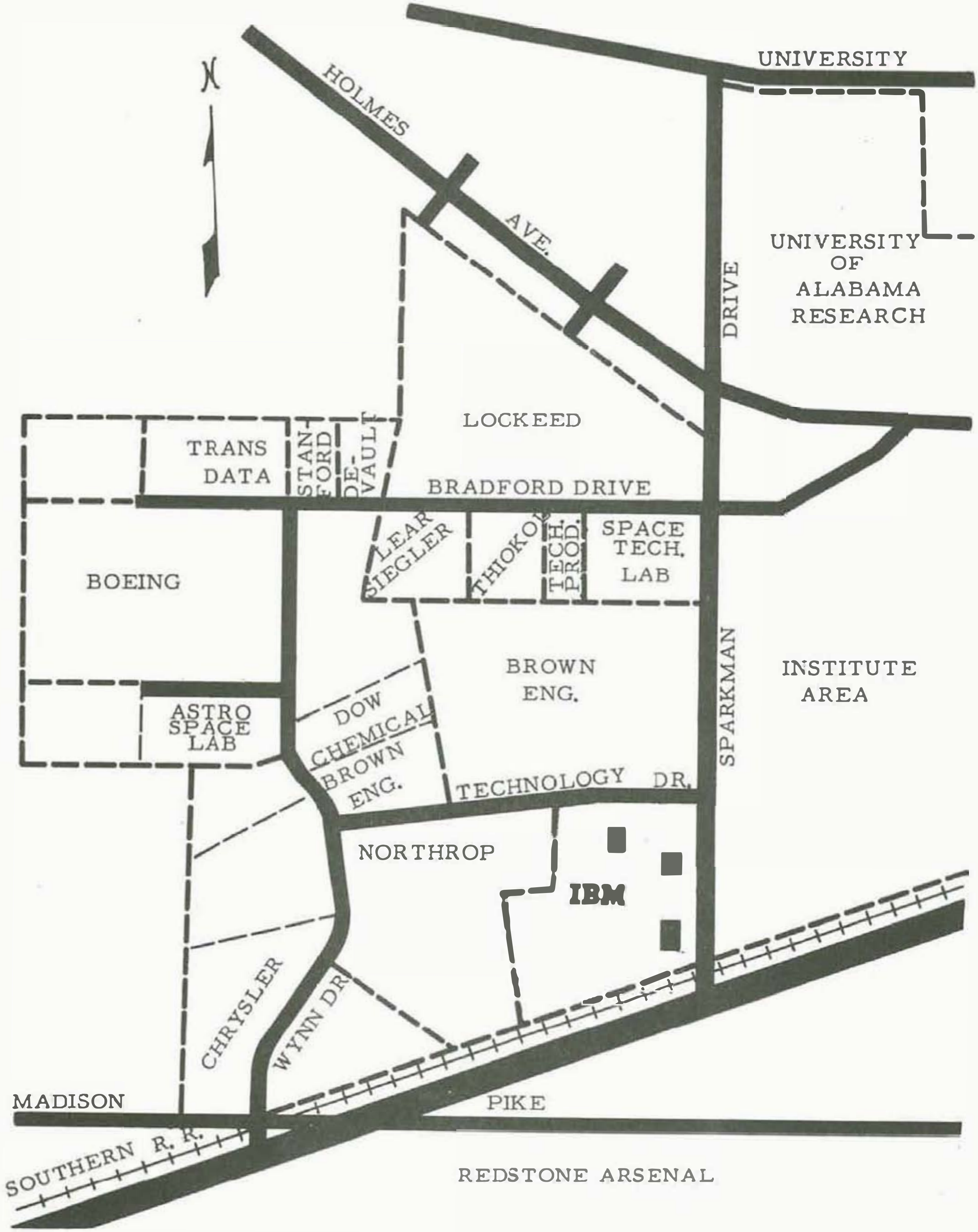


FIGURE - 1- HUNTSVILLE INDUSTRIAL COMPLEX

Mr. WILSON. Does IBM have any work in these facilities other than the Marshall-associated work?

Mr. GRACE. None. Not now.

Mr. WILSON. It is all entirely associated with the Marshall Space Flight Center?

Mr. GRACE. Right. In assessing the job that we had to do on the Instrument Unit Program, we determined that the most efficient way to handle this and, probably, as it turns out now, the only way it could have been handled, was to build the facility here. We did not have a facility anywhere that was totally adequate to handle the whole job. We had thought, at the outset of the work with Marshall, that we could do most of it in our Owego, New York facilities. But as it has turned out, we could not. We would have had to build new facilities anyway. We elected to build them here in Huntsville for the convenience of being close to the Marshall Center, and, of course, in this program, picking up a development that was well along, closeness was a great advantage. In phasing over the activity to us, they had a number of ground test programs going that we participated in. Being here, in proximity to the Marshall Center, has been very advantageous. Let me expand on this. You notice some of our neighbors (Figure 1) -- Lockheed, Boeing, Chrysler, Northrop-- ones who are pretty well known in the aerospace industry are located here with us. This Research Park location has turned out to be also very advantageous because local concerns do a considerable amount of support work for us.

Mr. GRACE (cont.). Let's take a look at the next slide which is an aerial view of the facilities. (Figure 2) This gives you a little better orientation looking this way into this building, where we are sitting right now--the third floor of this building which we consider, primarily, as our Administration Building. This is our Operations Building where the actual fabrication, assembly, and checkout of the Instrument Units take place. The High Bay area is in the back, and a two-story section is in the front. This is our Engineering Building which is a three-floor engineering facility. This is the IBM Commercial Sales Branch Office. IBM FSD occupies about one-half of that building, while the balance is occupied by the Commercial Sales Organization. We also are in some leased facilities around the community--about seven or eight small buildings that house the people who are necessary for the job. As you can see, we also have some expansion underway. Let me give you more detail on the buildings. This one, Building 1 (Figure 3), the one that you are in, we started to build in 1962 or 1963, I guess. The building was in planning so long, and then it was under construction so long that it was a real major project in terms of the time it consumed. In a way, this is kind of humorous. It was to be the Sales Office. This building was in the plans for IBM before we had any indication that we would be the prime contractor on the Instrument Unit. When we came down to Huntsville to support the Saturn I Program, we talked the sales people into making it two floors tall and we leased part of the second floor. They agreed to that. Part of the reason it took so long to get the building up is because we kept changing it. Then, when we were awarded the Instrument Unit contract, we made it three floors, and

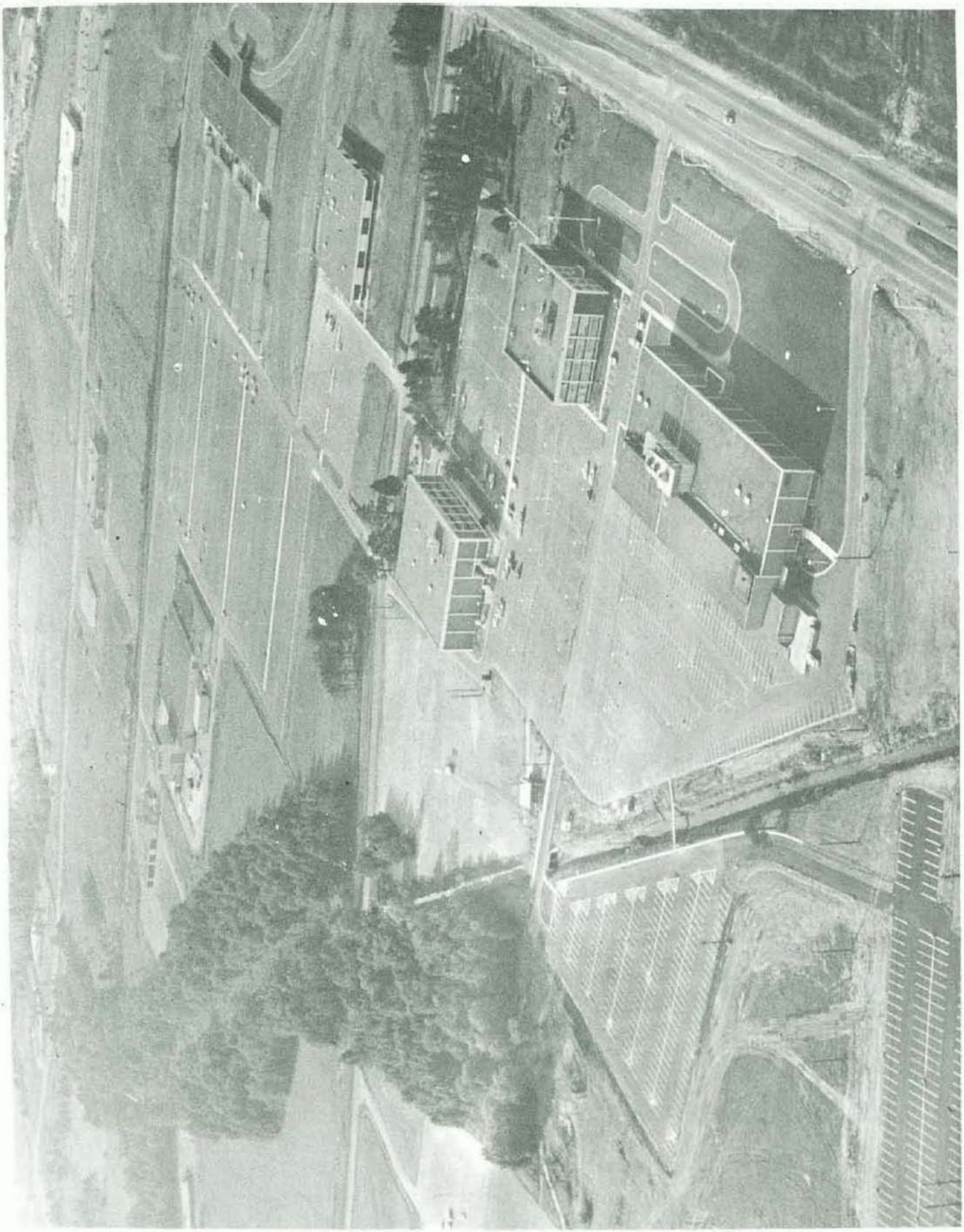


FIGURE - 2 - AERIAL VIEW OF HUNTSVILLE COMPLEX

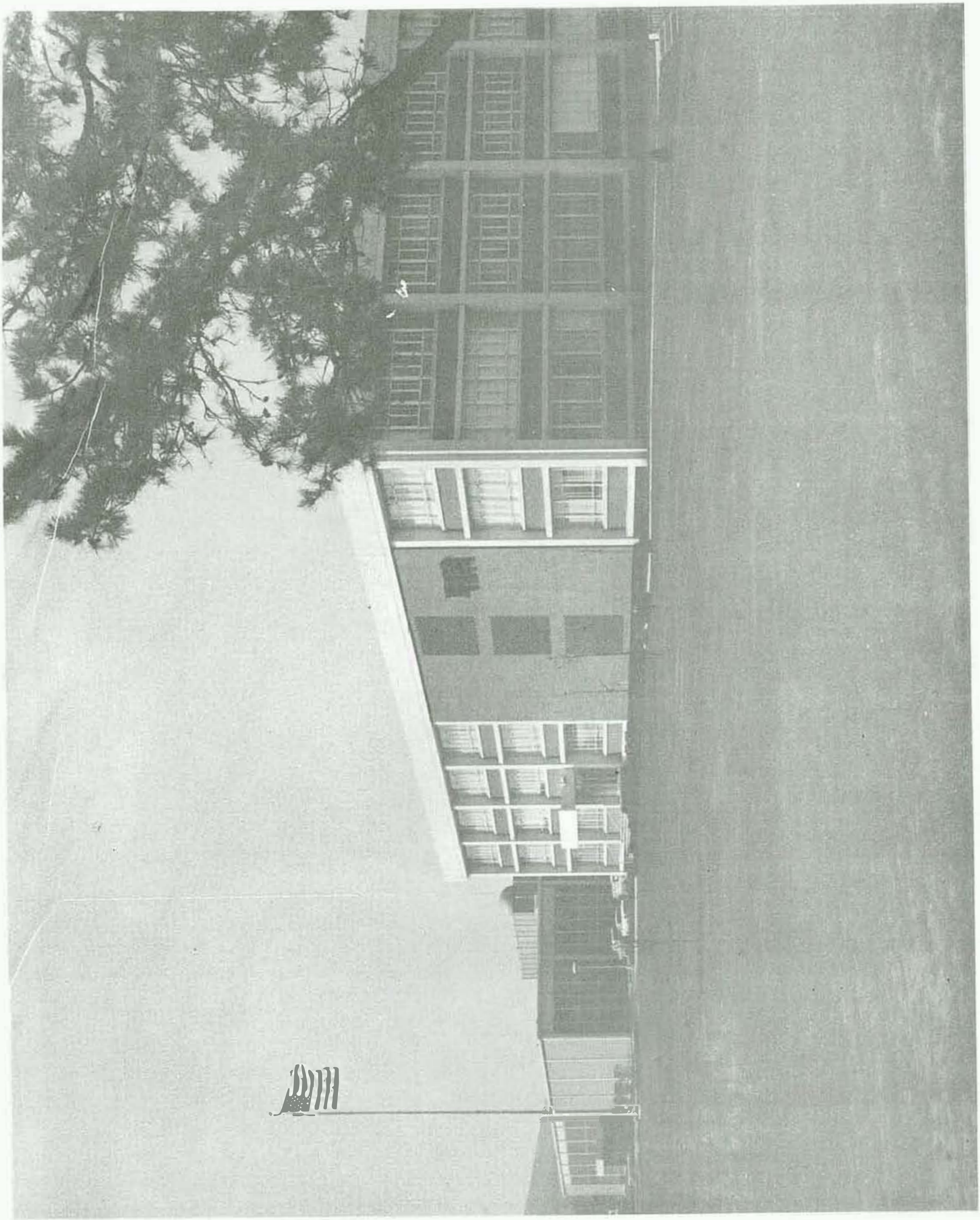


FIGURE - 3 - IBM BUILDING #1

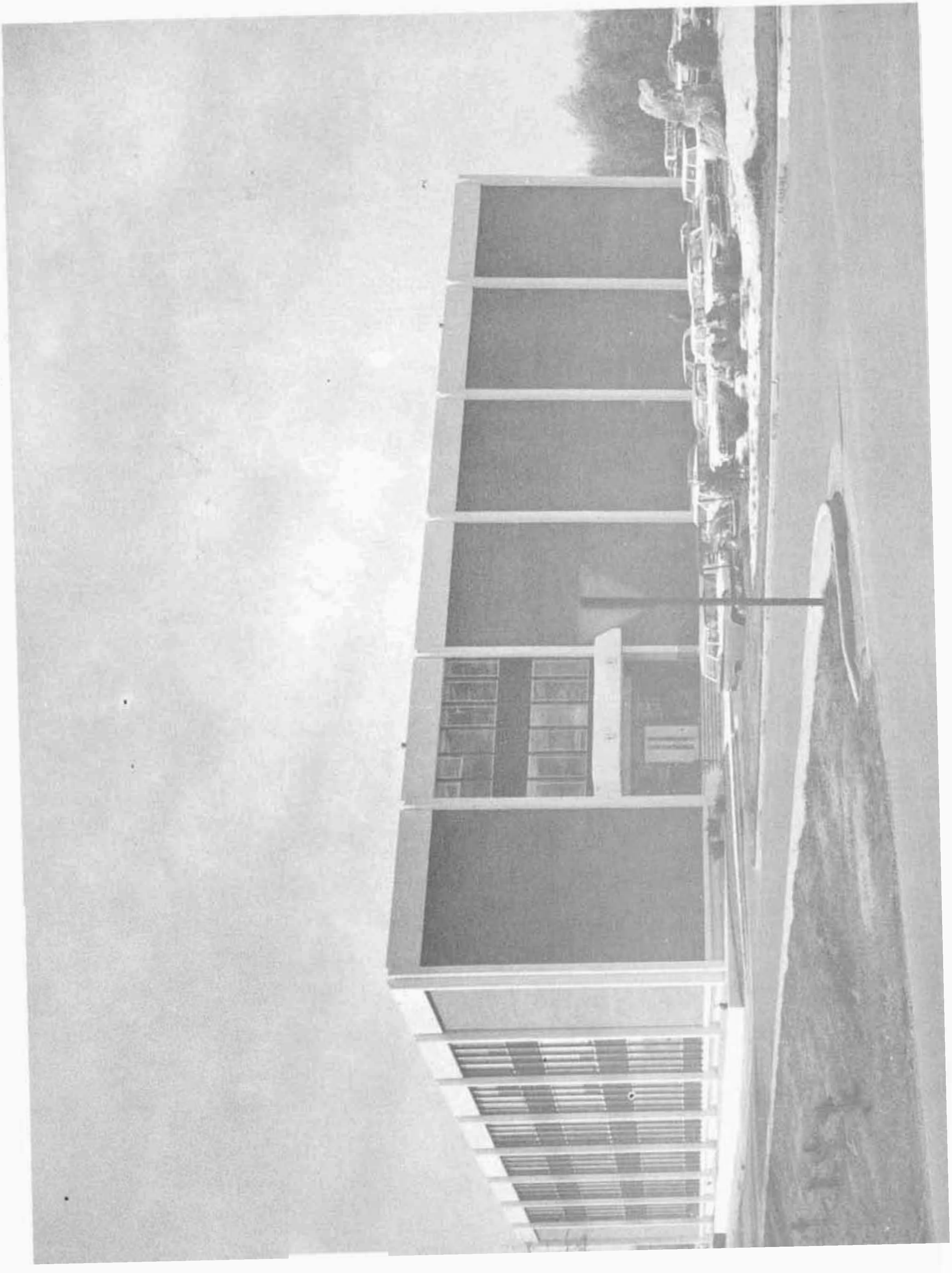
Mr. GRACE (cont.). we took the whole thing from them. The interesting thing about it is that at the outset of the program, when we met with Dr. von Braun and his staff out at Marshall on March 9, 1964, we said we would have the second building up and ready to go on October 1 of that same year. They knew we had been fooling around with the first one for about a year and a half, and it was still not quite finished at that time. So they had a lot of skepticism about our ability to get the second building up. I see Mr. Luther Powell smiling over there because he remembers this. That was our first milestone, I guess. We had Building 2 (Figure 4), ready for initial occupancy on the 1st of October. We had been able to meet, in terms of facilities, pretty much what was required. This building, as you will see on the tour later, is designed specifically with the Instrument Unit in mind. It has two floors on this front part, and is about 100 feet by 300 feet in the two-floor section. The first floor consists primarily of the elaborate equipment required for checkout of the Instrument Unit. At this end of it, from here down on the first floor, are two system checkout stations, one for the Uprated Saturn I and one for the Saturn V. On the other end are areas for unit checkout stations to check each of the elements of flight hardware that go into the Instrument Units. The second floor houses the Resident Manager's Office at that end, then the manufacturing engineering, quality engineering, and people associated with the day-to-day activities. The High Bay area is 50 feet wide and 300 feet long.

I should say at this point, that when we originally discussed the program that had to be conducted on the Instrument Unit, we felt that the two buildings

FIGURE - 4 - IBM BUILDING #2

Mr. GRACE (cont.) that you have just seen, Building 1 and Building 2, would be adequate. It was sized with not much spare room in mind. But we thought it would be adequate, with maybe the necessity to lease some extra space for storage, and so forth. It turned out that, as we negotiated the contract, we came to fully understand what was required, and we recognized that we had grossly undersized the facility required. This led to the construction of Building 5, the Engineering Building (Figure 5). So we moved Engineering into this three-floor engineering facility in which we have the IBM 360 Computer System. The computer system is associated with scientific programming that has to be done, as well as our administrative system. This building also houses the very important Simulation Facility where we simulate the computer programs that are involved in the system. I might just say a word about that.

I think it was a major decision made primarily by Mr. Haeusserman and the Astrionics Laboratory when they elected to have Saturn go to an all-digital system. As you probably know, their background was in the Jupiter and Redstone and some of these other systems with analog guidance systems. As I hear the story related, there was quite a period of time and a lot of discussion ensuing in terms of going to a digital system for this. From our point of view--although perhaps we are a little prejudiced in it--and trying to be objective when looking back in retrospect from what we have done here so far and from things we have seen, it just could not have been done any other way. But even the folks who made the decision to go all-digital in the flight hardware and in the systems checkout hardware had no way of envisioning the magnitude of the job and what would be required. As it turned out, part of the reason that the



5 - IBM BUILDING #5

Mr. GRACE (cont.). job we have is bigger now than it was at the outset has to do with the fact that the amount of programming--computer programming--required for the flight computer and the factory checkout system, and a tremendous complex of launch computer systems at the Cape, were just grossly underestimated.

Mr. WILSON. Do you do all the software work for this, here?

Mr. GRACE. We do the software work here, yes. We will be discussing that in considerable detail later. The other building I mentioned is Building 4 and, as I said, it is our Branch Office. (Figure 6) We do have some 200 FSD people over there. There are some engineering folks responsible for the design of some of the measuring systems, but most of them are in the Systems Programming activity. They have to do with software.

I mentioned the fact that we are expanding Building 2. We have an artist's conception here. (Figure 7) This is looking from the back of that building. Now, if you can recall the two-story building and the 50 foot by 300 foot High Bay area--that turned out to be just too small. We have two checkout stations, one each for the Uprated Saturn I and Saturn V. We have three assembly stations and two fabrication stands. As it turns out, to meet the current rate of delivery, we have something on those stands at all times. Because you do not always have the ideal situation--two in fabrication, three in assembly, and two in checkout, it is a juggling act just to have enough room. We have found ourselves just terribly cramped for space and it has been difficult to operate as efficiently as we would like. That is the reason for this expansion.

FIGURE - 6 - IBM BUILDING #4

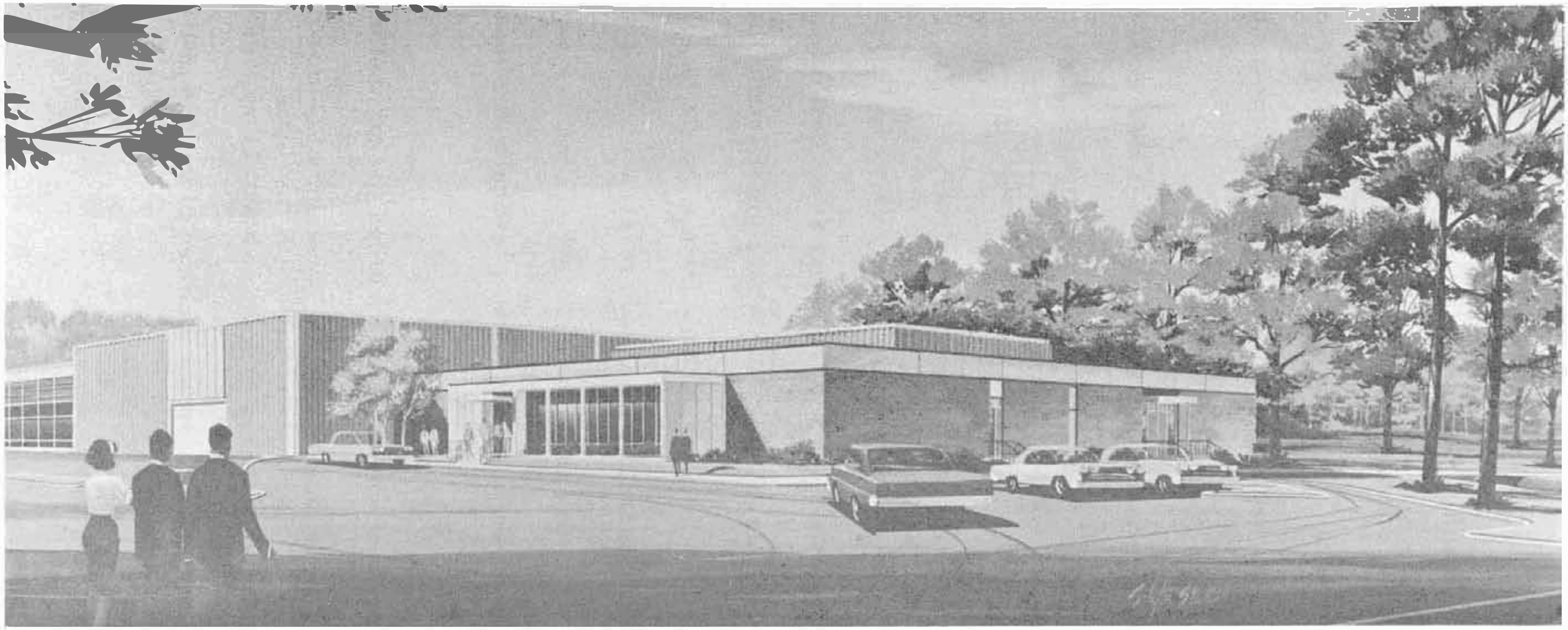


FIGURE - 7 - IBM BUILDING #2 ADDITION (ARTISTS CONCEPTION)

Mr. GRACE (cont.). We are going to make this 110 feet wide compared to the present 50-foot width. We are adding 60 feet more, full length, which will give us room to operate around the stations that we have in there. The 1-story area in the back is going to house some of the specialized facilities that are required in terms of clean rooms and the component working area, which is also rather cramped.

Mr. WILSON. How much total investment does IBM have in these facilities?

Mr. GRACE. We have some detail on that. Just to give you a round figure, including the furniture, fixtures, land, and buildings, it is about $14 million.

Mr. WILSON. And this is all IBM investment?

Mr. GRACE. We came here on the basis that we had a firm conviction that space was here to stay. We bought the land, we own the buildings, and they are on--what is it, Mr. Cleary, a 33-year amortization?

Mr. CLEARY. On a 50-year average for the buildings, with lesser average for furniture and fixtures. That is an overall average of about 33 years.

Mr. GRACE. Well, to answer your question--yes, we own it, it is ours. It is not completed, but we put it here specifically for space work, and that is what it is here for.

As you drove in, you may have noticed the expansion work underway. Actually, it is a little more underway now than since this picture was taken. (Figure 8) But this is the area in which we will be expanding this building.

Mr. WILSON. Is this new section included in the $14 million investment?

FIGURE - 8 - IBM BUILDING #2 CONSTRUCTION PROGRESS

Mr. GRACE. Yes. When this is finished it will be $14 million.

This is a glimpse of an area you will be seeing in more detail a little later. (Figure 9) You get an idea of what I mean by being squeezed in. In this particular instance, we do not have this Instrument Unit on a stand. Notice the three segments in the background which are ready to be mounted on this fabrication stand. This is a fixture that goes on the Instrument Unit for drilling and potting the holes in the interface where it connects to the S-IVB Stage and the Lunar Module Spacecraft Adapter. The Instrument Unit is, as you know, a structural element within the total system. It is a load-bearing element that comes to us in these three 120-degree sectors. Our supplier on this particular phase of the program is the North American Aviation, Tulsa Division, who also makes the Lunar Module Adapter. We went on a competitive procurement and they won. They deliver the segments to us with certain bosses already built in--in terms of their assembly activities. Then we do a lot of the fabrication work. There is the cutting of holes and putting bolts in, and so forth, which has to be done with a very precise drill fixture, as we have here, both fore and aft. Then we proceed through the assembly phases down to the checkout stations on the end. You will note in this particular picture, which is comparatively recent, that we have two Instrument Units, in checkout one on each checkout station.

The Instrument Unit (Figure 10) is built with a cable tray around the top. This is the upper surface. The cable tray, in this particular view, does not have many cables mounted on it yet. You will see more of that when we give you a technical description of it. The big duct you see in the inside of the cable

FIGURE - 9 - IBM BUILDING #2 HIGH BAY AREA

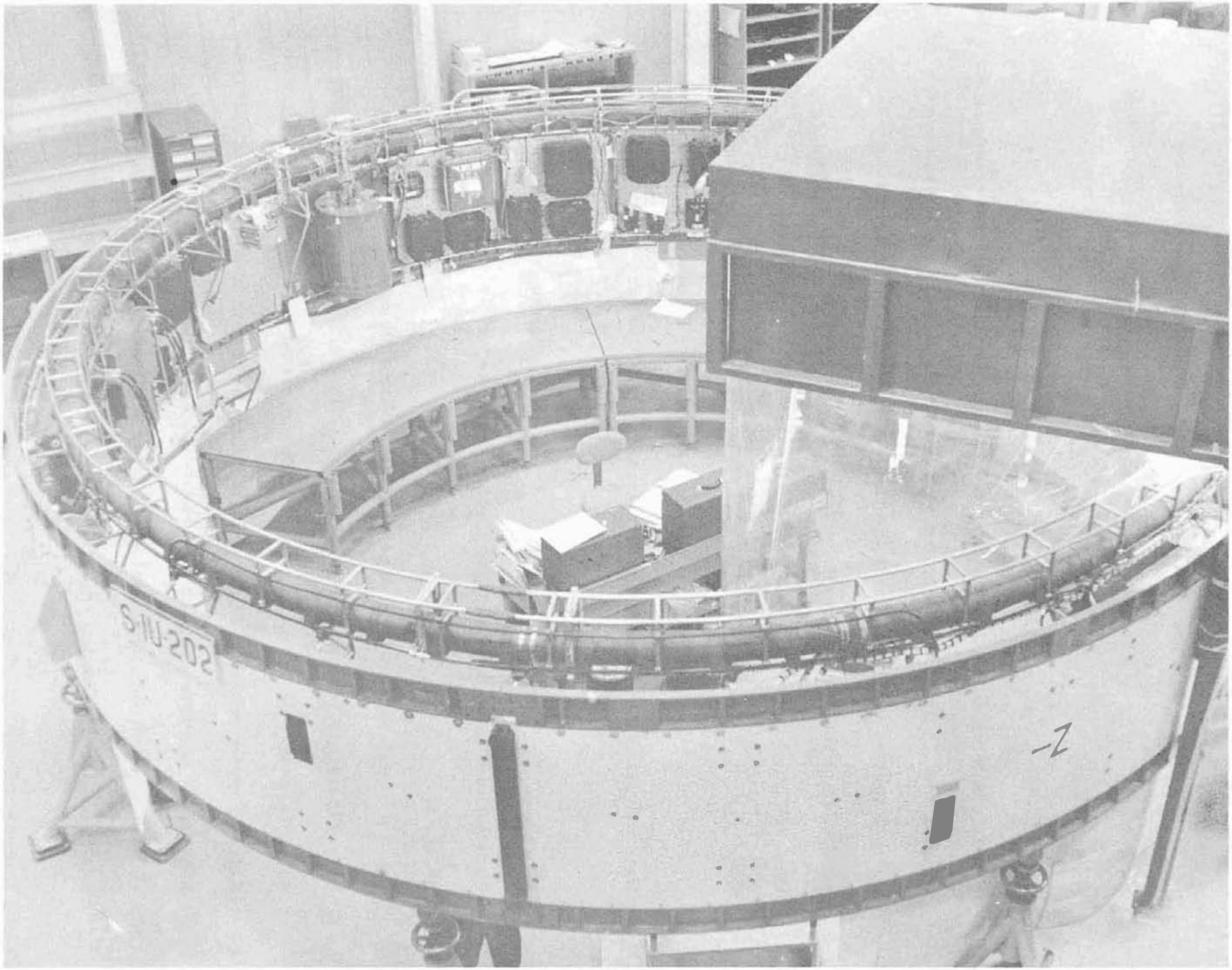


FIGURE - 10 - INSTRUMENT UNIT

Mr. GRACE (cont.). tray is the purge duct. When the vehicle is stacked at the Cape, it purges the dangerous gases out of the area while the men are in there working.

On the inside periphery, all of the equipment is mounted on thermal panels, called cold plates, which have a water-methanol mixture pumped through them. The water-methanol mixture runs through an environmental control system which regulates the temperature so that the operating temperatures of the units are kept within a reasonable range.

Mr. FELTON. How long does it take to check out one of the units?

Mr. GRACE. Normally it takes about 8 weeks to go through it. That is figured on a standard 8-hours-per-day work shift. We have done it in less time but with a tremendous crash effort.

Mr. FELTON. You have two checkout units?

Mr. GRACE. Two checkout stations, one for the Saturn V and one for the Uprated Saturn I. We will go into more detail as we discuss checkout a little bit later.

As you well know, the Uprated Saturn I and the Saturn V are quite similar in configuration going from the IU up toward the stages above. (Figure 11) The Instrument Unit is relatively small in terms of the size of the total Apollo-Saturn V moon rocket. The reason for showing this is to show that these are essentially the same dimension. However, as I pointed out, the Instrument Unit is different from each Saturn V to the next, and from each Uprated Saturn I to the next, in terms of the exact configuration. It depends on the mission

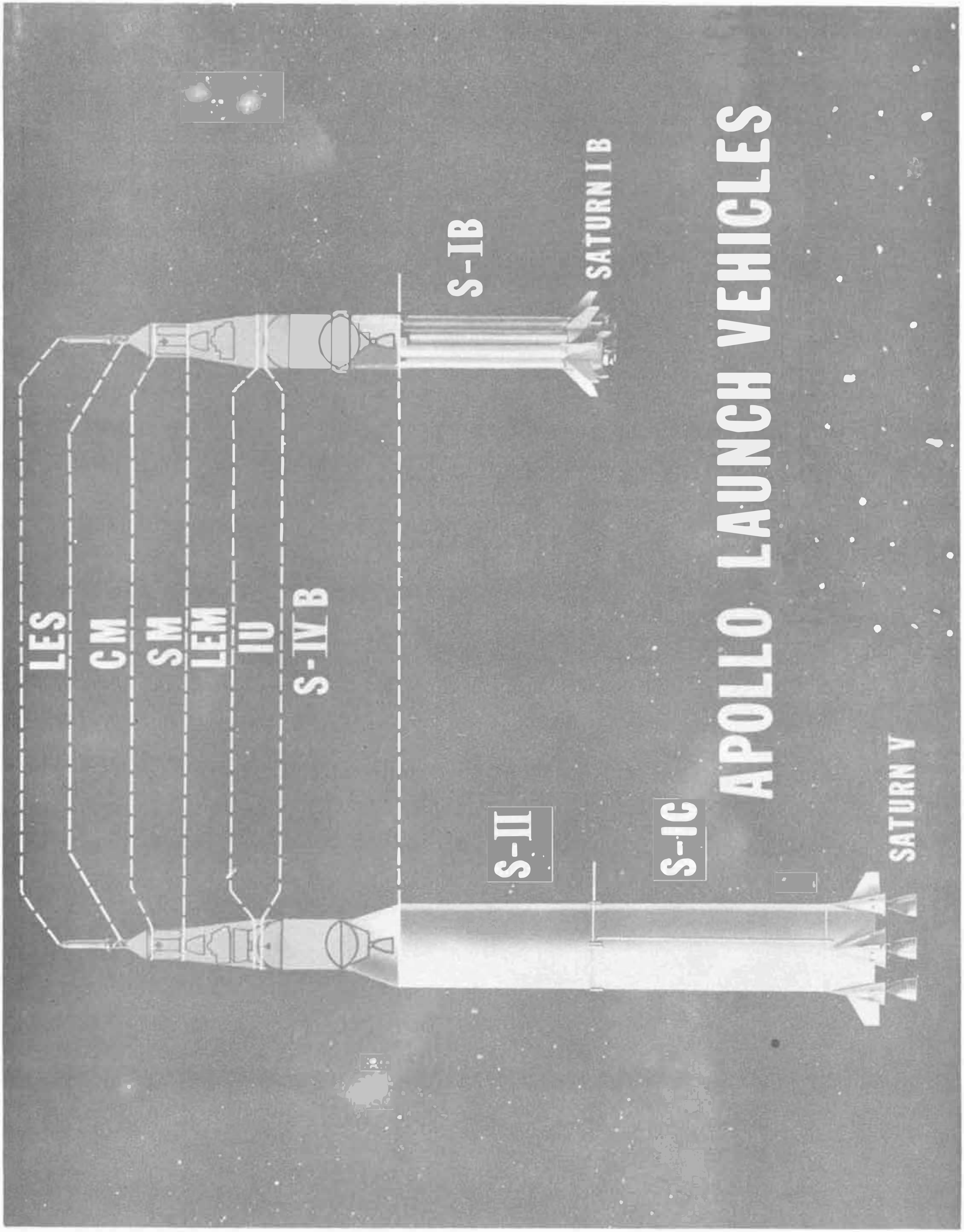


FIGURE - 11 - IB / V SIMULARITY

Mr. GRACE (cont.). that is planned, what is in there, and exactly how it is structured. The major impact from mission to mission is, as you would expect, in the electrical system that connects everything together in the specific units that are involved.

Mr. WILSON. Are we going to discuss these in some detail?

Mr. GRACE. Yes. We will discuss these in some detail.

We have a sequential event that must take place, and that is the checkout. We have a necessity to allow time for what we call refurbishment of the checkout stations, from one level to the next--in that the S-IU-204, for example, was different from S-IU-203 in certain respects--and we have to make the modifications to the checkout stations that handle these differences. You will see that later as I get into the status of the program. I wanted to spend a little time in discussing this in some detail so that you can see the interaction or, what we call, the domino effect. You get a real bad problem, and because we have a sequence that has to be followed it pushes everything out.

MILESTONES-201, 202, 203

Mr. GRACE. We have accomplished a certain number of things so far. Having started back in early 1964, we completed the building in October of 1964, and got underway really, in terms of fabrication of our first Instrument Unit, in early 1965. The first Instrument Unit, S-IU-201, was fabricated and assembled by IBM with assistance from Marshall, and checked out by Marshall with assistance from IBM. We had a very close working relationship here at that time.

This is a view of the S-IU-201. (Figure 12) Obviously, we were all pretty proud and pleased when that first one went out, and even more proud when it was successful in terms of the actual mission of the flight.

This is a view of the S-IU-201 on our big day last October, about the 8th. (Figure 13) This is a view of it going by the familiar Administration Buildings out at the Marshall Center on the way to the river. The Instrument Unit was carried on this transporter to the river and to KSC (Kennedy Space Center) by barge. We learned a lesson on that day, did we not, Mr. Powell? We had it ready at 3 o'clock in the afternoon, and we were anxious to let it go. So we shipped it at 3 o'clock in the afternoon. About 15,000 people wanted to get home from the Arsenal about 3:30 or 4:00 p.m., and we were right in the middle of the biggest traffic jam that Huntsville ever saw. They finally got us off to the side of the road out there until they got the people home. We had a lot of people mad at us that day. We have learned not to ship it at that particular time.

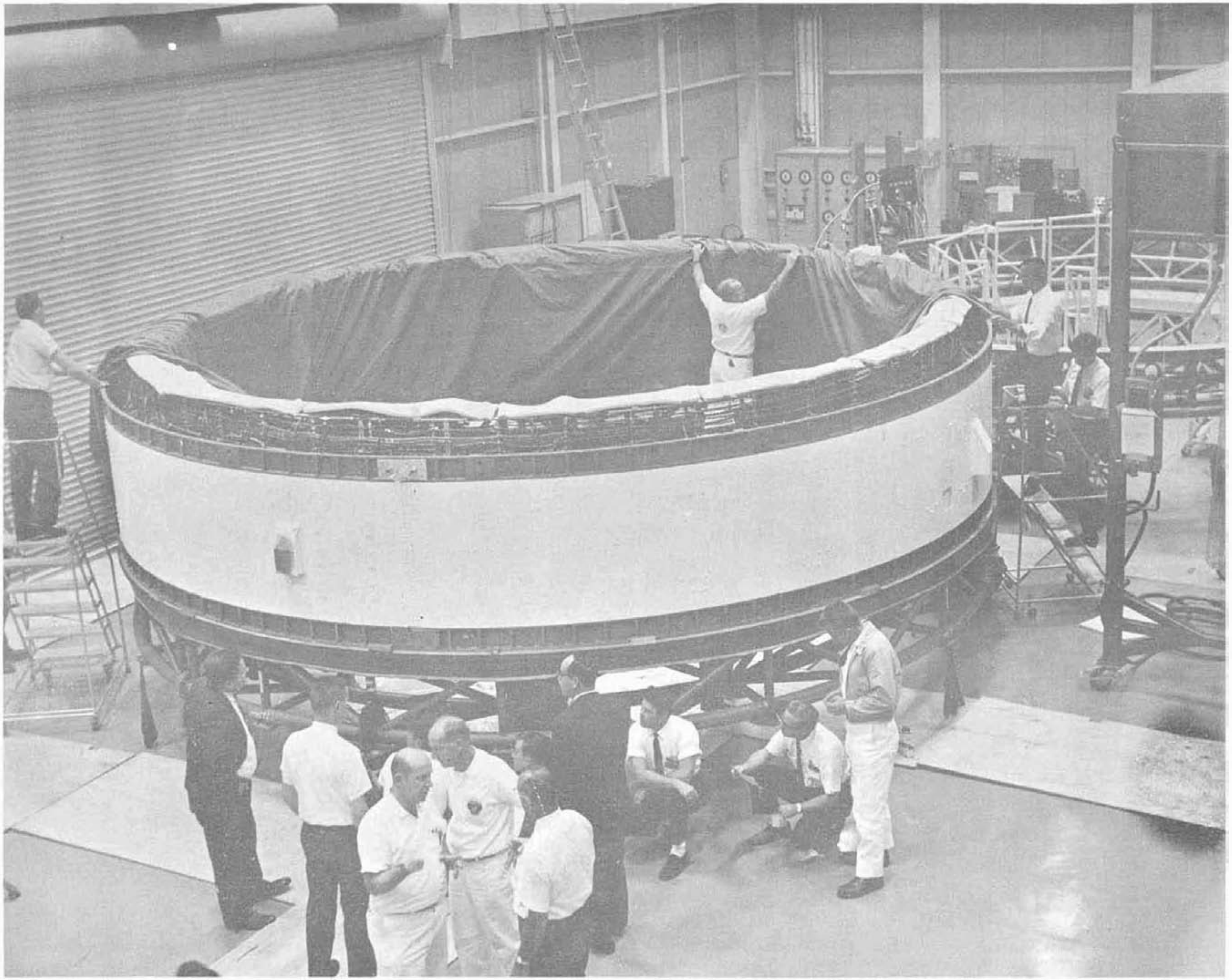


FIGURE - 12 - IU 201

FIGURE - 13 - IU 201 LEAVING IBM

Mr. GRACE (cont.).

This is a view of S-IU-202. (Figure 14) One thing you may notice--they are white. The first three were white; they are black now. This is one of the changes that was necessary because of the environmental control system. We determined that the color of the paint had a significant influence on our ability to control the temperature. As a matter of fact, our thermal control system was too good. It was making things a little too cold. So we changed the color from white to black on the Instrument Unit and modified the paint inside also.

The S-IU-202 was also shipped by barge and, just to give you a view of the size of the barge, it is big enough to transport the Uprated Saturn I Stage. (Figure 15)

The S-IU-203 was shipped in April of this year and, as you know, has been launched in the very, very successful hydrogen experiment which was recently conducted. (Figure 16) This is the first Instrument Unit that we were able to ship in the Super Guppy. (Figure 17) It makes a considerable difference--1-day transportation compared to 10 or 11 days by water. We are hopeful that the Super Guppy will continue to function as well as it has up to now and that we will be able to ship them all that way. It provides much more flexibility. However, as you will see in our status, even though we have problems--we will tell you about that, too--we feel fairly confident that we could meet the Apollo program requirements, as they stand today, even if we had to ship them by water.

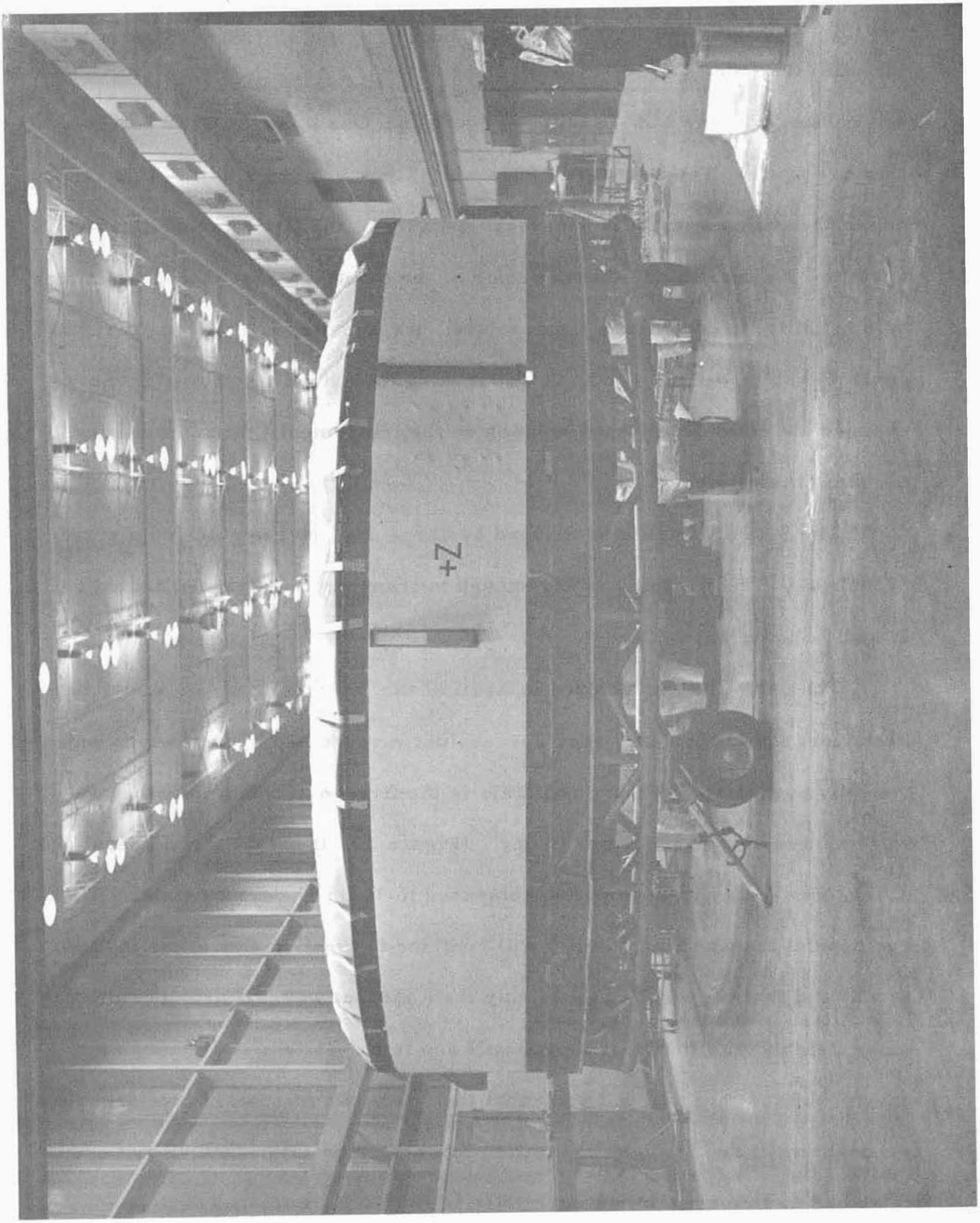


FIGURE - 14 - IU 202

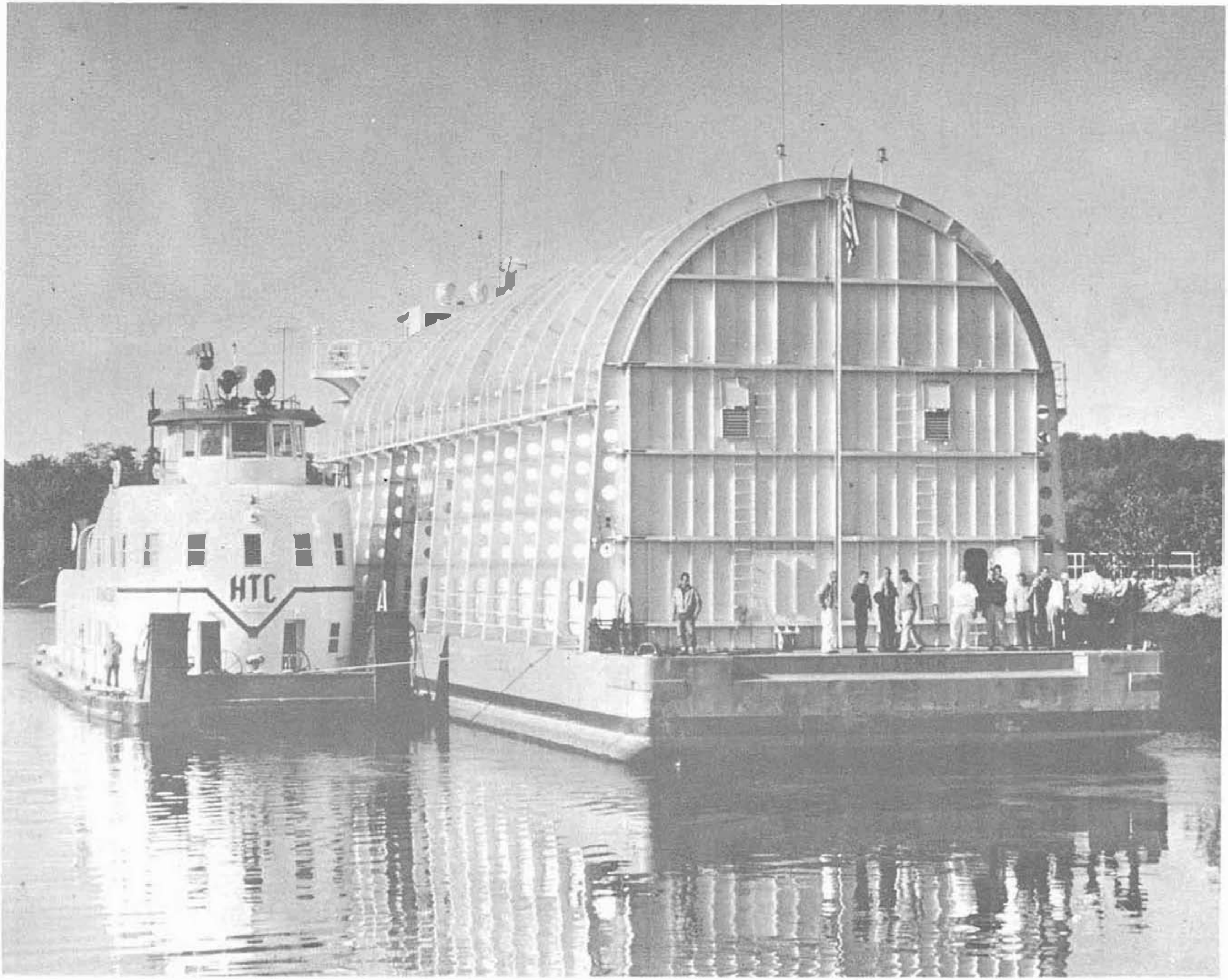


FIGURE - 15 - IU 202 ON BARGE

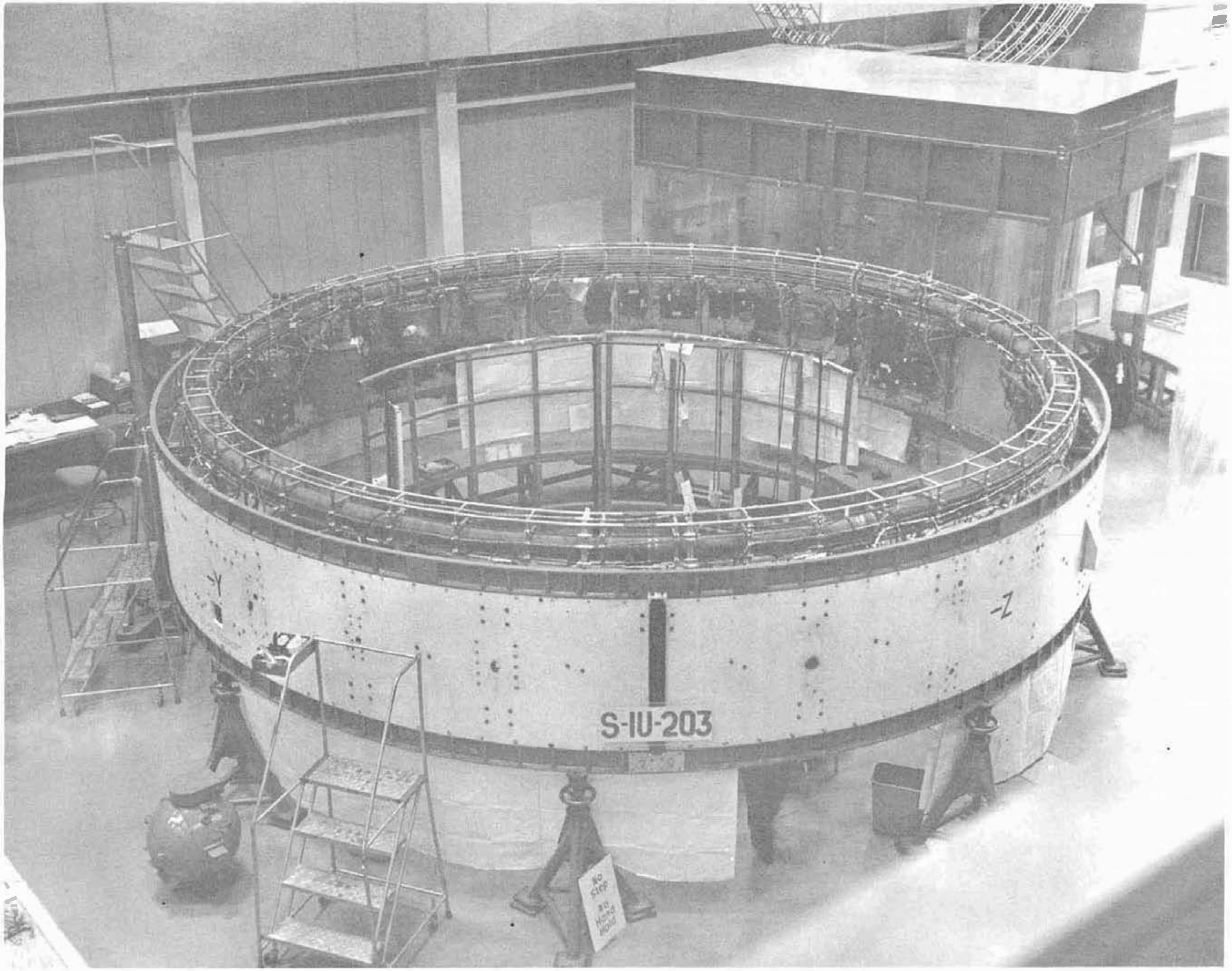


FIGURE - 16 - IU 203

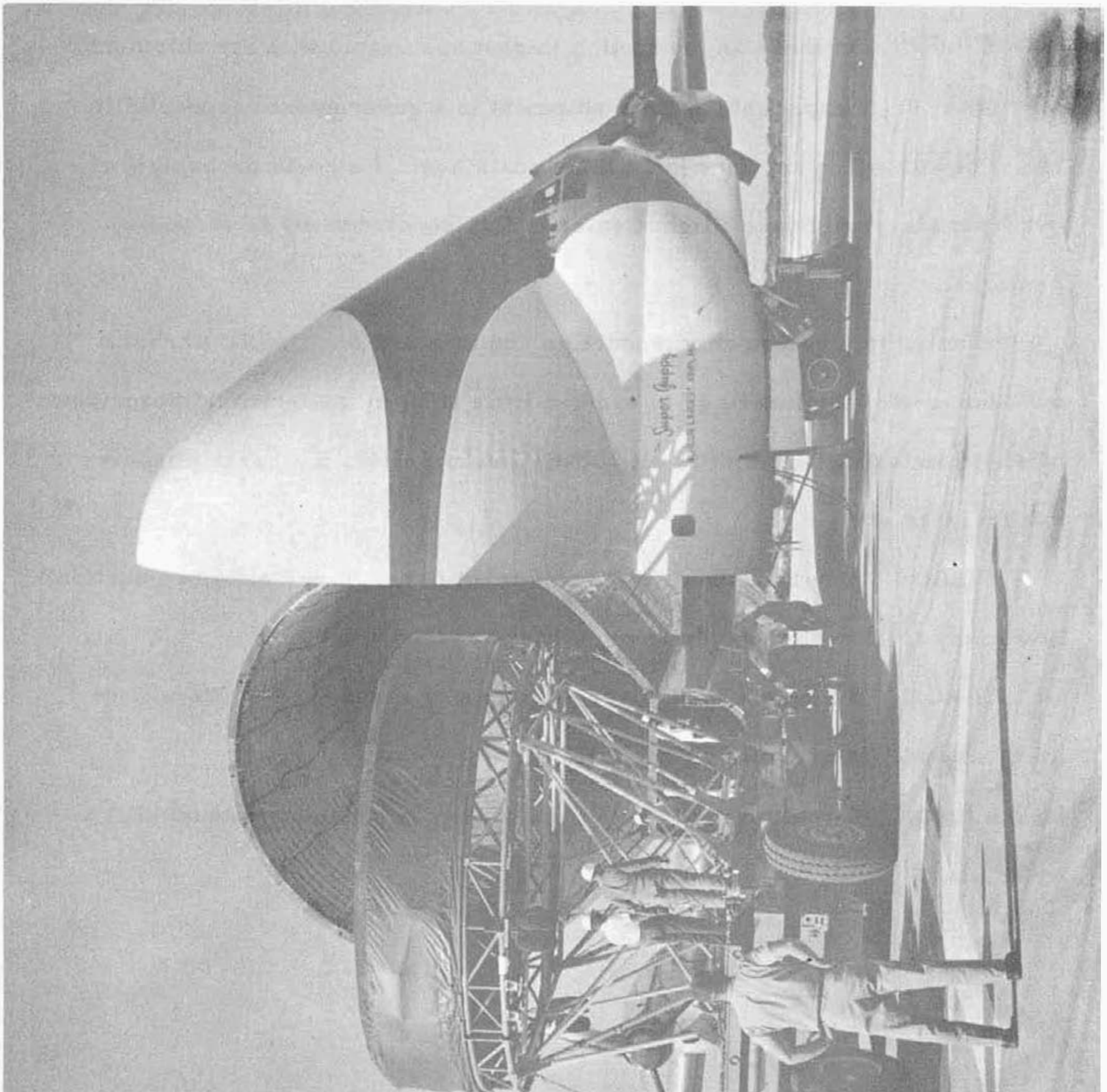


FIGURE - 17 - IU 203 LOADING ON SUPER GUPPY

Mr. WILSON. Is there any reduction in cost associated with air shipment?

Mr. GRACE. I expect so, but the shipment is a government responsibility. Mr. Powell? --I do not know what their costs are. We could probably find out from Marshall Space Flight Center. This concludes my introductory remarks.

I wanted to give you an introduction and then ask Mr. R. E. Ehrhardt, our Manager of Engineering, to spend a little time in the technical description of what the Instrument Unit is all about. Interrupt Mr. Ehrhardt whenever you feel like it.

Mr. WILSON. You talk about your investment here. May I ask one question? How many total people do you have on board at this time?

Mr. GRACE. We have a work force right now of about 2,000. We will go into that specific question a little later.

Mr. WILSON. I would like to leave time in your schedule to discuss that a little later.

I.U. DESCRIPTION

INSTRUMENT UNIT DESCRIPTION

Mr. EHRHARDT. I would like to describe the purpose of the Instrument Unit by first talking briefly about the role the launch vehicle plays in the overall Apollo Mission, and this first slide talks about that particular subject. (Figure 18) I am sure that you are all very familiar with the ultimate objective of the Apollo program--to launch Astronauts from the earth and get them to the moon, land them, and bring them back successfully. The trajectory, as outlined here, is essentially that. The basic plan is to first orbit the launch vehicle in an earth orbit, and then during any of the first three earth orbits, launch the S-IVB, Instrument Unit, and Apollo payload into a translunar trajectory, send the Apollo payload to the vicinity of the moon, land the LM on the moon, and then return the Astronauts to earth in the Command Module. Now the launch vehicle itself is concerned with that portion of the mission from liftoff into earth orbit, Orbital-type operations, insertion into the translunar trajectory, and control out to a point in time where we have turn-around of the Command and Service Module and reinsertion into the Lunar Module. At this time, separation occurs between the payload and the IU/S-IVB combination.

These pictures, around the side, give more detail of the mission. In the Saturn V Program, boosting into orbit requires the burning of three separate stages to get into an earth orbit. At the appropriate time we ignite the third stage again and insert into the translunar trajectory. We then provide the necessary stabilization while the turn-around maneuver is accomplished. At this point, then, the mission of the launch vehicle is essentially complete.

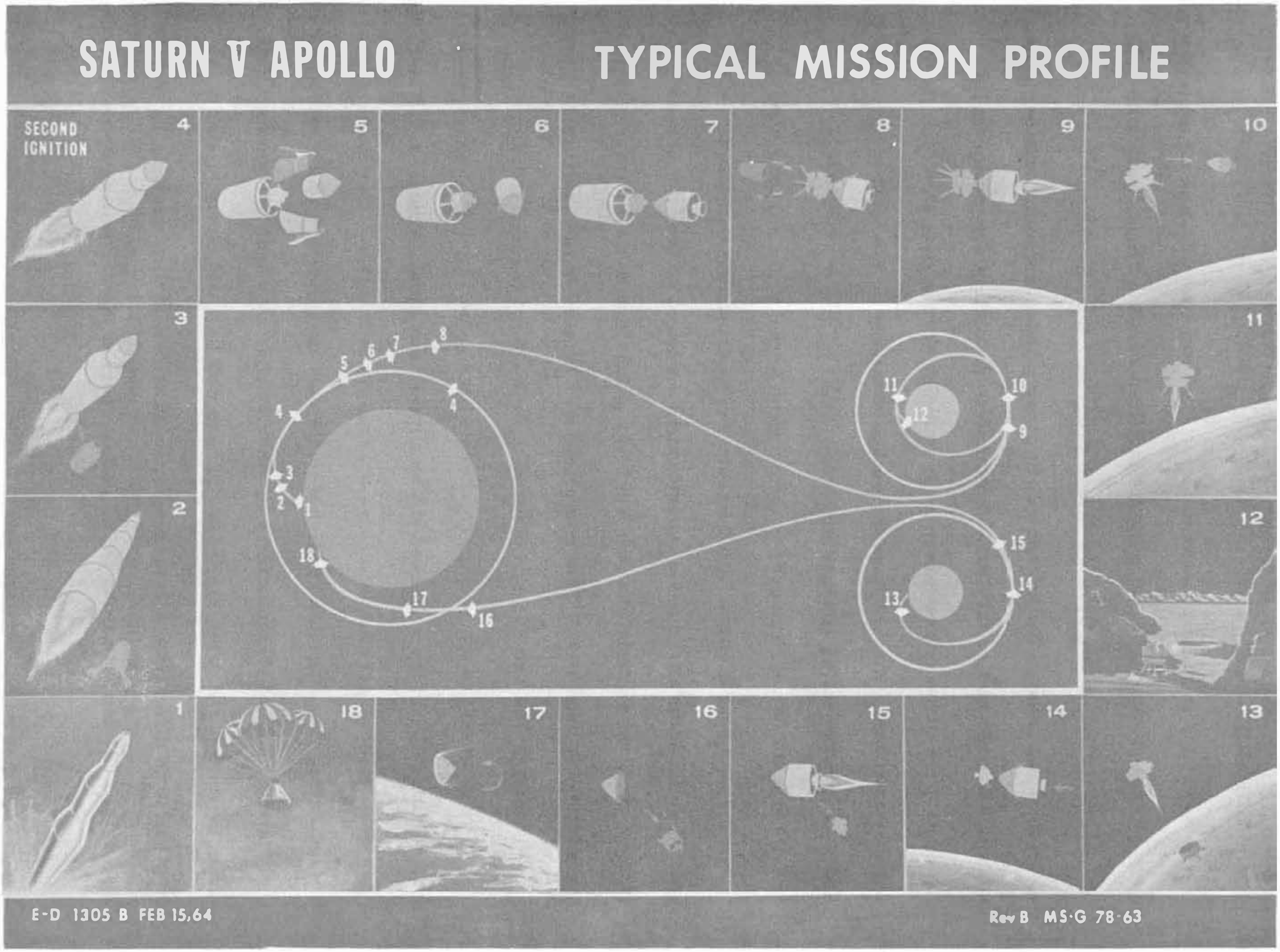


FIGURE - 18 - APOLLO MISSION DESCRIPTION

Mr. EHRHARDT (cont.).

Now, this is the ultimate mission. I am sure we all know about this one. Perhaps we are not all quite as familiar with the steps leading up to it. Specifically, in the Uprated Saturn program, the AS-201 and 202 missions are not orbital shots, but lob shots. In other words, we launch but bring them back down again before they make a complete revolution around the earth. The basic purpose of these two missions is to check out the heat shield on the Apollo capsule and insure that we have the design complete on the total launch vehicle and that it is operating successfully.

Vehicle 203 was a hydrogen experiment whose basic purpose was to prove that the S-IVB engine can be restarted in orbit. At that point in time, we had some additional television equipment on board so that the proper observations could be made to see just what was going on with the hydrogen during the weightless condition. This equipment was located in the Instrument Unit.

Vehicles 204 and 205 are planned to be the first manned missions. Vehicle 206 is one which is used to checkout the Lunar Module. It will be put into earth orbit and then checked out by actual operation. Vehicles 207 and 208 have been rather recently defined as a rendezvous mission. Our basic purpose for indicating these particular flights is the fact that they are going to be operating in different kinds of trajectories. In other words, they will be lobbing a few, and going into earth orbit on others. There will be a necessity to steer the vehicle in different trajectories, operate different time sequencing to turn the engines ON and turn them OFF, and to operate the various equipment on the

Mr. EHRHARDT (cont.). other stages to meet the particular demands of the mission.

Now, because of that, we feel Marshall was rather wise in their decision to take these mission-dependent functions, and, instead of distributing them through the whole vehicle, include them in one stage. Within this one stage they can be more easily adopted to the various missions and are able to accommodate mission changes based on the results of previous missions. Frankly, that has proved a little successful already. We have a lot of the functions for each mission planned out but, as you gain a certain amount of insight in each mission, you discover that there is a need to make some changes on subsequent flights. Again, the concentrated effort for these changes is not in each of the stages, but only within the Instrument Unit. The whole design of the Instrument Unit is aimed toward that particular goal--to insure that these changes can be made so that we can operate the launch vehicle in whatever particular mission is required and without a lot of redesign and lengthy lead times. Now if I can move on to the next slide (Figure 19), I would like to talk briefly of the requirements or capabilities of the Instrument Unit. The guidance and control function, which is the one that establishes our trajectory, is one of these mission-dependent functions. The monitoring and origination of vehicle events is another one that I have already mentioned in terms of the ON-OFF type functioning in the various stages of the vehicles. Ground communication is also very mission-dependent. Depending on the particular orbits that you are going to go into, you will be going over different ground stations at particular times which are different from

IU REQUIREMENTS

GUIDANCE AND CONTROL

LOAD BEARING

MONITOR AND ORIGINATE VEHICLE EVENTS

SELF SUSTAINED

RANGE SAFETY AND ORBIT DETERMINATION

GROUND COMMUNICATIONS

RELIABILITY

HARDWARE COMMONALITY (IB AND V)

FIGURE - 19 - IU REQUIREMENTS

Mr. EHRHARDT (cont.). mission to mission. Therefore, there is a necessity to sequence telemetry equipment and various flight control parameters ON and OFF so that you can correctly identify what is going on and monitor it correctly from mission to mission. The Instrument Unit has several other capabilities. Mr. Grace already alluded to one, that the Instrument Unit is a basic part of the total vehicle,and is therefore, a mechanical load-bearing member of the total vehicle interfacing between the S-IVB and the Apollo payload. It is pretty much of a self-contained unit as it has its own electrical system and is mechanically self-sufficient. In ground communications, I have already talked of orbit determination. There is a need to be able to track satisfactorily from a range safety standpoint during the actual boost operation to be sure we know where the vehicle is, and then to determine the orbit from ground station tracking data. There is also a need to track the vehicle once it has gone into translunar trajectory on later missions. In all of this, because the Instrument Unit is operative for the total life of the launch vehicles in each mission, there is a need for very high reliability.

And now we get into some details on how reliability has been approached in design. We have the basic hardware units which are common from vehicle to vehicle and from Uprated Saturn I to Saturn V. The notable exceptions between an Uprated Saturn I and Saturn V Vehicle is in the need for a command system in Saturn V that will operate in deep space--which is not required on orbital mission for the Uprated Saturn I. The other one is the Flight Control Computer, which outputs signals to the engine gimbals. Since we have three stages in the Saturn V and only two in the Uprated Saturn I, it necessitates that there would

Mr. EHRHARDT (cont.). be a difference in the actual Flight Control Computer construction. But the remaining Instrument Unit hardware is essentially common from vehicle to vehicle. The ability, then, to meet the particular mission requirement is accomplished, not by redesigning the whole assembly, but by building into the initial design the capability for programming it--and I use that word in two contexts. We will talk about some digital computers, of course, which are programmed by computer programmers. This is software as you may know it. The other programming concept is hardware programming where we have standard modules and, depending upon the particular job you are trying to do, you plug in this one or the other one, or put in Module A or B--depending upon the particular mission.

Mr. WILSON. Can you use either one of your test facilities for the Instrument Unit for the Uprated Saturn I and Saturn V?

Mr. GRACE. You are talking about the checkout?

Mr. WILSON. The checkout.

Mr. EHRHARDT. Right now we do use one solely for the Uprated Saturn I and one solely for Saturn V. We are investigating what it would take to allow testing of either type of Instrument Unit on either facility.

Mr. WILSON. You do have the capability of using them interchangeably?

Mr. GRACE. No, they are different at this period. You would have to modify one or the other, and because of the fact that we do have the constraint of only one Checkout Station for Saturn V and the other for the Uprated Saturn I, we are working up now, for Marshall, what it would take to provide the capability to test either Instrument Unit on either checkout facility.

Mr. WILSON. Is it because of schedules, and so forth, that you want to do this? Is it a problem to you?

Mr. GRACE. We are doing it because we had a problem recently that put us in a schedule bind. Although you do not anticipate these things, I think you have to recognize that they can happen, and it is insurance to have already figured out what you would do if you got into a situation where you had to convert one station into another.

Mr. WILSON. The impression you get is that you are simply adding units. Is this reasonably correct when you are adding subsystems to,or modules to,the Uprated Saturn I configuration to meet the Saturn V requirement?

Mr. EHRHARDT. We are actually replacing one with the other.

Mr. WILSON. I see.

Mr. EHRHARDT. The reason for the difference between the two Checkout Stations is the fact that we have specific configurations within this programmable capability of the hardware in the Saturn V program, which are checked out differently because of the configuration definition in the Uprated Saturn I program.

Mr. WILSON. Would it be worthwhile to build a third unit with a dual capability?

Mr. GRACE. Yes, as a matter of fact it would, and we have been discussing that with Marshall. One thing that we are doing on our initiative--in this new expansion to the High Bay area--we are putting trenches in the concrete that are required for the cabling, ducting, and the piping that is necessary for the Checkout Station. We had hoped that the 500 FS System, which is out at Douglas for the thermal vacuum system tests, might be considered. However.

Mr. GRACE (cont.). there must be at least four or five other needs for that particular system that Marshall is exercising. It does not look as if we are going to get that one right now.

What we are saying in answer to your question is--we think it would be advisable. We have gone ahead on our own initiative to make it possible, with the least amount of additional cost in our facility, to put another one in, should that decision be made in the future.

Mr. FRIETAG. Currently there is no plan for a third system.

Mr. WILSON. Do you, one for one, duplicate your checkout facilities at the Cape with the facility you have here at IBM?

Mr. GRACE. We check more here than is done at the Cape. The reason for that is, I think, fairly obvious. On a specific mission at the Cape, they check for that specific mission. Here, in the factory, we check the whole range and capability of all of the equipment that is installed. We do a little more.

Mr. EHRHARDT. We do check the basic interfaces that are used at the Cape, as Mr. Grace pointed out. We check those plus a little more. We have to go with break-out boxes and do more detailed checks than we would do at the Cape. The basic ground support to Instrument Unit flight hardware is checked here as part of our normal checkout. We have identical type interface equipment in our checkout installation.

Mr. WILSON. Do you intend to describe, someplace along here, your participation in total mission planning, tracing it back to the basic mission planning, and how it ends up in requirements that cause you to do things? I think that might be of interest to the committee--how the mission planning

Mr. WILSON (cont.). sequence takes place, starting all the way back to Bellcomm, if you want to go that far back, and how you get requirements.

Mr. GRACE. I think that, if I might suggest it, Mr. Meadlock, in your presentation of software, if you would go back to the mission-defining documents, make sure to show them how you have up-to-date information, how changes affect you, and so on....

Mr. MEADLOCK. I think that will be a very important part of it.

Mr. GRACE. Of course, we are very actively involved in post-flight analysis....

Mr. MEADLOCK. Right.

Mr. GRACE. ....and quickly getting the information back that can be injected into the program to make the necessary changes that are required. We can pick that up, too.

Mr. EHRHARDT. I think we will be covering most of those elements. If we have not covered them to your satisfaction, we will be certainly happy to expand on them at the end.

Mr. WILSON. I think it is an important ingredient--how you do the work here.

Mr. MEADLOCK. I had planned to touch on a couple of them in here. I will be extra certain that I do.

Mr. WILSON. And you might even wish to discuss some specific problems; take a couple of excursions like on abort problems and engine-out problems and things like that. Show how it works--how you plan for these.

Mr. EHRHARDT. I would like to get down into a block diagram now (Figure 20) to talk briefly of the flow of information and the various functions that go on within the Instrument Unit. Certainly one of the most important, if not the

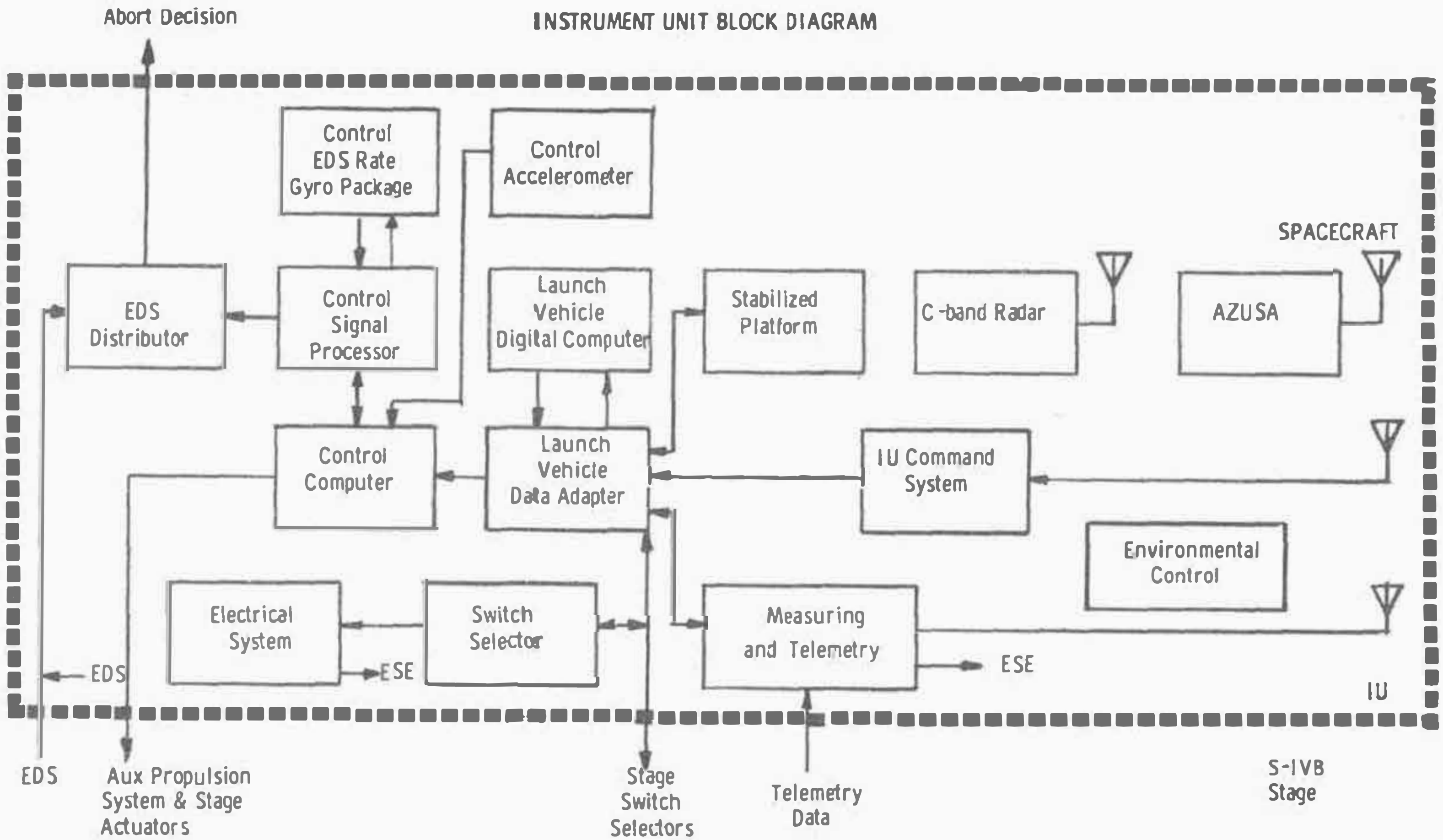


FIGURE - 20 - IU BLOCK DIAGRAM

Mr. EHRHARDT (cont.). most important, is the guidance and control function, which puts the launch vehicle on the trajectory for the particular mission that we are talking about. Within the Instrument Unit, we have an Inertial Platform whose basic function is to measure acceleration and attitude of the vehicle. That information is fed to our Launch Vehicle Data Adapter. The Launch Vehicle Data Adapter is the interface unit which handles digital information to and from our Launch Vehicle Digital Computer. We have many analog devices of which I will be talking briefly, and this provides the interface with them. When we send something in, usually an analog signal, it is converted to digital form so that the computer can work with it, and, in a reverse direction, digital information flows out and is converted to analog signals so that we can interface correctly with the rest of the system.

Information from the Inertial Platform is used to establish our actual present position and attitude of the vehicle. Within the Launch Vehicle Digital Computer-Data Adapter combination, we compute the end-conditions of the trajectory that we are trying to obtain, and establish, from that computation, what attitude and velocity vector we need in order to get there. These are usually different from the current attitude and velocity vector such that we get steering correction signals from the Launch Vehicle Data Adapter to our Flight Control Computer. Coming into the Flight Control Computer, as well, are accelerometer inputs and rate gyros, inputs to provide the necessary control system stability of the vehicle for all three stages of flight. The net output, then, are steering signals to the engine gimbals in each of the three stages.

Mr. EHRHARDT (cont.). Switching occurs, as staging occurs, to allow the signal then to drive the appropriate stage engine gimbals. The other overall vehicle-type activity is the ON-OFF sequencing for the total vehicle. Here we use information generated within the Launch Vehicle Digital Computer to either monitor certain functions that are going on in the vehicle and, as a result of something happening, issue commands to something else, or we output that information from the Launch Vehicle Digital Computer into a Switch Selector at a particular time when we want certain events to occur. The Switch Selector is a device which allows us to control 112 different functions in each of the various launch vehicle stages. We have a Switch Selector in the Instrument Unit and one in each of the stages. Particular vehicle functions are controlled by signals from the Launch Vehicle Digital Computer-Data Adapter-Switch Selector operations. Tied into this program is our communications capability. We have the command system, which allows us to send commands from the ground, and this, in turn, allows us to update the on-board computer with new data generated on the ground, or go into alternate mode-type operations, as the case may be. And, finally, the down-link of communications is our telemetry, wherein we monitor the actual operation of the equipment and determine how well things are going from the ground.

Mr. GRACE. If I may interject here for a moment--a point of interest on this last mission, AS-203. Fairly close to the launch date, while verifying the program, we determined that there was a time in which the computer would not be able to accept a command to switch the cameras. This was a very critical thing in this flight. We wanted to be able to switch from camera A to camera B if one of them went out. You know the drama that surrounded AS-203.

Mr. GRACE (cont.). One of the cameras was not working when it was launched. We went through a crash effort to get that program corrected so that it could accept a command. And, sure enough, it went through an automatic sequence in which it switched from camera A, which was working, to camera B, which was not working. We had to command it over one of the ground stations to go back to camera A, and then we fixed the program which could do it. This was one of the kind of things that could be done.

Mr. EHRHARDT. Things worked pretty well.

Mr. GRACE. There were a few fellows that sweat a little bit during the process when they knew the automatic sequence switched over to the wrong camera and wondered, "Was it going to work?" and it did.

Mr. EHRHARDT. There is one other point that I would like to make here to give you a better feeling for the design of the Instrument Unit.

The elements that I have just gone over are mission, vehicle-oriented, and are certainly vital to the successful completion of the mission. Marshall and we have taken some extra steps in here to provide as much reliability as possible. For example, in the Launch Vehicle Digital Computer we have what we call TMR, Triple Modular Redundancy. This is, essentially, a technique wherein there are essentially three circuits doing the identical program. Their outputs are compared, the majority of the outputs is used so that if there is a random failure in any one of the circuits, we will still get correct operation.

Mr. WILSON. Sort of a voting-type procedure.

Mr. EHRHARDT. Yes, sir. Now, we have another redundant technique over in the command system which is slightly different. We send up 14-bit data words to the command system--7 data bits are needed to either input data or to change an alternate mode of operation. The remaining 7 bits are complements of the first 7 data bits. These two sets of bits are compared with each other in the Launch Vehicle Digital Computer. If for any reason they do not compare, the command is rejected, and the command is retransmitted so that if we have transmission difficulties from the ground station, due to atmosphere and the like which occur from time to time, we avoid getting erroneous data into the computer by sending it up again until the data is correctly received. From a reliability standpoint, these are typical examples of what is built into the hardware itself. The program that we put into the memory of the Launch Vehicle Digital Computer also has additional backup capabilities to insure that if there should be a hardware failure of various types, the failure will be recognized and alternate courses of action will be taken to continue the mission. For an example, for acceleration inputs from the Platform, we have a table within the computer which gives prescribed values for the acceleration we would expect to see during a given mission. We compare the measured accelerations with the prescribed accelerations to see if they are reasonable. If they are not reasonable, we switch over to the previously stored value which will allow us to still satisfactorily complete our mission. It is that type of technique, both from a hardware redundancy standpoint and the software backup-type capability, that we have been able to, we feel, cover most any case that might come up so we

Mr. EHRHARDT (cont.). can attain a successful mission. Let us discuss some of the other systems. Electrical systems are, of course, required in order to supply power to the various units. Environmental control systems keep a controlled temperature environment on the various units and minimize the temperature changes that we have to go through. We have two other RF (Radio Frequency) systems that are used--one for safety and one for orbital tracking--in the Azusa and C-band Antennas.

Mr. WILSON. How much hardware in this Instrument Unit does IBM develop and manufacture, and how much of it is from other sources, which you buy or subcontract---just a rough figure?

Mr. GRACE. Well, most of it is subcontracted.

Mr. EHRHARDT. The major ones that are IBM developed and produced are the Launch Vehicle Digital Computer, Launch Vehicle Data Adapter, and Switch Selector. We do electrical work, such as distributor and 56 Volt Power Supply manufacture here, also.

Mr. WILSON. What would it be--about the total unit cost of the Instrument Unit--roughly? I realize it differs as you go along.

Mr. CLEARY. If you average them out, it is roughly....

Mr. WILSON. The total Instrument Unit?

Mr. CLEARY. $5-1/2 million. About 30 percent of that is purchased.

Mr. WILSON. About 30 percent of the dollar value?

Mr. EHRHARDT. Lest we lead you astray there, Mr. Grace has already mentioned that some of these items were GFE. The Platform and certain

Mr. EHRHARDT (cont.). other major dollar items are GFE.

Mr. CLEARY. Those are over and above the million and a half of purchase cost we indicate for purchase of the Instrument Unit. I am including in the $5-1/2 million the support activity, the programming software activity, which is also about 30 percent of the cost.

Mr. WILSON. Then, of the total cost, only about $4 million--about 70 percent of the cost--is hardware?

Mr. GRACE. Yes. Mission-related engineering and software development activities make up the balance.

Mr. EHRHARDT. On the next slide (Figure 21) we show the three structural segments. The structure was designed in three segments because initially it was thought that the Instrument Unit would be disassembled and shipped in these three segments. Further down the line it became more appropriate to ship the Instrument Unit totally assembled because of the transportation availability of the Guppy and of the barge. This would require less rechecking when we get to the Cape.

Mr. GRACE. I think you asked the question, Mr. Wilson, on the savings in transporting by Super Guppy as compared to barge. I think one of the things that needs to be recognized in the savings is that you do not have to disassemble it, and break all the electrical connections, plumbing connections, and splice plate connections. You do not have to do an awful lot of realignment and assembly that takes time and expense at the Cape. We greatly reduced that

Mr. GRACE (cont.). activity at the Cape. Sometimes that savings gets ignored when you talk about transportation savings.

Mr. FRIETAG. Is there a reliability factor that is also benefited between the barge and the Guppy?

Mr. GRACE. Reliability?

Mr. FRIETAG. As far as the amount of checking that has to be done?

Mr. GRACE. No. It is basically checked the same way at the Cape--put in the ground station down there and run through a sequence of tests which are programmed.

Mr. WILSON. The C-band and the Azusa just happened to be located here. As far as you are concerned, you do not need a common power source and all that sort of thing for these systems. They are really independent of the basic Instrument Unit. They are housed with it, but. . . .

Mr. EHRHARDT. We provide power supplies--totally self-contained power systems within the Instrument Unit--and the C-Band and Azusa are supplied power from our power system. The three segments here are manufactured by North American, Tulsa, and are shipped in pretty much the same configuration as you see them here. The brackets from which we hang cold plates and the other units are put on at Tulsa. The painting that Mr. Grace alluded to is also done there.

Mr. WILSON. The painting interests me. You say the system was too cold with the white paint on there? Does this mean you have fundamentally some problem with your environmental control system?

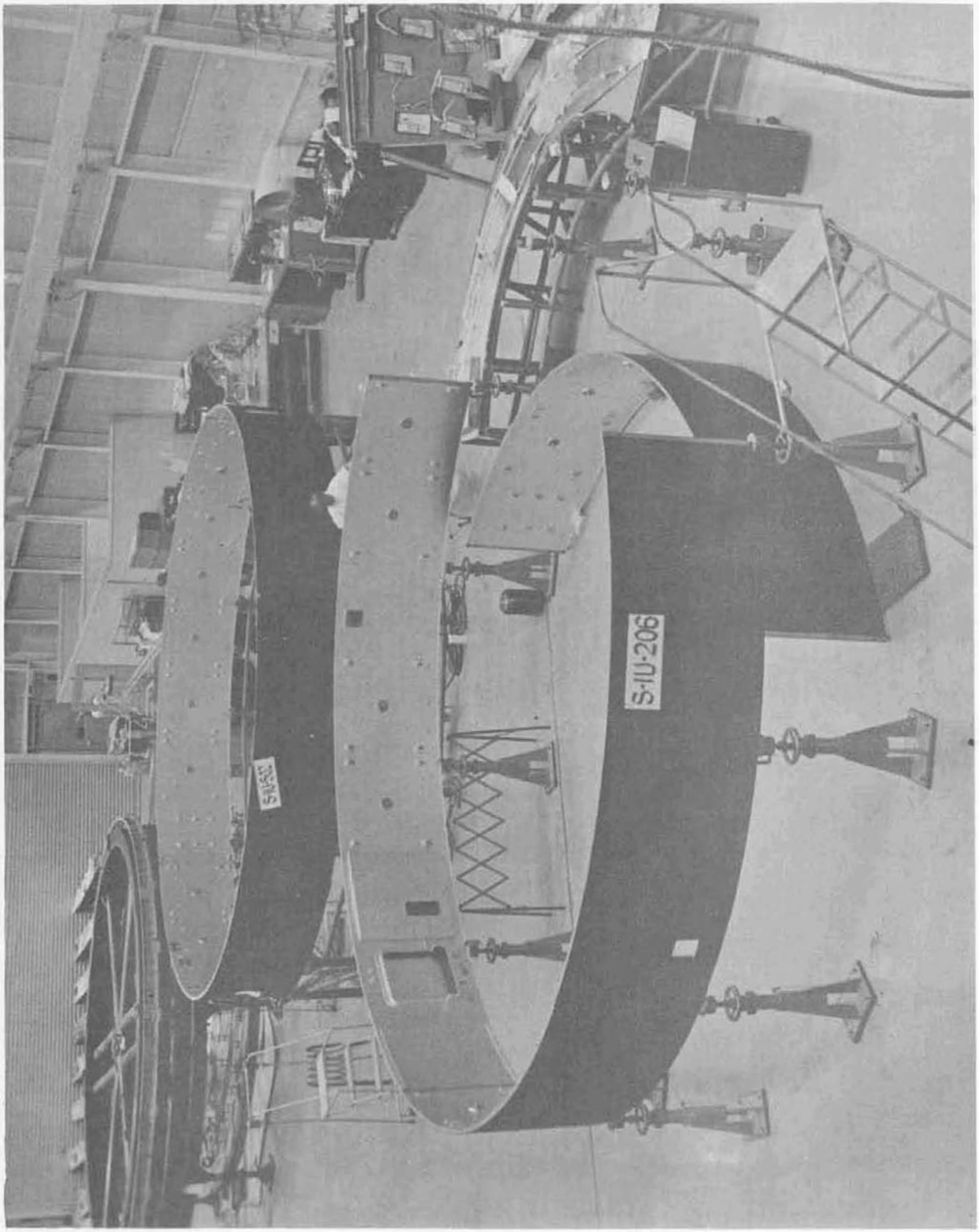


FIGURE - 21 - IU SEGMENTS

Mr. GRACE. It is difficult, of course, to simulate all of the actual environments you are going to get into. We did not have initial flight data--201 was the first time we got that data. I guess there were engineering opinions as to what we would find there. What we found was that it was much cooler than had been anticipated. In other words, the cooling system was much more effective--more efficient than was anticipated it would be.

Mr. EHRHARDT. We are presently evaluating the data on AS-203, which is really the first chance to get a large amount of data to see what is happening.

Mr. WILSON. Does it mean you are pushing the environmental control system and its capability when you make these paint changes? Does it mean that you have to operate at either end of the extremes of the specs?

Mr. GRACE. Actually, it is the other way. There is a lot more capacity there to handle the heat than we would have to have. We could add considerable equipment in there, in terms of heat generation, and still handle it with the environmental control system.

Mr. EHRHARDT. It is a self-adjusting system so that, as the temperature drops, it essentially shuts itself down so that it does not take away more heat than necessary.

Mr. WILSON. It is not a mis-estimate of the environment--it is the efficiency of the environmental control system?

Mr. EHRHARDT. Not a mis-estimate of the environment.

Mr. WILSON. Not like the Pegasus program where the environment actually was different?

Mr. EHRHARDT. Here is another slide of the ring fully assembled (Figure 22).

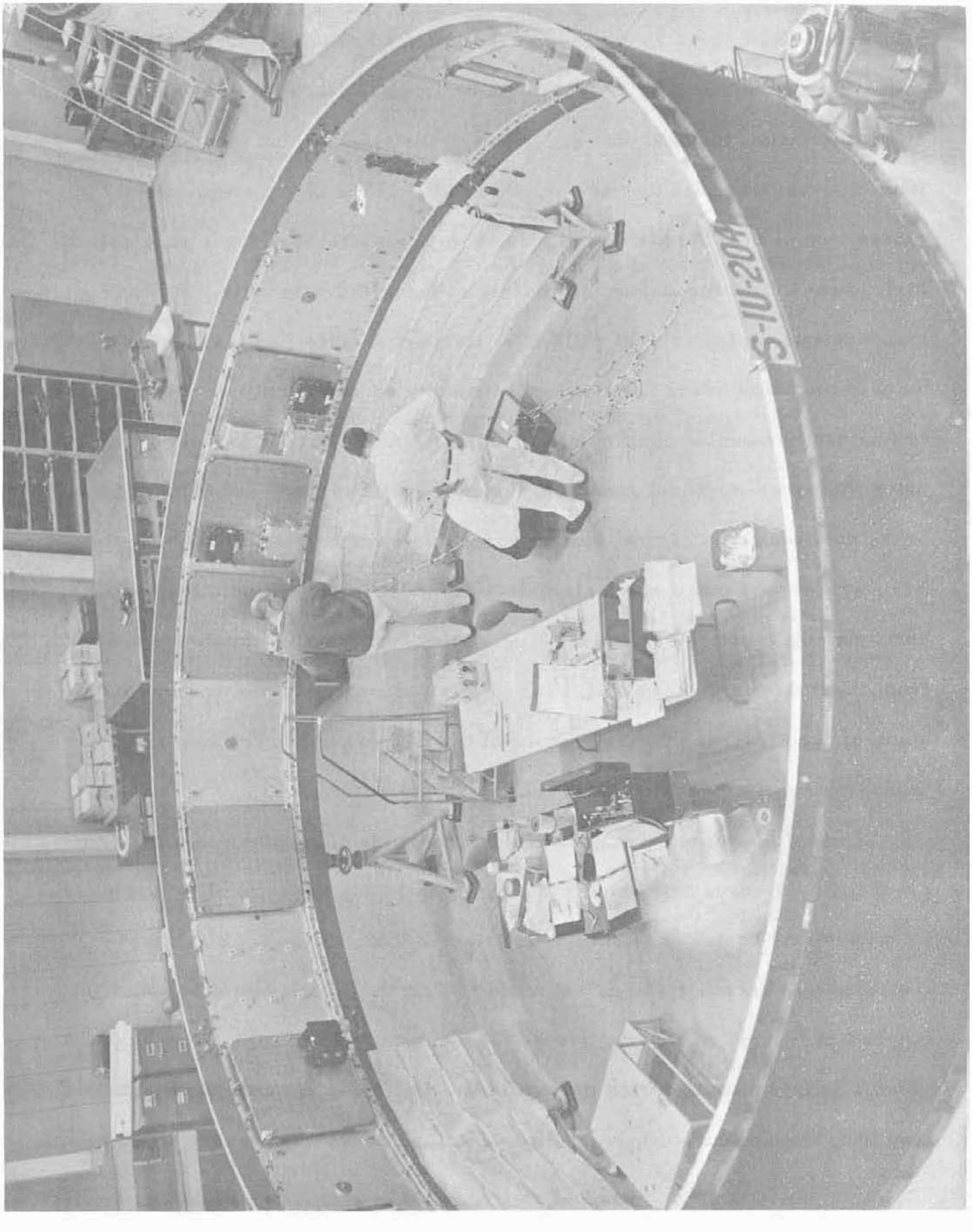


FIGURE - 22 - IU 204 ASSEMBLY (COLD PLATES)

Mr. EHRHARDT (cont.). When the splice plates are located and bolted on, we have a ring essentially 22 feet in diameter and 3 feet high. Now here we started to install the cold plates. They are the panels which take heat away from the various boxes that are mounted to it. In the next picture, we get a closer look at the cold plates. (Figure 23) There are 16 of these panels in the Instrument Unit. Black-box components are mounted with bolts. We have standardization of the actual drill holes in the cold plate. So long as the mounting units of the black boxes are 2 inches on center, or some multiple thereof, they can be easily mounted onto the cold plates. Manifolds at the top and bottom bring the water-methanol coolant to the units, pick up heat, and bring it back to the environmental control system panel shown on the next slide. (Figure 24) Here we have the pump which circulates the water-methanol solution in the environmental control system and sublimating device which expels the heat from the Instrument Unit itself. Take water, introduce it into the sublimator element, and it turns into ice because of the temperature. The heat from the water-methanol causes the ice to sublimate into water vapor.

I would like to move on to the electrical system and give you a little idea about that. We have four primary batteries to supply power to all of the electrical systems contained within the Instrument Unit. They are electrically isolated from the other stages as is true of all the launch vehicles. We have our cables located on the tray around the top here (Figure 25). Some 7 miles of wire go into manufacturing these cables. The basic purpose of the cable tray is to mechanically support these cables and provide necessary spacing,

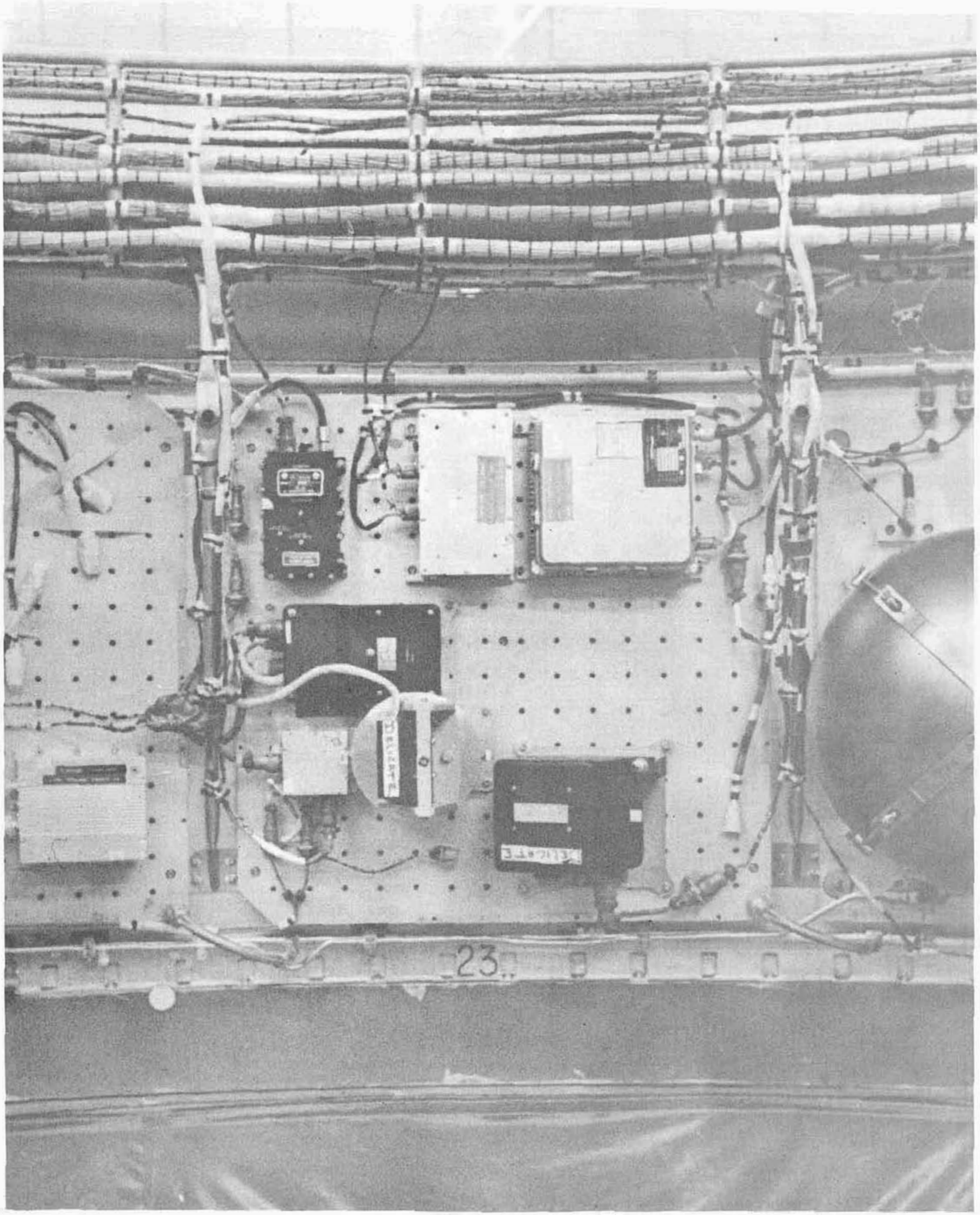


FIGURE - 23 - ECS COLD PLATES

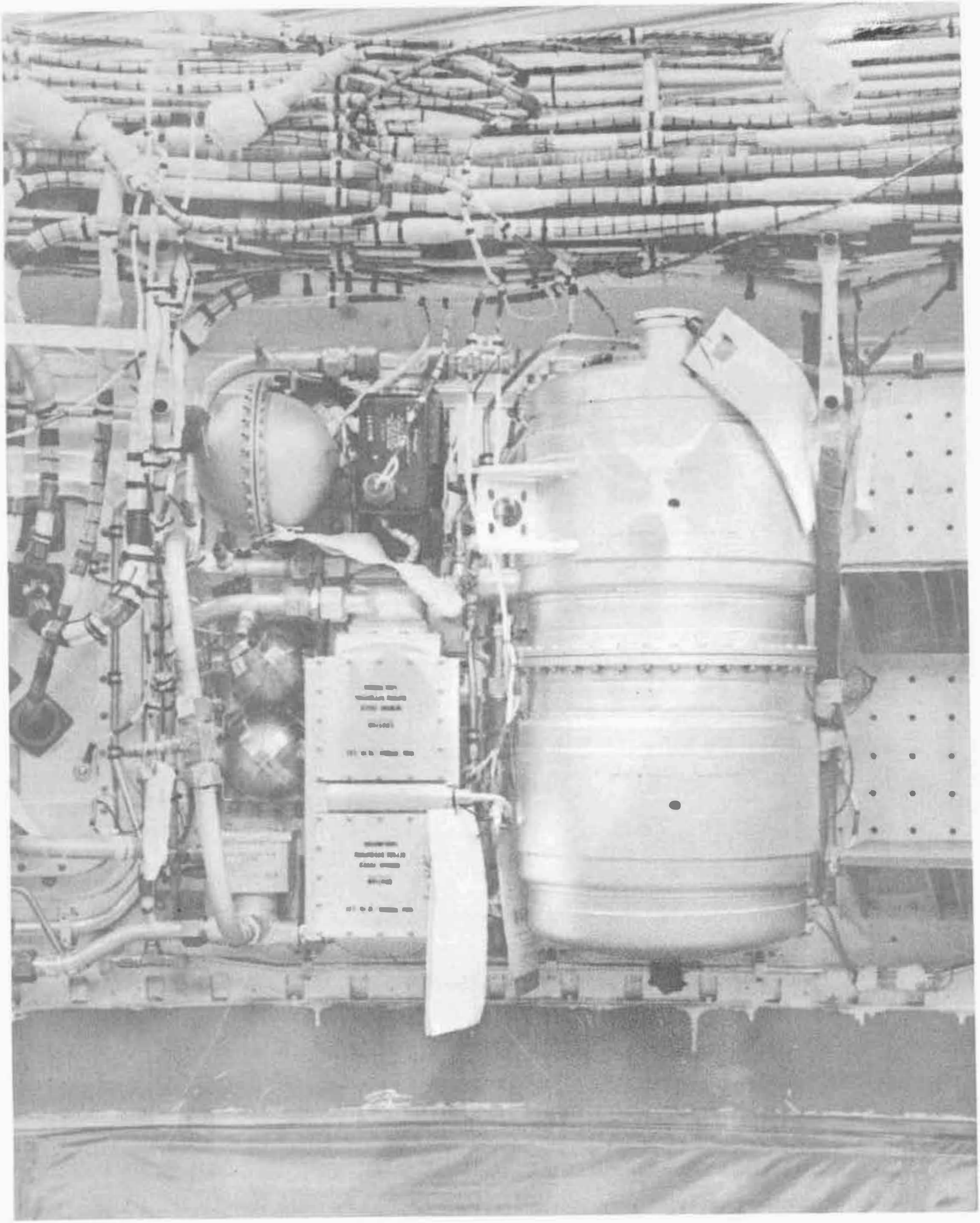


FIGURE - 24 - ECS PANEL

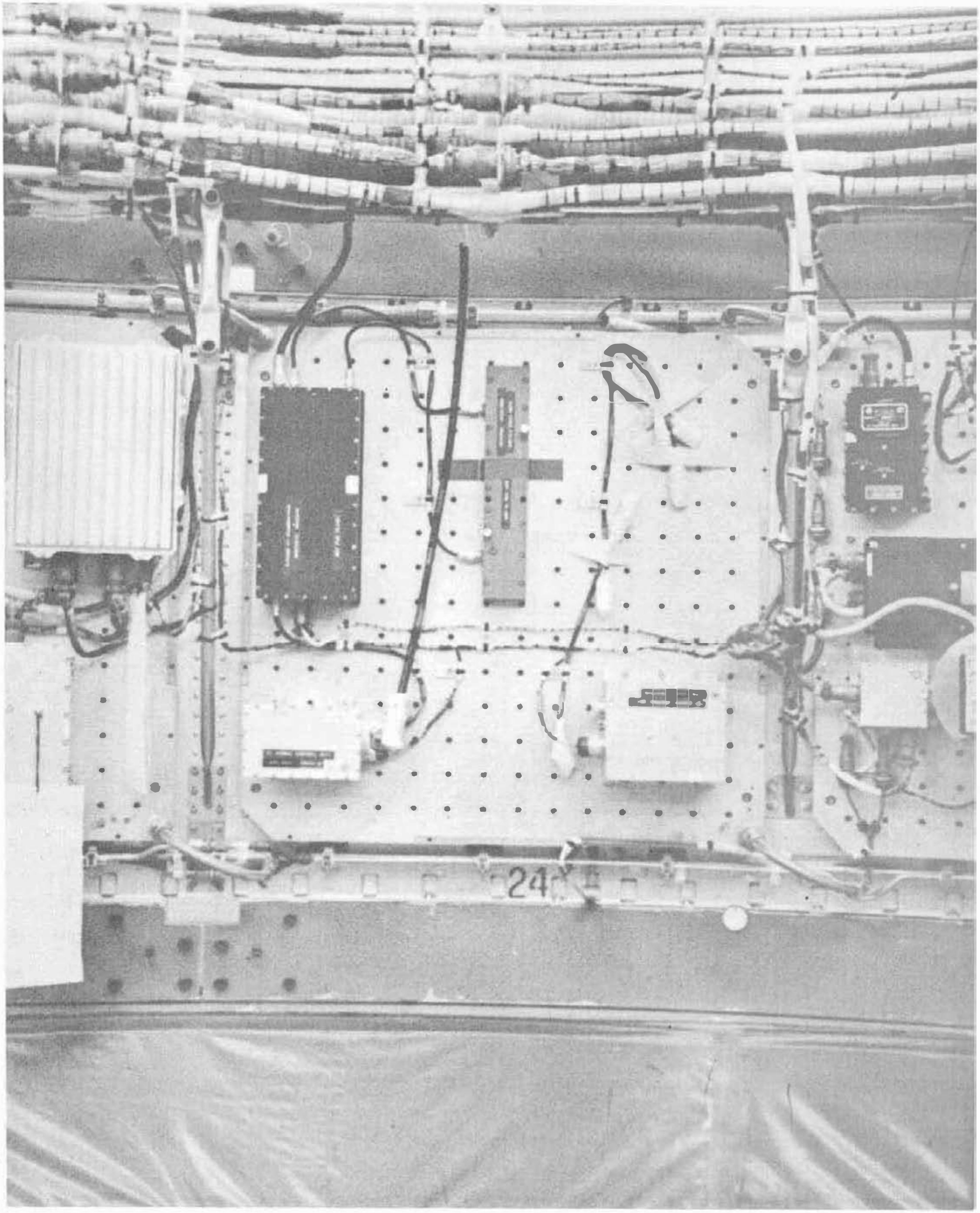


FIGURE - 25 - CABLE RUN

Mr. EHRHARDT (cont.). electrically, so that we minimize any interference problems and, essentially, eliminate them. The cables then drop down to the appropriate black boxes. The cable tray is actually mounted slightly in-board of the structure itself so that it fits with no interference difficulties up into the next stage. We had a little problem in the beginning, in terms of getting those lengths right. We now have our jigs set up so we get our cables in just right.

Mr. GRACE. We have an interesting interface problem there. As you know, the Lunar Module fits up in there and the folded feet come down right around the inside, and the hydrogen dome comes up in the middle. It is a very compact space there. We had a situation where some of the cabling on the outside could actually interface with separation.

Mr. WILSON. Other manufacturers have had considerable difficulty in fabricating, fitting, and checking out the cabling. Do you experience these kinds of difficulties with your cable in the Instrument Unit?

Mr. EHRHARDT. In case there were major differences from vehicle to vehicle, we have gone to some extra effort in terms of fitting the cables because we do not want them flopping around in there.

But moving on down to S-IU-205, for instance, many of the measurements are taken out now because the evaluation period is over. The cables become more or less standardized. We expect that some 70 percent of the cables, from one vehicle to the next, will be essentially identical and 30 percent will absorb these mission-type changes.

Mr. WILSON. It is only 70 percent standard? You do not simply have a standard cable system of the same type for the one that would be required for the flight?

Mr. GRACE. What we have--not that this is exactly what would happen--but perhaps this particular unit is not required. Obviously, you do not have all those breakouts down to that, if it is not in there. If it were not in there before, you have to put it in now--all those breakouts have to be added. So, the answer to your question is: Yes, we only have about 70 percent commonality, and that is just a rough figure. It varies considerably from unit to unit. Cabling is an area where we have to plan to make changes.

Mr. EHRHARDT. Well, in order to meet the varying mission requirements, there is a need to modify cables. The electrical system has certain flexibilities built into it, and that will be my next slide. (Figure 26)

A typical example: On S-IU-203, a television system was employed, and special cabling was needed to service it. The television system would not be on subsequent vehicles. If there were a need for a television system on a later vehicle, in that case, there would be some cables added.

In order to allow a circuit change, without redoing cables and developing a brand new Distributor, the Distributors are designed to be essentially like a plugboard. Like one of our IBM machines, we can plug in and out to hook it up. An incoming terminal wire may be connected to an outgoing terminal simply by using a jumper wire. If there is a need to connect A to A in one mission and A to B in the other mission, we make the change in the final buildup

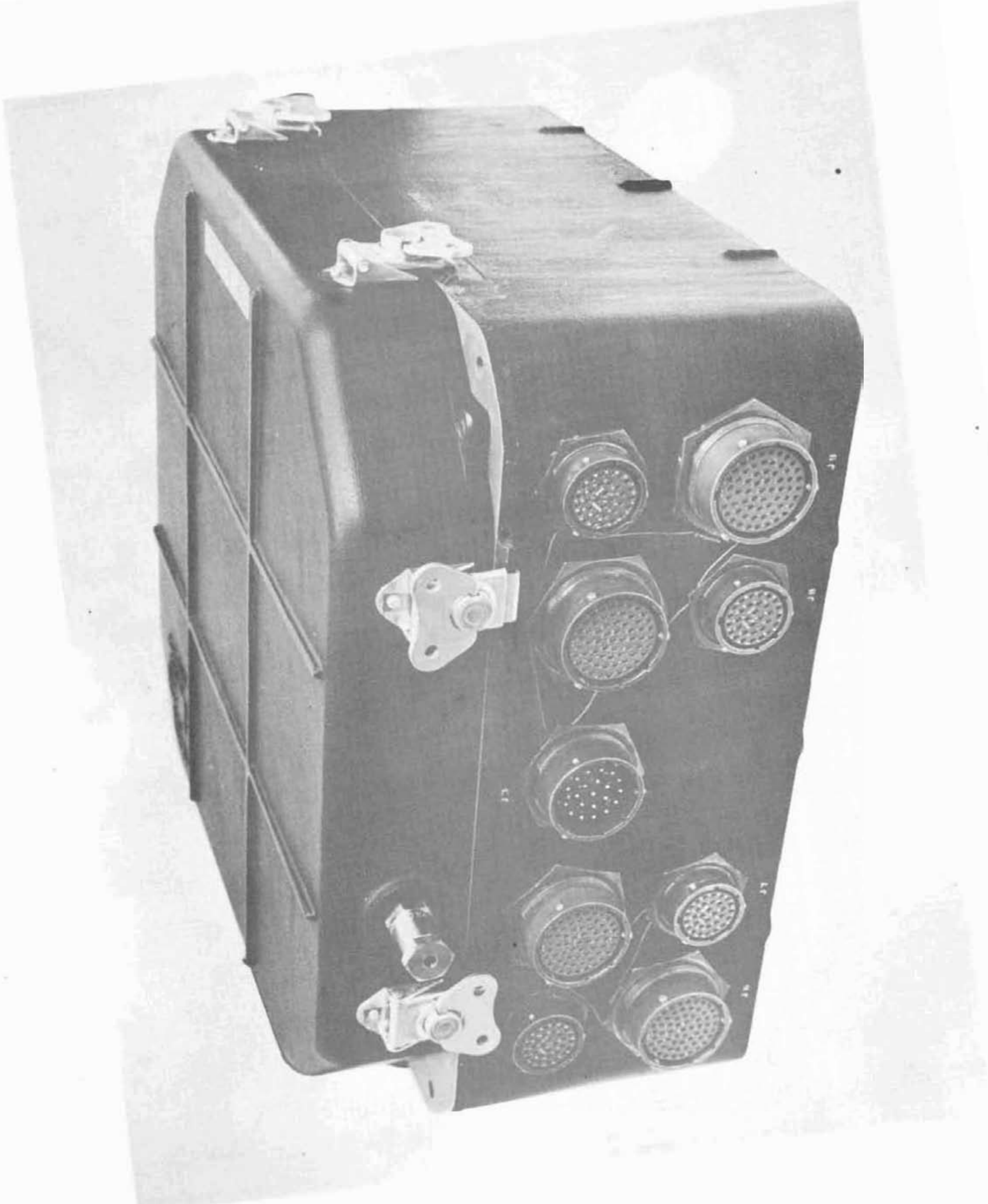


FIGURE - 26 - DISTRIBUTOR

of the Distributor itself. Therefore, the cables and the basic Distributor do not have to change. This scheme considerably reduces the lead time to design and fabricate the Instrument Unit electrical cables and Distributors. We make most of the wiring changes in the Distributors.

Mr. WILSON. Is this susceptible to field changes as well as here?

Mr. EHRHARDT. We have made changes at the Cape. We try to minimize these.

Mr. GRACE. Mainly because we like to have as near to 100 percent checkout of the exact configuration here in the factory and not have to do that kind of thing at the Cape. You always have to do a little, but the more we can minimize that, the more comfortable we feel. IBM makes the Distributors here at its Huntsville facility.

Mr. EHRHARDT. Since there is also a need to modify switching requirements from a mission standpoint, there are pluggable relays that can be put into this unit as required. Again, not the need for a redesign of the Distributor, but just to plug it in at the appropriate relay.

Mr. GRACE. Mr. Ehrhardt, how many of these are in the unit?

Mr. EHRHARDT. There are five different types. There are two Measuring Distributors and they service most of our measuring equipment, a Control Distributor and two Power Distributors.

Mr. GRACE. The number of these vary, too. In an instance where you have a lot of measuring going on, you may have more Distributors because you have more things that have to be done.

Mr. WILSON. I am wondering, as you go through the flights, whether, in fact, will there be less than the 30 percent change in the Instrument Unit that you are talking about now?

Mr. EHRHARDT. That could well be. It could become completely standard. I have to point out that, to date, the various missions which are outlined require some mission-type changes, and we expect them to continue.

Mr. FRIETAG. What was your estimate as to some sort of percentage number regarding change from mission to mission?

Mr. EHRHARDT. That was the 30 percent.

Mr. FRIETAG. Is every mission the 30 percent?

Mr. GRACE. No, that is an average of the first ones. Though we have not had a great deal of experience so far, we are up to S-IU-204 in the Uprated Saturn I and we are on the S-IU-501 and 502 on the Saturn V.

Mr. EHRHARDT. There was a net reduction in the number of cables in the total electrical systems from S-IU-204 to 205. The plan in the program was to significantly reduce the number of measurements, essentially going operational. Cables go from something like 170-180 down to 120-130. It has been just a complete deletion of a lot of cables and Measuring Distributors, simply because, on the operational vehicle, they are not required. Now, I guess, I have to fall back and say that we want to get a little more experience on those--maybe my 30 percent is high.

Mr. GRACE. The present thinking on the program is that launch vehicles will be more standard as we get further into the mission. We talked early in the contract negotiations with MSFC that they would be fairly standard. We have

Mr. GRACE (cont.). modified our thinking a little, based on our experience to date.

Mr. WILSON. Change infers additional cost, and, I assume, you will explore this in further detail as we get on in the presentation. Change would seem to have some effect on both schedule and cost.

Mr. GRACE. What you say is true. Change ordinarily is associated with increased cost. However, I think we need to very carefully understand, in the case of the Instrument Unit, that it was specifically designed to provide the capability to modify the overall system from flight to flight and be adaptable to what you want that mission to be. This is not a change in the sense that you might ordinarily think of it. If we had big problems, we incorporated the change. We anticipate these changes, and we do a lot of things in designing the Instrument Unit since we expect that these things are going to be there. In other words, having the flexibility in it that will allow us to put these changes in with a minimum impact on schedule and cost.

Mr. FRIETAG. I think you might add to that, that in addition to the fact that we did decide to concentrate the variability in the Instrument Unit, S-IU-201 to 204 and S-IU-501 to 503 are designated as vehicle development flights. This is where the development changes, superimposed on the mission assignment changes, would be. It would be greater in these seven Instrument Units than it would be in the S-IU-504, which is quite standard. Of course, the Uprated Saturn I is a little different because the mission variation there is quite different from that of the Saturn V series.

Mr. EHRHARDT. I want to give you a quick look at some of the components so that, when you go on the tour this afternoon, you will have a better feeling for what they look like. Here is the Inertial Platform which we mentioned is GFE to this contract. (Figure 27) It is built by Bendix Corporation. It has integral cooling, as do several other components. The Platform, the Launch Vehicle Digital Computer, Launch Vehicle Data Adapter, and Flight Control Computer have integral cooling, as part of the actual design, to remove the heat from the interior of the components by circulating a water-methanol mixture through them. The information flow from the Platform, we said, was to the Launch Vehicle Digital Computer and the Launch Vehicle Data Adapter shown in the next picture (Figure 28). The information then flows to the Flight Control Computer which outputs the signal to the power stages (Figure 29).

Mr. WILSON. What is the size of the memory bank?

Mr. EHRHARDT. That is variable. You can have up to eight modules with 4000 words. Each word is two instructions, so you have a possible 64,000 instructions. We are flying four memory modules on S-IU-201. S-IU-203 has six memory modules, and S-IU-501 is going to be eight memory modules.

Mr. GRACE. The usual problem with digital computers is that, no matter how big you make the memory at the outset, everybody says, "What in the world do you need that much capacity for?" No matter how big you make it, there are people who can figure more things to do than the computer can handle. That makes a little problem for Mr. Meadlock because he has to sandwich it all into the program.

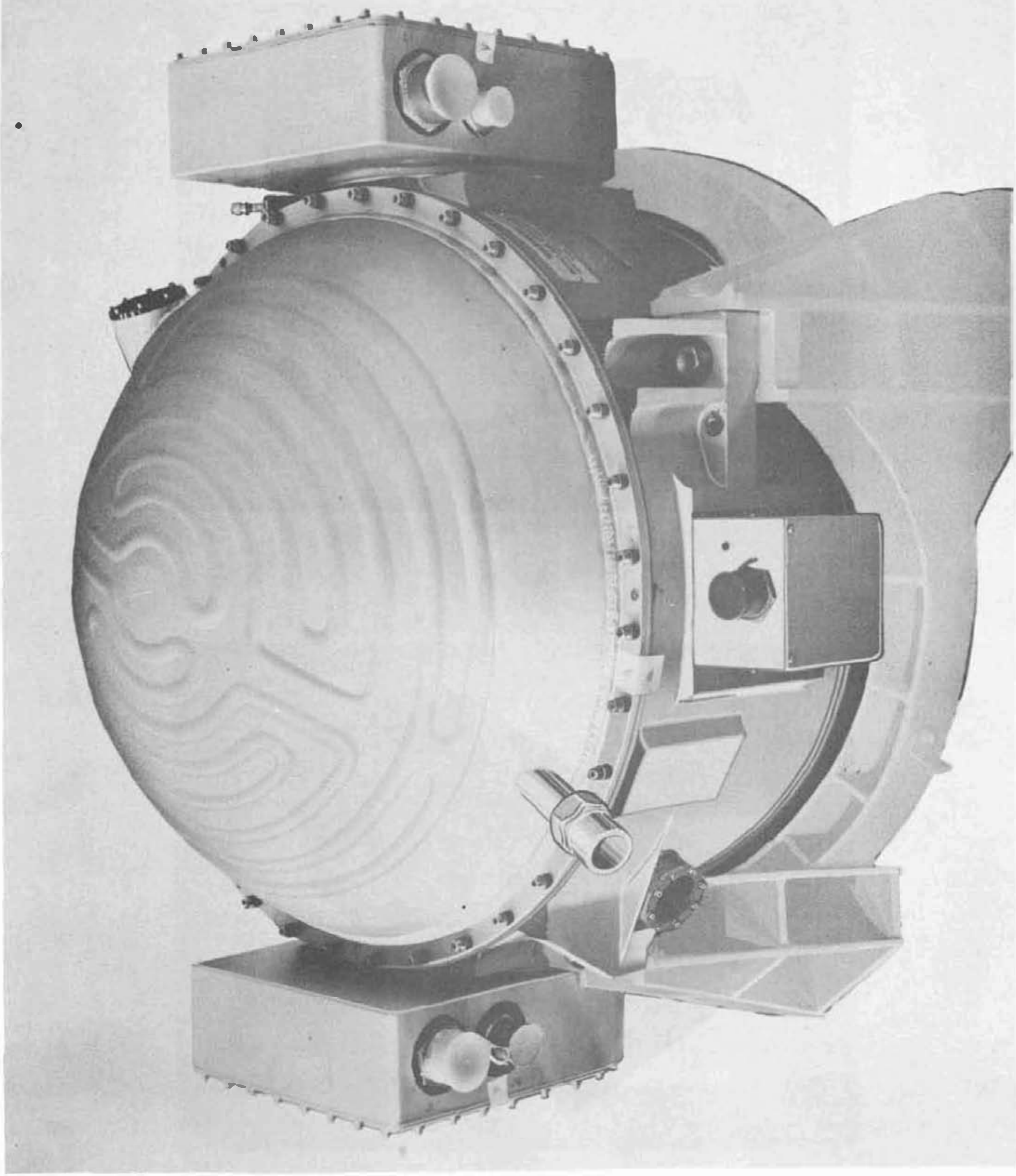


FIGURE - 27 - ST-124 PLATFORM

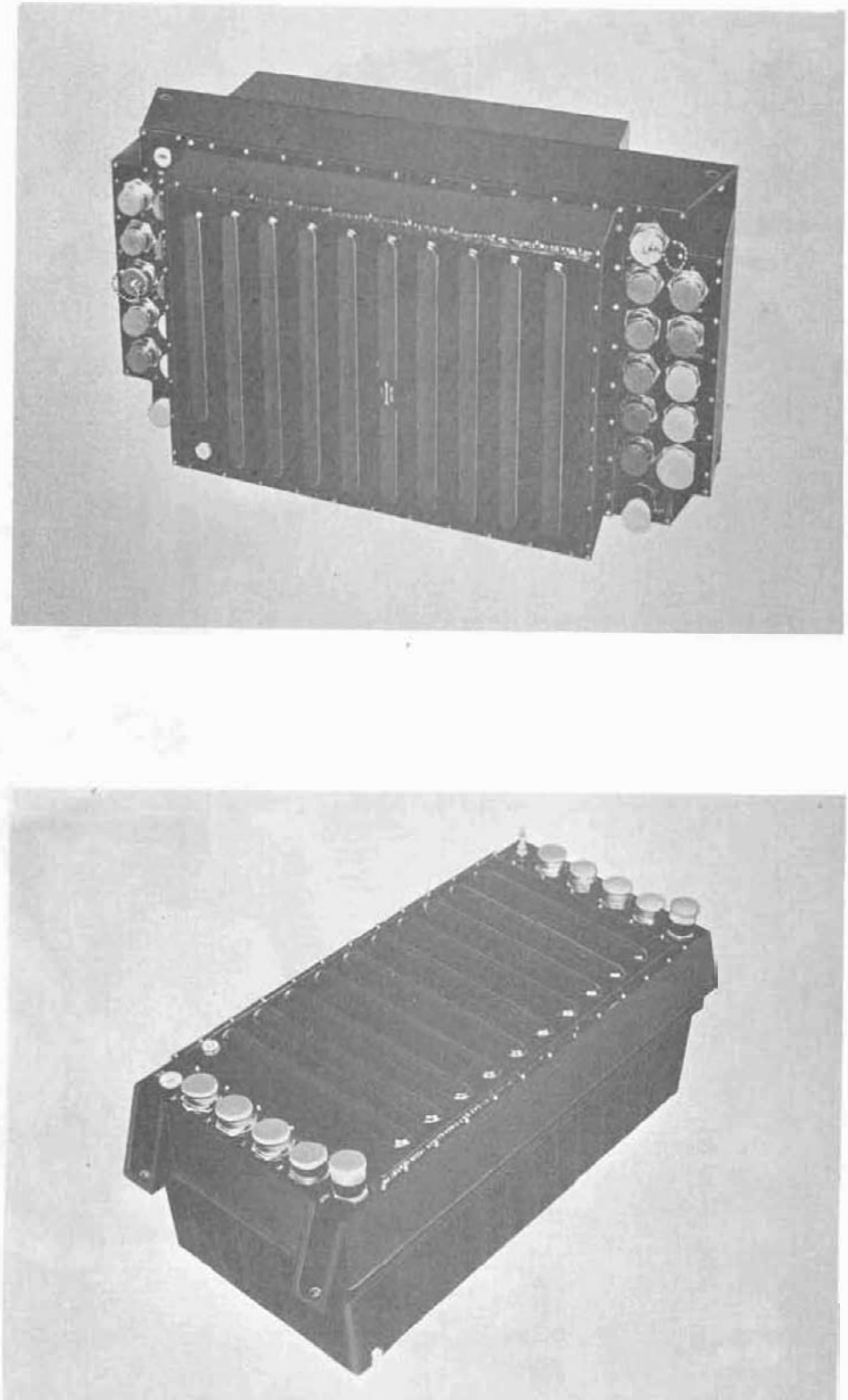


FIGURE - 28 - LVDC / LVDA

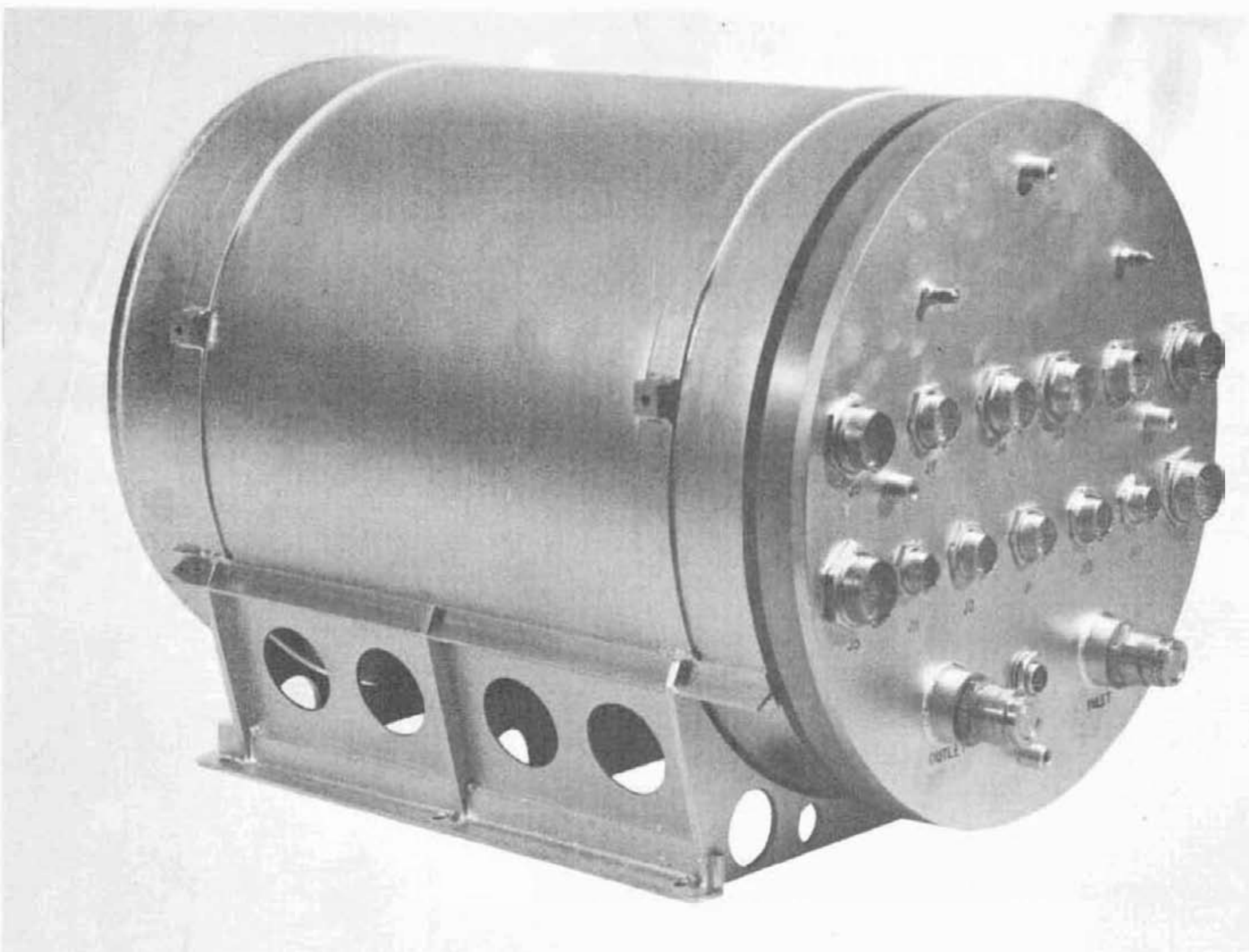


FIGURE - 29 - CONTROL COMPUTER

Mr. WILSON. That is an interesting point. Just how much of the change work you have seen in these early development vehicles was NASA-initiated, as opposed to IBM-initiated, in terms of seeing problems and changes? You say 30 percent change. How much of this would you tag IBM and how much NASA?

Mr. EHRHARDT. May I clear one thing here? You have picked up my 30 percent, which is only for the Electrical System, and I think you are thinking of it now in terms of the total Instrument Unit.

Mr. GRACE. To put a number on that, I can give you a few numbers, just for statistics....

Mr. WILSON. I am not interested in a number and statistics to the decimal point.

Mr. GRACE. In S-IU-201, just to give you a feel for it, we had over a thousand changes, and S-IU-202 had four hundred of them. Back in those early phases of S-IU-201 and 202, I think you would have expected to have a lot of them because there were a lot of problems that had to be worked out as we put things together. That kind of change is way down at the noise level. The kind of changes we are now getting are changes that we put in to correct things that we discover in the test program, dates of actual launches, changes that had to do with additional requirements that get imposed as a result of a mission, and conditions in terms of the program. To try to decide who originated this change, whether it was Marshall or IBM, is a little difficult. I would say that most of the changes in the early phases came in as directed changes. That does not necessarily mean that Marshall decided to make the change and imposed it on IBM. We are working so closely together on this that it is hard to say, in many

Mr. GRACE (cont.). instances, who found the need for the change.

Mr. WILSON. Do you have a formal change procedure?

Mr. GRACE. Absolutely.

Mr. LERNER. From a statistical standpoint, we received 205 directed changes prior to the launch of AS-201. They were instituted by either Marshall or IBM. From AS-201 on, to date, we have only received an additional 166--that includes a series of vehicles. So there is already a significant downward trend.

Mr. GRACE. You recognize, of course, that the Instrument Unit is a Marshall Center development, and we are taking over responsibility for it. A number of things were still in the final stages of development, with considerable testing still going on at the various laboratories at Marshall Center, while we were in the process of trying to buy these units and put them in. Changes were incorporated as a result of this testing. They were doing as well on testing as we were doing. It is very difficult to answer your question in a very straightforward fashion.

Mr. WILSON. Is this type of testing still going on in-house with IBM?

Mr. GRACE. Pretty much in-house with IBM, but there are additional requirements for testing. For example, if a change is made to a subystem or a unit, we must run through qualification tests to prove that it is flightworthy. There are still some tests like this to be run.

Mr. WILSON. Are you going to talk about your Quality Testing, on a current basis against current units, a little later?

Mr. GRACE. We can give you a general update on that.

Mr. WILSON. That does not alter the statistics, as you would like to see them?

Mr. LERNER. Those are the actual numbers.

Mr. WILSON. These are changes that are still in process, but have not been completed.

Mr. GRACE. We still have quite a few, and I think that every time you look at any of these presentations--of the type that you are referring to--you have to remind yourself that this Instrument Unit is designed to have these changes concentrated there. Thus, there will be a higher number of changes in the Instrument Unit than you will ever see in the powered stages--if the program runs according to plan.

Mr. POWELL. Exactly. One thing, to get a feel for what kind of a static change level we will have, we will see more of that with a standard vehicle. But, if you look at the statistics Mr. Lerner just gave out, you are looking back at S-IU-201, and we have a large number of what we called "make it work" changes. We developed the Instrument Unit strictly on paper and we went through a separate test program, but we never really ever put a full flight configuration together until we got to S-IU-201. We started putting the bolts in the holes, and sometimes the hole may be square and the bolt may be round.

Mr. EHRHARDT. That is why, sometimes, these change numbers tend to be a little deceiving. Someone can think we have tremendous problems. Some of them were, but there are small changes, that still count as a change.

Mr. WILSON. Some of these are schedule-critical or cost-critical, where others are not?

Mr. LERNER. To correct a misapprehension on an upward curve of these 205 changes, there is one particular change that Mr. Powell has referenced to as a "make it work" change. This was a single change document against which 439 specific actions were charged. My statistics, from a contract standpoint, show 205 directed changes, against 1 of which there are over 400 specific actions.

Mr. EHRHARDT. Perhaps I can put the subject in perspective this way. We do have a number of control documents which recognize when there is a need for something to be different from vehicle to vehicle. In the measurement area there is an Instrumentation Program and Components list which defines the instrumentation requirements 18 months prior to vehicle delivery.

Mr. GRACE. As a result of this list, there is some early planning in terms of things which would affect the cable, power distributors, and the like. But we have not built them at that particular point.

Mr. EHRHARDT. But here is planning information that there is a need for--something to happen--and we are starting to recognize that early enough to get it into the program. We have a final design review with Marshall on the actual Electrical System some 16 weeks prior to the actual checkout of the hardware. Here is where we finalize anything that has come in. We have essentially done the design change, and we now present a total system design package to them. You might say we are at the point where, if you change something from there on down, you would start to see cost or schedule impact. But at that point, we think we have a layout that minimizes costs. I am not going to say it changes

Mr. EHRHARDT (cont.). at no cost, you know you always have to put pen to paper. But it is not the large type of cost impact where you have a bunch of hardware built, and it all has to be changed. The same thing is true in software. We do have mission defining documents that come out nine months ahead of Instrument Unit delivery. These documents define the basic trajectories, and the like, that we are to use for this mission. Basically, there is an in-house control document that defines the actual logic of the software, and this is what we program against. Within these bounds, there are definite plans to confine the ability to make changes so there is a minimum of change done, and yet, remain sufficiently flexible to accomplish the desired mission objectives. We are getting more and more successful every day, too.

Measurement system--just a quick few words on this one. (Figure 30) Quite a number of different measuring devices are used. Essentially, Marshall has developed a number of different types of transducers to measure pressure, acceleration, acoustics, and flow rates. If there is a need for a measurement change, we can usually accomplish it by using one of the existing transducers. We are not talking about having to go out and design something. What we do to program our measurement system is to put in one of these available devices, assign it to the appropriate measuring rack (Figure 31) for conditioning, and to the telemetry system for multiplexing and transmission to ground stations. We try to get standardized modules and just plug in the right one for the specific use and it goes into the appropriate slot, depending on the mission requirement. There are a number of antennas located around the periphery of the Instrument

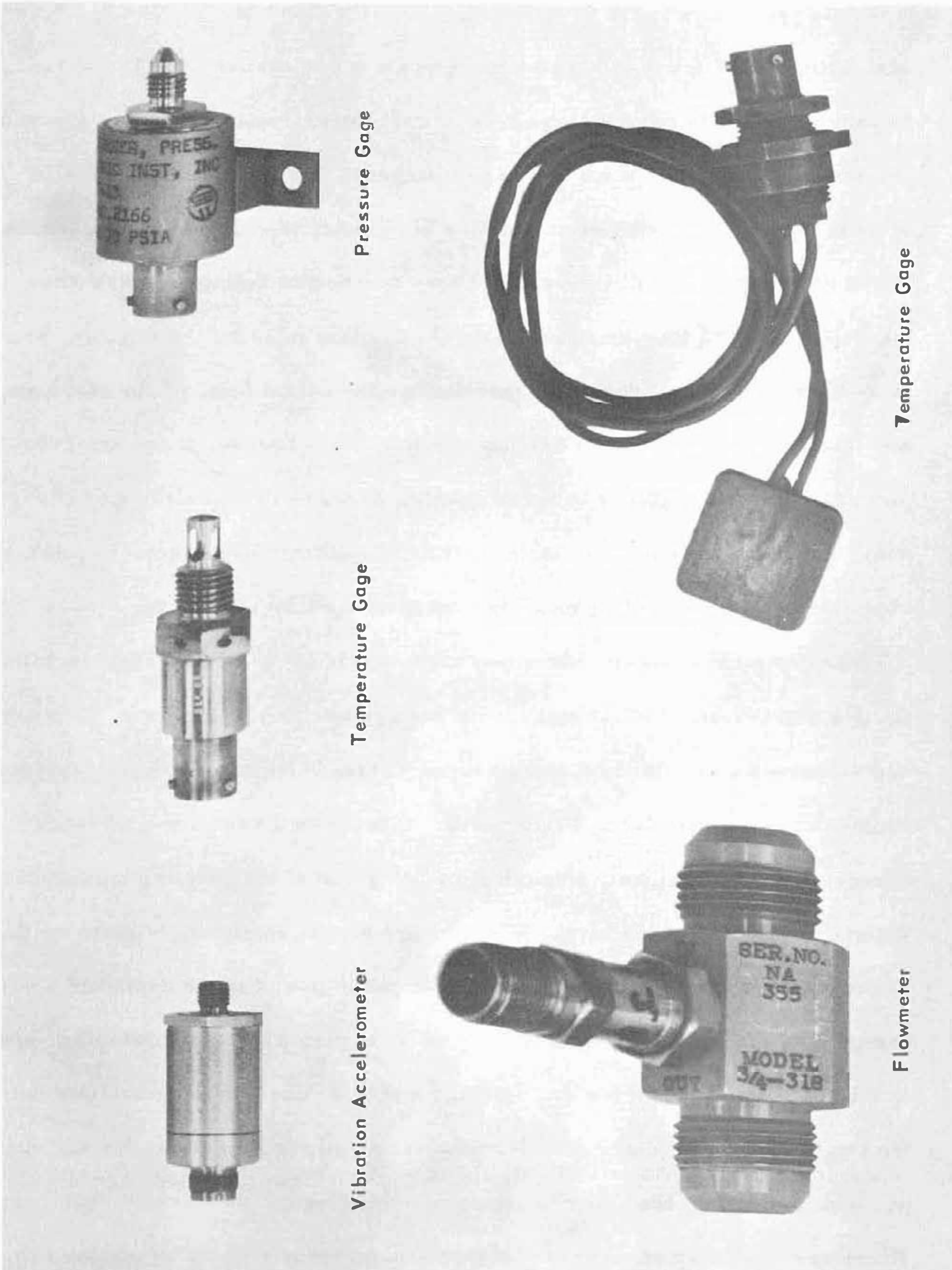


FIGURE - 30 - TRANSDUCERS

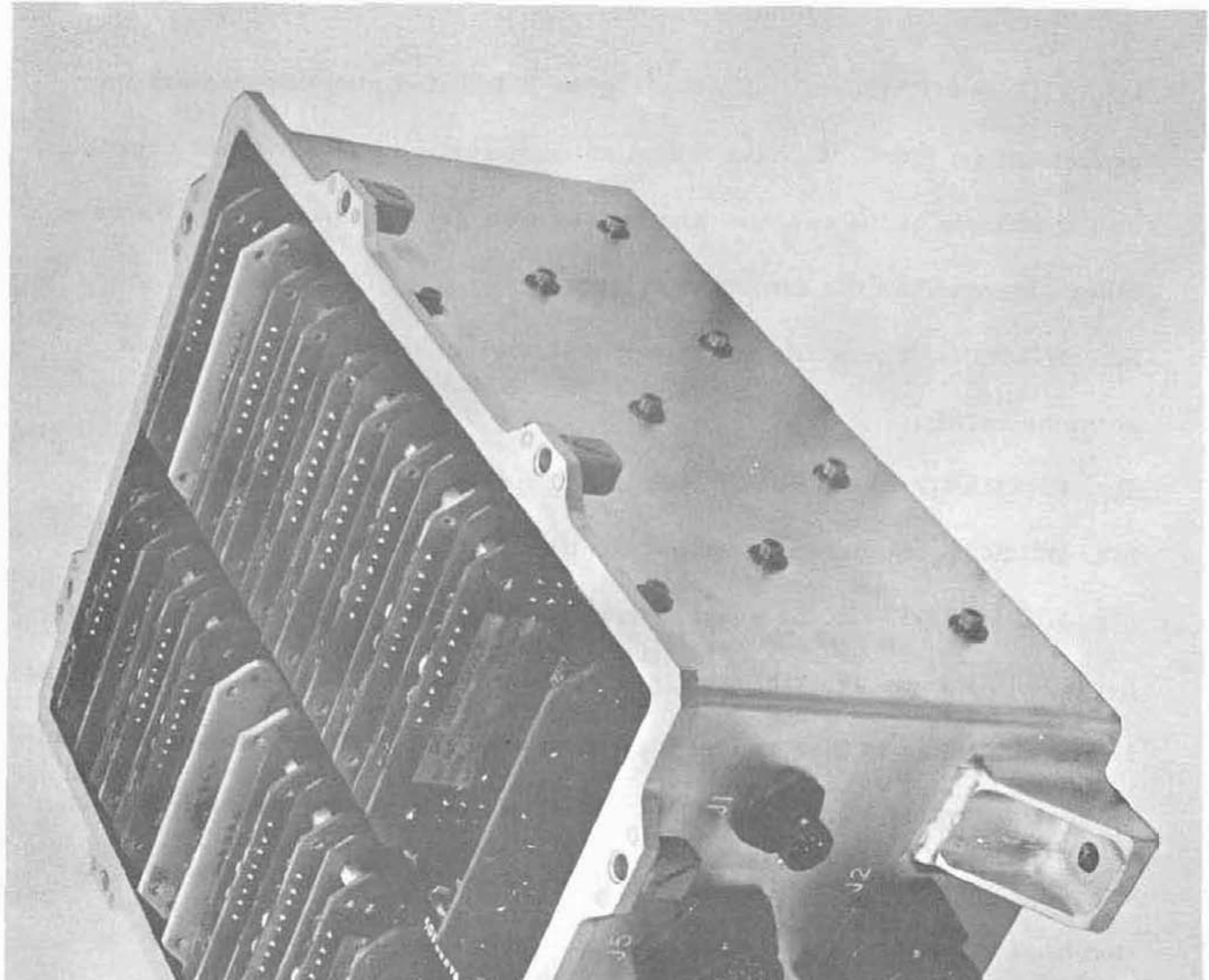


FIGURE - 31 - MEASURING RACK (COVER OFF)

Mr. EHRHARDT (cont.). Unit. (Figure 32) Telemetry coverage is independent of attitude. We have a dual antenna system so we are not dependent on the attitude of the vehicle, and we can still get our data down. We have other antennas for the command system.

Mr. WILSON. You would not lose it with violent roll? You could still communicate?

Mr. EHRHARDT. We do not have any programmed violent roll.

Mr. WILSON. Sometimes you get it without programming for it!

Mr. EHRHARDT. In the event it does come up, we have some emergency detection systems available that are sensing that kind of a thing. In summary, I have attempted to give you an idea of how the flexibility of the vehicle, in performing various mission roles, is concentrated in the Instrument Unit, how we plan to minimize the cost and schedule aspects to meet the requirements of the mission. Further, I hope I have been able to show you some of the reliability that has been built in so that we can count on success of each mission. Is there any other question?

Mr. GRACE. We will be getting into more of the specific technical aspects of the program. We did bring a few items to give you an idea of the technology. The items are on the table in the back of the room.

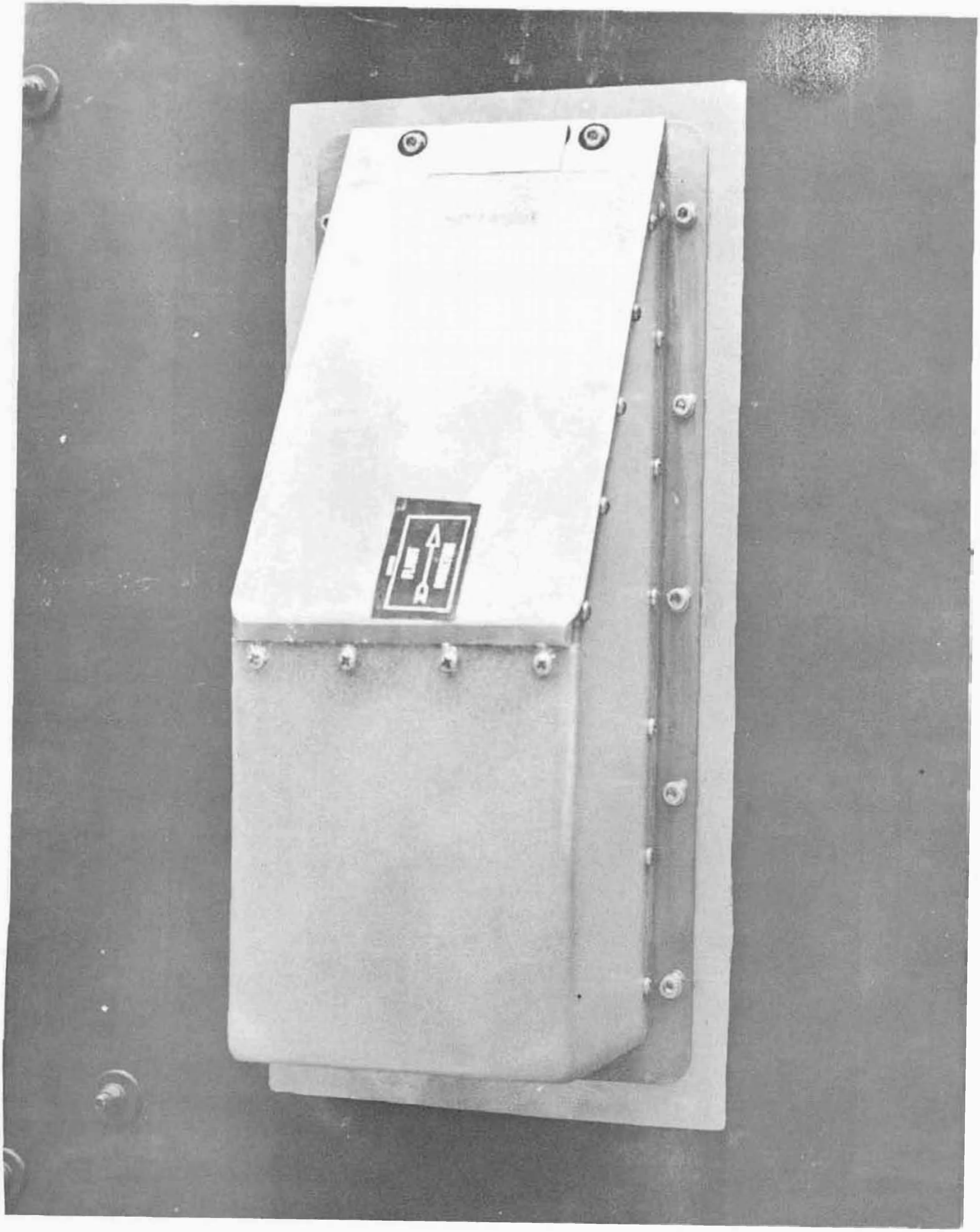


FIGURE - 32 - ANTENNA

PROGRAM STATUS-PROBLEMS

PROGRAM STATUS - PROBLEMS

Mr. WILSON. You are going to start off on program status and problems and lead into this question, I am sure. As I understand it, the Instrument Unit contract was negotiated before you had the current schedule to follow. Is that essentially correct?

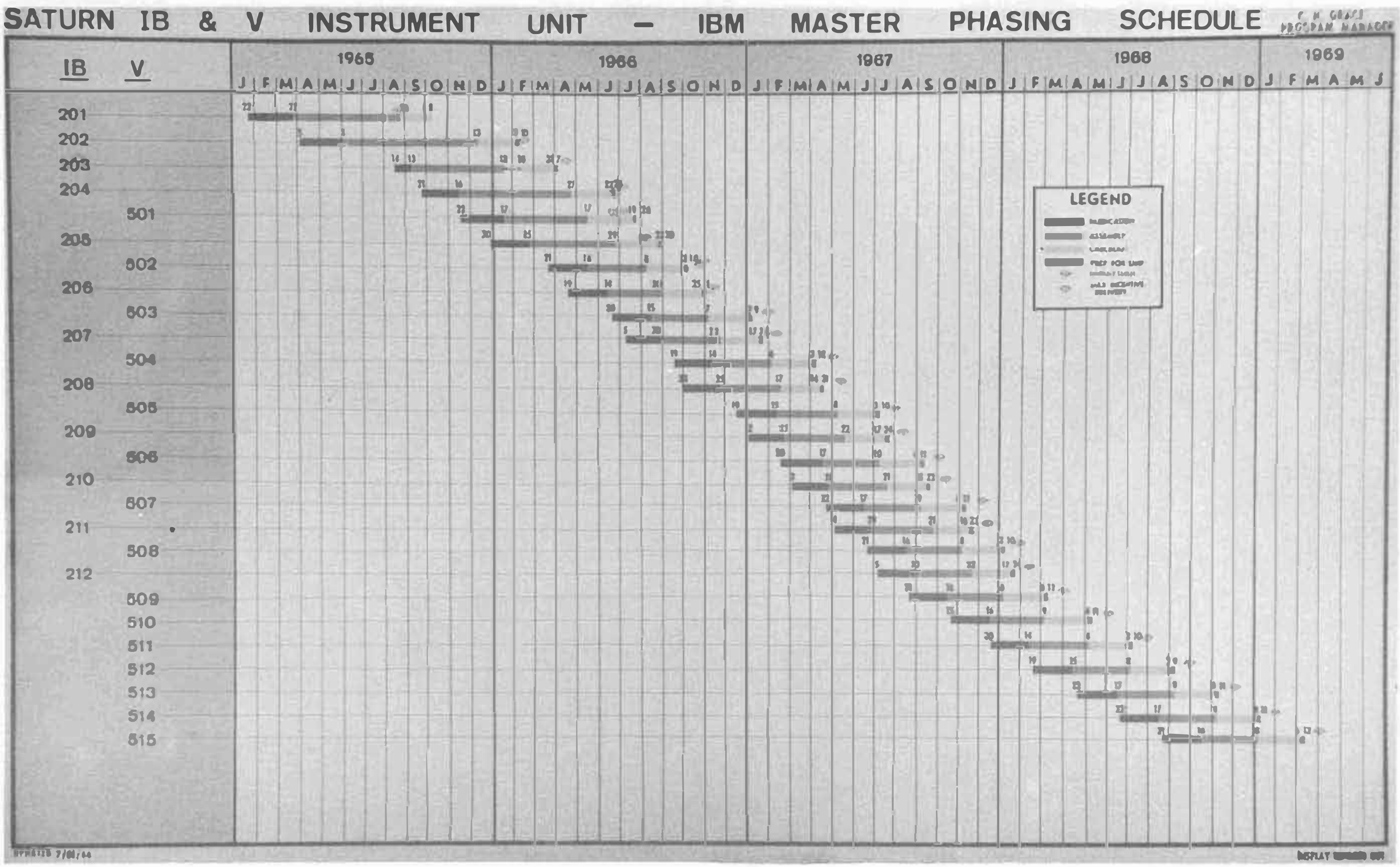
Mr. GRACE. I think so. We want to be sure we answer you correctly. The contract was a little over a year in definition and negotiation, before it was finally executed. We were awarded the contract in February 1964, and in March 1965, I believe, it was executed. In the process of doing that, there was considerable evolution in the scope of work with all of the Marshall laboratories, as they jelled their thinking in terms of what we were to do. We had, at the outset, supported Cape Kennedy. We still do, as a matter of fact--considerably more than we originally discussed. All this was negotiated in terms of a schedule which at that time was, I think, generated in an environment of recognizing the tremendous amount of problems in the phase-over from Marshall to us, and so forth. It is the desire on the part of the Marshall people, and I believe it is a natural desire, to give themselves enough cushion to recover from difficulties, if they did occur, in getting the Instrument Unit out. As a result, the schedule was negotiated into our contract. It was a compromise between the easily seen, near-in problem which says we must have that much time to do it and the influence of such a big job of getting it phased over, out in the future, where we can allow ourselves a little more time.

Mr. GRACE (cont.).

I might as well get started here, because in discussing status, we can cover this in relation to the total program.

Mr. WILSON. My specific question here is: "How has this affected the cost, and has it been an advantage to you to make changes, in terms of total cost and time, based on the difference in what you originally started and what actually is happening now?"

Mr. GRACE. Up until this point in time, the fact that our contract schedule is in advance of the program requirement has not affected the cost. In our opinion, it would have been just about the same, because in the early phases of this contract, we had our master phasing schedule--our internal IBM schedule that we are working to in order to meet the contract schedule dates. We were just barely making the deliveries consistent with the Apollo Program requirements. We are talking about activity that took place in here when we were pretty much on the schedule we had to be on, so the impact (cost) of the program schedule has not yet been felt. But it will be felt now, and we have been working closely with Marshall to assess this. They are well aware of this and understand what we are talking about. When you look at this schedule, it is based on the delivery of the Instrument Unit to our current contract. (Figure 33) This little arrow here is the contract target right out of our negotiated contract. This is within weeks of when it ought to be in terms of program requirement. When you get down here to the last few, it is 7 months in advance of the currently defined program requirements. Now, if we address ourselves to this schedule and gear ourselves to the pace it takes to meet this schedule,


SATURN IB & V INSTRUMENT UNIT – IBM MASTER PHASING SCHEDULE
IB
V
1965
1966
1967
1968
1969
J F M A M J J A S O N D
201
202
203
204
501
205
502
206
503
207
504
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212
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514
515
LEGEND

FIGURE - 33

Mr. GRACE (cont.). it is going to increase the cost because of the necessity for extra effort and working around the clock to resolve problems.

If the contract schedule is moved out to this, the MA2 schedule, which is consistent with the program requirements, we have, as will be shown in a little more detail later, determined that it will reduce the cost of the program in FY67. It should be understood that Marshall had a good rationale for retaining us on this schedule. It will not reduce the overall program cost, because the present contract is scheduled to be finished in 1969, compared with moving it out into 1970. There is a level of effort that, in effect, is being deferred to a later time of year rather than be accomplished now. The total program cost for a stretch on this schedule is, in fact, greater. However, in FY67, this time period presented here, when you take a lot of activity and move it out into a later time period, you can reduce the cost in that time by deferral, and you do gain some actual dollar savings from the overtime that is eliminated. But the fact that you have to sustain a level of effort over a longer period of time, actually results in a net increase in the total program cost. These are the things that are being debated within Marshall in terms of what should we direct IBM to do. I think we are close enough with them to understand why we have been on the schedule we have.

Mr. WILSON. You are showing your incentive dates here, and you are well in front of those, of course, as you go out later and later.

Mr. GRACE. We want to get in front of them.

Mr. WILSON. How has this incentive contract affected you? And what is your opinion of the incentive contract from a performance, not from the profit, point of view?

Mr. GRACE. We really have not needed the incentive of the dollars in the incentive contract to motivate us to do what had to be done on this program. I would say, unequivocably, that on any program that we are involved in, dollar incentive is not the motivation that we have to get the job done in the time required. Up until now, we have had a fight on our hands to get the incentive fee earned, mainly because of the tremendously dynamic aspects of the program. There are so many changes, many of which have not been negotiated yet. Mr. Lerner is going into more detail on this for you. But a quick net on it; the incentive contract in this particular phase of the program has been a little difficult, I think, from Marshall's point of view and ours. I think it does provide Management motivation, but I frankly feel that in the case of IBM, we do not need that motivation to do our best to get these Instrument Units out to meet the program.

Mr. WILSON. During the current period, is your incentive primarily based on schedule or cost?

Mr. GRACE. It is a little complex. That is one of the things about it. Because it is a very complex structure, I would like to defer that, if I might, until Mr. Lerner talks about it. Let me just spend a little bit of time on this particular chart. By way of orientation, we had a difficult time in instilling, in everybody in Marshall, the level of confidence that we wanted instilled there--that we had a handle on this program, that we knew where the problems were, and

Mr. GRACE (cont.). that we were addressing them in a timely and aggressive fashion. We went to the extent of establishing this Program Control Center and including, in here, the things that you are going to be seeing--devices for program control and communicating, where we stand, and so forth. I think I can say without contradiction, that we now have that level of confidence from Marshall--now that we do have the program control. We know where the problems are and have taken action in a real timely fashion. It has been a wonderful relationship since we put all this together. Basically, what we do is take every Instrument Unit--on the Uprated Saturn I, we have 12 under contract and on the Saturn V we have 15. The contract shows that they are required through the First Quarter of 1969. What we show by color code here is the fabrication phase, assembly phase, checkout and delivery phases. We delivered S-IU-201 on October 8, S-IU-202 on February 10, and S-IU-203 on April 7.

Mr. WILSON. What was the break between assembly and checkout on S-IU-203?

Mr. GRACE. This is something that I will get into in more detail. Notice the blue checkout. You cannot have two of the same kind of units in checkout at the same time. If you finish assembly and the previous unit is still in checkout, you cannot begin to test the second until you get the first out of checkout. Actually, I think we were still incorporating changes and putting in modification kits during that period of time.

Mr. WILSON. This goes back to the fact that the checkout stands are not interchangeable?

Mr. GRACE. That is right.

Mr. WILSON. Are they done simultaneously?

Mr. GRACE. Yes, we do run the Uprated Saturn I and Saturn V simultaneously. We can do that with some exceptions. We did make some program savings by not duplicating the total facility. For example, the telemetry room and some of the RF rooms are shared between the two vehicles. We have to schedule the test to use that particular function for measuring that element within the Instrument Unit. We have to schedule them in sequence. We cannot do both of them at the same time. There is a completely independent and separate control room and computer for primary equipment involved in the checkout.

Mr. WILSON. Have you experienced much problem--does the checkout equipment change appreciably as the mission changes from vehicle to vehicle?

Mr. GRACE. The electrical support equipment, the specialized panels in the control room--some of the specific ones--do change and we have modifications that have to be made.

Mr. WILSON. Is this part of this gap that you show here?

Mr. GRACE. A little bit. You will notice here, for example, we completed assembly on the 3rd and we started the checkout on the 10th. That week we did need a little time to refurbish the checkout stations, as you will see when I get into a discussion of this particular unit. A week is the minimum time to make the changes necessary after you vacate the stand with the preceding vehicles.

Mr. WILSON. What is the normal time between your shipping it out and the actual firing, and how long can it stay down at Kennedy before the Instrument Unit starts to deteriorate?

Mr. GRACE. We do not expect it to deteriorate, but we have not thought about periods like 5 years or something like that. The kind of time we are talking about is 3 months, 6 months, or 1 year in which there should not be any deterioration.

Looking at what we are talking about here, it was the 8th of October when S-IU-201 was shipped to the Cape, and the launch was in February. The S-IU-202 was delivered on the 10th of February and is not launched yet, of course. It has been down there 5 months. The S-IU-203 was delivered the 7th of April and was launched about the 3rd of July. How long they are there varies somewhat, but we think it is generally going to be in range of 2 to 6 months.

Mr. WILSON. This chart would then indicate that all flights are going to go before 1970?

Mr. GRACE. Well, this chart, as I have already said, is well in advance of the launch dates, and we are going to show you another one over here which is the one on which we have been working with Marshall to get this schedule adjusted. In effect, it takes the delivery dates and does this (indicating movement to right) to them; in effect, the delivery dates run out into 1970.

Mr. POWELL. For clarification, let me just inject here that this was the OJ-2 schedule. This was the old schedule before they slipped to MA2, and the last two, S-IU-514 and 515, are scheduled for, I believe, February and May of 1970, now, on the Master Apollo Schedule No. 2. This was the old schedule which was the one prior to that one and which was never stretched out before.

Mr. REDFIELD. I believe that IBM is the only major space contractor that has not been adjusted to the MA2 schedule. There are a couple of other minor things; I think the engines are on the old schedule. Things that were standard production items, a lot of them are kept in the old schedule and a lot of the subcontracts. For example, out at North American Mr. Meadlock saw data which indicated that the Collins Radio and Communication equipment for the Command and Service Module are being delivered within one year. Their schedule is vertical; they will deliver 12 items in the first year.

Mr. POWELL. An old pipeline philosophy from Marshall's viewpoint, the pipeline is not full yet, it is relatively empty and until we get that fullness, we will not feel like we have the confidence to make tradeoffs and move the schedule. To date, we have not seen any reason, I think, from a cost standpoint, to re-project something in 1970. Since we do not know what kind of perturbations we are going to have in the next 2 years. We get a feeling of uneasiness if we start moving things around drastically.

Mr. WILSON. This has considerable effect on manpower and the type of manpower that IBM retains here, and I assume you will be talking about that as we go along; this is the other side of this coin.

Mr. GRACE. We have been talking with the Marshall management in these general things.

Mr. CLEARY. The reason we did not stretch out the Instrument Unit was that the total cost of the contract would go up if we stretched it out. The sustaining engineering and fixed overhead items would be used over a prolonged period of time, but now, in the spring of 1966, we have run into a serious expenditure problem--actual disbursement of dollars. If we can reduce the amount of current expenditures, --that is good, so far as a current dollars position is concerned. The only way we have to do this is to stretch it out. We are going to save money now, invest money now, and we are going to pay for it later on.

Mr. GRACE. One thing I think we need to recognize--we were asked a year ago to give you a quotation on the MA2 schedule. It came out, as I recall, over the total program, a $200+ million program--a $12 million addition as the total program cost for stretching it out like that. I am sure that was one of the reasons that MSFC then went slow about implementing it. Because of the additional cost of the program, they let us wait awhile and see how things progress. I would have done the same thing myself. Now we are talking about some things that we will be talking about later--follow on and the possibility of additional vehicles. If you do this and you shut the facility down, in a couple of years--a year later--you want to start it back up, you buy yourself a substantial additional startup cost. Besides, you have lost all the team. So

Mr. GRACE (cont.). there is a lot to be thought about in terms of program planning and to adjust this out in a way that you phase-in the anticipated follow-on. We have done pretty well on the schedule. Back in November (1965) we renegotiated the schedule of S-IU-202 to take into consideration all of the changes that had been done, and we set up a target date for delivery of the 15th of February (1966). Internally, we worked toward the 10th of February. We actually made the 10th. We have renegotiated delivery dates on those two Instrument Units, based on the direct changes we got. Obviously, the Government has the right to direct a contractor to do things under the Directed Changes Clause. The contractor has an obligation to come back within 60 days and say what the direction is costing in terms of money and schedule. Several of those impacts have not been negotiated for many Instrument Units--they were on these two. They have not been on S-IU-201, as a matter of fact, and that was the one that was probably impacted the most. Actually, the joint effort on 201 was pretty fantastic. I feel quite proud about it, and I think the Marshall folks ought to, too. We are in a situation now on S-IU-204 and 501 where a lot of things have to be taken into consideration in negotiation. Yes, there were a lot of changes that were involved and we ran into some trouble. For the first time we had a problem that impacted our ability to recover in terms of the schedule.

Over here, I will show you the near-term expansion of our portrayed schedule. This is what we call our status chart--that is our schedule chart (Figure 34)--from this period through S-IU-505. This is a little bit complicated

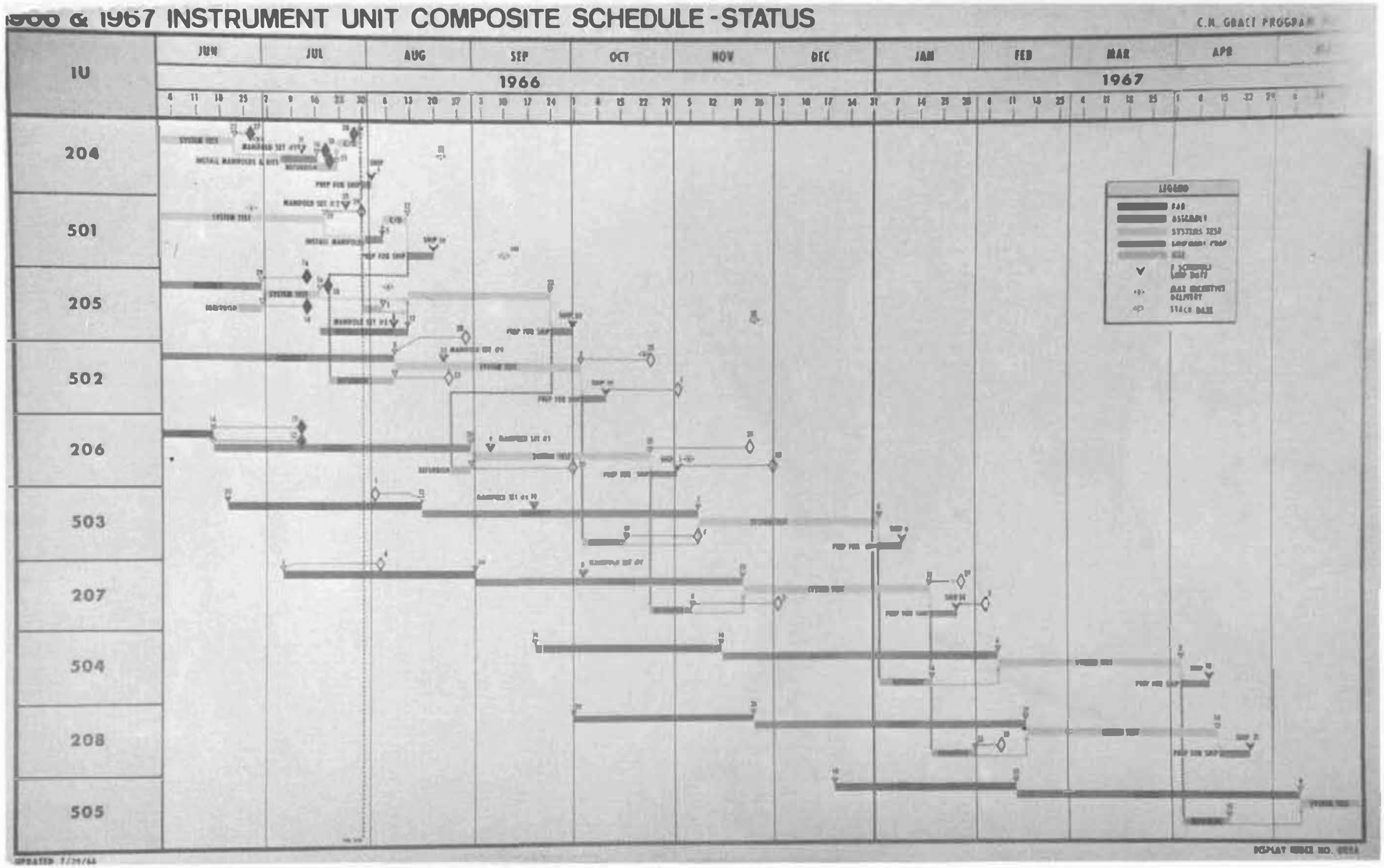

1966 & 1967 INSTRUMENT UNIT COMPOSITE SCHEDULE - STATUS
IU
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
1966
1967
204
501
205
502
206
503
207
504
208
505
LEGEND

FIGURE - 34

Mr. GRACE (cont.) if you are not used to sitting in here every week and watching things go on like we do with the Marshall people. I think it is very informative and I would like to take time to discuss it with you.

Obviously, it has dropped off the three units that were delivered. We are addressing ones that are in the house. That chart on S-IU-204, as you can see, calls for a delivery on the 29th of June. The S-IU-204 is still on the checkout stand; it is essentially finished. We are talking about a delivery by the 1st of August--about a month's delay. You can see what happened here. We were in systems test and scheduled to complete on the 22nd for our 29th delivery when we ran into a problem concerning the environmental control system.

We found a problem that led us to suspect the welds in the manifold. We found it necessary to meet with Marshall, our supplier, and our own engineering people and really evaluate what we had. The net of the evaluation was that IBM had no confidence that we could sign a certificate of flightworthiness with those manifolds in it. We felt that we had to make a decision, and we made it.

Manifolds are the pipes that carry the water-methanol mixture around the Instrument Unit--a part of the environmental control system. (In discussing the environmental control system hardware, Mr. Grace refers to items on display.) If you can visualize, each of the cold plates has a flexible inlet and a flexible outlet. There is a connection from the manifold or pipe that goes around for each one of those coming in and out. This is what we are talking

Mr. GRACE (cont.). about, the piping that goes around the inside of the Instrument Unit. There is a connection for flexible hose going up to a cold plate or coming down from a cold plate. Because of the bosses, we have many welds. In each one of those locations, there is a weld on either side of it. This big long pipe that goes around the inside is made up of sections. A piece of pipe falls into a fitting, and another one welds in the other side and around. It looks beautiful. We had a lot of trouble with it, and went to a different supplier to come up with one that is very good in terms of appearance. But after we were well along in checkout in S-IU-204 and 501 and S-IU-205 was well along in assembly, we lost confidence in the manifold and, frankly, made the decision that we had to pull them all out.

Mr. BROWN. What happened to make you lose confidence?

Mr. GRACE. We had a leak at a weld while undergoing tests. It was not a gusher, but in a period of several hours, a drop was formed on the outside of the weld, actually coming through the weld. Looking into that, we had two developing in S-IU-204 and one developing in S-IU-501. We had one to start with, then we had a couple more. The fact that we had three of them, really shook us. We ran a real investigation of welds, X-rays, and micro-sections, et cetera. We came in one Sunday, about a month and a half ago, and checked all S-IU-204 manifolds that we could get to. You understand, that once they are installed on the Instrument Unit, you cannot get in there too well with X-ray machines. Of the 108 or so welds in this system, we could get at about 56 or so. Of those, we found 8 of them that we felt possibly had a defect.

Mr. GRACE (cont.).

With that kind of data and the kind of evaluation we ran, we made a decision and presented our decision to Marshall. We had to take them all out. We had to re-X-ray every single one to be sure that they were all right. You know, when you start doing something like that, you really throw a "glitch" into the program. What you see here, then, is the impact of that. We had to get a complete evaluation of the manifolds, take them out, re-evaluate them, and put them back in. We also had another thing happen. Follow me down to S-IU-205. We had S-IU-205 finished in assembly when we took S-IU-204 off the checkout station. We refurbished the check-out station with the S-IU-205 configuration. Those are the changes to the station we talked about. We wanted to get through the electrical tests on S-IU-205 to make sure that we had everything checked out there. We find that if we get the electrical system, with all those connections and miles of wire all checked out, we are over a big hurdle. So we wanted to do the checkout, in terms of minimizing the impact on the program, we knew that we were going to get out of the manifold problem pretty quickly, and then we were going to have the domino effect of the single checkout station. If we would get as much done as we could, we would be better off. We did complete those tests on S-IU-205, then went back, refurbished back to the S-IU-204 level, repeated the tests that had to be repeated as the result of pulling off manifolds, then put them all back in again. We are now back to the point where S-IU-204 is finished and just about ready for shipment.

Mr. FRIETAG. How does this one-month slip affect the launch schedule? Is it a one-for-one slip?

Mr. GRACE. No, as a matter of fact, we have not impacted launch schedule. It will not impact launch schedule. This little note that you see here is the stack date at Cape Kennedy. We are still three weeks ahead of the stack date. Three weeks ahead of when Kennedy needs it. So, even with the 1-month slip, we had enough time. As you know, they have had a few difficulties at the Cape that bought us a little time. As it turned out, the schedule requirement is the 23rd of July and we make shipment by the 1st of August. We are going to make it in terms of program requirements. In terms of our situation, as you know, incentive fees, et cetera, we may have a problem.

Mr. WILSON. On S-IU-204, it still meets launch?

Mr. GRACE. Yes, now we have other problems as a result of this. This shipment on the 1st of August and getting out of the checkout station on the 29th of July means we have to refurbish back to the S-IU-205 level. We have manifolds to reinstall in the S-IU-205. As a matter of fact, we are going to have the checkout station refurbished again at the S-IU-205 level before we get these manifolds back in. So you have the unhappy situation that, in both S-IU-204 and 205, the manifold problem kept us from utilizing our checkout station to the maximum extent we possibly could. That hurts because that is the sequence of activities. From now on, the checkout station is going to cause us problems if the manifolds do come in. But we come off of the checkout

Mr. GRACE (cont.). station on S-IU-205 on the 23rd and this refurbishment cannot start here for S-IU-206 until then. So the refurbishment is not going to be done until then. The systems test on S-IU-206 is going to be delayed to that extent, of course, down to S-IU-207. This refurbishment will be delayed until the 25th and end by the 2nd.

I did not explain the diamonds to you. I should have. This dangling diamond technique is one that Marshall evolved to indicate a delay in the schedule. The S-IU-206 is going to be delayed this much. The delay you can see is decreasing. Down here on the S-IU-207, you have a little over a week. The S-IU-208, of course, is back on schedule--no impact.

Mr. WILSON. How are you working around this delay to close this gap? Are you just simply going to use your equipment as it stands now? Or you were talking about the possibilities of changing your checkout stations or adding capabilities?

Mr. GRACE. Nothing we can do in terms of adding capabilities would give us any relief in this time period. The lead time of getting another facility going is too great. We are doing one thing that has not been completely tied into this yet. That is, we are re-assigning personnel. We are adding more people to our checkout function to enable us to work double shift on the Uprated Saturn I checkout. You can see how we are currently scheduled to work--we had enough people to run a double shift on S-IU-201, 202 and 203. Then, with S-IU-204, we had S-IU-501 at the same time. We took the S-IU-501 people and put them on their planned assignment. This gave us two single

Mr. GRACE (cont.). shifts in checkout. With this (manifold) problem, we are adding people to that area to run a double shift on the Uprated Saturn I station and a single shift on the Saturn V station. What we think we can do, is perhaps move this delay back a bit as a result of the double shift. As it currently stands, this is the impact that we expected from that problem. There was some impact on S-IU-501 since we had to take the manifold back out and recheck them. We did not refurbish the Saturn V checkout station as we did on the Uprated Saturn I. We went from the S-IU-204 configuration, to the S-IU-205, back to the S-IU-204, and then back to S-IU-205. The reason for that was, as you know, we wanted to get as much testing done as we could. It was the lack of manifolds that was holding us up from even doing that (two extra sets of refurbishment). We still have a little time where we cannot check out something because of the manifolds.

Mr. WILSON. It appears that on the S-IU-502 that your delivery date would be after your planned stack date. Is that correct?

Mr. GRACE. No, that is not so. The stack date for S-IU-501 is the 10th of September. We plan to ship the 19th of August. On S-IU-205, the stack date is the 25th. We do not show the stack date on S-IU-502, but it is out here. This little note here is our maximum incentive. We just stuck that up there to show ourselves that this is a maximum incentive plan. In a sense, the incentive contract does provide you some motivation, but when you are in a problem like this, you are more interested in solving the problem.

Mr. WILSON. On the manifolds you took off the later stages, did you find the same percentage of defects that you did on S-IU-204?

Mr. GRACE. Yes, just about. As a matter of fact, the reason Mr. A.R. Beckhardt, our Operations Manager, is not here today is that he is out at Solar, a Division of International Harvester, along with Marshall technical people on this particular problem. They are making sure that the processes we are using and the products we are getting are going to continue to come in on the schedule we want them on. We did find problems.

Mr. WILSON. What about those manifolds on S-IU-201, 202 and 203?

Mr. GRACE. They were different manifolds. They had different kinds of problems, but their problems were technically assessed by Marshall and by us as problems that we could live with. Specifically, the big problem was porosity on the S-IU-201, 202 and 203. The manifolds were hand-welded with the variation in that kind of a process. We got a lot of leakers in S-IU-201, 202 and 203--lots of them. It was a nasty kind of problem because it depended upon the individual welder, whether you got a lot of material, or whether you had a little or a lot of porosity. We had cracks. But we did, by brute force, net out our manifolds in S-IU-201 and 203, which were considered to be flightworthy.

Mr. BROWN. If you could have lived with leaks on them, why could you not live with it on S-IU-204?

Mr. GRACE. Because S-IU-204 is man-rated.

Mr. EHRHARDT. S-IU-201 and 202 are sub-orbital shots. They are of short duration. Frankly, if it had sprung a leak, it could have got by. When you start into the continuous orbital shots, you do not have that option. The S-IU-204 is man-rated and is a 14-day schedule.

Mr. WILSON. You are working on correcting the welding problems you have? Will these units be subjected to vibration test, environmental tests?

Mr. GRACE. Will, are, and have been--let me get into that on the manifolds. Specifically, I want to give you more of a feel for that problem. I just want to show you the impact of it. Now, I do not know whether you noticed it as we were going through--you might want to run back through those pictures. (Figures 35 through 40) This is a view of S-IU-204 on the checkout station--these pictures are not more than a week old at this point--S-IU-501 is on the Saturn V checkout station. The S-IU-205 picture is a little older than that because it has been completed in assembly. It has been checked out electrically on the checkout station, and is back in assembly with the manifolds taken off for refurbishment. The S-IU-502 is in the final phases of assembly and, as you can see here, it is not complete. Notice the cable trays are not full. The S-IU-206 is in assembly also. This is less far along in assembly. We did not even have the purge duct in this one. The S-IU-503 is in fabrication, with the forward protective ring and aft protective ring not on yet, but it gives you a feel for where it stands. The S-IU-207 is coming into assembly. As you note here on this chart, we are now in fabrication on S-IU-503. The S-IU-207 is scheduled to be in fabrication here and will be in fabrication

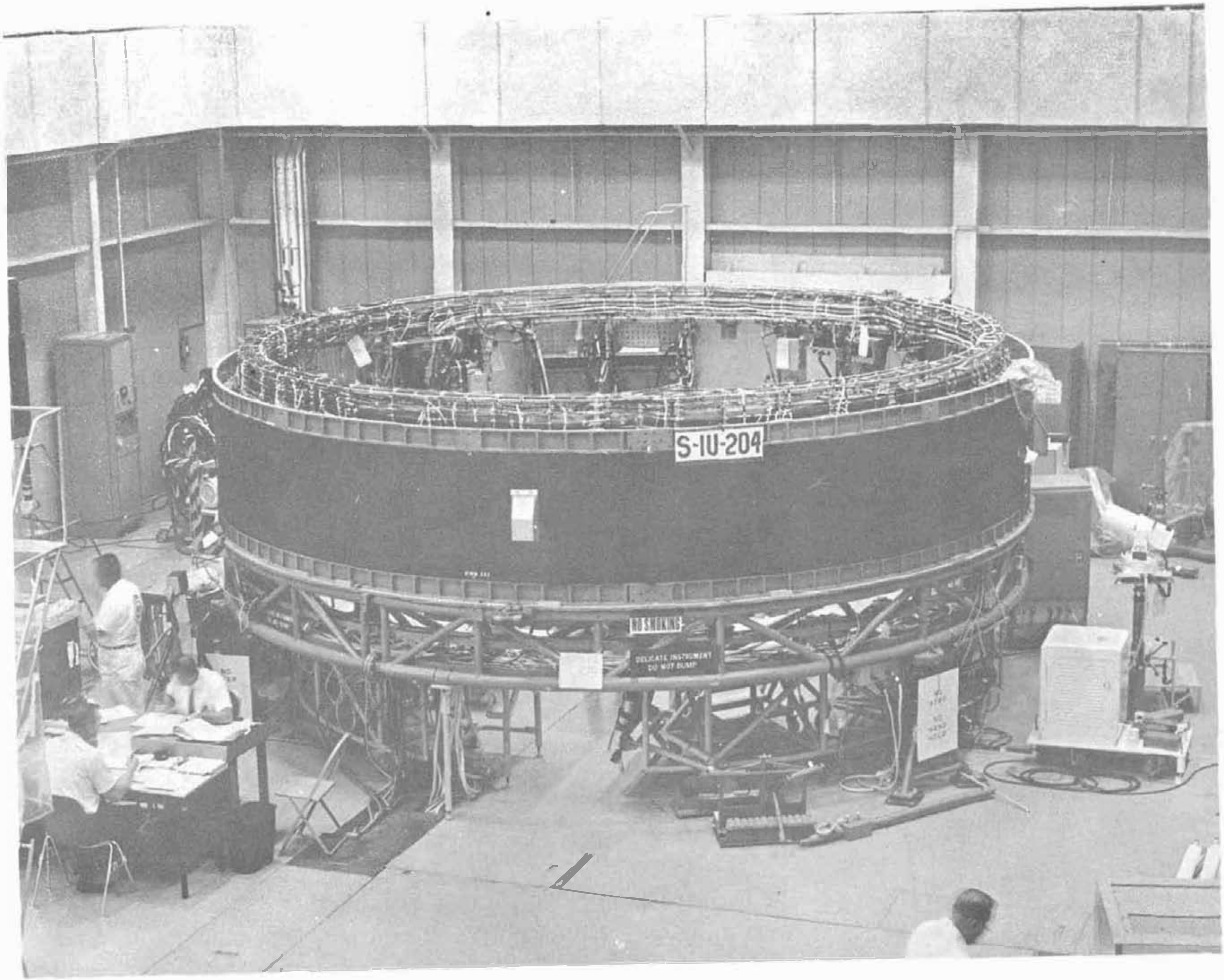


FIGURE - 35 - IU 204

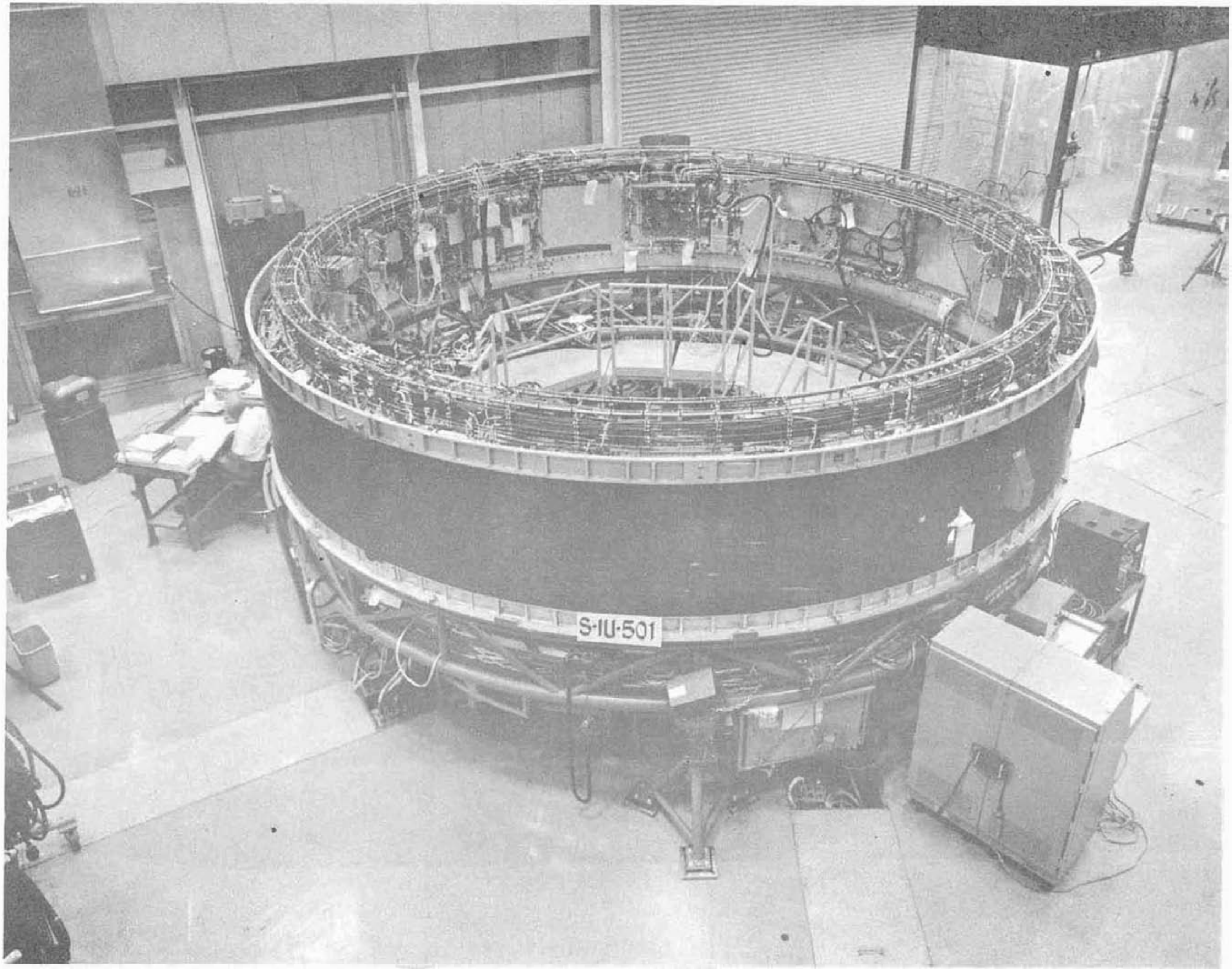


FIGURE - 36 - IU 501

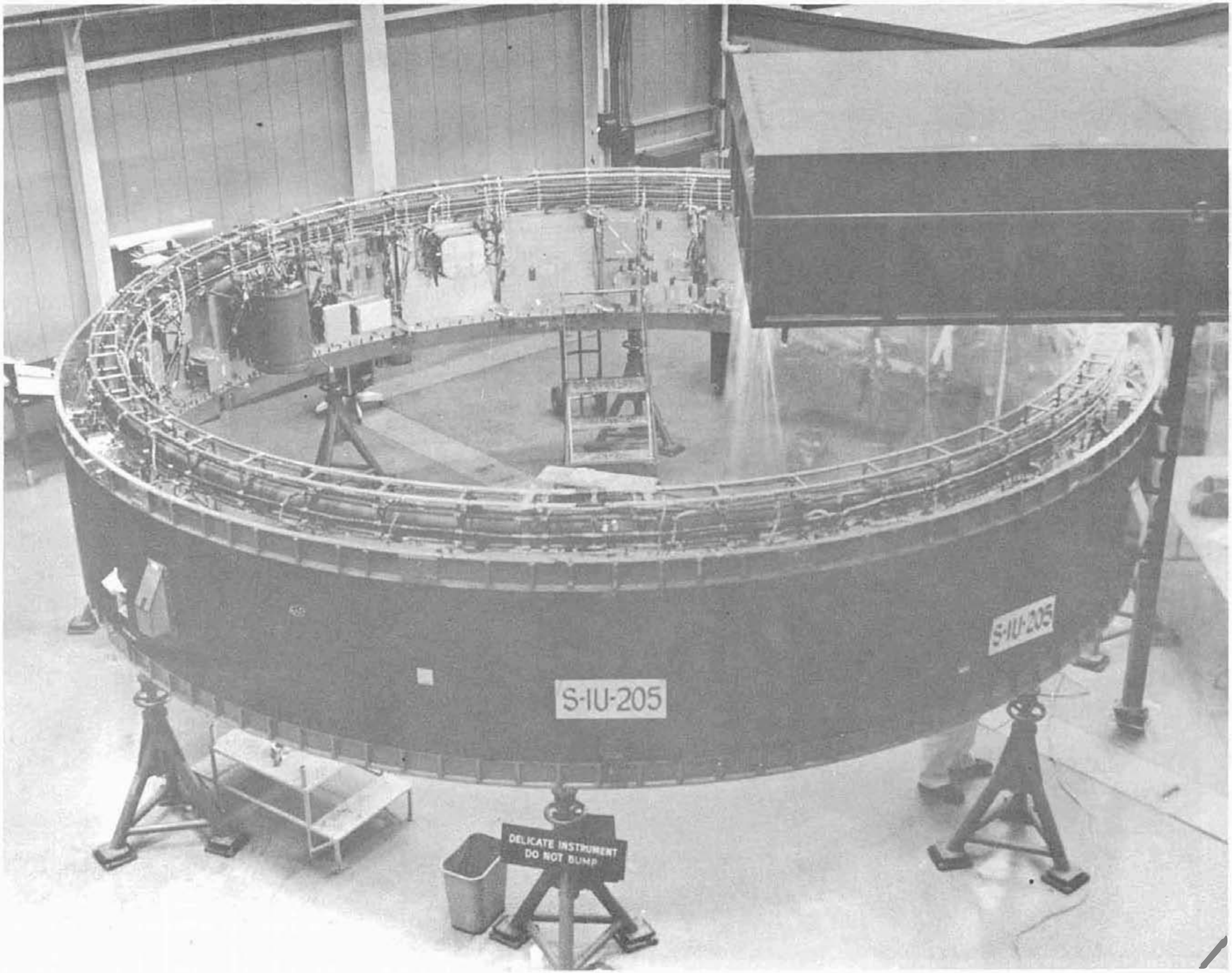


FIGURE - 37 - IU 205

FIGURE - 38 - IU 502

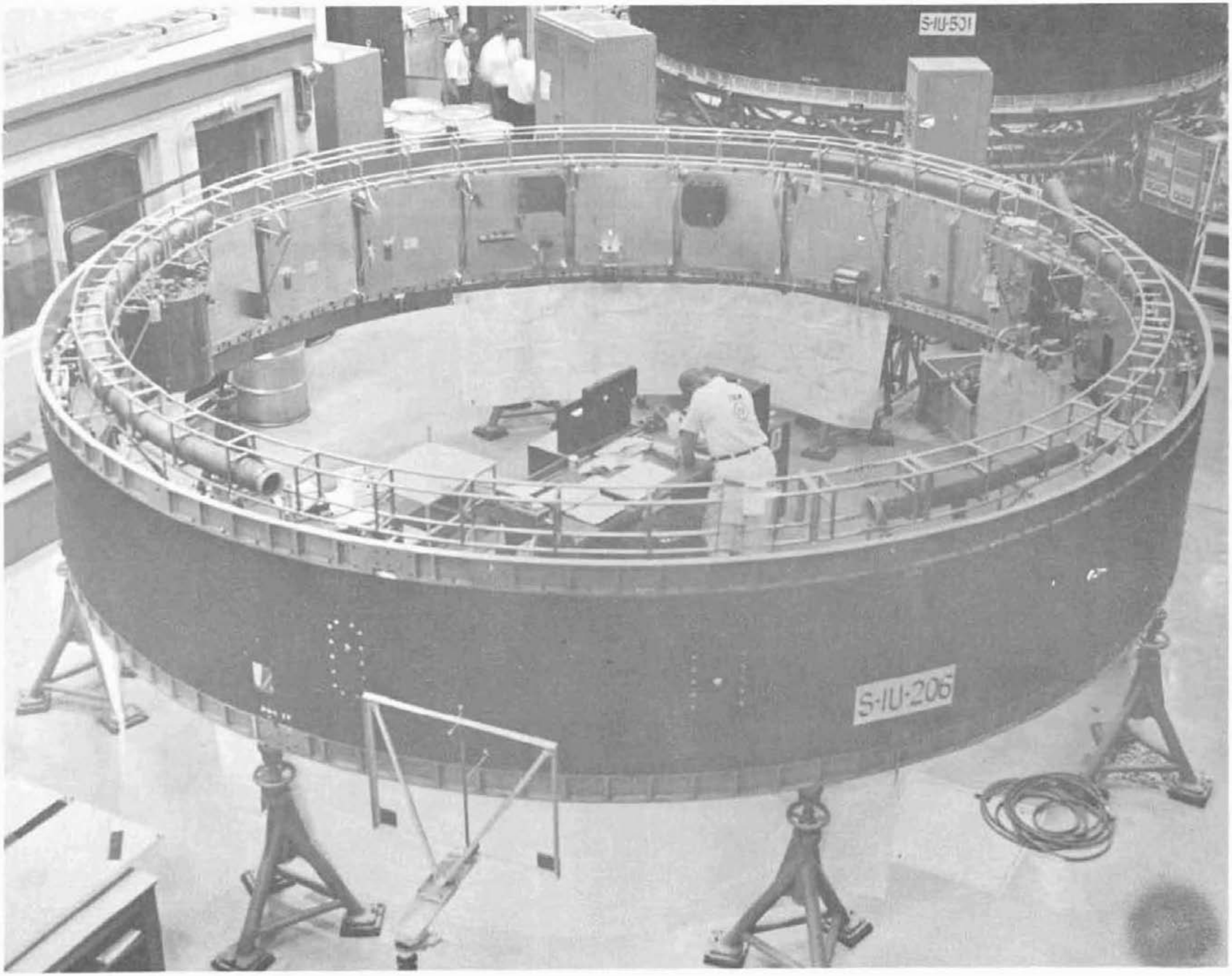


FIGURE - 39 - IU 206

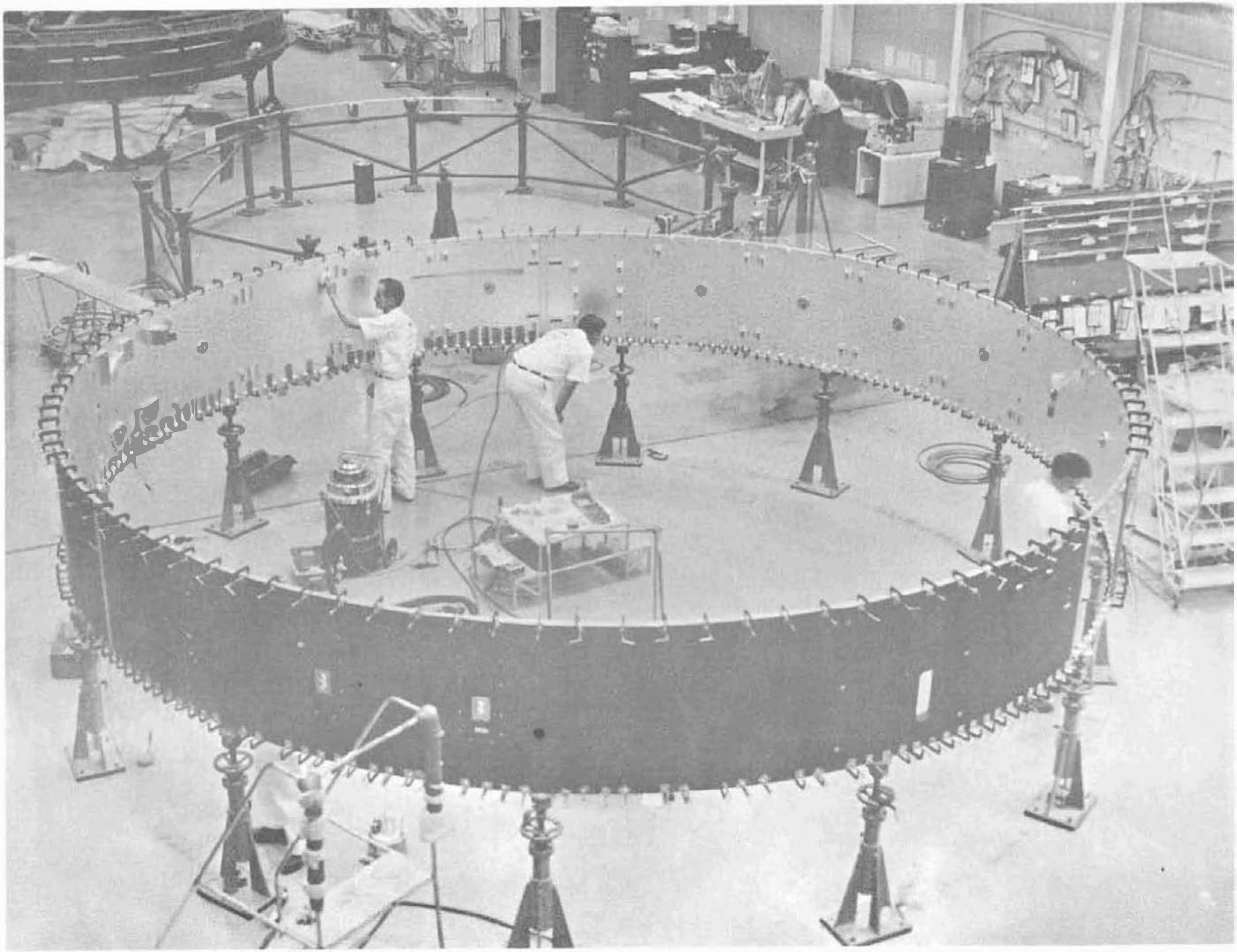


FIGURE - 40 - IU 503

Mr. GRACE (cont.). at that point. We had delay in delivery of the structures in S-IU-207 because we ran into other things that sometimes come up. We had a big debate among the inspection agencies as to whether a certain requirement was necessary and whether it was being met. We became involved at North American. No problems are going to occur on this one. We can actually complete this fabrication in less time than scheduled.

Mr. WILSON. You have talked about the effect of schedule for this problem. What is your costing experience now that you are in this problem and your schedule has slipped? You are adding people to shifts and trying to catch up, you are looking at the problem. What effect does this have on your costs?

Mr. GRACE. At this point, I do not know the exact effect on the cost. Mr. Cleary, have you got an assessment on it at this point? Mr. Cleary is our Financial Manager.

Mr. CLEARY. You cannot really tell, at this point in time, what it is or what the total impact on cost is going to be. For one thing, we have not really resolved with Solar for their rework. We are on a fixed-price contract with Solar so the repair, to get good workable units, is Solar's responsibility. Now, double checkout is probably only going to cost us a premium for the shift differential because, actually, you are still going to have the same number of hours. Where we have the doubling-up effect is in putting the units on the stands to do the electrical tests, then taking them off to reinstall manifolds, and then putting them back on again. We have not really assessed this because we do not have them all pegged. As you can see up there, they are not completely checked out and ready for shipment. We really cannot assess it.

Mr. GRACE. Let me give you a little better feel for the kind of things we do in here on a weekly basis. To do that, I thought I would take S-IU-205 which is one that is fairly current, in terms of activities, and you can see what has happened. I am going to make a specific point, and, when I do, I want to be able to show it to you. There is a message to be had from this one. First of all, let me give you this before you go into a state of shock--a little explanation for these tremendous delays here. We had a couple of things happen to us on the programs. I think it proves the adaptability and flexibility of the Marshall-IBM team. We had a structure, and the first three units, by the way, were built with Government-furnished structures which had been procured under the development test program by Marshall from suppliers they had building them. Actually, it was General Dynamics in Fort Worth. We went competitive, and General Dynamics, Fort Worth, lost to North American, Tulsa. However, on the program, when you change the supplier for a major element like that, you have to repeat certain tests. We had to repeat structural tests. In the repeat of those tests--the static test and simulated dynamic load at the Propulsion and Vehicle Engineering Laboratory--we reached the required 140 percent safety factor, and the thing collapsed. We had a failure of the structure. Now, we had other tests that were expected to continue using that same structure, so we had the questions: "Well, do we have to re-do those tests, or do we not? Should we really run additional and other tests on this one since we did have a failure?" In actuality, it had its rated load, but it collapsed at that point. This was the

Mr. GRACE (cont.). maximum--140 percent of the maximum Saturn V load. At any rate, working with Marshall, we determined that we should have another structure, and we should run it through the static test again. We had to bring in an additional structure. We did not have one in the plan. What we did was this: Since S-IU-204 was just beginning assembly, we disassembled it and we sent the structure to Marshall for the testing. We then put another set of structures into S-IU-204. The same impact was felt in S-IU-205. That was one time. Then we had another situation where we determined, between us, that we ought to have even one more structure test. We ought to run some additional tests in terms of vibration, et cetera, on another structure. We took another one out, and what you see here is, look at the original schedule--we show on these detailed charts a repeat of what we call an F level schedule. That is what we originally planned to do to each of those phases of fabrication, assembly, checkout, et cetera. What you see here is the impact caused by virtue of pulling out of the stream, if you will, two structures. This caused our completion of fabrication to be way beyond what was originally scheduled. We absorbed that impact, in terms of getting the Instrument Unit together, with only that much impact on the completion of the assembly--which is, on the schedule, from about the 1st of July to the 14th of July. We expected to complete checkout on schedule. We would have,if we had not had the manifold problems.

Mr. WILSON. This is still after Marshall had required you to provide two extra structures for structural tests?

Mr. GRACE. You say, "required". We agreed to it. We agreed to do it and still meet our schedule. We felt definitely convinced that we could.

Mr. WILSON. This may not be an appropriate question to you, but was the requirement for the second structure to repeat the same test that was done on the first one?

Mr. GRACE. We did repeat the static loading test on that second structure, but we also used that structure for additional tests which had been planned in a ground test program. We would have done these tests if we had not lost the structure at that particular point.

Mr. WILSON. You were completing the test on the lost structure?

Mr. GRACE. Right. The third structure was primarily the vibration test. There had been some questions come up in vibration test--the tests that Marshall had run. The question sufficiently concerned us, and it was definitely felt, in the interest of the program, that additional vibration tests should be run. That was the reason for the two extra structures being called for.

Mr. POWELL. I think there is another basic message there.

Mr. GRACE. We will get to the other one.

Mr. POWELL. I do not think we should leave anybody with the interpretation that the additional structure was bad, and I base it on the fact that they could have been available. I think it was a mandatory requirement, and based on the schedule we had and the work we had to do, it just so happened that it did not work out that way.

Mr. WILSON. Were the original test plans as fair as possible as far as Marshall was concerned?

Mr. POWELL. The structures were there and, when we lost them, the test program had to be continued. We felt like we could not fly S-IU-203 or S-IU-204 without completion of the test programs. It was, in essence, the qualification program.

Mr. GRACE. Well, it turns out, as Mr. Powell is saying, even if they impacted the schedule somewhat--if it had to be done--it turns out that happily we could accommodate that requirement without impacting our schedule. Now, there were other things that were involved, which leads me to another point I want to make. If we had not pulled those structures out, you would have still seen a lot of these dangling diamonds because we have had one awful time getting all the bits and pieces in here on schedule. We ran into some dark days with Marshall about 9 months or so ago. We were using the technique of PERT (Program Evaluation and Review Technique) and simply cranking into the PERT system the availability dates on the hardware. PERT showed us dropping off at the end in terms of schedule delivery, because PERT is developed, as you know, on a logic flow of activities. You take one key point, and when you move it 3 months, the whole delivery moves 3 months. Well, we were simply cranking it through as required by contract, and we got into a situation where we were always having to explain ourselves. PERT showed, at one point, S-IU-501 being delivered in November 1966. We said we just did not believe that because we have things we can do to prevent that from happening. As a result of having to explain it every time anybody saw it, we got into an awful mess. People were angry with us and probably justifiably so. We were frustrated ourselves because we could not explain.

Mr. GRACE (cont.). satisfactorily, that in this assembly phase we had a lot of flexibility. If one piece was not there, it would not stop the whole program--it would stop that element If we had to work around it and, Mr. Powell well knows "work around" got to be a real common word around here. As a result of this unbearable pressure on our production control organization, where they just plain could not stand up under it, one of the men over there came up with a technique that we are most elated about. We call it our Multiple Operation Sequencing Technique (MOST). In the vernacular, "it's the 'most.'" Basically, what it does is take the sequencing events of assembly and breaks out the individual stations.

Now we talked about having 16 cold plates or thermal panels distributed among 24 possible locations around the inside of the Instrument Unit. There is not a cold plate on every one because as you know from Mr. Ehrhardt's talk, some of these components, like the Platform, Launch Vehicle Digital Computer, Data Adapter and Flight Control Computer, are integrally cooled. It is pretty easy to see that you can take any location and put out a sequence of assembly for that particular location. For example, you cannot put that cold plate on until you get that little transducer mounted behind it. (Mr. Grace refers to Figure 41) So on this particular activity, that transducer is a major item. You cannot put that bracket on until you have the cold plate installed. This is what we are showing you in this exploded view--that there is a sequence of events that has to take place. On each Instrument Unit, 24 locations had to be dealt with; that meant 24 parallel activities Also, those events that were oriented to the cable tray, manifold, and structure itself

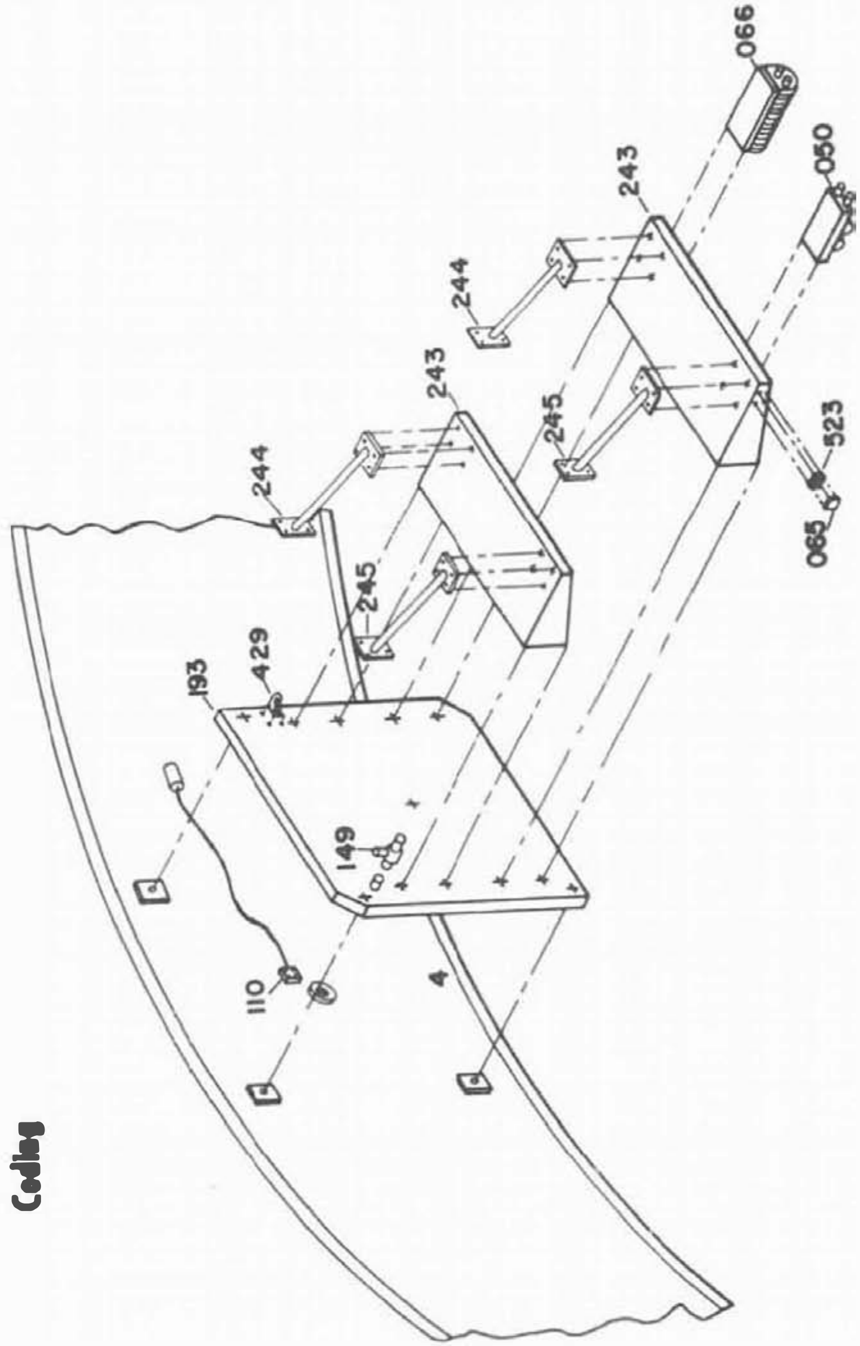


FIGURE - 41 - EXPLODED VIEW (BATTERY RACK)

Mr. GRACE (cont.). had to be included. And what happened? Let me use this chart. (Mr. Grace refers to sequence chart which is not included with the figures) We now have a programmed method of laying out the sequence of events that have to take place at each one of those 24 locations and other areas mentioned. From that, we now get daily reports to our factory floor and production control. These reports list what has already been installed, what we can install, what we cannot install, (because it is not here), and highlights the ones that are the most critical--this includes the delivery date, the purchase order who has it, and the name of the expediter. It has been terrific. Mr. Carl Crebar, our Program Administration Manager, is delighted with it.

We are getting PERT tied into this--the very same basic data that is going into the MOST system is also going into the PERT system. Now PERT is no longer a rigid sequence of logic events. It adapts itself to the sequence that we are actually employing in MOST. It comes out with a predicted date that is now compatible with what we are talking about here, instead of being 3 or 4 months off. I think we are going to get some real fine reaction from this.

Mr. WILSON. Have you had enough experience with this system now to tell how much it will improve your ability to work around these problems?

Mr. GRACE. Yes, I think so. When you go down to the manufacturing floor you will find the manufacturing management men down there with the MOST report, going over it, and using it in terms of their routing. So I know it

Mr. GRACE (cont.). is working. Before I used to ask a question about a specific part and it would take 2 to 3 hours to find all the answers on it. It does not take that long anymore--we have the answer right there. We know who is doing it, when it is coming in, et cetera.

Mr. WILSON. Looking at these schedules it looks like a pretty effective sort of thing

Mr. GRACE. It does a real good job. Mr. Powell, you might comment. You and your folks observe the way it works on the floor.

Mr. POWELL. Well, when this first came out we were in one of the "black" days We were back to Marshall giving IBM the monthly "massaging" by Col. James, Dr. Rudolph and Dr. Reese. I made the statement that, "If that thing gets to operating in the next 2 months, we will have Instrument Units coming out of our ears." It was amazing--the number of raised eyebrows of the IBM people--"By George, that thing really works." Then over night, just all of a sudden, a lot of hardware went in the Instrument Units. I think, overall, that it has really helped IBM in capability of knowing when they have to do something and planning ahead for doing it. When that PERT room--that stockroom--looks like it is empty, that thing is really working! And it stays empty!

Mr GRACE. Thank you, Mr. Powell. He did not rehearse that part. but I am pleased with his comment. His job here, I think, is to really keep the pressure on, and he and his folks do that pretty well.

Essentially, MOST got us out of a situation where the people, who are involved in an operation this complicated, are not milling around in a daze--

Mr. GRACE (cont.). not quite knowing where they stand. It is to a point now where everybody has a good handle on where they stand and the actions that are taking place. The work that most of the people are doing is effectively directed toward solving the problem. It has been just delightful.

Well, that was the story we wanted to give you here. This is a kind of thing we go over with Marshall program management people every week in here. We have a chart like this on every Instrument Unit. We use this control room as a working room. Everyday we get in here and consider specific problems. I hold a management council meeting, on Wednesdays, where we just "beat each other" back and forth in terms of what we are going to do. On Fridays, we bring the Marshall people in.

Well, I would like to go into more detail on some of these problems that I mentioned earlier; specifically, the manifold problem. I said that we had a leak that occurred in S-IU-204 and 501. As a result of those leaks, we started to look at the manifolds. (Figure 42) We X-rayed them in S-IU-204 to determine if we, in truth, had a question mark--at least in our minds. We needed to know that. In terms of X-ray techniques, there are real variations. It depends on the X-ray technician. I will try to illustrate that. Take a piece of manifold, like that one we have here, and X-ray it. To you and me, you look at that, you might say, "That looks fine. What is wrong with it?" The X-ray technician says, "That tiny little bit of shading there. I think there is a defect in it." Now, another X-ray technician may look at it and say, "I do not see anything there!" And we are down into that kind of situation. If we had not had a leak in S-IU-204, we may not even have got

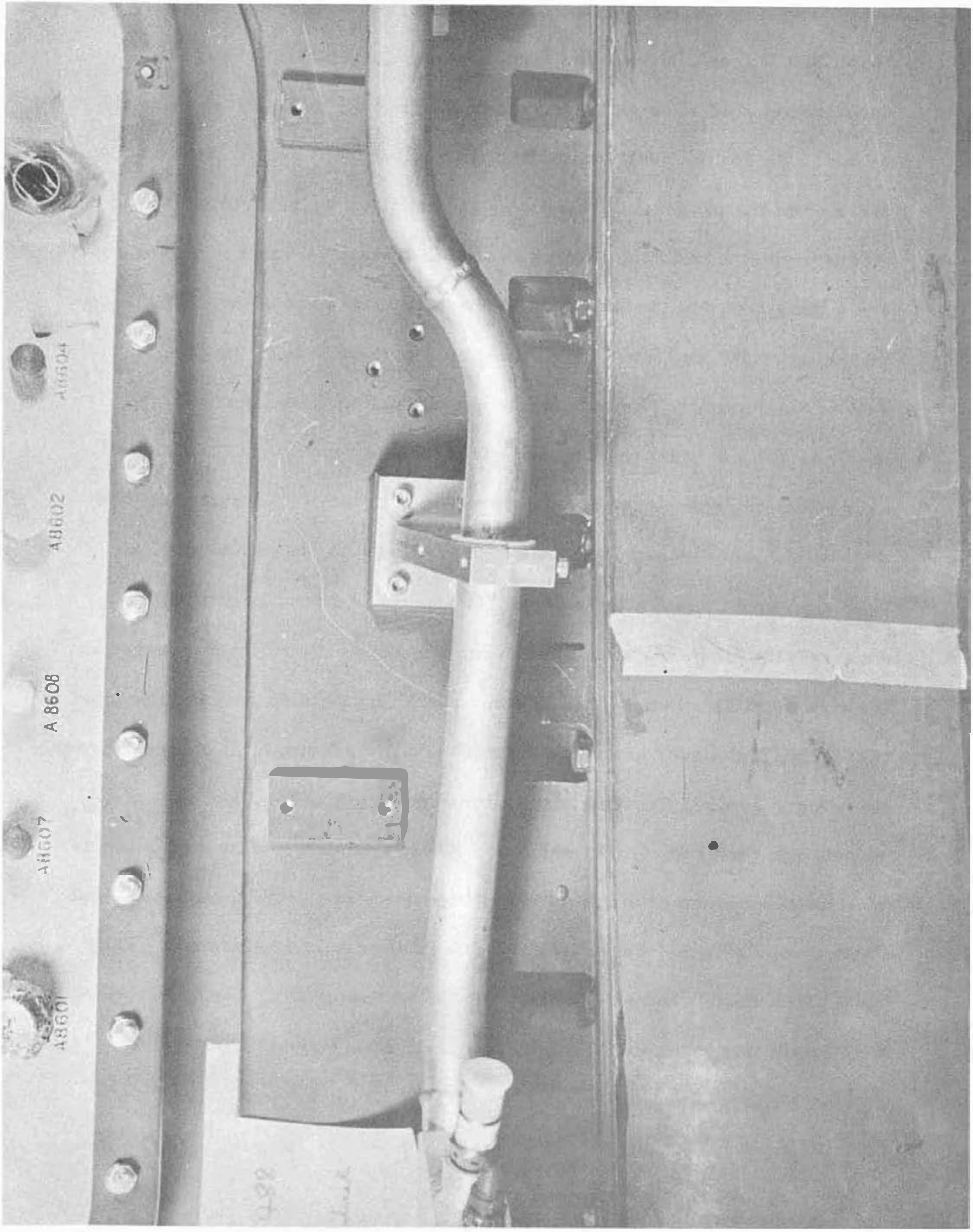


FIGURE - 42 - MANIFOLD SECTION

Mr. GRACE (cont.). into this problem for quite a while because it is down in that kind of level. I just thank God that we had the leaks when we did! We got the problem and had it fixed before it really caused a disaster in the program. This is the kind of thing we get into. Here is a case of one, a bad one, that we saw on an X-ray. (Figure 43) If you see a thing like that, nobody debates whether it is there or not. But that thing might not leak. The fluid enters at the inside of the pipe and gets to the outside. The fluid has to get through up here--and there really is not a hole there--but there is a big one down there. You must have a way to detect those flaws before you get them into a system. The one we had--that leaked--was this kind of thing. In an hour or two, a bubble formed there--a little drop. You would go over and check it. As a result of this, we went to what you see here. This is a microsection. We took manifolds that we had in stock and X-rayed them with high resolution X-ray technique, and we found a lot of little shadings, et cetera. Frankly, there were some interesting discussions between Marshall and us. Mr. Powell can recall the one in which our X-ray technicians saw three defects. We took the section of manifold with three welds in it--three bad ones--out to the Propulsion and Vehicle Engineering Laboratory at Marshall. They called Mr. Powell and said, "You sent us the wrong one. There is nothing wrong with this manifold." Remember that, Mr. Powell?

Mr. POWELL. Yes, sir.

FIGURE - 43 - MANIFOLD CRACK (X-RAY)

Mr. GRACE. We said to them, "There are three bad ones in there." Finally, by pointing out where they were, we got them to say, "Well, yes, there is maybe one there, but we do not agree that the other two are bad." But, frankly, just to show you the confidence we have in the ability we have here to look at X-rays, we have yet to find--when we have actually gone to microsection--a weld where our men have said, "We think there is something in there," that we did not find something. Maybe just a little thing that was no real problem.

Well, let me go back and give you a little of the background in manifolds. In the beginning, when manifolds were handmade, we had the problem of porosity and some cracks. Porosity was the biggest problem because it is difficult to weld 6061 aluminum. This was the metal selected for the other properties that are required. We went out to suppliers to get samples made of welds. A number of them just said, "We just are not interested in that. It's too tough." We had a few that did provide us samples. Solar submitted us samples that looked beautiful--better than anything we had seen. In working with the Propulsion and Vehicle Engineering Laboratory, we decided to go with Solar and their techniques in making these manifolds. Solar, in spite of the problem that we have, is a real fine outfit and does real good work.

Mr. WILSON. 6061. Is it T6? Will you find that out?

Mr. EHRHARDT. It is T6.

Mr. GRACE. Well, at the beginning, we ran some engineering tests because--these manifolds are on the inner periphery of the Instrument Unit, on a radius

Mr. GRACE (cont.). of about 10 or 11 feet and they have to be formed that way. In the hand-weld procedure, the forming was done as they were held in a jig with the pipe already set. In other words, when you are doing it on the machine, you cannot let that end flop around. It has to be done in a straight path and then formed. We ran a lot of tests with Solar and most weld experts agreed with this old axiom of, "When you have a good weld, it is as strong as a parent material." Now they started with that kind of a preset mental condition, ran a number of tests, took a lot of manifolds, welded them, made sure they were good with X-rays, bent them, heat-treated them, and then checked the X-rays--still good. So we did not require additional X-rays after forming on the basis of those engineering tests.

It is expensive to run 100 percent X-rays on all of these. It gets pretty expensive to do that across the board. We do have to X-ray 100 percent as we make it up,because you build this manifold up a piece at a time. You obviously have to check as you go along because, if you have one weld that is too bad and you do not repair it, you may end up scrapping the whole assembly. We require 100 percent X-ray as you build it up. Then, on the basis of the tests, we did not require it after forming and heat treat. When we got into the problem, the question was raised. "Could it be that, in spite of those tests, something did happen to those welds when you formed or heat-treated?" First of all, people said, "It is the installation that is bending or torquing them. It is the handling that is doing the

Mr. GRACE (cont.). cracking of the welds." We ran some tests that led us to believe that that was not true. We did not really affect the welds when we put forces on them, so we went to the stockroom and X-rayed those that were in their constrained shipping cartons. We found defects we thought were cracks. We went to Solar and had them X-ray materials in process. Chagrin was all over the place because they found cracks that were not there before forming and heat treating. We had a disaster on our hands. This is the reason we made the decision to pull them out. Frankly, we did not know what we had. Now we require X-ray after forming and heat treating even though it is expensive.

Mr. BROWN. But you still require X-rays during building?

Mr. GRACE. We have to because of the way the thing is made up--these things get 10 to 12 feet long. There might be 10 or 15 welds to the section. Sometimes, these things are non-repairable. In trying to repair it, the pass does not work, you scrap the whole thing. It is cheaper than to try to keep going. So, we have to do it as we proceed along with the welding. We do it again after the heat treating and forming. Solar found that some of their people were not really following the manufacturing instructions to the letter. It was in a critical area, at one of these locations, where you have a boss like this. (Mr. Grace is referring to a sample manifold) It was a requirement that a fixture be applied, during the forming operation, to prevent excessive forces on the weld area. Those fixtures were being put on but not securely and not well. Solar determined it themselves and came

Mr. GRACE (cont.) back very apologetic. They found that the number of cracks and the number of defects were greater because their people were not following instructions carefully. They went back, tightened things up, and are getting a much higher yield. This does not change the fact that this is a tough operation--it is difficult to weld these things.

In the course of the kind of microscopic inspections that we have been doing lately, with the laboratories at Marshall, there were differences of opinion as to the best technique to use. Solar uses the technique of chamfering the pipe ends, assembling it, and then putting it in the fixture. One pass is made to heat it--melting it, somewhat. On the second pass, the pipe is fused together. On the third pass, the filler rod is added in. Solar firmly contends that this is the way to do this job because it prevents blow-through and dirt on the inside. Recognize, now, that we have a tremendously high cleanliness requirement inside that pipe.

We seldom have a reject after forming heat treat. What we see over here (Mr. Grace points to a schedule chart, Figure 34), those are manifold sets Nos. 1, 2, 3, 4, 5, 6, and 7. We show when we expect to get the manifold sets in and, frankly, Solar is just "scratching and clawing" to try to meet these delivery schedules. We did not quite meet this one. We are absorbing the impact of that so, until we get another month or so under our belt, we will not really have a good handle on just how healthy we are in this area.

Mr. FREITAG. What alternatives do you have in this piping system? Do you have any? I assume that you have considered some alternatives and fallbacks.

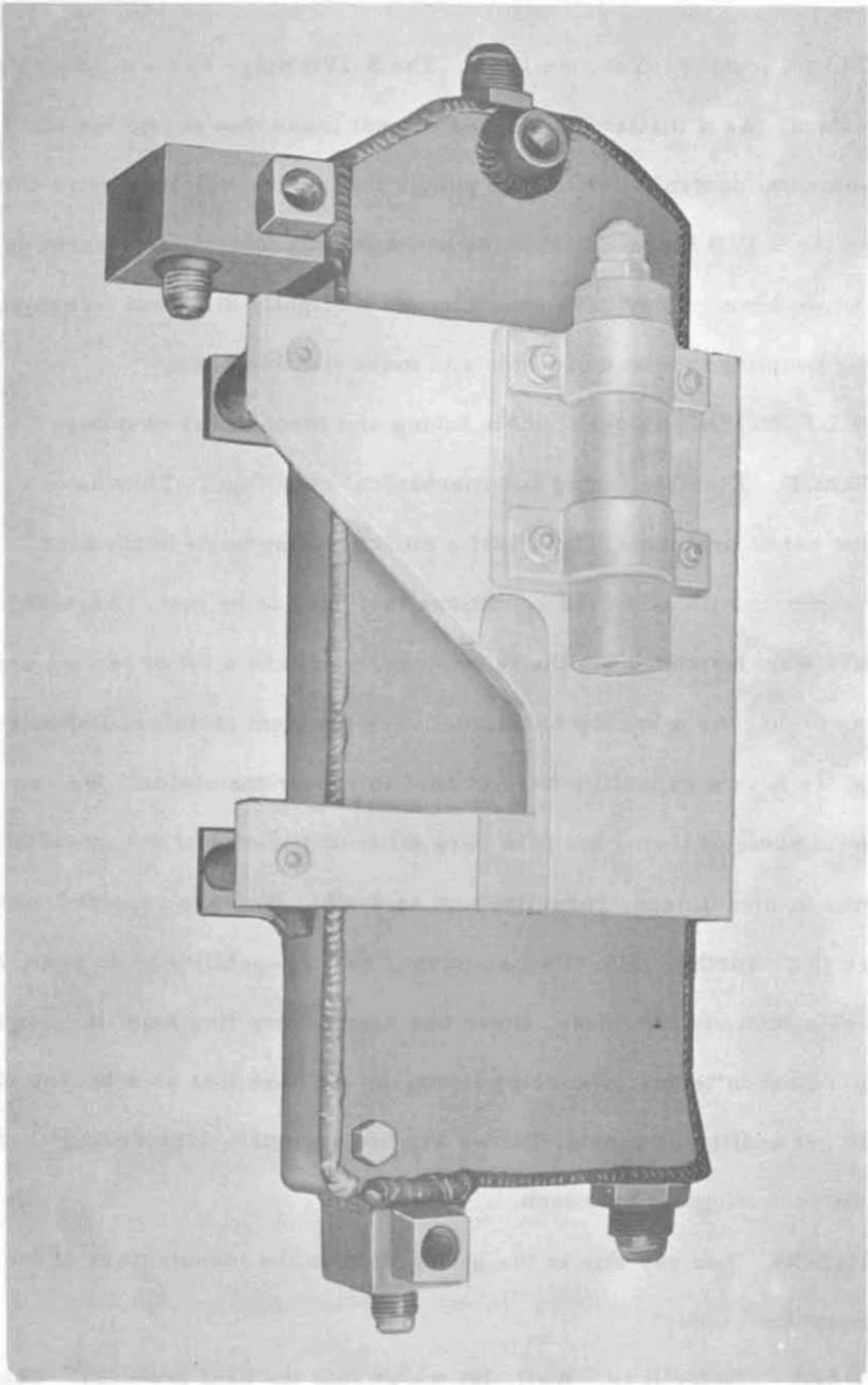
Mr. GRACE (cont.). Yes, we have. The S-IVB Stage has a similar kind of a system. As a matter of fact, we did not make this point, but our environmental control system also pumps fluid to the electronics in the upper skirt of the S-IVB Stage. They have had a lot of problems in manifolds just like we have. They have gone through a slightly different technique by using couplings instead of welds and more flexible hose.

Mr. FELTON. Do you use flexible tubing and mechanical couplings?

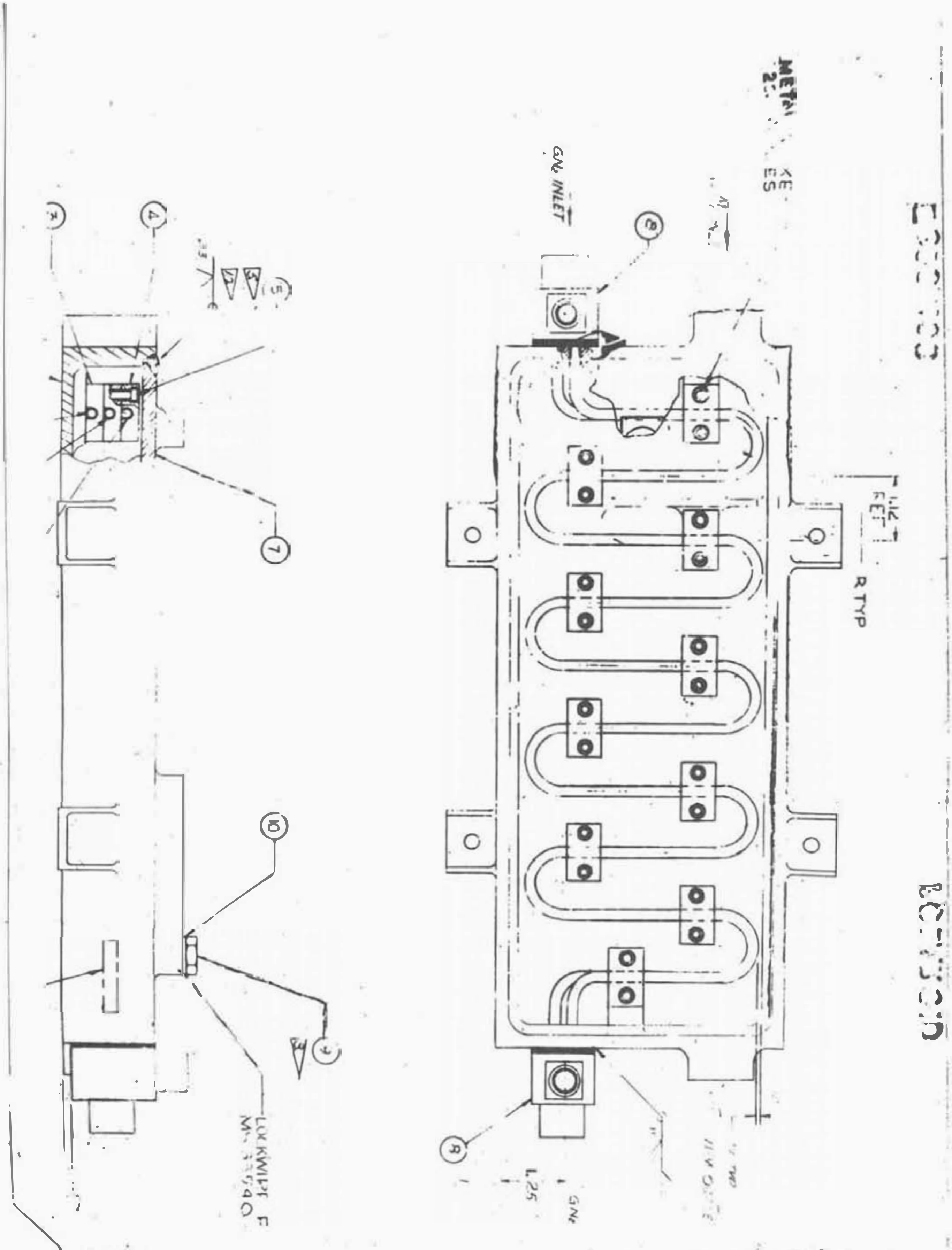
Mr. GRACE. Flexible tubing and mechanical couplings. They have a different set of problems. It is just a difficult thing to do in the kind of environment with all of the conditions that have to be met. Anytime you make a major change in the technology, you have a lot of testing and proofing to do. As a backup to this delivery problem of Solar, I should say that we have a capability here at IBM to repair manifolds. We can hand-weld some of them, but it is very difficult because of the attendant problems of cleanliness, porosity, and so forth. We have repaired some that are flightworthy. MSFC's Laboratory has a capability to do some and, in crises situations like these, there has been a very fine hand-in-glove kind of cooperation in terms of working it out, so we have that as a backup capability to get additional assets, but we are not seriously considering changing the basic technological approach.

Mr. WILSON. You say this is the gating item in the manufacture of the Instrument Unit today?

Mr. GRACE. Today it is. Well, let me go into the next problem. The one I am going to talk about now has not been a pacing item up, until now, partly



44 - GAS BEARING HEAT EXCHANGER



45 - GAS BEARING HEAT EXCHANGER SCHEMATIC

Mr. GRACE (cont.). because it is not so profusely distributed throughout the Instrument Unit. In the environmental control system, we have what is called the Gas Bearing Heat Exchanger. In the Inertial Platform we have an air-bearing system, as you know. We use dry nitrogen to provide the gas to that system. This gas has to be controlled in temperature pretty carefully. What we have is a device here which is called a Gas Bearing Heat Exchanger. (Figure 44) This is an inside view of one. (Figure 45) It has three sets of little pipes like this that carry the gas through. The water-methanol mixture comes in and flows across the pipes. It has a little stud that holds these pipes in here.

Mr. FREITAG. A heat exchanger?

Mr. GRACE. A little heat exchanger. This drawing gives you an idea as to how the three pipes are snaked back and forth in the configuration that you see there. They have a mounting stud that holds them in position. We ran into a lot of problems with that. We had a lot of problems at the outset with the welding around here. It is a hand-weld operation around all these bosses and around the ends. We had difficulty meeting the specification requirements of the class of welds, et cetera. It was pretty much of a nightmare. As it turns out, the poor man who was doing a fine job in a lot of areas, and a reasonably good job here, was Solar again. They have had some real nightmares to live through. Anyway, we ran a number of tests to prove that a lesser quality weld, like a Class V instead of a Class III, would be suitable and flightworthy. We ran a lot of vibration test, pressure

JUNE 2, 1966

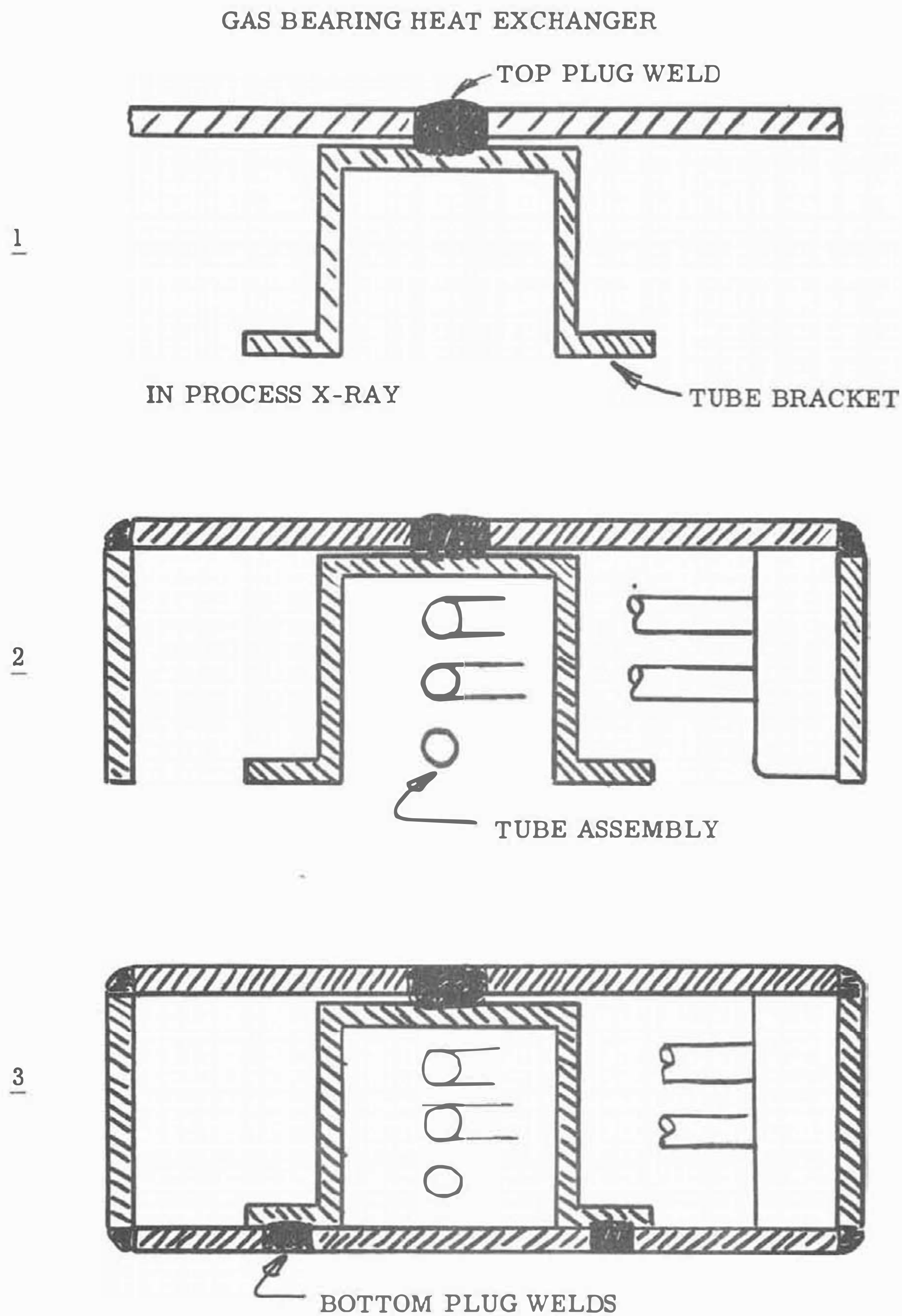


FIGURE - 46 - GAS BEARING HEAT EXCHANGER WELD DIAGRAM

Mr. GRACE (cont.). tests, et cetera, to prove to ourselves that it is right. We had too tight a spec on it. We would live with a relaxed spec on the welds around here; there are a lot of them. However, the little mounting studs that hold these pipes are mounted to welds at the bottom and these are called plug welds. (Figure 46) It is a hole drilled into the body of the material and a weld filled in there to weld this fast to it. It is welded in two places on the bottom and one on the top. We were concerned about the seam welds around the side, but they proved to be okay. When we ran the vibration test under pressure, that single plug weld gave us trouble--it popped off. We spent a lot of time trying to figure out what to do with it. We had a number of assets in the line. We had, I think, ten Gas Bearing Heat Exchangers with these small plug welds. We went to a larger plug weld to increase the size of it, and that has provided a better yield and better strength. However, it is still just an awfully doggy thing to do. In this case, to help us out of this disaster, which would have impacted schedule, the Mechanical Engineering Laboratory at Marshall has made up a couple of these. They have some real talented people out there who developed a slightly different concept. They actually made some filet welds instead of plug welds. They made up a couple of assets to keep the program going.

Mr. WILSON. Are you constrained as far as the envelope of this thing is concerned? Does it have to be rectangular?

Mr. GRACE. To a certain extent, in that it has to fit in behind the Platform. It does not have to be exactly that size. It could be varied some, but it does have to fit behind the Platform. What we have done, if I can go to the next

GAS BEARING HT. EXCHANGER MODIFIED DESIGN

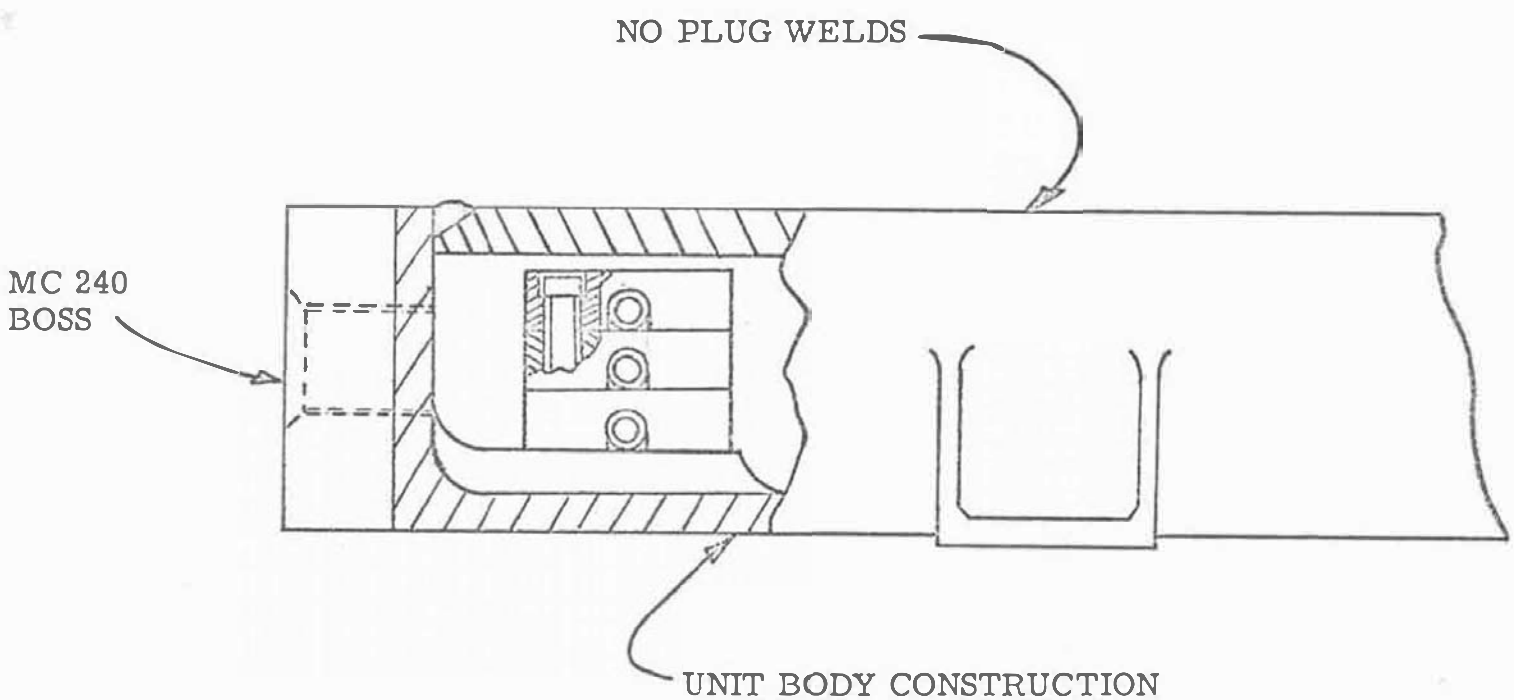


FIGURE - 47 - GAS BEARING HEAT EXCHANGER NO WELD DESIGN

Mr. GRACE (cont.). slide, is to show you the new design that we are currently working on with Solar. It will eliminate most of the welds, which are the problem. (Figure 47) We take a box and machine it out this way with a lid that goes on top, and the only weld is this weld here which is relatively easy to make. These three interior items are not held by welds at all--they are held by blocks that are bolted down to hold them in place. The assembly technique is completely different. We also changed this boss. The end, which you notice on that sample, was a problem. We had a couple that were fine in terms of welds, but the boss on the end got damaged--that was no good either. We changed to a different boss that does not stick out. These are currently being built up at Solar, and we have several of them that are in the test phase.

Mr. WILSON. In the alternatives in solving this problem, this is the one you have chosen to back up this condition. Is it possible, or even sensible, to consider using a simple shell and tube heat exchanger behind this pipe?

Mr. EHRHARDT. I think it is possible, and one of the things which we pursued.

Mr. WILSON. I wondered if you pursued that along with the others.

Mr. EHRHARDT. I think there were six or seven alternatives which were discussed. We looked at a cartridge type, too. We are not pushing this one, at this point, as we think that our present solution will resolve our problem. The cartridge would require us to go in with some configuration changes to actually install it. One of the reasons for its location is that

Mr. EHRHARDT (cont.). we are trying to condition the gas temperatures as close to the Platform as possible. We would have had to relocate the cartridge, and we may have encountered other difficulty. We may have had to get into the business of insulating the pipe that carried it off.

Mr. WILSON. It is obvious, then, that you have looked into many possibilities?

Mr. GRACE. We have, along with Marshall, and it was a joint venture saying, "No, one is the best." We are still not out of the woods completely on the Gas Bearing Heat Exchanger, but we do have the capability of working with Marshall to get assets that will keep us on the program.

Mr. WILSON. If this heat exchanger fails to function properly, how long before you get into real bad trouble--possibly partial or complete failure, and still have the gyros function?

Mr. GRACE. I think you can; it really gets into the safety factors built into the design of the Platform. There are some, I think. There are some on the temperature of the gas. When you talk to the gyro people, of course, they say, "No, sir, that thing has to do the job, and there just cannot be any relaxation there!" No argument. The Platform is a very critical precise element of this system, and we have to maintain what they say is required, but when you get right down to it, with everybody in the room, and with a crisis situation, I am firmly convinced that the Gyro Lab people would say, "Well, yes, maybe that would not wipe us out if that happens." However, how long you can operate with a gas bearing temperature way out of control, I do not know. Probably not too long, if it were way out. It is a relative sort of thing.

Mr. GRACE (cont.)

I have selected what I think are the key kind of problems we have had, and the point I want to make, is that we have absorbed a number of things like this. These are the ones which are most recent and that we have worked our way out of without schedule impact--with a single exception of the manifolds, that we just could not absorb without schedule impact. One problem more I would like to look at is in regard to cables--we had near disaster here. I give it to you because it is the thing you run into in this sort of a program. The cables that you see located around the inner periphery are pretty extensive--there are lots of them (Figure 25). You will notice the kind of brownish color--most of them are just a single wire. The white ones are either wrapped or twisted pair with a different insulation over it. The wire that you see--the one with more light on it--rather a gold-looking color, is fairly clear, and you can see the copper through it. This wire was developed by Marshall working with some cable manufacturers back when weight of the vehicle was a significant problem. This goes back now about 2 or 3 years when there was a real concern about keeping the weight down. Everybody was working on getting the weight out of this vehicle. As you well know, we now have less concern about weight. However, it was not for weight alone this wire was selected. One of the things that we learned in these programs is that an awful lot of problems you have in terms of failures are associated with connections, wires, cables, and connectors. This wire is very flexible. As a result of being flexible, it is less likely to put a strain on the connection. It is also very tough, and when made right, you can hardly get through this insulation. So it has the features of being extremely tough, extremely

Mr. GRACE (cont.). flexible, and therefore, much more reliable. It also has one other characteristic--it is a "dog" to make. There is only one company in the world that can make it, and we were in serious trouble because they had about a 95 percent reject rate on what they were making. Because of the tight specification, the wire was costing us better than a dollar a foot. There could not be any defects in it because if there was a crack in it, corrosion occurs, and you are out of business. We had an extremely tight spec, every foot had to be tested 100 percent. If there was a little flaw in it, it was rejected. ITT (ITT Surprenant Inc.), who make this wire, was having an awful tough time making it. We eventually developed a second source for the wire. This wire looked good and passed all the qualification tests. However, the problem with this wire is that it is easy to get out of manufacturing control. You will notice that there are two layers of insulation--the inner insulation, which is relatively thick, and the outer one, which is tough. (Figure 48) The inner one has a tremendous dielectric strength for the small size. The problem is that the curing temperatures are different on the inner and outer one but are very close together. It must be controlled to just a "gnat's eyebrow". Of course, if you try working it a little bit so that you are not going to have any problems when you put the outer one on, the inner one will deteriorate with time. This is the situation we ran into. We received this wire from the new supplier and started to use it in building up our cables. Our supplier on the cables at that time, Hayes Aircraft, caught a little tiny nick in one of the cables

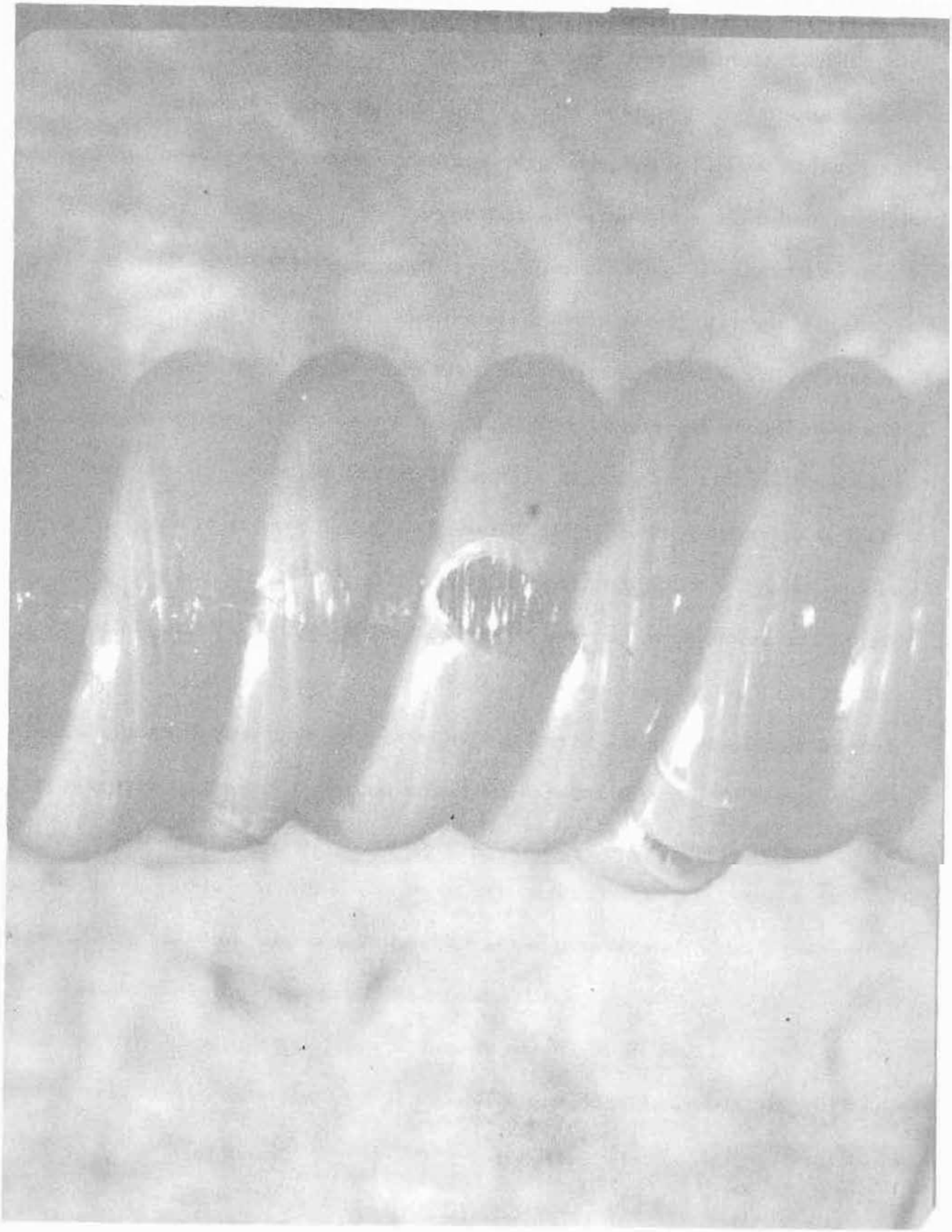


FIGURE - 48 - WIRE ON MANDREL

Mr. GRACE (cont.). they were making for us. As a result, they started looking and found a couple of others. Our quality people stopped the whole line because we had a potential problem on our hands. As a result of that, we discontinued the use of that particular wire. We ran a lot of tests, one of which was to take it and wrap it on a real tight mandrel, such as the picture here. (Figure 48) It was given the maximum bend radius the wire would encounter. We determined from the tests that even if the wire looked OK a tremendous deterioration took place. What we have here is a length of the good product and you can see the flexibility and strength--you just cannot get through it at all. (Mr. Grace refers to a sample of wire) You can cut through it with your fingernails if you try real hard, but it is very tough. The solution, of course, was to pull all of this wire from the line until we could get an answer to the problem. The supplier decided to discontinue manufacturing the wire, and we were back with only one supplier--ITT. Much to their credit, they have really put heart and soul effort into this. They have upped the yield on the wire to where they are getting a good yield on it now. We have enough wire in stock for the next six or seven Instrument Units. In essence, we are "out of the woods" in cable problems. When this happened, we had S-IU-204 and 501 in assembly and some cables to be made up on S-IU-205. We went back to our traceability system and found that we had three cables in S-IU-203 at the Cape which could have some of their wire in it. We checked and sure enough, it did. We removed these cables from S-IU-203 after it was erected on the pad and replaced them.

Mr. GRACE (cont.). We pulled all of this wire out of the system and had to remove and replace some 40 cables in S-IU-204. About the same number were in S-IU-501. They caused several of those dangling diamonds that you saw here, too. Usually, in places like that, we were able to absorb the schedule impact.

Mr. FELTON. You have a sole source for this particular wire then?

Mr. GRACE. Yes, the sole source.

Mr. WILSON. Does the manufacturer have any other requirements for the use of this wire other than this for the Instrument Unit.

Mr. GRACE. It is my understanding that this wire is used in the spacecraft also.

Mr. WILSON. If you get to a point where you get most of these units built and you no longer buy wire from the manufacturer, does he shut down his equipment and get rid of his people? If you want to start up again, you have to go back to the problem again. It is possible that could happen?

Mr. GRACE. As a matter of fact, there are not very many people who would pay the price for this wire. I feel ITT does not have other requirements. At the time we were involved in the problem, there was no other person using the wire, other than us, on the Saturn program.

Mr. WILSON. Is DOD using them?

Mr. GRACE. No, there was no other use for it at the time, as I recall. And anyway, ITT is doing this particular job, to a large extent, out of patriotism and interest in supporting the effort. Obviously, they make lots of other wire, and we buy a lot from the company, and the government buys

Mr. GRACE (cont.). an awful lot more from them too. There were lots of times when they felt like "throwing in the sponge" on it, too. But they stuck with it, and they have it well licked now. It is a real fine product.

Mr. FELTON. Since you mentioned that weight is not so critical, why did you stay with this type of wire?

Mr. GRACE. Because of the other aspects that I mentioned. We did have a back-up using standard Military Specification wire, which is bigger. It requires different connectors, and we had the problem of the connectors. We also had the problem of the stiffness of the wire and the necessity of requalifying everything. We had three or four alternatives going. We were prepared to go to a heavier, more readily available wire if we had to. The reason we have not gone to it is--and it could be done in the future, by the way, in answer to your question--because it would require a lot of additional testing assurance. Another reason that we have not gone to it is because ITT did "up" the yield--they did come through with the product. The best interest of the program was served by staying with this. It did not cause a lot of other questions to be raised that had to be answered.

Mr. WILSON. Do you have a large number of single manufacturers to make components where the need for these things would be limited--so that it would require them to shut down whatever capability they may have for this, disperse their people, and perhaps close the factory when your program needs end, and then require a new start-up to make the product--do you have a large number of suppliers like these?

Mr. GRACE. No, there are other items like the Gas Bearing Regulator little specific items like valves and things that are proprietary to some companies. There was one element, it was material that was used in the mounting rings on the Platform. It was determined that to control the temperature of that Platform more precisely, it would be good to insulate it. When you are talking about maintaining really tight alignment and insulating at the same time, you have an interesting problem in the insulating material. It has to be tremendously dimensionally stable or have the same coefficient of expansion of the aluminum Platform casting. There was a material called "Tayloron" that some outfit made, provided to Marshall, and just met these needs. Marshall made up a few shims out of this and tested it. It was terrific. IBM was directed to use this to make these shims. We went to Tayloron to run some. They said, "We do not make it." We said, "What do you mean, you don't make it? You made it all!" "We provided that material to Marshall awhile back. We developed it at our lab and thought maybe people would want to use it, but there was just no requirement for it. We don't make it." That is the kind of interesting thing you get into. Actually, we brought enough persuasion to bear on them that they went back into production. This is the kind of thing that can happen in a program like this.

Mr. WILSON. Do you have any IBM electronics that you schedule peculiar to the system, that are extremely difficult to make, and the company will not manufacture after completion of this current run?

Mr. GRACE. I think the Flight Control Computer would probably fall into that category.

Mr. EHRHARDT. The Flight Control Computer is made by ECI. His specific question is: one that IBM is making, like the digital computer.

Mr. WILSON. The question is, is there any technology that you use only for this program that is difficult to recover?

Mr. GRACE. There are some, yes. We would have to go through and pinpoint the specific ones. In the case of the Launch Vehicle Digital Computer and Data Adapter, we use a variation of our S-I-B technology. It is a variation--it is smaller, lighter, meets the requirements of aerospace environment of the Saturn. It is only made for our Saturn requirements. It does employ standard semi-conductor chips that are made for the commercial line. It is something that our Owego facility is negotiating with Marshall now to try to maintain a steady rate on the Launch Vehicle Digital Computer and Data Adapter so they do not have to shut down the line in our components division and have to reactivate it later on. We are not going to shelve the technology, but there is a reactivation problem. In answer to your question on the suppliers in terms of turning them OFF and starting them up, I think it is significant to note that a lot of the people who are providing us with material for this program--better than 1000 small suppliers and 250 or 260 large suppliers--are doing this, to a certain extent, to build up prestige because they want to be involved in the program, not because they are making a heck of a lot of money out of it. Frankly, the kind of requirements that have to be met are pretty tough in a lot of cases. They have been very cooperative and we have had fine relations with most of our suppliers. As

Mr. GRACE (cont.). has been mentioned, we buy a large part of the materials on a fixed price basis. Sometimes, when difficulties are encountered, they even lose some money. I do not like to see that, and I do not think the government likes to see it either. A lot of the kind of cooperation and support is more from patriotism than strictly business. As long as you keep things going, you keep this atmosphere of cooperation and support going. If you shut them off, start them up, and shut them down, and make it unduly tough on them. I think we can get the impact on the kind of cooperation we get. We have found, just to put it in the proper prospective, that the job of procurement of the elements of this Instrument Unit is about three times the size that we assessed it would be in the beginning simply because of the diversity and special problems and the small runs, long schedules, etc. It just takes a lot of work on the part of the purchasing organization to keep everybody happy and keep everything coming. If you cut it off and then start it up again, I think we would find difficulties in many specific areas. Let me just wrap up the problem area we were discussing by saying, that I have listed three major ones. We have had a bunch more. We have pretty well resolved all of those. The only one that has caused us any problem, schedule-wise, is the manifold one and we know where we stand on it.

I have taken more time on that than I intended to. I do not want to take too much time away from Mr. Jim Meadlock, who is our System Programming Manager for a very major part of our responsibility in the software.

SOFTWARE

Mr. MEADLOCK. IBM has a major software role in the Instrument Unit contract. We begin with the checkout of the Instrument Unit at the Huntsville IBM facility. This is an automated checkout with a computer system. The Instrument Unit is then taken to Cape Kennedy and stacked on the total vehicle. At Cape Kennedy, much of the Instrument Unit checkout uses similar software to that used for checkout at the Huntsville facility. In addition, we have the in-flight guidance and navigation problem from liftoff through the burn of the S-IC and S-II Stages, the first burn of S-IVB Stage, the orbital operations, and finally, the ejection out of orbit using the second burn of the S-IVB Stage. We also stabilize the vehicle as the Service Module turns around and docks with the Lunar Module.

First of all, I will talk about the in-flight guidance problem and then come back to the checkout problem.

We define navigation as the ability to know where you are and at what speed you are traveling. Inputs to the navigation scheme are the accelerometer data from the Stabilized Platform which we receive as velocity data. (Figure 49) Velocity is accumulated in the Launch Vehicle Data Adapter (LVDA) on an incremental basis and then on a major computation cycle. We keep track of the total velocity and perform integration to find vehicle position. We come out of the navigation scheme in the computer system with velocity and position.

We must also know how to orient the vehicle. This requires a solution of the guidance problem. There are many different schemes in the industry to solve a guidance problem. The particular thing we are trying to achieve is a

NAVIGATION

Compute Vehicle Position and Velocity During All Phases Of Flight

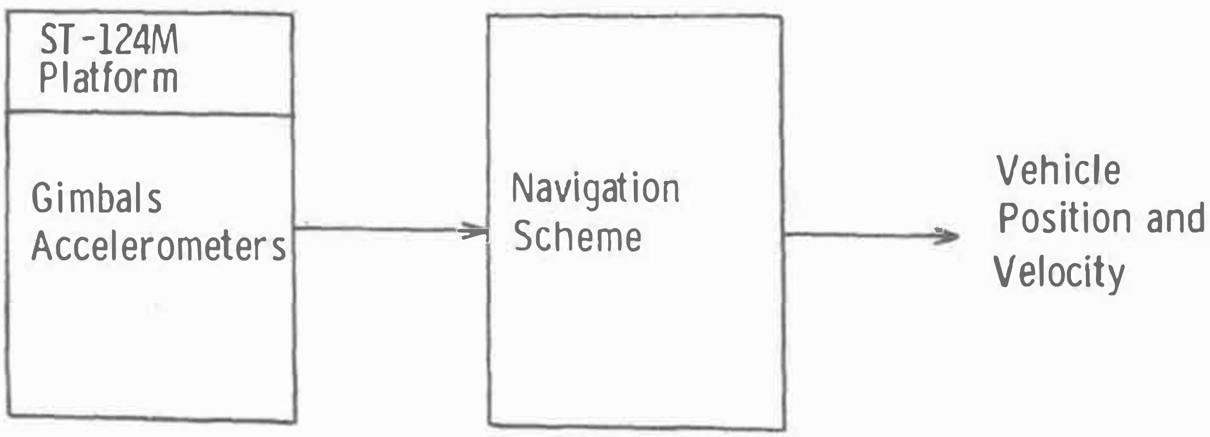


FIGURE - 49 - NAVIGATION

Mr. MEADLOCK (cont.). desired cutoff velocity vector and attitude. We do not have a downrange constraint. Incidentally, in the particular scheme we use, we do relax the attitude constraint over the last few seconds to try to have a more stable cutoff. As inputs to a guidance scheme, you must have navigation data and the desired end conditions. (Figure 50). The guidance scheme computes the desired attitude of the vehicle to achieve these end conditions.

The other problem we solve in the Launch Vehicle Digital Computer (Flight Computer or LVDC) is the control scheme. (Figure 51) In contrast to the Saturn I Vehicle and some of the other missile systems, we do close the control system through the Flight Computer. We must have the guidance problem solved (how we want to orient the vehicle), and we must know vehicle position, relative to some stable element. The control scheme in this particular vehicle is solved 25 times per second. In the Flight Computer, we have an interruptable system where we can set a counter that periodically (every 40 milliseconds) gives an interrupt which tells us to solve the control scheme. In orbit we relax this by solving the problem 10 times per second. The control commands must be resolved back to vehicle coordinates to control the input to the engines on the stages.

Pictorially, we show another of the capabilities we must provide. (Figure 52) We have a digital command system which permits us to add the capabilities of updating pre-selected quantities from the ground when we are in orbit. S-IU-203 was a good example of this as we explained earlier. We had pre-programmed the switchover from camera 1 to the backup camera on

GUIDANCE

Compute Vehicle Attitude Required to Meet
Prestored End Conditions Using
Minimum Fuel

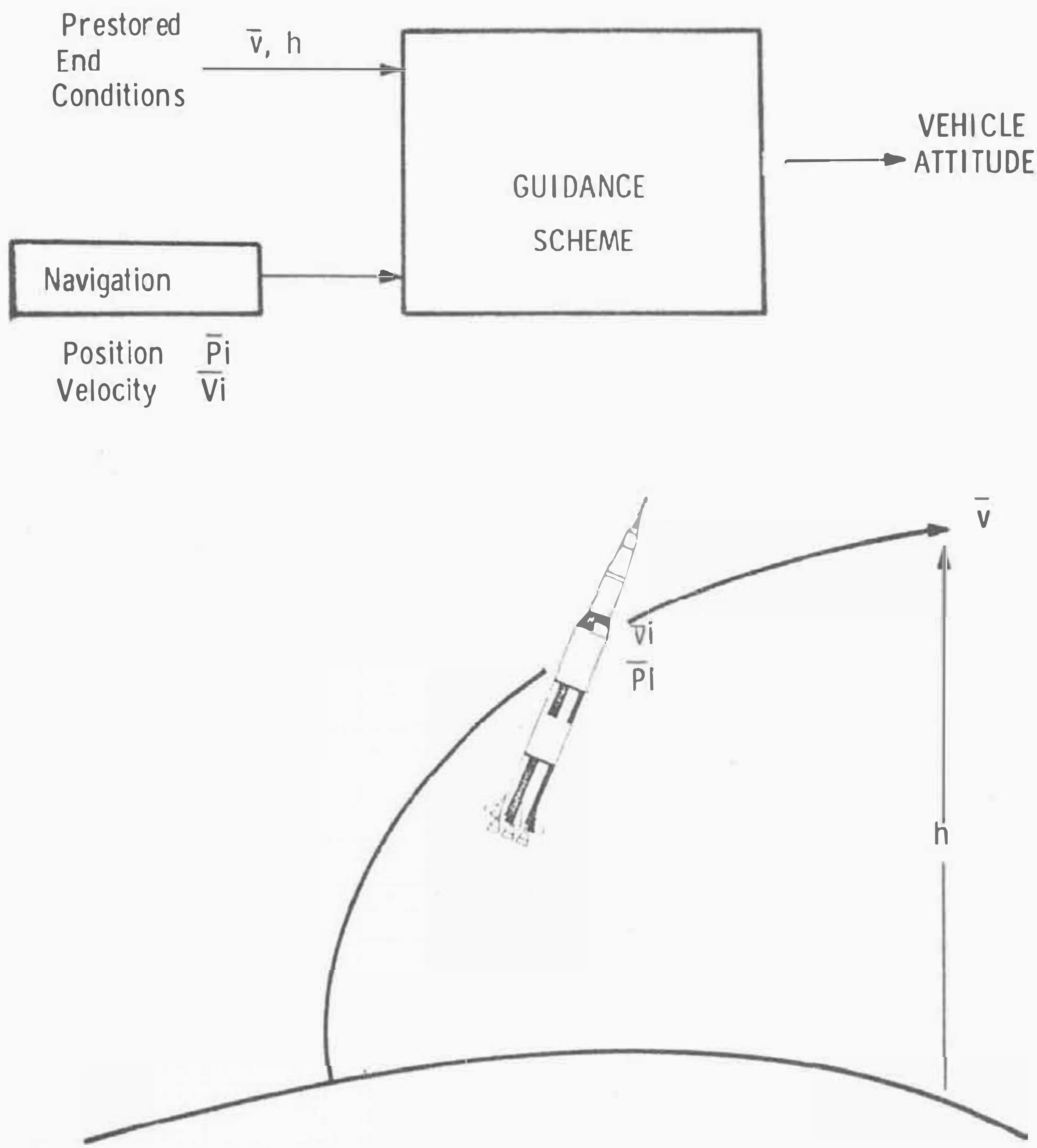


FIGURE - 50 - GUIDANCE

CONTROL

Compute Steering Commands That Will Control the Engines Causing the Vehicle to Assume the Attitude Computed by the Guidance Scheme

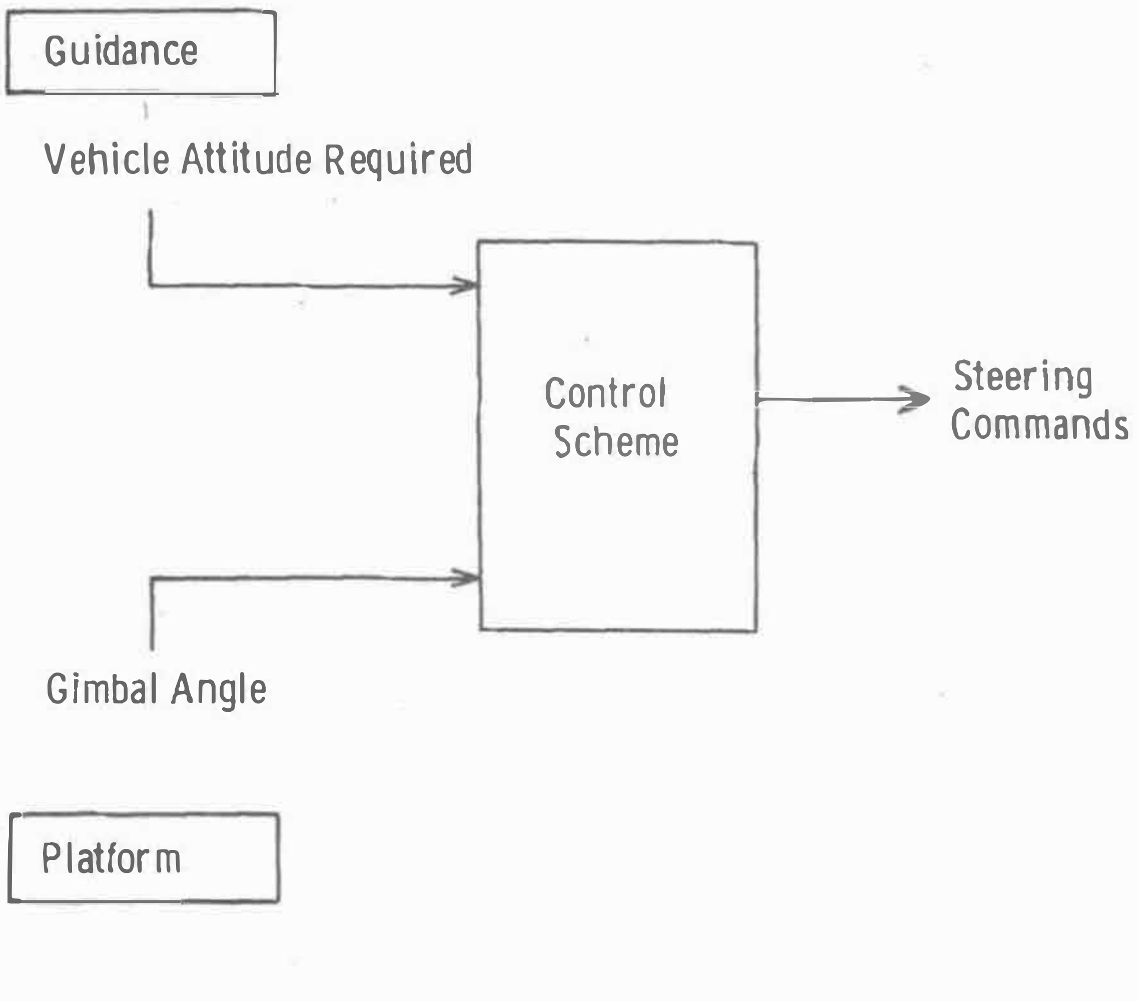


FIGURE - 51 - CONTROL

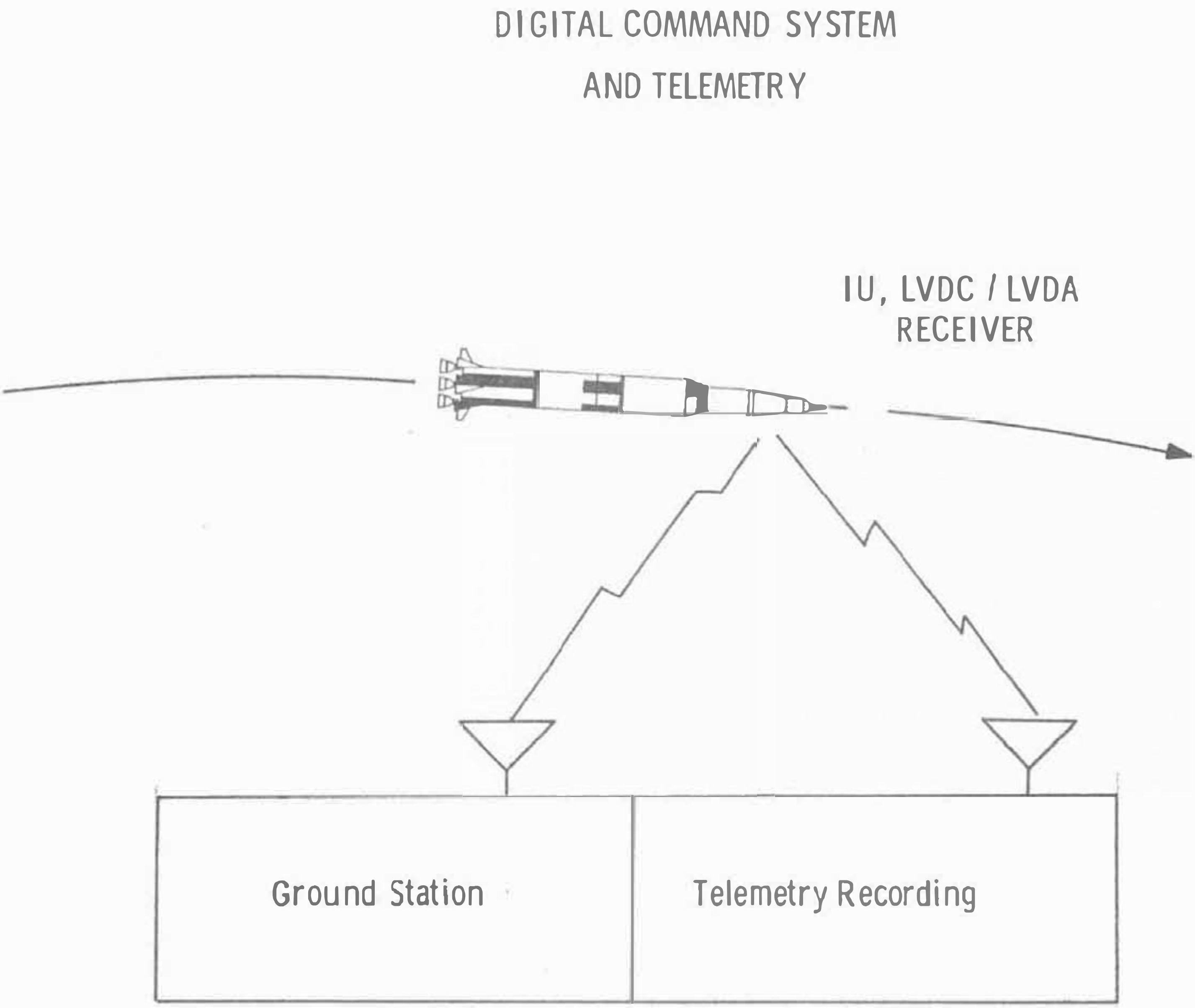


FIGURE - 52 - DIGITAL COMMAND SYSTEM & TELEMETRY

Mr. MEADLOCK (cont.). the third orbit. We also provided the capability to permit selection, from the ground, of whatever camera they wanted over any ground station. So even though we did pre-program the switchover, they were immediately able to tell us to switch back via the command system. Another important thing that we do over the dark spots, of which there are many in the world wide tracking net, is use the memory capacity in the Flight Computer to store many parameters regarding the S-IVB and Instrument Unit Stages. When we are over a ground station, we telemeter these down. While we are in orbit, we also use this ability to do checks on the S-IVB Stage and on the Instrument Unit interfaces to insure that we are ready for the second burn of the S-IVB Stage on the Saturn V missions.

Mr. WILSON. Could you go ahead on the second burn even if you could not update from the ground?

Mr. MEADLOCK. Yes, that is basically true. So far, we have considered the command system as not being critical to our mission. In other words, it is backup capability. I cannot guarantee, as yet, that this will be held on the manned Saturn V mission. This is a problem which is continually being discussed. The feeling is that, yes, we can do it, by the fact that you can still communicate with the Apollo system.

We control all of the vehicle's sequencing, as I think was explained earlier in the description of the interface between the onboard vehicle. (Figure 53) We do this by the Switch Selector, which is also a redundant device similar to the Flight Computer technology. There is a Switch Selector in each stage and,

VEHICLE SEQUENCING

Control of Vehicle Switching Functions

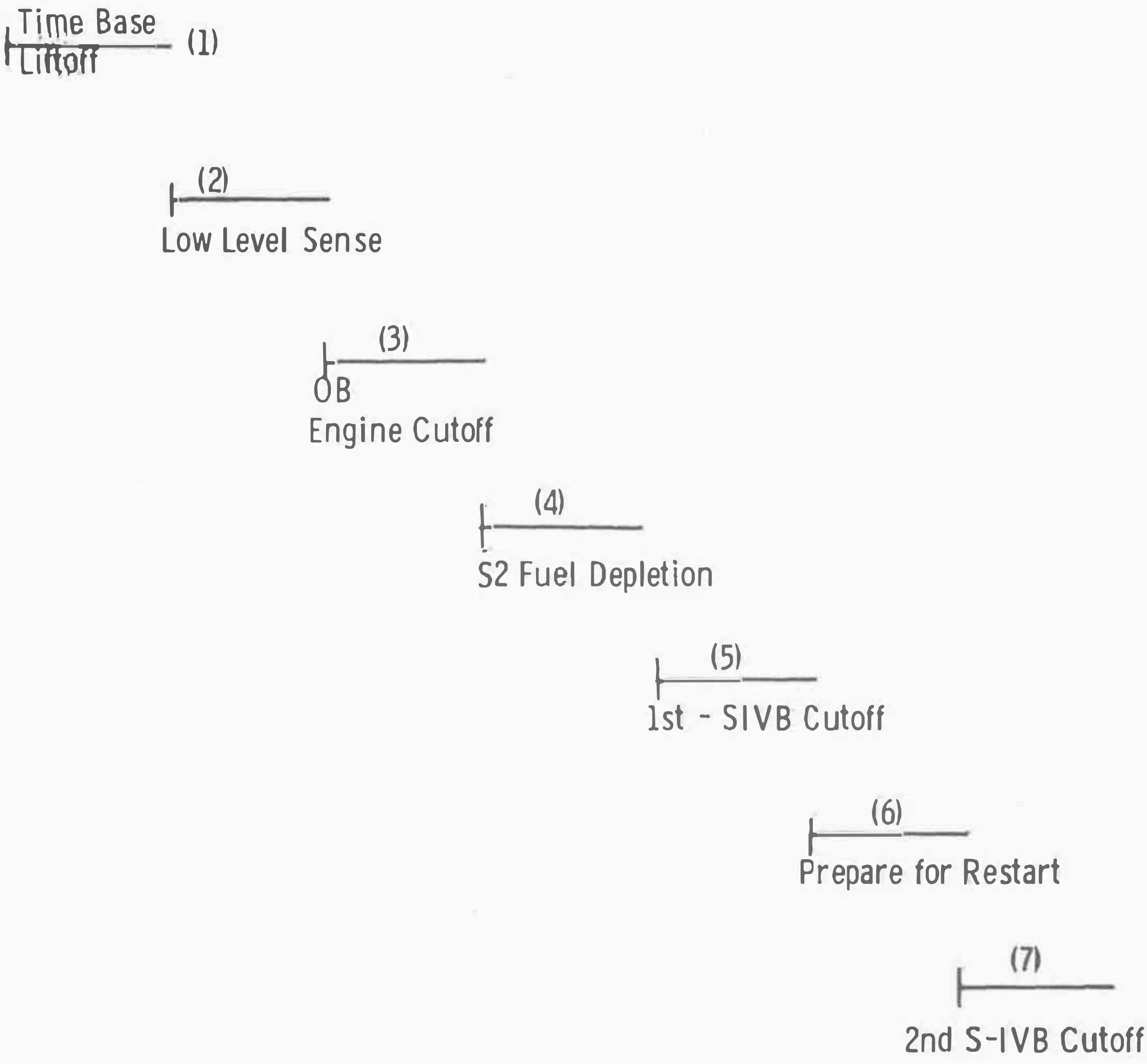


FIGURE - 53 - VEHICLE SEQUENCING

Mr. MEADLOCK (cont.). basically, we are able to send out 8-bit codes that are decoded within the stages. As typical of the number of sequences; on AS-201 we issued 104, and on AS-203 we issued 480. The increase is because of the longer orbital time. On AS-203 we controlled turning OFF and ON the cameras, the lights, and the time of the sequences. On AS-501 we are presently planning on 280 sequences, which we expect to increase as we begin to get closer to the time of launch. In terms of trying to time things as precisely as we can, we key off of different time bases. For instance, we take the liftoff signal as an input into the Flight Computer and we time the events in the S-IC or S-IB Stage based on this liftoff time. The low level sense indication is, of course, a sensor in the fuel tanks that indicates when fuel is below a certain level. We then have a series of events that are sequenced from that event. The fact that we use this low level sense indicator lets us adjust the time basis for the S-IVB burn, depending on the mission. This also gives us the capability of adjusting the flight path in case we have an engine out condition, particularly on the S-IB Stage. So, I think it just points out the fact that with a computer system you do have the flexibility to adjust the program to the various things that can happen to you on a mission. And again, it is one of the advantages of the computer system. These are also the same sorts of things that give you problems in trying to verify that you do have a good program. This entire computer system and the redundancy that we built into it gives us no real problem because it is not really under program control. However, all of the inputs to the computer system, for instance in the Platform, have duplex resolver inputs for gimbal

Mr. MEADLOCK (cont.). angles and duplex inputs for accelerometers. We pre-program the ability to switch from one of these to the backup system in case of failure. The problem in checking out the program is quite a serious problem in insuring that you can do this for the total mission and for any type of circumstance. For instance, with the gimbals and accelerometers, not only must we be able to detect if they fail on a nominal flight, but we must also have the ability if an engine goes out. Of course, the expected profile changes, and we must adjust the test that we use to see if the input is still bad. Those are some of the things that are most troublesome in insuring that we can recover from a failure.

Mr. WILSON. Are you saying you complicate your circuitry when you do this?

Mr. MEADLOCK. We complicate the logic within the program; and it grossly complicates the checkout problem. . ."

Mr. WILSON. Then it is a software problem?

Mr. MEADLOCK. Yes. It gives tremendous capability, but it also gives you tremendous headaches. Let me show you the things we discussed and in the periods of the flight in which they are active. (Figure 54) I did not say much about prelaunch checkout. There is a major part of the instructions within the onboard computer, that is used to check out subsystems during prelaunch operations. In other words, we have the capability to verify all of the interfaces with tests while it is on the pad. In the last few hours, this gives the advantage of completely verifying that all the interfaces in the system are working but without breaking those interfaces.

FLIGHT COMPUTER TASKS BY PHASE

PHASE					TASK
1	2	3	4	5	
PRIOR TO LIFTOFF					PRELAUNCH
X	X	X	X	X	NAVIGATION
	X	X	X		GUIDANCE
X	X	X	X	X	CONTROL
X	X	X	X	X	TELEMETRY
X	X	X	X	X	VEHICLE SEQUENCING
		X			ORBITAL CHECKOUT
		X			DIGITAL COMMAND SYSTEM

FIGURE - 54 - FLIGHT COMPUTER TASKS BY PHASE

Mr. WILSON. Can you make software and take it to the Cape and use it without any modification to this prelaunch?

Mr. MEADLOCK. Yes.

Mr. WILSON. There is no difference?

Mr. MEADLOCK. There is no difference in prelaunch. There would not have to be any difference in the flight program in comparison to what we do in Instrument Unit checkout. However, there are always some changes in requirements between checkout and launch time.

Mr. WILSON. What kind of changes have you experienced and what are you beginning to see?

Mr. MEADLOCK. It has been gross. AS-201 was a new vehicle, a new computer, and a new program. We had a long development period, and we almost started over in November and December. We changed, for instance, the entire guidance scheme in November and December because of a propellant utilization oscillation problem that developed during the static firing.

We use an iterative guidance scheme that measures your thrust vector, and depending on that, it tries to calculate how to orient the vehicle. Effectively, on AS-201, we only had about 60 seconds of pure guidance.

Mr. WILSON. Then you really cannot take any updating from the ground on this?

Mr. MEADLOCK. Yes, we can. We have also tried to design it so you can, but it gets very complicated when you have to consider the different things you have to do.

Mr. WILSON. You say your program alteration is really heavy at this time?

Mr. MEADLOCK. Yes, it is.

Mr. WILSON. Let me ask you two questions. Has your experience on programming been one of under-anticipating requirements for the software program? Do you anticipate your high-level of change activity in this area to continue?

Mr. MEADLOCK. Let me answer specifically to the flight program and avoid the other two areas until later. First of all, the prelaunch part of this flight program, the programs required prior to liftoff, has been pretty stable since AS-201. I think MSFC and we did a very good job of anticipating what was needed. I think we had a little more hand-and-glove effort than any of the other efforts. It was mainly based on the past experience we have had on the Saturn I and other similar vehicles. We anticipated a lot of changes in the in-flight guidance problem -- other people did not. I have lived through this thing before. Definitions never become really firm, interms of exactly what you want to do, until the people get close to the time they want to launch the vehicle. This is a fact that is with us and will always be with us. I do not think we will have the magnitude of change like we had on AS-201 again. I do think we will continue to have a reasonably high rate of change. For instance, let me talk about AS-501. It is the same sort of problem. We are getting awfully close to the AS-501 launch time, and we are beginning to look at some of the things that have to happen. We have it programmed, right now, for AS-501 as originally defined back last January. We have now been asked to look at the possibility of what can be done if the S-II Stage does not burn correctly. And as you know, there is some

Mr. MEADLOCK (cont.). concern about the S-II Stage. We are trying to look at the many different things that can happen in the S-II Stage if one engine goes out, if they all go out after 100 seconds, if they should all go out after 150 seconds, et cetera. How can you throw away the S-II Stage, ignite the S-IVB Stage, and then continue the mission? All of these things get very complicated when you look at all the alternatives, and I see a good deal of this ahead. It is always worse on the first vehicle of a series.

Mr. WILSON. How many programmers do you have down there?

Mr. MEADLOCK. We have about 170 programming/engineering-type people. It is hard to draw the line sometimes between the two types.

Mr. WILSON. Do they do the work that is necessary for your work at Kennedy?

Mr. MEADLOCK. Yes. I personally have people at Kennedy and at Huntsville.

Mr. POWELL. Do you happen to have a slide depicting this long,drawn-out thing that is generating all of the requirements for a program?

Mr. MEADLOCK. We have a Mission Defining Document from Marshall, which is required some seven months prior to the Instrument Unit delivery, and from that, we develop an Equation Defining Document. This is a more detailed description of how we are going to implement the requirements that are placed upon us. From that, we go into the program development, checkout, and delivery to the Cape. This particular chart begins to show you some of the things that happen to the schedule. A new guidance equation here, a major change here, and now, in July, we are being asked to consider some other alternatives. In terms of late mission requirements, it is a problem that I think we are going to be faced with for a long time.

Mr. WILSON. Mr. Meadlock, has it been difficult for you to recruit your programming staff?

Mr. MEADLOCK. No, I think we have been very successful. It is the type of programming work where we have a mixture of all the types. We have been very successful.

Mr. POWELL. I think, Mr. Meadlock, a message in this kind of chart is that we get smarter after each flight, and we learn a lot of things. This alternate mission situation in AS-501 is an indication that we are beginning to look into the reliability now that we can obtain via software. We have looked for years for reliability in hardware; now, we are looking for reliability by software techniques. So the whole thing just smacks in that rhythm.

Mr. WILSON. It appears that you have a long term, continuing requirement for a high level of programming.

Mr. MEADLOCK. Yes, I think that is a true statement.

Mr. WILSON. Is that fair?

Mr. MEADLOCK. Yes.

Mr. WILSON. Is it much above what you anticipated at the beginning of the program?

Mr. MEADLOCK. It is somewhat above what we anticipated in the flight program area. I think it is grossly larger in the Launch Computer Complex area, about which I will discuss later. It really involves the total scope of what you consider within the programming area.

Mr. WILSON. If, in fact, you make the lunar flight in 1968, there is considerable reassignment of vehicle missions after that. Would you anticipate your current, trained, knowledgeable people in programming could handle problems you would be faced with in the last vehicle?

Mr. MEADLOCK. Yes.

Mr. WILSON. You do not think this would require a lot of "quarterbacking" to increase the people?

Mr. MEADLOCK. I don't think so.

Mr. GRACE. Mr. Meadlock's presentation as he continues. . . he will answer some of the things and will also give you a little better appreciation of the three major areas that he has. One is the Flight Computer, another the checkout program, and the other is a Saturn Launch Computer Complex at the Cape. The last one is the one that he referred to as grossly exceeding what we desired or expected.

Mr. MEADLOCK. So the prelaunch checkout -- I think I covered it in sufficient detail -- is a verification of all the interfaces it does permit us, with a digital system in combination with the checkout computers on the ground, to do this very close to liftoff time.

We have to solve a navigation problem, of course, during the five phases of the mission. We only have to solve the guidance problem during three phases of the mission -- during the S-IC burn and the S-IB burn we do not have active guidance. We really begin the active guidance on the second stage. The control problems, of course, we have to solve in all phases of the mission. We send telemetry back to the ground during all phases of the mission -- both live telemetry as it occurs and the data that is stored in the computer. Vehicle

Mr. MEADLOCK (cont.). sequencing by the Switch Selector must also serve for the total phase of the mission. The orbital checkout, which I discussed briefly, is accomplished while we are in orbit and preparing for the second burn of S-IVB Stage. During this phase, we must be capable of accepting navigation updates to the calculated position, we must be able to update real time, and we must be able to take care of various alternate-type sequences that are peculiar to each mission. On AS-203, we had five specifically pre-programmed alternate sequences on command from the ground. In addition, we give the capability, via the digital command system, to command any Switch Selector function that is determined to be desirable from the ground. In other words, if something happened that was completely unanticipated, and they do wish to command a Switch Selector function, they can send us up a code and the Flight Computer then executes this command. While in orbit, we also have the ability to verify memory back down to the ground, if there is some question about the capability of the system.

Mr. WILSON. Do you have the data rate to be able to go into that computer and completely update it?

Mr. MEADLOCK. Not to completely update it, no. For every flight instruction, there are two identical memory locations (two separate banks), and there is computer circuitry that votes on these two. It can flip-flop back and forth. But to completely update it, no, there is not sufficient data rate capability for us to do that -- unless you had an extended mission.

Mr. WILSON. When you have a complete dropoff, can you go on your Command Service Module system then?

Mr. MEADLOCK. Yes, I will get to it on the functional block diagram. There are inputs, from the Command and Service Module system, into the same outputs that we have from the LVDA, and there is relay switching that is under control of the Astronaut. In the last phase, we stabilize the vehicle and that is about all we do. We must solve the control problem, navigation, and still some vehicle sequencing that is based on S-IVB Stage second burn cutoff.

This is a block diagram similar to the one you saw before. (Figure 55) The control commands, which come out of the Launch Vehicle Data Adapter, are in the vehicle coordinates. They are sequenced into whichever stage is burning. We control the gimbals in the S-IC and S-II Stages. In the S-IVB Stage, we control pitch and yaw with the single engine, and we control roll with the auxiliary propulsion system. When we are in orbit, the pitch and yaw commands are also switched into the Auxiliary Propulsion system for control.

Mr. WILSON. If, after you start the S-II burning, you lose computer capability in the Instrument Unit, how much Command Service Module capability have you at that point? You have an alternate, can it do it any good?

Mr. MEADLOCK. Theoretically, yes, it can. They can get into the same outputs we have from the guidance system. However, they do not have vehicle sequencing capability. There is the additional problem that we have been guiding on our Stabilized Platform, and they must now take inputs from their Stabilized Platform. There is no communication of that data across the interface.

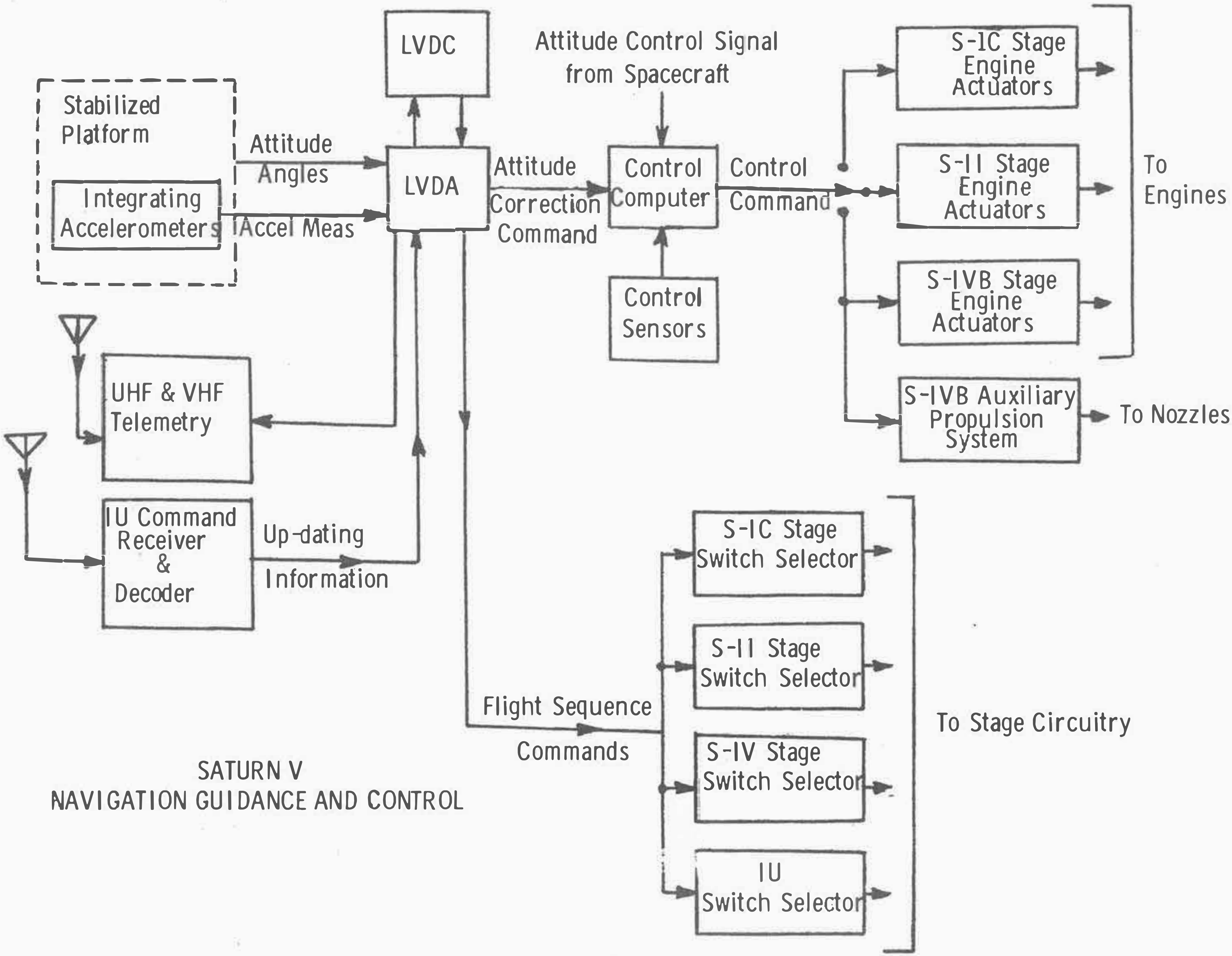


FIGURE - 55 - NAVIGATION, GUIDANCE, & CONTROL SCHEMATIC

Mr. WILSON. You do not know if the two Platforms could do the same thing or not?

Mr. MEADLOCK. Theoretically, yes, they can pick up the guidance and control. Whether it will be programmed to do that, I do not really know. We are, of course, assuming that they are not.

Mr. POWELL. It has been discussed for a long, long time. I think Dr. Miller brought it up first. Can we somehow have a switch that we can throw to go back and forth between the spacecraft and the launch vehicle? That is at the investigating stage between MSC and Marshall, and there is now a planned approach to verify whether we can or cannot.

Mr. MEADLOCK. (Mr. Meadlock refers to Figure 56) The program requirements come to us in the form of a document from Marshall, which is a Mission Defining Document. Of course, there are the other requirements that come filtering down through the line. But in any case, we developed from this something we call a flow chart. Those of you who are not familiar with programming, flow charting is taking the requirements to solve a problem and laying them out in a block diagram fashion. If it is programmed correctly, the computer will do exactly what the flow chart says and exactly no more than it says.

We then enter the program coding phase, where this is particular to the computer that you are going to solve this problem on. The flow chart is relatively independent of the computer system. It only begins to be dependent on it when you start considering the fact that you have core memory limitations and may have a bit length limitation which makes you pick a particular solution

PROGRAM
DEVELOPMENT

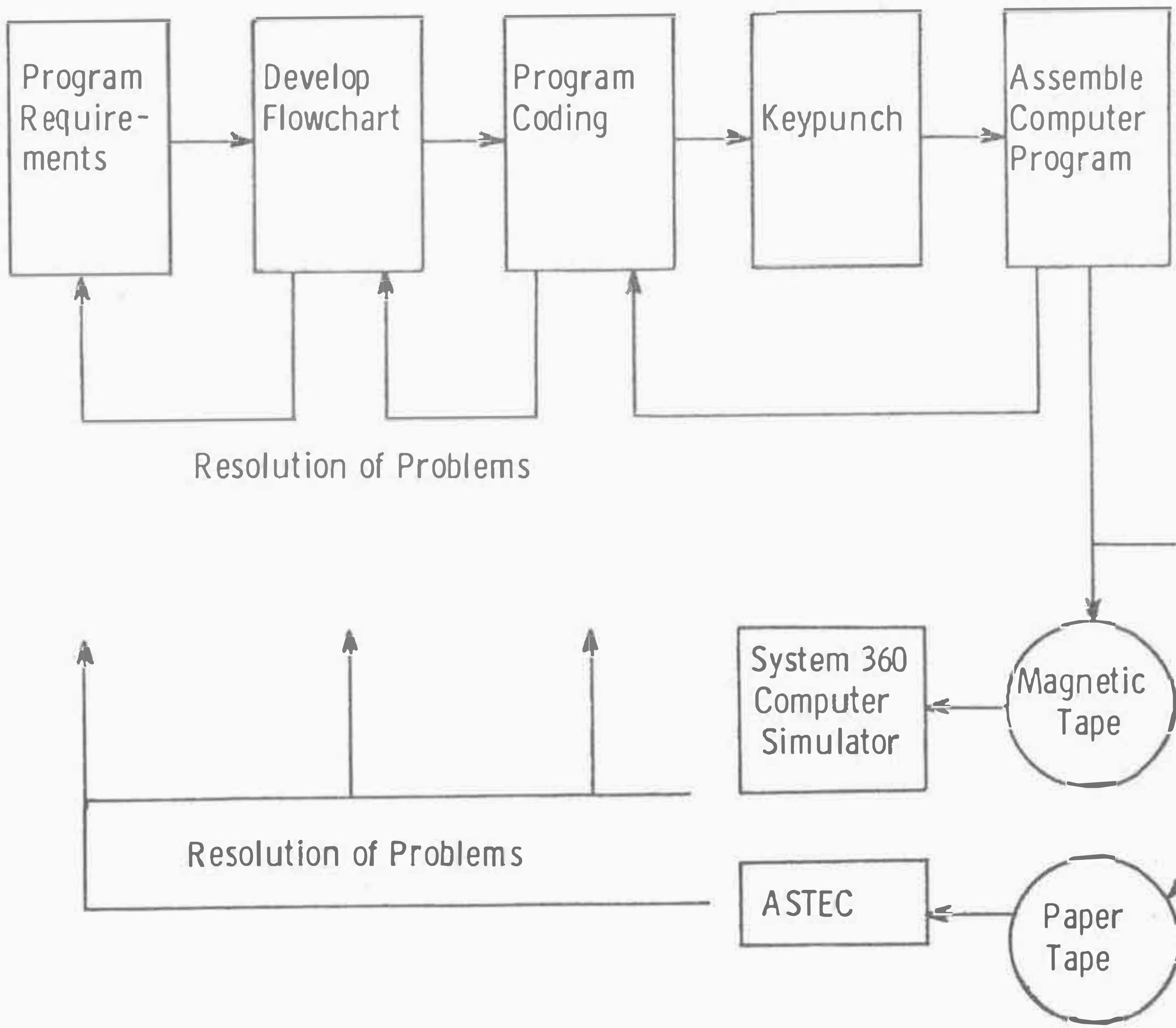


FIGURE - 56 - PROGRAM DEVELOPMENT

Mr. MEADLOCK (cont.). to a problem. On a different computer, you might pick a different solution. Once we have programmed the problem, it is key-punched, assembled on an IBM System/360 Computer that we have here. (Figure 57) This is an assembly program that takes coded input for the onboard computer and converts this coded input to an output that is acceptable to the onboard Flight Computer.

Mr. WILSON. What language do you use?

Mr. MEADLOCK. It is symbolic language with extensive "macro" capability.

Mr. WILSON. That assembly, then, is peculiar to this computer?

Mr. MEADLOCK. That is correct. It is very similar to the ones we have used in all the other aerospace programs. It is special for this computer. You can still develop a more elaborate language, and we have experience with this type of development. Any generalized solution to a problem involves some inefficiency. When you begin to consider the core memory limitations you have in any flight system, you like to be as good as you can in using that space. So, we prefer symbolic language with the Macro capability. Many of the simulations in vehicle models and so forth, are all done in a higher language.

Mr. WILSON. If, for any reason, you appreciably increase the size of your Instrument Unit memory logic, are the programs still any good?

Mr. MEADLOCK. Yes, we have complete capability there. There should be no change in the assembler.

Output from the assembly process is a magnetic tape and paper tape. Paper tape is the normal input to the flight computer through the test equipment

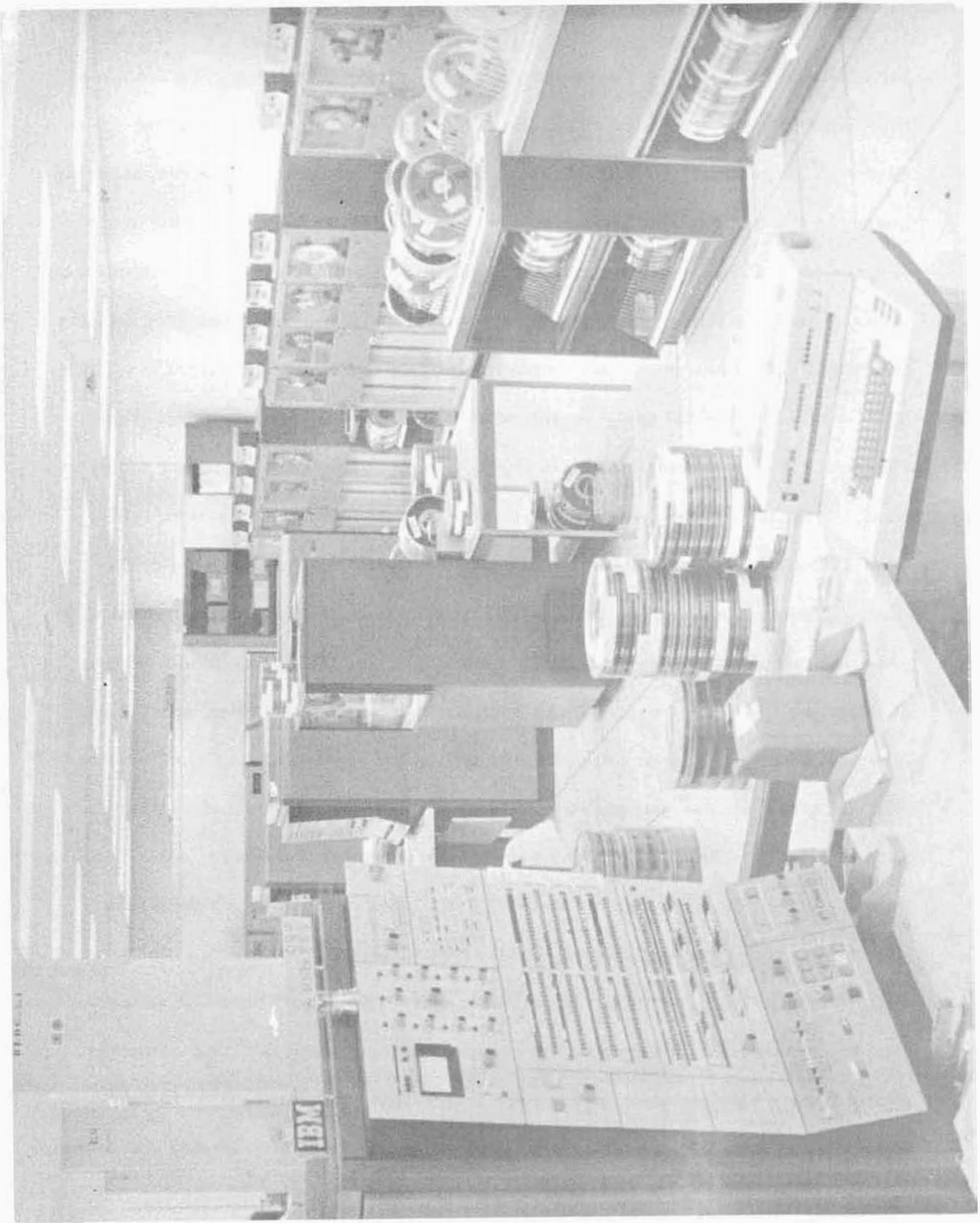


FIGURE - 57 - IBM 360

Mr. MEADLOCK (cont.) associated with the Flight Computer. We also use this capability for the initial checkout of our program, to simulate some input data and, in general, a static checkout of the flight program. The magnetic tape goes into the System/360 Simulator which I will discuss in more detail in a minute (Figure 58). It is the same tape that is made available to the launch complex and gives us the capability, via the ground computer system, to completely reload the Flight Computer on the pad without removing the computer from the vehicle. This is a picture of the test equipment which we use for our initial program checkout. It has a Launch Vehicle Digital Computer and Data Adapter mounted on it. Most of our checkout is done on this facility which is a System/360. Over in Building 5, we presently have a System/360 Model 30, 40, and 50--three different computer systems. Our first computer was received about a year and two months ago. It was the second System/360 off the Model 40 production line. We have successfully been using it since then. For every flight type program, we have developed a simulation for the mission on the System/360. In other words, you cannot really fly a mission to find out if you have a good program. The most economical and useful way that we have found to do this is on a general purpose computer. This computer can be made to look like the computer in the vehicle. In other words, you program this computer system such that it gives exactly the same answers as the Flight Computer. You take your actual Flight Computer programs and read them into this computer. A program in this computer takes each instruction, interprets what is the instruction, and solves exactly what that instruction will do. During the develop-

FIGURE - 58 - SIMULATION LABORATORY

Mr. MEADLOCK (cont.). ment of a computer system, you must develop a simulator as part of it. Extensive checks are required in terms of running specific problems on the computer system and simulator to assure that you do have an accurate simulator.

We do our initial program checkout on this particular simulator with rather unsophisticated inputs. In other words, you solve a specific nominal flight. Then we go to something that is more elaborate and add the vehicle simulation. In other words, what can this vehicle do? What are the bending moments, what is the sloshing, et cetera? So, you have in this same computer system, models of the vehicle, responses of the vehicle, and responses of the engine output. You try to build in the same delays that you have throughout the system. You can fly a total mission from this computer system. We have the ability to read in the thrust tapes from the static firing and to vary the thrust on these tapes over the range of tolerances that are specified on the different stages.

Mr. WILSON. Do you have the capability to simulate the total mission? How many other computers have the same capability that you are aware of? Do they do the same thing on 7090's?

Mr. MEADLOCK. They did originally. Since then, we have used the System/360 on S-IU-203 and 501. We worked with Marshall in doing the simulation on the 7094's for S-IU-201.

Mr. WILSON. How do you evaluate the utility of running these programs? How do you make management say how much is enough?

Mr. MEADLOCK. Well, that is a tough one. I am sure you always end up making the decision to do more than you have to. We are cautious; there have been so many cases where we almost goofed.

Mr. EHRHARDT. There is a test plan laid out defining precisely what kind of tests are to be run. And, then, as Mr. Meadlock points out, sometimes we think about something -- one more thing to be done. There is a rather planned activity in each mission to know ahead of time what is going to be done.

Mr. MEADLOCK. It is one of the reasons that we tend to, sometimes, even though we have a digital computer system, make some people think we are inflexible in taking last minute changes. The computer program is a dangerous thing especially when you have one that is interruptable. In other words, it can be interrupted by inputs from the outside world and it is very difficult to simulate all the conditions under which that interrupt can occur. You can sometimes go in and make a very simple change in the total program, and if this interruption is at exactly the right time, that affects something else.

Mr. WILSON. I realize that you have test programs in the development. When is enough, enough? This is the thing I do not understand.

Mr. EHRHARDT. Oh, well, Mr. Meadlock outlined it. We run our nominal flights, in other words, everything is kind of right down the center,and we run with the winds varying as we expect they could happen. We then make it a point to check out each and every one of these backup modes. That is how we know when is enough. We do check each one of these out so that if any of those things happen,we have proven that it will take care of the situation. After the

Mr. EHRHARDT (cont.). program is complete, it takes from 4 to 6 weeks, depending on the mission lengths, for actual total program verification.

Mr. GRACE. We deliver our flight program to the Cape and we continue verifying in the simulation facility and the digital system. We put every kind of conceivable failure and mode into it to make sure it works. We find some things, occasionally, in that. When have you done enough? When you have checked everything out. If you go back and change the program, you get into the debate, "Do we have to go back through the whole thing or can we settle for something else?"

Mr. MEADLOCK. Now the real problem comes when you get close to launch and someone decides to change something. Now, what is enough to go back and re-verify this? There you get into the pure judgment decision. You cannot, in the constraints of the launch, redo this total amount of verification. You have to look at the particular change and use some judgment. That is a difficult decision, and you cannot lay any fixed ground rules.

Mr. GRACE. Just to state our position on it, we feel very deeply about the responsibility that we carry in this particular area. Mr. Meadlock, in particular, and his people are very, very much concerned about it. Because of the loss of a $30 million vehicle, and even more important, if it were a manned mission, there is a tendency to want to check it out and to want to verify it to make sure that everything is right. That tendency may lead us into more than would be absolutely necessary. Determining what is absolutely necessary is a problem to solve. We want it checked out.

Mr. WILSON. On the AS-201 mission, can you put in perspective how much your total cost for developing the software goes into the verification?

Mr. MEADLOCK. Well, probably 40 percent if you consider the total cost of the computer and the people required to support the Simulation Laboratory and the System/360.

Mr. POWELL. Mr. Meadlock, I think an analogy to that answer would be if you could, by hook or crook, project on that screen up there a picture of the simulation facility and a picture of the Instrument Unit checkout station, then relate that blue bar called systems test to that red bar called verification, and then look at times and people involved, I think you would be amazed at the analogy there.

Mr. WILSON. This indicates that this is the place we can afford to spend money to improve your confidence of when enough is enough. Do you have any internal programs of your own as far as management programs are concerned? Do you evaluate this to decide when you can reduce the amount of verification in this sort of thing? Are you looking and inventing a "better mouse trap" in verification?

Mr. GRACE. We have been doing a lot of thinking, as this area has been badly overworked. The hours that our programming people had to work, to stay on schedule, is unbelievable. We can sit here today and say we never delayed a launch because of not having a program--we do not ever want to. We have been faced with saying that we do not have an ideal situation. We would like to have the mission defining data into our systems engineering group earlier and would

Mr. GRACE (cont.). like to get the Equation Defining Document out so the programmers could work. We would like to get the program done, then verify it, and launch it. All this gets piled on top of each other. They continue changing the mission, modifications to it, et cetera. What we really have done is to recognize the fact that this ideal situation is probably not going to exist for a long time. Now we must figure out some way to accept the real world situation and still be able to come out with something we think we can ride with confidence, that this is a complete and accurate program to do the job. Up until now, we have been faced with a fear that we have not had enough time to check it out adequately, that we have not had enough time to verify it. That is a most uncomfortable position to be in -- to hope everything has been covered. It is not the way you want to run a program like this. It has not been the case where we have been able to say that we cut any of this out because it was big and expensive. We have had to cut down the verification because of time. Some of the time it has been available for verification with last minute changes. From any good Program Manager's point of view, it has been too little.

Mr. WILSON. NASA arrives at the decision for program change. Are all changes mandatory?

Mr. GRACE. Yes, it has to be mandatory. A lot of things are mandatory.

Mr. POWELL. I think you have to agree that the program changes late in the game. I do not think there is anybody in Marshall who will disagree that the program change usually gets directed by the Program Manager himself, Col.

Mr. POWELL (cont.). James, and Dr. Rudolph. There are no substitute people that get into the act when you are in a stage like that.

Mr. EHRHARDT. A couple of things we have done towards trying to move the thing back and. . .I think to answer your question, one of the things we have observed is that the Switch Selector sequence functions do seem to change late in the game. We have started to build ourselves a little reserve in the initial program. In the first early stages, we wound up exceeding what we had in the way of available memory left. Now we are building to anticipate that. We have set some better requirements ahead of time. As far as the thrust information which, in the past,has just been programmed and not exactly in the best phasing, we worked with Marshall and they are getting that information earlier. So, those things that are anticipated will be pushed back. We will still have the last minute changes, I am sure. We are working to push some of these other things -- that we have been more or less anticipating -- towards the beginning.

Mr. MEADLOCK. The next major area of programming that I would like to discuss is that of factory checkout of the Instrument Unit. Early in the program, it was decided by MSFC to use automated computer checkout for all the major stages of the Saturn Vehicle and, at present, all stages are being checked with the computer system. Our particular computer system is an RCA 110A with all the different systems on the Instrument Unit. The main reason for our computer system is because of the overall complexity of the Instrument Unit. The fact is, a computer system will do repeatable-type tests on vehicle to vehicle with speed and reliability inherent in it. This is the test console from which

Mr. MEADLOCK (cont.). the test conductor controls the entire testing sequence. (Figure 59) In this particular computer system, there are two displays: one in the control room and another in with the computer. From this console, you can request the automated test to be called up and exercised. The voice communications around the different instruments also allow control. However, the main control is your console. All tests are called from there, and the controlling sequence is from that console.

It is significant to note that we have no real simulation facility to check out these programs. I believe that all of the stage contractors have a simulation facility of the type where they check out their programs. That gives them a computer system, which allows them to check out all of the programs prior to interface with the other stages. We developed these programs without the simulation capability, and have been successful in getting them running with the actual Instrument Unit. There has been a minimum impact on schedules. I think we have passed the point where the computer is more useful in checkout than any other use of the computer system on the program.

A couple of other photographs here, this particular one, is the DDAS Ground Station, which makes available all of the PCM Telemetry Data to the computer system. (Figure 60) It also has recording equipment to record the analysis of the overall test. This is the I and C console, and the next one is the Telemetry Ground Station. (Figures 61 and 62, respectively) The overall function flow of this is, as I stated, the controlling operation from the display console, into the RCA 110A Computer, and down through the various interfaces.

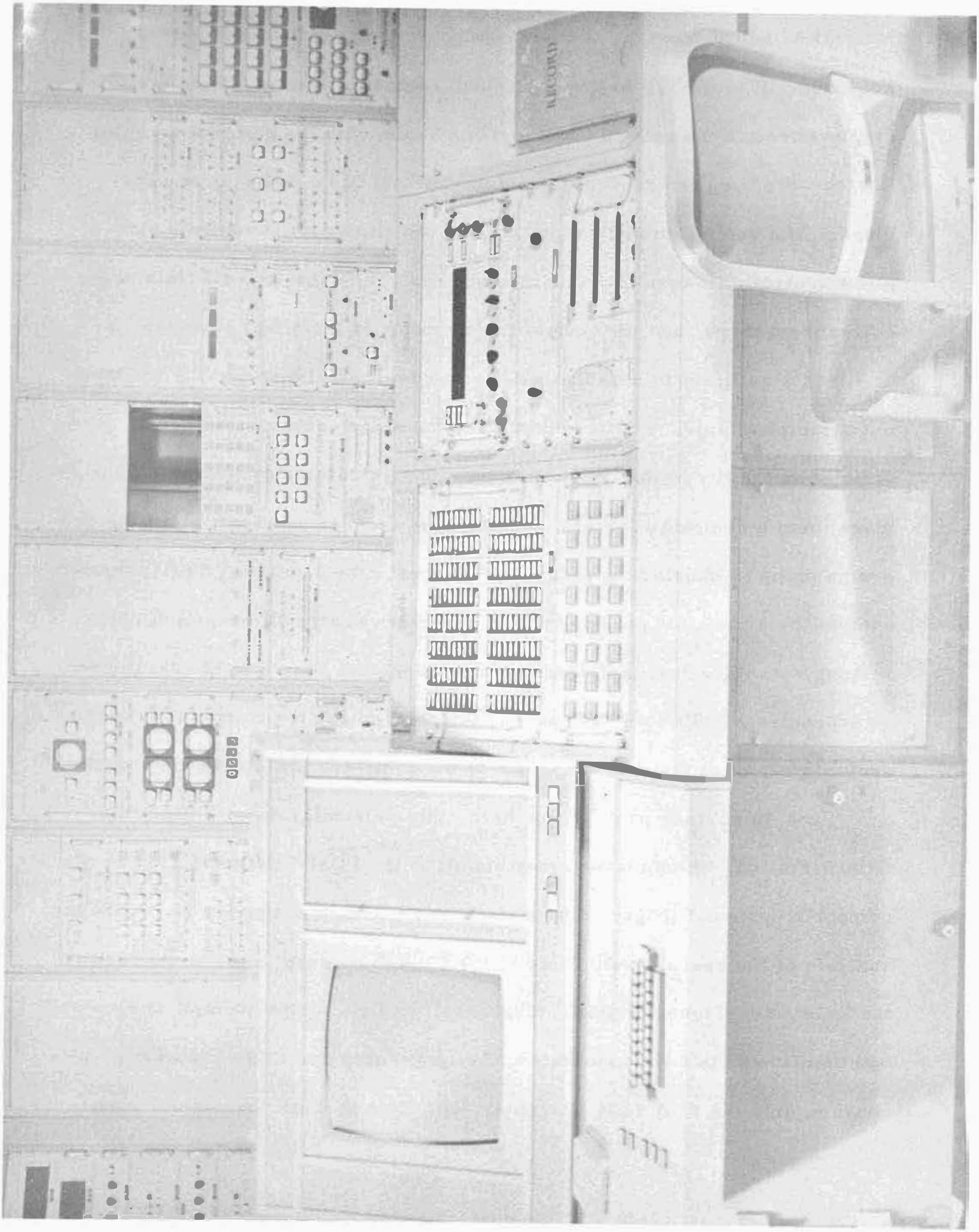


FIGURE - 59 - CONTROL ROOM

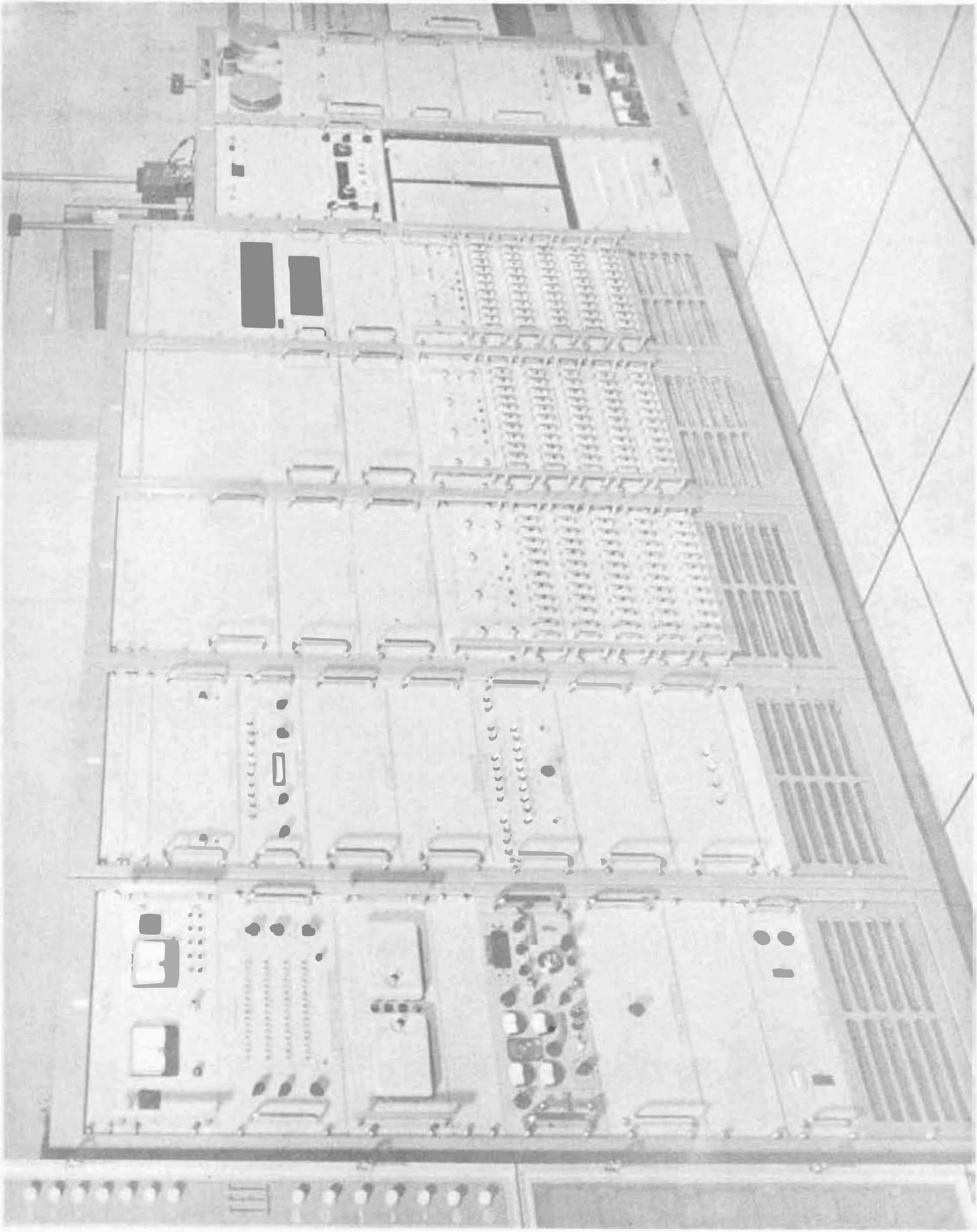


FIGURE - 60 - DDAS GROUND STATION

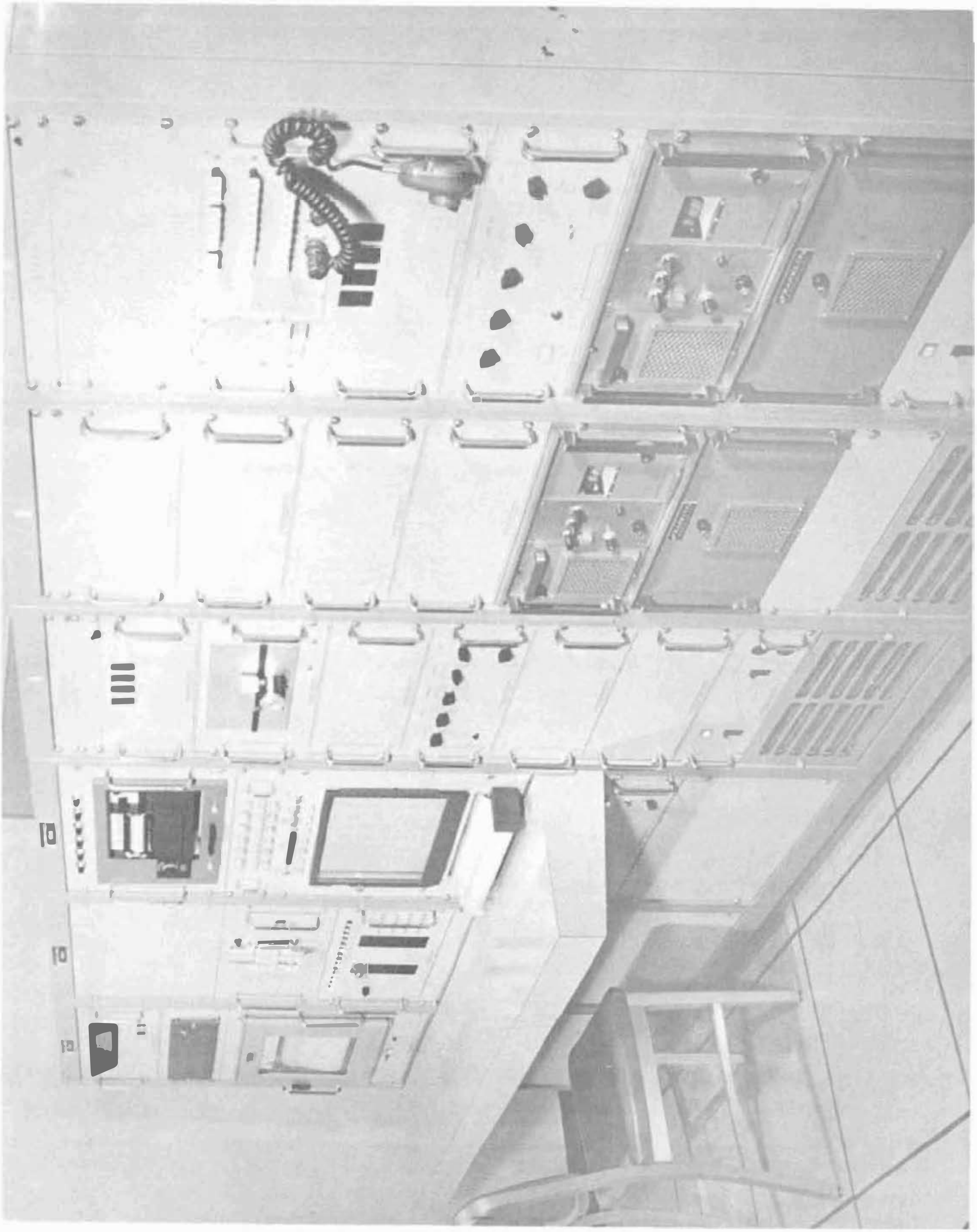


FIGURE - 61 - I & C ROOM

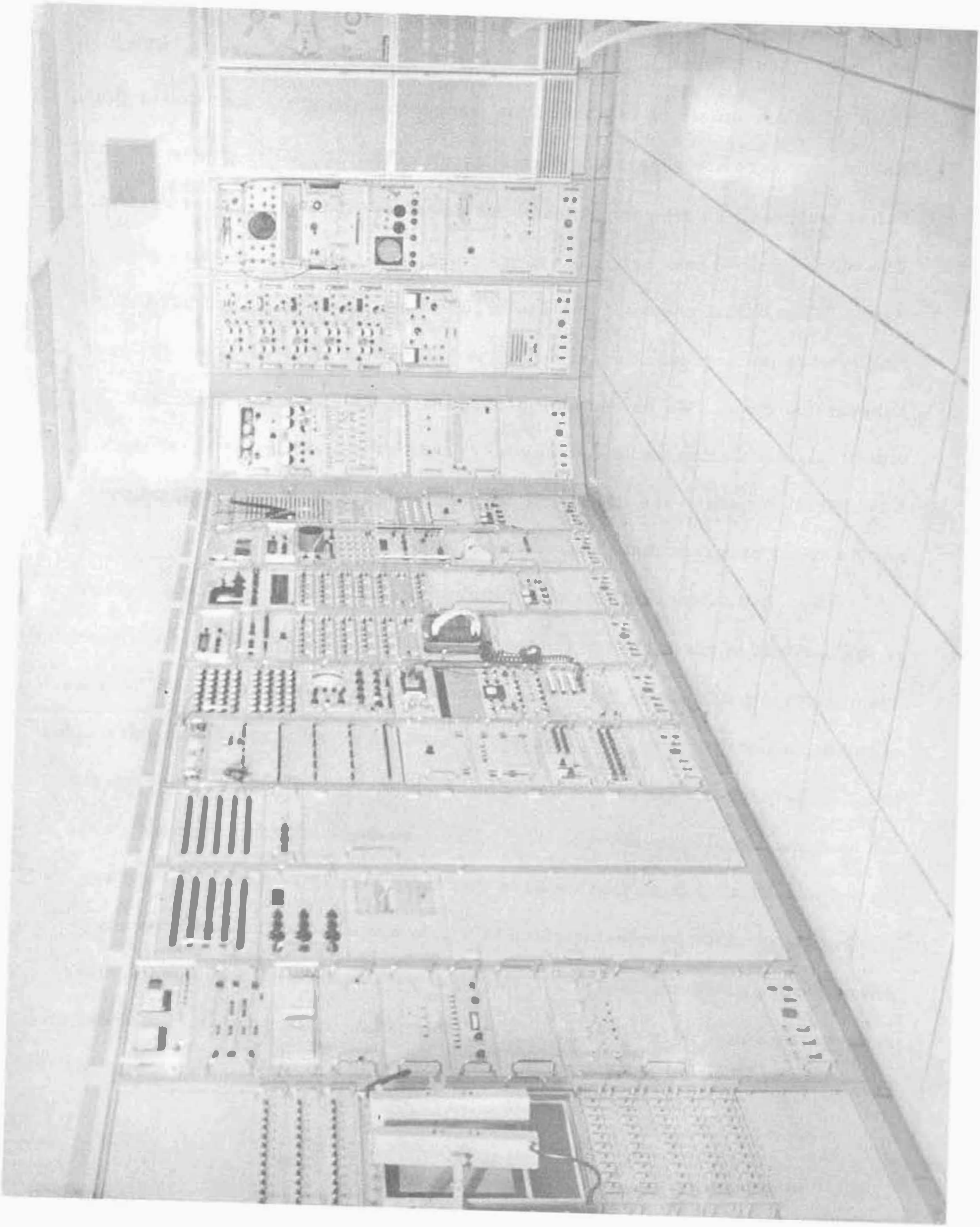


FIGURE - 62 - TM GROUND STATION

Mr. MEADLOCK (cont.). (Figure 63) It is difficult to say, exactly, which is an interface and which is a functional representation of the Instrument Unit. Normally, there are separate controls for all of the ON, OFF, power ON, and safety features. In the normal tests, we do control it by a computer system. The other parallel path patterns are provided as backup, if something goes wrong. The actual checkout itself is begun with a subsystem checkout and finally ends with an overall test, which is a combination of all of the different subsystems tests. We do run a plug-drop test in which we disconnect the umbilical, similar to the launch day test, and run a flight program for the total duration time of the flight. As we mentioned earlier, this is usually not the flight program that flies. In fact, it never has been.

The flight program that was defined, prior to Instrument Unit checkout, is the one that is available for the Instrument Unit checkout. We hope to someday reach the point where that is the flight program that flies. Again, because of the definition problem, I do not think we will ever quite reach that point. This is not a big problem for us. It was a big problem on S-IU-201 because we did not have the simulation ability. We did have to check out the programs on the Instrument Unit. I think that we have this totally under control. The reason is, that most of the people-interface is within our own facility and, on any programming problem, the people-interface gets to define the problems. This reduces the complexity of the problem. This is about all I have to say about the Instrument Unit checkout.

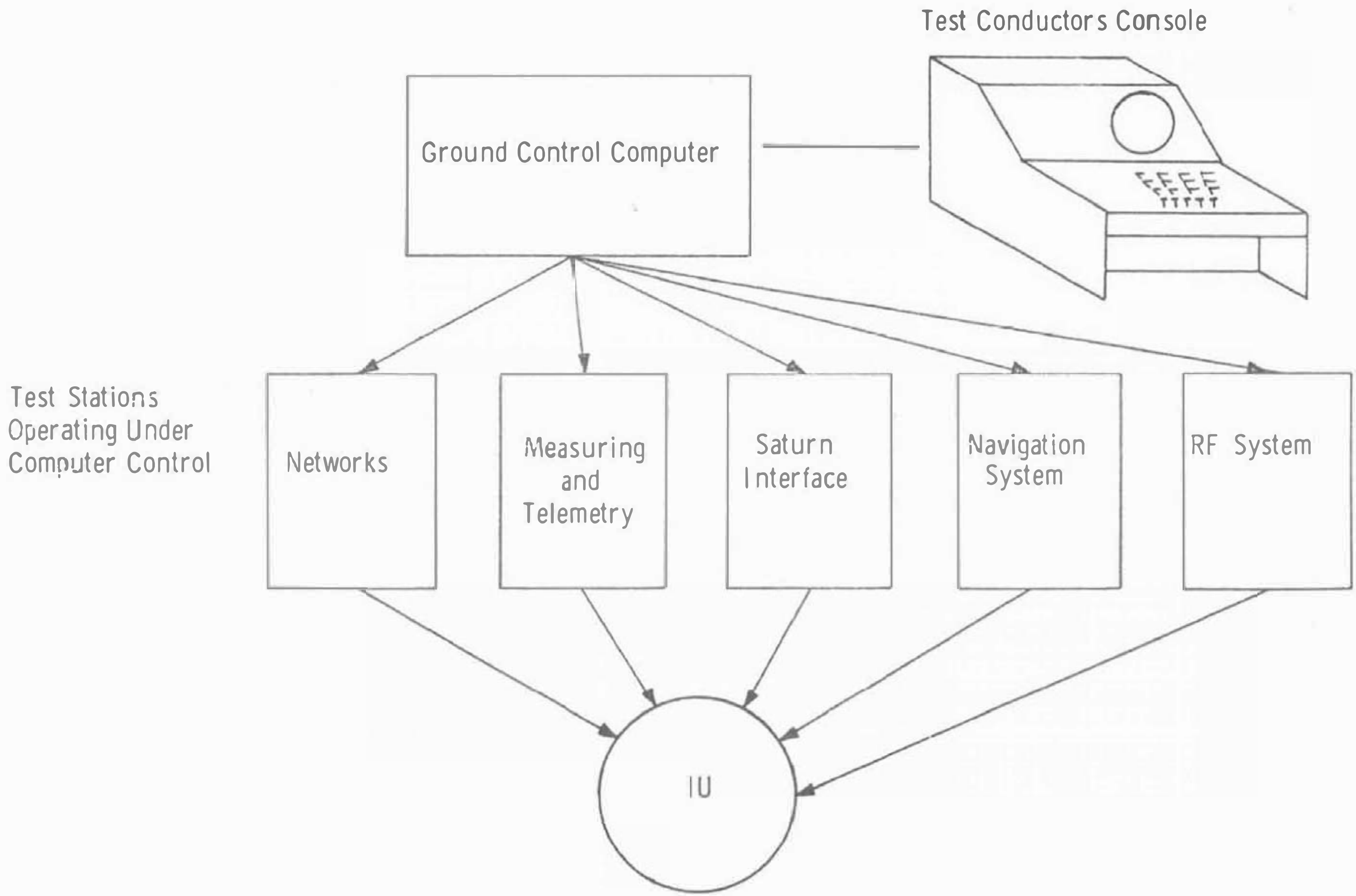


FIGURE - 63 - TEST STATION RELATIONSHIP

Mr. MEADLOCK (cont.).

I would like to discuss an area of programming responsibilities, probably not widely known, that we have. The problem at the Cape -- we have a vehicle out here -- a very complex one -- and a Launch Control Center about 5 miles away. (Figure 64) The Mobile Launcher is unmanned for the last few hours. People are back in the Launch Control Center. You must have communications between these people and the vehicle. In the process, you also have to check out the vehicle prior to liftoff -- as late as you can -- to insure that all of the subsystems are working. To do the total process manually, and do it as close to liftoff time as you can, is probably an impossible task. For that reason, a computer system has been placed in the system to provide the repeatability testing and the capability to do system checkouts close to liftoff. Our basic problem is making these two computers talk to each other and to provide the people with these two methods. The system is simplified with switches to turn things ON and OFF within the vehicle and display consoles from which they can call up automated tests. This is a very simplified diagram which I am sure you will understand. The DDAS system comes into the two computers. There is analog to digital output and digital to analog output, and, if you try to draw the total picture, it gets very confusing.

Mr. WILSON. What does DDAS stand for?

Mr. MEADLOCK. The Digital Data Acquisition System. This takes the PCM (Pulse Code Modulation) data. On this particular configuration, there is a core buffer that the PCM data is stored in. The buffer could save a whole frame of

VERIFICATION OF "GUIDANCE ABORT"

(Portion of EDS Test)

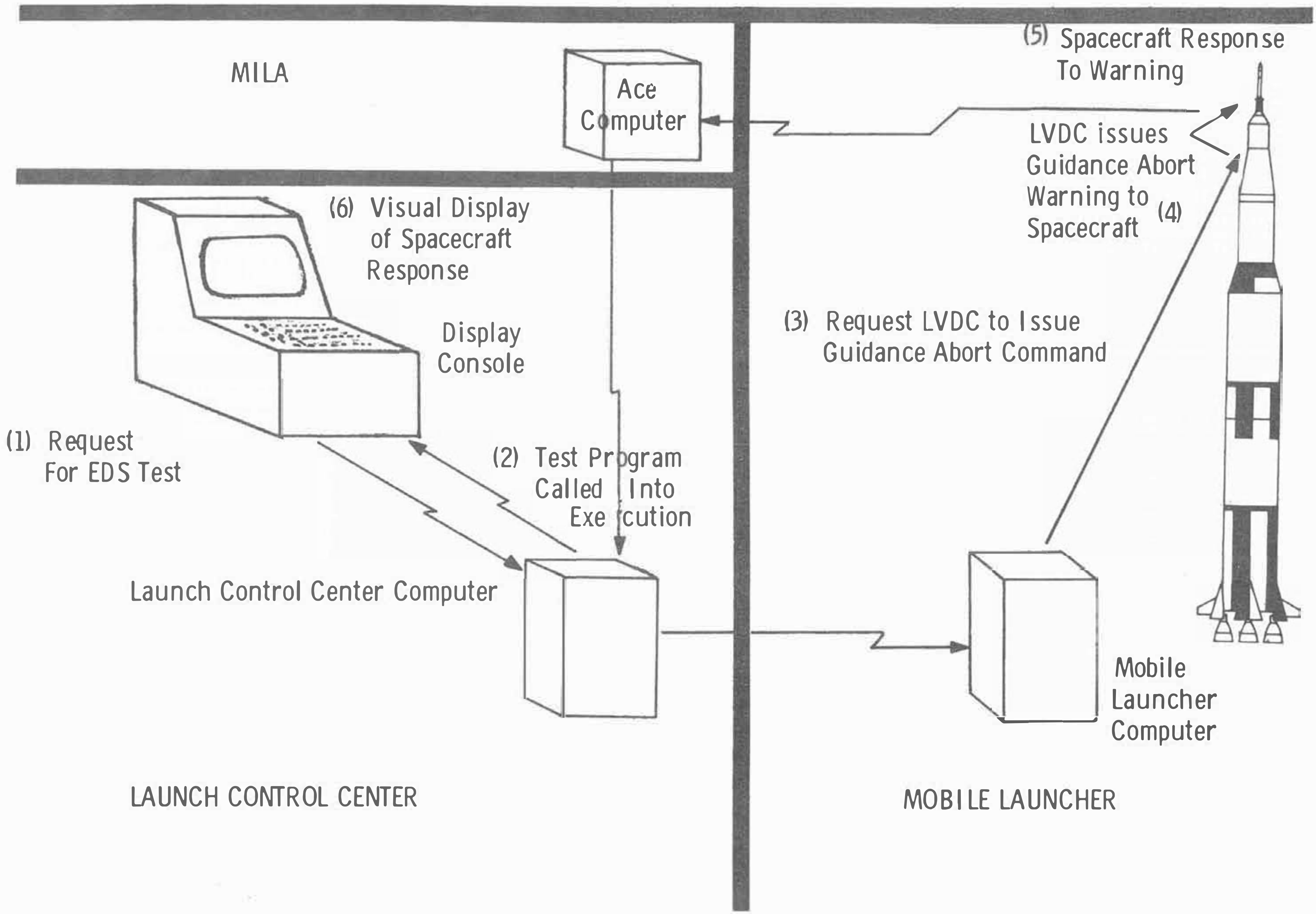


FIGURE - 64 - VERIFICATION OF GUIDANCE ABORT

Mr. MEADLOCK (cont.). the PCM data, if they desire it to, whereas in Instrument Unit checkout we do not have the capability.

Mr. WILSON. Do you have any conception of how far short of complete automation in checkout you go and can still go?

Mr. MEADLOCK. Yes. I will give you more opinion than fact in this answer. I do not know that I can give fact. I think a completely automated checkout with the system, as it is defined, is not feasible. If you are going to completely automate the system, you have to start from the original design and design the system accordingly. This has not been completely done. The design goal, from my point of view, was to provide the engineer with the capability of doing things the way he always does them. In other words, we have not replaced any of the manual controls he has always had. That complete capability still exists, it is just not serviced through the computer system. What we have attempted to do is to construct a building-block, if you will, type of system so that we have a system that provides this capability. In addition, working down under that system, is the ability to run automated procedures. On one vehicle, we can have this system or procedure, and on the next vehicle, we can increase it to accomplish a little more.

Mr. WILSON. Now, how much of the vehicle can you finally do in that manner?

Mr. MEADLOCK. I would say perhaps 80 percent. I would say that is the maximum I would ever think you would want to have. I do not think you would want to reach the point where you would let the computer make all the decisions without any operator intervention. We have come up with a system that allows

Mr. MEADLOCK (cont.). the engineer to incrementally call up any test that needs to be run. He tells us which to run and we run it. We give him options, et cetera. I do not think we want to reach a point, within the configuration, where you push a button and sometime later you fly. I just do not think we are built for that.

I am sure you have all seen these pictures, but, just to put them in the right perspective, this is the Launch Control Center. (Figure 65) There are three of them located in the same wing of the VAB. This is a picture of the 500 F roll out.(Figure 66) We did successfully support the 500 F test checkout in the VAB (Vehicle Assembly Building) with the computer system and its program. As you know, the three launch control centers can be tied either into three vehicle checkouts in the VAB, three out at the three pads, or any combination of these. This is another picture of the roll out of 500 F. (Figure 67) The mobile launch computer system is located in one of the rooms down under the pad. This is connected to the VAB through a cable that simulates the length out to the pad. When you get to the pad, there are electronic interfaces to it for connection back to the Launch Vehicle Digital Computer. We are supporting the checkout for the 500 F in terms of the fueling of this vehicle and checking out the facilities, and we do have an operating system to work with.

Mr. WILSON. How close to the final configuration of the real equipment is the final software? Where do you want to be?

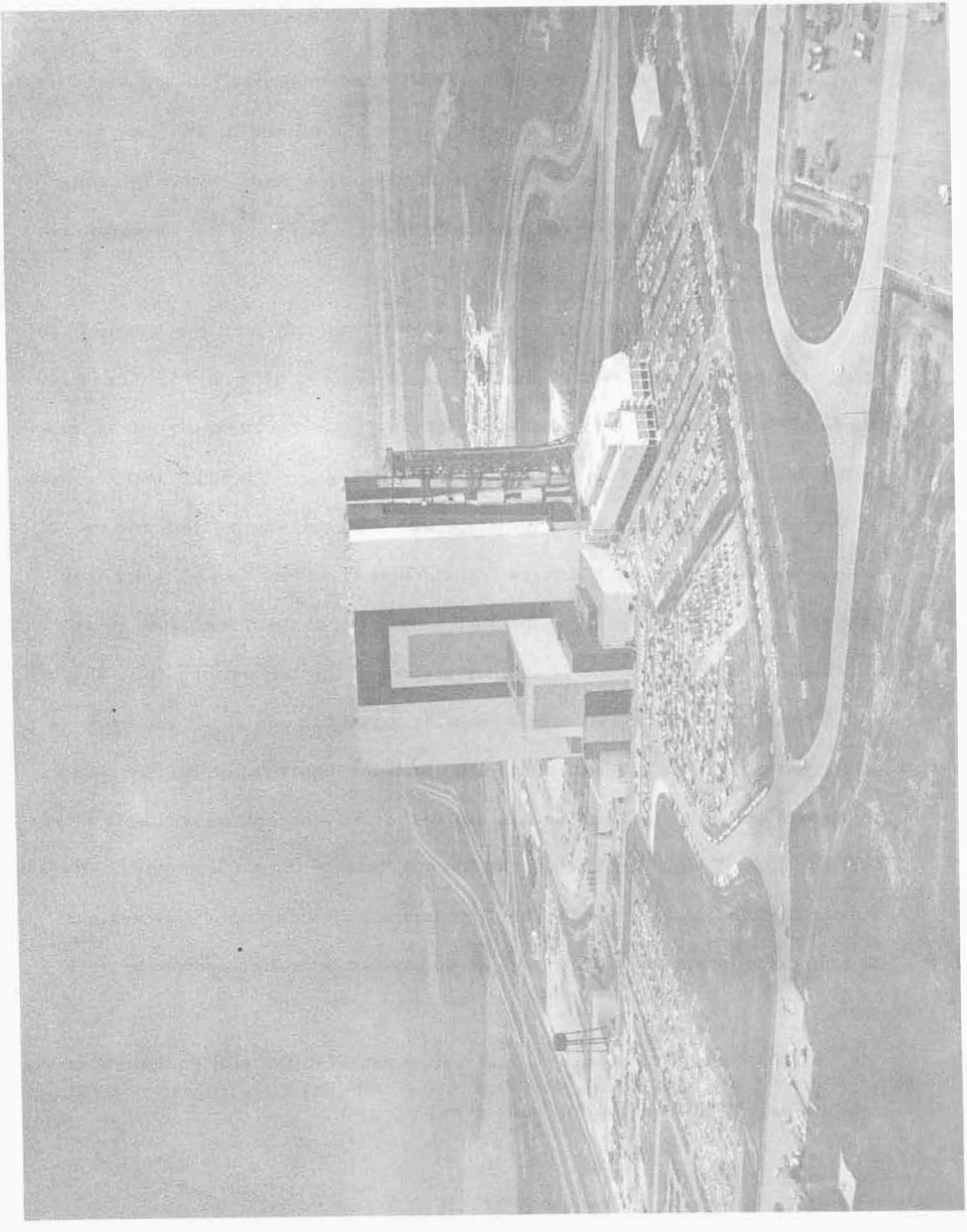


FIGURE - 65 - VAB

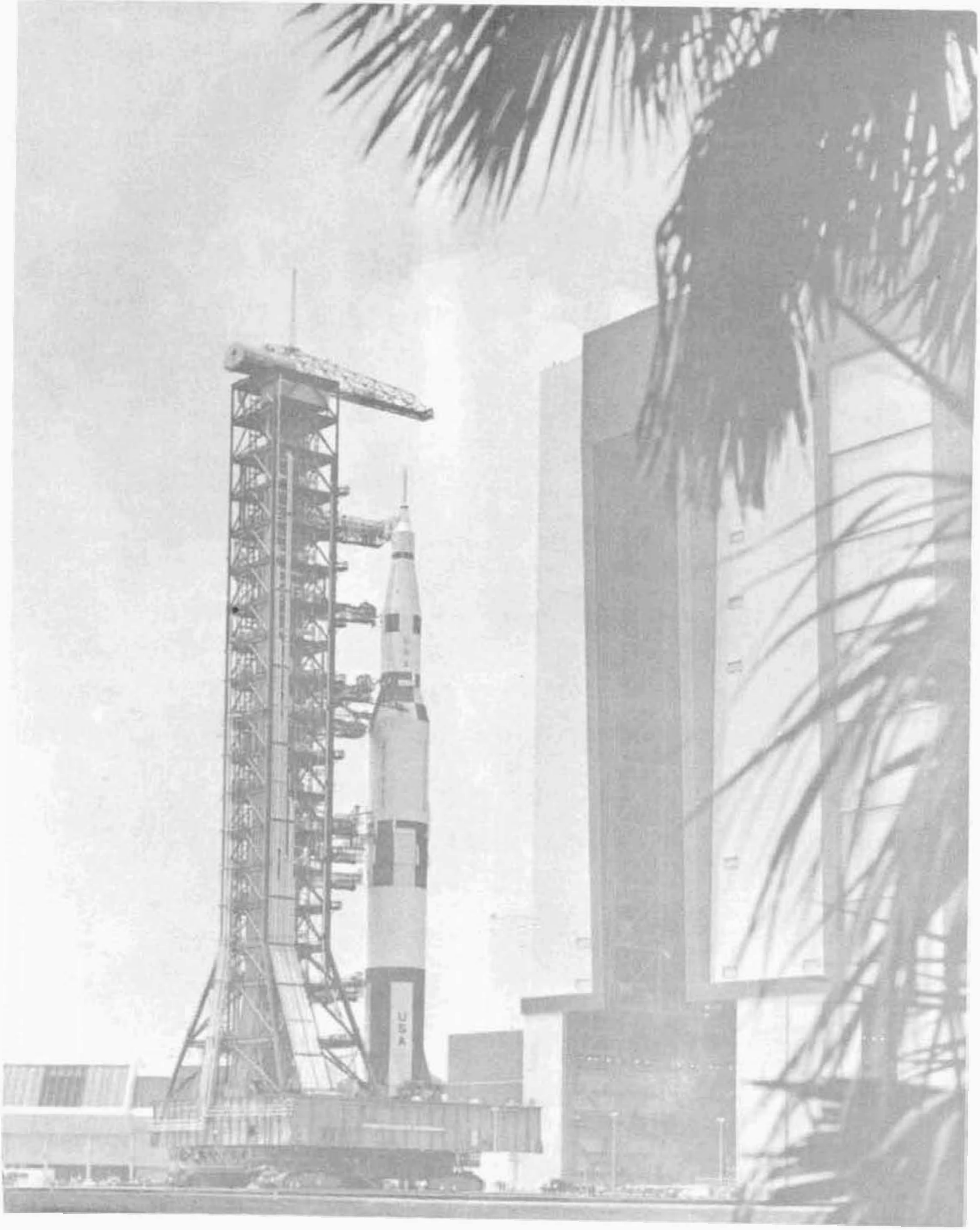


FIGURE - 66 - ROLLOUT OF VEHICLE

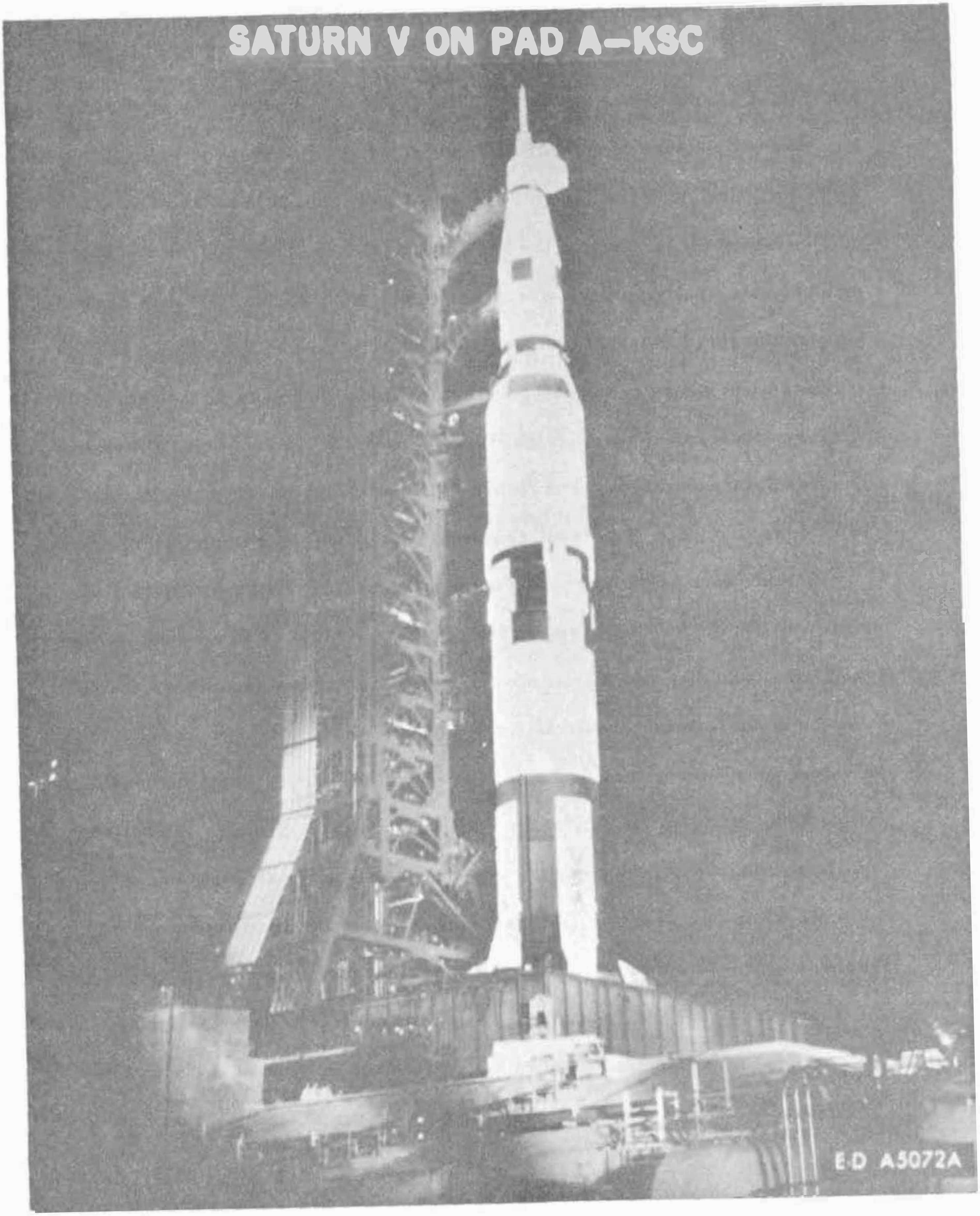


FIGURE - 67 - PAD "A"

Mr. MEADLOCK. Not very close. The 500 F is a modified Uprated Saturn I, if you will, series of software. In view of the schedule problems that we had in developing the Saturn I system of software, it has a similar configuration. It is just that the two computers are closer together. The original Marshall approach was, "Let us build the Uprated Saturn I computer-wise and program-wise like we are going to build Saturn V." This was done so that, when we got to the Saturn V, we would know how to do it. The particular software configuration that is used on the 500 F vehicle is a modified Uprated Saturn I system. The Saturn 501 operating system in the test program, et cetera, is a 50 to 70 percent redesign. So, it will be completely replaced.

Coming back to the previous diagram (Figure 64), let me elaborate about what we tried to do. As I said before, we have attempted to give the engineer the same capability that he has always had. The engineer can throw a switch and the signal will go through this computer system, to this one, and energize a valve, or whatever it is connected to. All of the discretes in the vehicle, some 3000, are continuously scanned by this computer system. Any time one of them changes, we come back to light the appropriate light or, if there is logic within the program, we may send it out to the flight console where there is a pre-defined system to determine what can happen. (There are 15 of these consoles.) We must also provide the console with the ability to monitor any measurement onboard the vehicle and to request the status of any measurement or discrete. We also provide the capability to let him do

Mr. MEADLOCK (cont.). high or low tolerance checks that have been done automatically in the computer on any measurement within the vehicle.

All of this is kind of a simultaneous process. In other words, any test engineer should not care what the rest of the system is doing. We handle this by what we call the Operating System, or the Executive Supervisor for the computer control. You define things that have to be serviced at all times, of which I just mentioned some. We log them into the so-called Operating System for this complex. The Operating System must also take care of servicing all of the peripheral devices (for instance, the magnetic tape). We log every discrete that occurs on the vehicle. We log every message that goes up to the console. We log every input that comes in. This has proved to be very valuable. We have been accused of issuing some discretes sometimes. When we go back and analyze the log tapes, it turns out that someone else really flipped the switch. After you prove it, they finally admit they did. It is an interesting situation.

The Operating System services the total requirement for things that must always be in process. Running under the Operating System, then, are the things we call test programs. For instance, if you want to check out the Platform on the vehicle, you can define a test program that will take the rack inputs to one of the gyros, and expect a certain response from this gyro. There are program steps to insure the vehicle has its power, and you get a "go-no go" type test. Under our present arrangement, the test programs must be run in series, and you must call them up from the display

Mr. MEADLOCK (cont.). console. The test engineer has a whole series of test programs in his control. He can call them up at any time. In certain cases, there are options that he can exercise over the running of this test. We display them back on the console and he chooses the specific one. In addition, if we get a "no go", we come back to him with a tutorial message. So, that is the test program capability within the system.

There are several tests which I think are worth mentioning. We must control the azimuth on the guidance system for the launch-wind problem that is controlled by the computer system. In other words, we know at what azimuth we should launch and, if there is a "hold", we must track a given azimuth in order to get a launch that is controllable in the computer system. In addition, on the dual-launch missions of AS-207 and 208, we must update some data in the Flight Computer at the last minute, after tracking the first vehicle. The way that will happen is that these computer systems will command the Flight Computer into a mode that is looking for an input from the digital command system--which will then be sent from the Houston Computer Complex to the Cape.

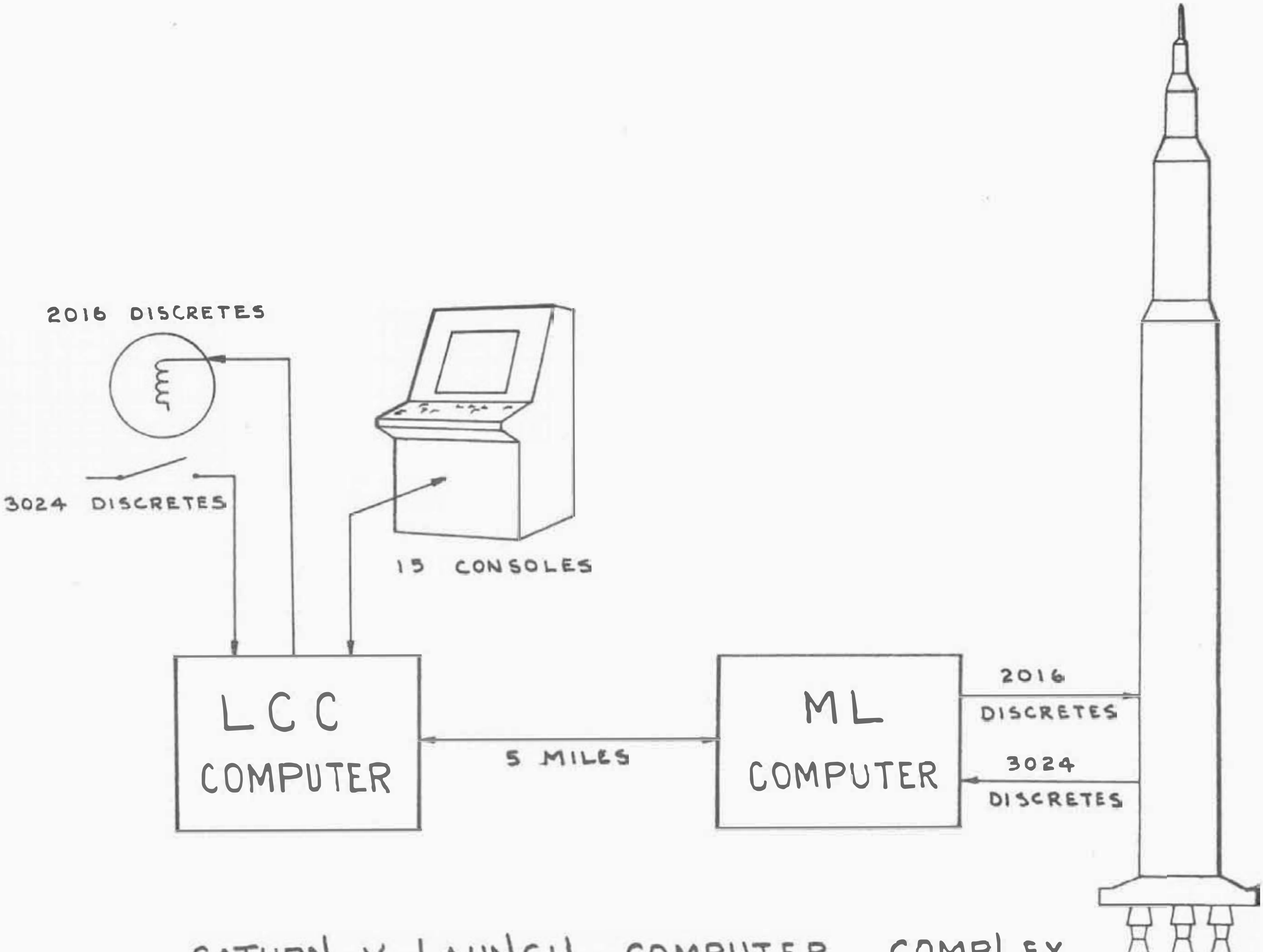
Overall, it is a tremendously complicated system, in that there are so many different stages involved and there are so many people involved. We run the gamut of a small subsystem test to an overall test, some of which are contained within one stage and, of course, the overall test that affects all stages. We provide the test conductor a console, from which we can control the overall operation of this computer system. In other words, from all of the 15 consoles, any one engineer can be calling up any particular test on

Mr. MEADLOCK (cont.). his stage. However, there is one console at which there will be a summary of all of this presented. We also give that individual a capability of selecting which of these is most important--delete this one, et cetera. In other words, we try to centralize control at one point.

This is a picture of the display system for the Saturn V configuration. (Figure 68) The Uprated Saturn I configuration had a different display console--one identical to the one you saw for the Instrument Unit checkout station. This particular display system is driven by another computer system. In other words, inherent within the display system, there is another computer. This display system is built by Sanders Associates and the computer by Computer Control Corporation, It is only used to service the display system. Any button you push here is an interrupt into the computer which then services the display. It is strictly dedicated to the display. It is a very powerful, flexible display system, and it is very useful.

I would like to use one example to show the overall complexity of the system and some of the things that cause us the most problems. In this particular test, I will show only one step of a rather large test, the checkout of the EDS (Emergency Detection System). This is the system that spreads throughout all the stages of the vehicle. (Figure 69) We are required to test this sytem on launch days, as close to liftoff as possible. Here, again, is one of the advantages of the computer system. To try to check this out

FIGURE - 68 - SANDERS DISPLAY



SATURN V LAUNCH COMPUTER COMPLEX

FIGURE - 69 - SLCC

Mr. MEADLOCK (cont.). manually would be an impossibility on launch days. The computer system test requires about 35 minutes for AS-201. In particular, I would just like to walk through one step of the overall EDS test. The test engineer calls it up from the display console. Of course, this would go into the display computer which would service the request and identify the RCA 110A Computer over at the Launch Control Center. Whenever the previous test program has completed execution, this computer system will then call the EDS test program from magnetic tape. In addition, the test conductor has the capability of aborting the test in progress in favor of the new one. In any case, you call in the EDS test program. When you get to the particular step that I would like to discuss, this computer system will tell the computer down in the Mobile Launcher to instruct the Flight Computer to issue a guidance support signal. This is a discrete signal which is sent up to the spacecraft as a warning that there are problems in the guidance for the launch vehicle. (We have internal program tests in the Flight Computer. If we detect something from which we cannot recover, we send a signal up to the capsule and say, "We have a guidance abort, so try to switch in your system, or do whatever is appropriate." And that is, of course, part of the EDS system.) The discrete is issued. The ACE computer system, which is the checkout system for the Apollo capsule, is continually sampling the discretes in the Apollo system. When this particular discrete comes on, it will notify the Launch Control Center computer. This computer, since it has been expecting

Mr. MEADLOCK (cont.). this particular discrete to occur, will note the fact that it has changed and will consider that step complete. In addition, it will go out and light an indicator. For each of these discretes, there is an indicator which tells the test engineers that it has happened. An indication also goes to the test console, which is controlling it. If we do not receive this indication, we will go out and indicate a "no go" to the test conductor. You begin to see the complexity of the interfaces over which we must work. First of all, we have to worry about the interface between the Instrument Unit and the Apollo system. Then we have to worry about the interface between the ACE computer and the other computers. This is in addition to the normal interface over which we have control.

Mr. WILSON. You have no hard lines between the vehicle and the analog equipment in the Launch Control Center?

Mr. MEADLOCK. No, there are hard lines for vehicle safety functions. That is about the limit of it. I cannot give you a good number. However, all of these hard lines come into the computer system to tell us if they have done something.

This is a picture of the facility that we used to check out the program of the Saturn V Launch Control Computer system, the Saturn V breadboard facility. (Figure 70) This is a picture of the Instrument Unit in the foreground. It is a real Instrument Unit with the associated hardware. In the foreground and out of the picture there is a S-II Stage and S-IVB Stage. They do not have live propulsion, of course, but they do have one engine. They also

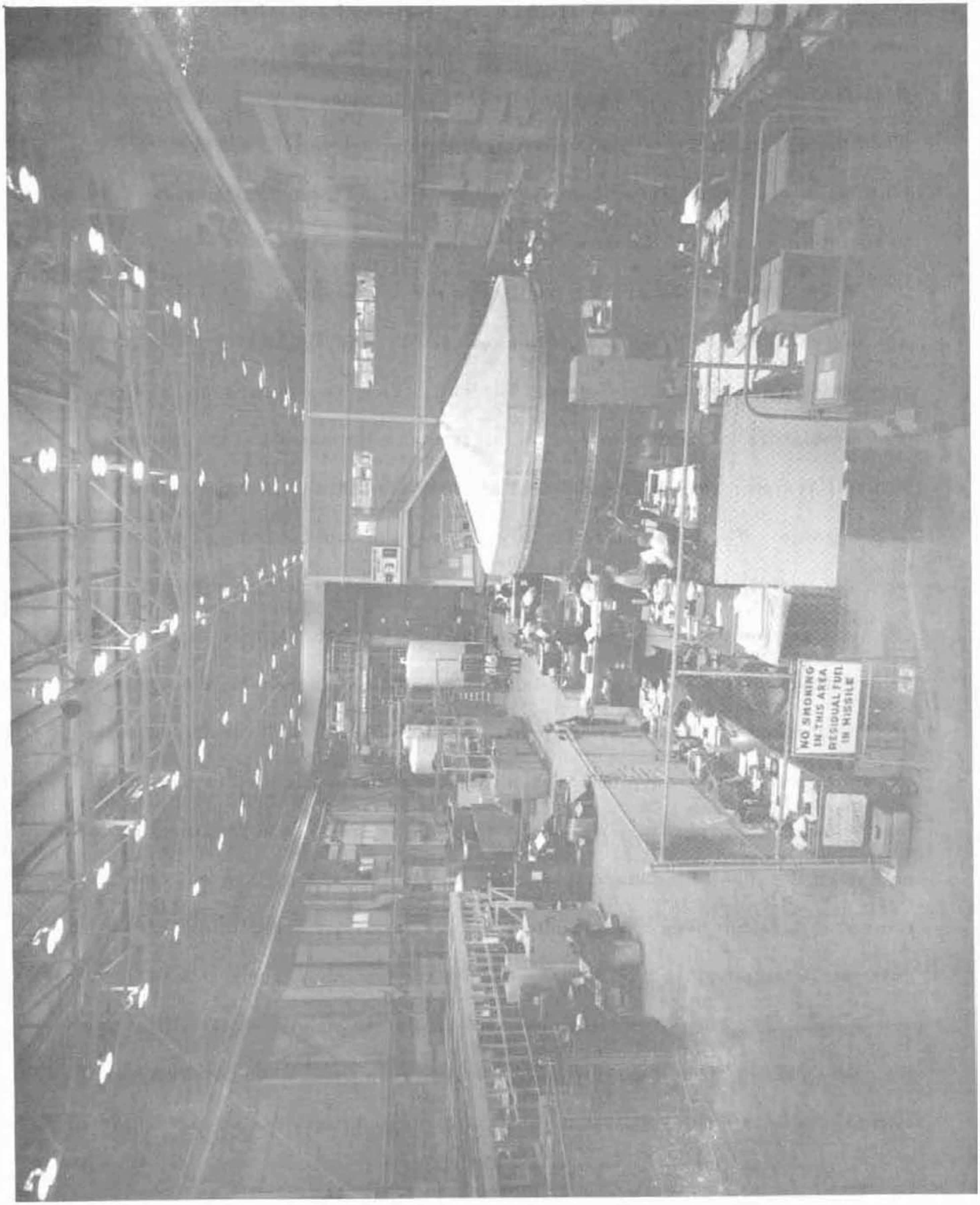


FIGURE - 70 - SATURN V BREADBOARD

Mr. MEADLOCK (cont.). have the electronics in the stages. In the background, there is an F1 engine and the simulators for the S-IC Stage. They have both electrical and mechanical simulators for the subsystems on the vehicle. It is a very complicated facility and a very difficult facility to maintain because of the complexity of the overall system.

In the upper room, are the computers for the Launch Control Center, and in the lower room, are the computers for the Mobile Launchers. There is a similar system for the Uprated Saturn I. They do not have the mechanical simulators but do have all of the electrical simulators for the Uprated Saturn I system. We had a good deal of trouble on this particular system of programs. The breadboard facility was very late in becoming operational for checkout of these programs. We spent a very hectic Christmas here trying to get the program ready to launch AS-201. But, in spite of the problems, we were successful in doing that and have successfully supported AS-201 and 203. Because of the problems on the Uprated Saturn I program, the appropriate steps have been taken to assure that facilities are available for the Saturn V program. We see no real major problem in meeting delivery on Saturn V. The breadboard is working correctly. There are still some systems that have not been brought into line. Presently, I see nothing that is going to cause anything like the last-minute rush on AS-201.

People have been in the vehicle checkout business, especially at the Cape, for many years. They have grown up with the idea that, when you flip the switch, there is a hard wire that goes out there and turns on the valve. Now, Mr. MEADLOCK (cont.). suddenly, you stick two computers in between the switch and the valve. Before, when the command did not get out there, they got an ohmmeter and found out why it did not get out there. Now, they have to call the programmer. This causes a great deal of difficulity. It is very difficult to get them to talk the same language. This has caused a great deal of confusion as could be expected, and points out the validity of the approach that has been taken--that of having a building block program where you do not enter into too much automation on the first vehicle. You try to build a capability that you use, then add to as you go down the road. That is the approach of the present system. I think that completes the words that I have to say.

Mr. WILSON. How much of your programmers' time is devoted to the Uprated Saturn I and the Saturn V at this time?

Mr. MEADLOCK. On the flight program, we have a good deal more. We probably have 70 percent of our effort on the flight program area. The Instrument Unit checkout is evenly divided because we are basically finished with the programming on AS-501, and now it is mainly a maintenance effort on both vehicles. The launch control effort is significantly greater on Saturn V because we are just now going through that final first vehicle. We are probably divided about 75 percent on Saturn V and 25 percent on the Uprated Saturn I. On Saturn V, we are still developing the "guts" of the system whereas, on Uprated Saturn I, we have the basic system working and are basically adding on.

Mr. GRACE. Thank you, Mr. Meadlock. I know it has been rather a comprehensive presentation, but I thought you would be interested in it since the software program has the tendency to be overlooked in terms of the real relative role in this program. What we would like to do now is to proceed into some of the areas of major concern relating to the contractual aspects of our program. Mr. Lerner is prepared to give you some specifics with regard to our contract.

CONTRACT MANAGEMENT

Mr. LERNER. Before we begin to look at some of the slides, may I make a personal comment about incentive contracting in general. Incentive contracts are not very old, by and large, even though the Wright brothers had one. However, the new and more detailed multiple incentive contracts are pretty new to both Government and industry. I think we find that a tremendous new challenge. In addition, and recognizing Mr. Grace's earlier remarks, there are specific individual motivations of a tangible nature when you get down to the departmental manager level. Sometimes he can see more readily, if you will, that the delivery of a particular report, at a particular time, may tangibly be worth X-dollars or a loss of X-dollars. We go about the facility talking to some of the men working on a specific aspect of the program with regard to incentives which are directly tied to their activity, and some of the first-line managers, as well, and they have an additional motivation notwithstanding the fact that they are highly motivated because of the company's reputation and the desire to do the kind of job that is necessary for the program.

In that light, a comment or two about what we found out about incentives, having operated under this contract. Let me preface that by saying that we think, and certainly hope that Marshall thinks the same, that we have a reasonable and equitably structured contract. As far as our incentive arrangements are concerned, both Marshall and IBM negotiated a mutually equitable contract. And we have learned a few things. As a result of that

Mr. LERNER (cont.). negotiation and the performance to date, we think that multiple incentive contracts are best used where you have a reasonable, objective, and measurable set of criteria against which to measure your performance so there is a minimum of subjective problems as to whether or not particular parameters may have been met, or failed to have been met, during your performance, especially when they tie directly to performance. Additionally, of course, you always hope that in the negotiation of an incentive contract, the criteria that is established for performance is reasonably well enough along the way that, from a developmental standpoint, if you will, maximum performance could be achieved. Further, especially if you have a complex multiple incentive contract, such as we have, the incentives utilized are mutually consistent, not inconsistent. So the achievement of performance goals, schedule goals, and cost goals may all occur because one is not inconsistent with the other. We believe, that in the negotiation of this contract, that has been achieved. A fourth thing which is of concern, and I will mention it now, relates to change activity. The engineering people, as Mr. Grace has indicated, designed flexibility into the Instrument Unit. Incentive contracting, however, is less flexible in accepting changes and this, of course, gives us more difficulty in the administration of the contract itself. As I indicated before, we have 371 directed changes to date, not all of which have been negotiated and incorporated into the contract. As such, there are some very complex arrangements, negotiations, discussions, and tracking necessary in the administration of this kind of a contract.

Mr. GRACE. Such as how do you determine what the incentive ought to be if the work is already done?

Mr. LERNER. A little thing like that, yes.

Mr. STICH. Would you also add that the criteria to be incentivized should be meaningful?

Mr. LERNER. I have made the supposition that neither party would incentivize something that has no meaning or that they are not interested in buying or expending effort against.

Mr. WILSON. How many of your people are tied up full time in administering this contract?

Mr. LERNER. We have a single major contract here in Huntsville and I have a staff of nine professional contract people. They are not administering the incentive portions of the contract alone; they administer the entire contract as such. Now, I cannot give you a comparison against any other similar contract. We have had incentive contracts of a smaller amount at other IBM locations. We have administered larger contracts; but not with multiple incentives and change activity as well. If we were to have a straight CPFF (Cost Plus Fixed Fee) contract with this kind of change activity, we would still have a significant amount of administrative work.

Mr. WILSON. Have you placed any of your subcontractors on incentives?

Mr. LERNER. At this time we have a few, but we try very hard to primarily place them on a fixed-price basis, wherever possible, since fixed price offers the greatest incentive, obviously.

Mr. LERNER (cont.).

With these general comments, let us take a look at our contract. (Figure 71) Our contract is divided, as I say, into three major incentives--cost, performance, and schedule. The weights were established as 55 percent on cost, 22-1/2 percent on performance, and 22-1/2 percent on schedule. For a moment let us tie incentives to the Instrument Unit itself, not considering the cost element of the total program--just considering performance and schedule. Subsequent to S-IU-204, (I will discuss briefly the first four vehicles), all vehicles have as much as $140,000 of additional fee, or loss of the fee, based on our ability to perform, deliver, and meet our reporting and programming obligations. So there is a reasonable, additional award for excellent performance. Of course, the reward is based on what would be said to be the Government's advantage as well. Our excellent performance has a payoff in a successful flight, and early delivery has a payoff to the Government in obtaining its needed, stated requirements promptly and to save them trouble at the Cape. Additionally, as Mr. Meadlock indicated, the significant operations in the programming area and the documentation are a benefit to the Government when we fully meet our requirements in a timely manner. Look at the cost for a moment. (Figure 72) Right now our contract is $172 million, estimated for total cost, with close to $14 million target fee. The maximum total fee available for excellent performance, at this point in time, is a little in excess of $21 million. A minimum fee which

CONTRACT NAS 8-14000

IU INCENTIVES

1. COST - 55%
2. Performance - 22.5%
3. Schedule - 22.5%

Performance	$ 60,000
Delivery (After 204)	50,000
Flight	17,000
	$127,000
Reports & Documentation	7,500
SLCC Programs	5,500
Total per IU	$ 140,000

FIGURE - 71 - PROGRAM INCENTIVES

ESTIMATED COST, TARGET COST, AND TARGET FEE

The total estimated cost and target cost for the performance pursuant to this contract is $172,359,078 exclusive of the target fee of $13,933,409. The total target cost and target fee is $186,292,487. The final amount of fee to be paid for performance will be determined in accordance with the provisions set forth in Article VI - Fee Incentives of this Contract.

'II.A. The fee is based on the following range:

Maximum Fee	$21,030,434.00
Minimum Fee	$ 6,894,363.00'

'II.B. 1 Cost Criteria	+$3,605,104.00
	-$4,327,131.00'

'III.A. Cost Incentives - The amount of fee applicable is computed as follows:

Variance of Total Allowable Cost from Target Cost (T. C.)	Sharing	Change in Fee
$12,017,017.00 under T. C.	70/30	+$3,605,104.00
1st Increment $ 5,000,000.00 over T. C.	95/5	-$ 250,000.00
2d Increment $ 5,000,000.00 over T. C.	90/10	-$ 500,000.00
3d Increment $15,442,996.00 over T. C.	85/15	-$2,316,424.00
4th Increment $ 5,042,828.00 over T. C.	75/25	-$1,260,707.00
TOTAL		+$3,605,104.00
		-$4,327,131.00'

FIGURE - 72 - ESTIMATED COST-TARGET COST-TARGET FEE

Mr. LERNER (cont.). could be earned is close to $6.9 million. Of these maximums and minimums, the increase to this target fee of $3.6 million is available for significant underruns, and a decrease of this $14 million, in the amount of $4.3 million, could be taken away as a result of significant overrun. The incentive application formula in this CPIF (Cost Plus Incentive Fee) contract is, in the case of underruns, a sharing arrangement of 70 to 30 for every dollar under; 70 cents to the Government's benefit and 30 cents to us. And a four-part incremental approach in the overrun situation which result, if the program was significantly overrun, in a loss of $4.3 million; or, significantly underrun, in a gain of $3.6 million.

Talking about schedule incentives first, the first four vehicles are somewhat special. In the first place, in the basic contract, we had a different set of requirements placed upon us for the first four vehicles from the standpoint of total responsibility. Under the contract, full responsibility for the vehicle was given to us with S-IU-205 and 501 onward. (In the following discussion, Mr. Lerner refers to Figures 73 through 77) The schedule for 201 is broken into two parts, a date for assembly completion and a date for shipping. As Mr. Grace mentioned earlier, we completed on August 18 and shipped on October 8. At this point in time, agreement has not been reached with NASA as to what was the required delivery date for assembly complete, what was the required shipment date in view of the changes, and the perturbations the program had during the period of time from commencement to this point. We are in the process of negotiating this now. The S-IU-202, however,

IU-201

SCHEDULE INCENTIVES

IU-201 Assembly Complete:

	Per Day	Per System
1-7 days prior to target	+ $1,602.00	+ $11,214.00
Target to 14 days late	0	0
15 to 28 days late	- 801.00	- $11,214.00

IU-201 assembly completion date has not been negotiated to date. We sent MSFC a proposal to adjust assembly complete date in September 1965. Negotiations are anticipated to commence momentarily.

IU-201 Shipping:

	Per Day	Per System
1-7 days prior to target	+ $ 534.00	+ $ 3,738.00
Target date	0	0
1-7 days late	- 534.00	- 3,738.00

IU-201 assembly completion was accomplished by IBM on August 18, 1965, MSFC Form #71 partial 12.

IU-201 was shipped by IBM on October 8, 1965, MSFC Form #71 partial 21.

FIGURE - 73 - IU 201 SCHEDULE INCENTIVES

IU-202

SCHEDULE INCENTIVES

IU-202 End Delivery:

	Per Day	Per System
1-14 days prior to target	+ $1,000 per day	+ $14,000
Target	0	0
1-7 days after target	- 2,000 per day	- 14,000

IU-202 Delivery schedule has been negotiated with a target date of February 15, 1966, and with Max date of February 1, 1966. IU-202 was shipped on February 11, 1966. We are in the process of negotiating an equitable adjustment to schedule incentives in accordance with the requirements of Exhibit "C" (Incentive Fee Formula) of the subject contract.

FIGURE - 74 - IU 202 SCHEDULE INCENTIVES

IU-203

SCHEDULE INCENTIVES

IU-203 End Delivery:

Max Reward	April 11, 1966	+ $18,000
	April 12, 1966	+ 16,000
	April 13, 1966	+ 14,000
	April 14, 1966	+ 8,000
	April 15, 1966	+ 5,000
Target	April 16, 1966	0
	April 17, 1966	- 2,000
	April 18, 1966	- 4,000
	April 19, 1966	- 8,000
	April 20, 1966	- 11,000
Max Penalty	April 21, 1966	- 14,000

IU-203 Delivery schedule has been negotiated with Target Date of 4-16-66 and Max Reward date of 4-11-66. IU-203 was shipped on April 11, 1966. We are in the process of negotiating an equitable adjustment to schedule incentives in accordance with the requirements of Exhibit "C" (Incentive Fee Formula) of the subject contract.

FIGURE - 75 - IU 203 SCHEDULE INCENTIVES

IU-204

SCHEDULE INCENTIVES

IU-204 End Delivery:

Max Reward	June 29, 1966	+ $14,000
	June 30, 1966	+ 12,000
	July 1, 1966	+ 10,000
	July 5, 1966	+ 7,000
	July 6, 1966	+ 4,000
	July 7, 1966	+ 2,000
	July 8, 1966	0
	July 9, 1966	- 3,000
	July 10, 1966	- 6,000
	July 11, 1966	- 9,000
	July 12, 1966	- 12,000
	July 13, 1966	- 14,000

IU-204 Delivery schedule has been negotiated with Target Date of July 8, 1966 and Max Reward date of June 29, 1966.

FIGURE - 76 - IU 204 SCHEDULE INCENTIVES

IU-205-212 and 501-515 DELIVERY

Delivery Date	Per Day	Per System	Total
1-7 days prior to target	+$7,058.00	+$49,406.00	+$1,136,388.00
Target to 14 days late	0	0	0
15 to 28 days late	- 3,529.00	- 49,406.00	- 1,136,388.00

FIGURE - 77 - 205 / 212 & 501 / 515 DELIVERY INCENTIVES

Mr. LERNER (cont.). was negotiated with Marshall and we agreed upon new target dates, new maximum dates and new minimum dates which were based upon changes and the like. We delivered S-IU-202 earlier than our target date but not all the way to the maximum date. The S-IU-203 was renegotiated with a varying incentive in which we have a maximum reward date of April 11. In fact, we did deliver on April 11. In the case of S-IU-204, which we dwelled upon this morning with regard to the manifold problem, our maximum delivery date was June 29, our target date July 8, and July 13 maximum loss date. As you are aware, we have not yet delivered S-IU-204. All subsequent vehicles operate under the same incentive program. Notice that the per-day loss or gain, either plus or minus from target, has substantially increased. Now, delivery of each vehicle is worth close to $50,000 gain or loss, based upon our ability to deliver earlier, or our inability to deliver on time.

In addition, we get into the performance area. (Figure 78) The performance area is also a relatively complex system of requirements, certain of these apply to only one vehicle. All of the additional requirements in the system checkout area start with S-IU-205 and 501 because that is the point of time we are, under the contract, to pick up full responsibility for those requirements. We are required to submit a complete test plan, significantly prior to checkout of the S-IU-205 for which, based on the completeness and timeliness, we can earn as much as $14,000 or lose as much as $12,000.

PERFORMANCE INCENTIVES

FOR

IU's 205/212 & 501/515

IV. Performance Incentives

a. The incentive fee performance area is broken down as follows:

1. IU System Checkout

		Effectivity	Fee Range
a.	End-Item-Test Plan	IU 205 only	+ $14,017.00 - 12,145.00
b.	Test Procedures	IU 205/212 & 501/515	± 9,050.00
c.	Test Procedure Evaluation Documents	IU 205/212 & 501/515	± 6,033.00
d.	Adequate Validation of GSE	IU 205/212 & 501/515	± 3,017.00
e.	Status of IU Prior to checkout	IU 205/212 & 501/515	+ 3,017.00 - 6,033.00
f.	Adequate Validation of IU Systems	IU 205/212 & 501/515	+ 36,199.00 - 18,100.00
g.	Completeness of IU at the end of Checkout	IU 205/212 & 501/515	+ 3,017.00 - 6,033.00

FIGURE - 78 - PERFORMANCE INCENTIVES

Mr. LERNER (cont.) The same thing is true with procedures, evaluation documents, et cetera. A special instance is the status of Instrument Unit prior to checkout and this relates to specific hardware, rather than documentation. This particular incentive covers the requirement that the Instrument Unit must have 18 specific major components on it when it enters checkout. To have one or more missing components results in a loss of approximately $1,000 for certain components or $1,500 for certain other components. Thus, if we enter checkout for any of these vehicles with missing components, we could be taking a loss.

Specific flight incentives, covering the actual performance of the vehicle in flight, are incentivized, on the plus side only, for excellence of performance. These performances include: no failures, no failures or holds from battery to liftoff, successful separation, and successful orbital injection (Figure 79). For each of these, we have the ability to get additional money. Obviously, this is our aim or goal, and we do not want the Instrument Unit to be responsible for failure of any mission.

We have a series of documents--documentation required by various appendices of the contract such as: equation-defining documentation, program documentation, flight programs, and the like (Figures 80A & 80B). There is a total of 120 reports, 6 reports per system. There is a plus or minus $7,000 for delivery of these reports prior to or later than a target for each report. These reports are targeted, based on time prior to delivery of an Instrument Unit, so there are calendar days of time covering the submittal of these

FLIGHT INCENTIVES

TOTAL IU-PROGRAM

2. <u>Flight</u>

a.	No failure or holds from battery activation to lift-off	IU 201/212 & 501/515	+ $4,326.00
b.	Successful Performance through:		
	S-IC/S-II Separation	501/515	+ 865.00
	S-II/S-IVB Separation	501/515	+ 1,731.00
	From S-II/S-IVB Separation to Orbital Injection	501/515	+ 1,732.00
	S-IB/S-IVB Separation	201/212	+ 1,730.00
	S-IB/S-IVB Separation to Orbital Injection	201/212	+ 2,595.00
c.	All Primary mission objective are met during orbital operations	201/212	+ 8,652.00
d.	Lost or Destroyed Vehicle	501/515	

3. <u>Summary</u>

IU System Checkout	+ $1,401,676.00
	- 1,121,343.00
Flight	+ 467,226.00
TOTAL PERFORMANCE	+ $1,868,902.00
	- 1,121,343.00

FIGURE - 79 - FLIGHT INCENTIVES

DOCUMENTATION INCENTIVES

IU-PROGRAM

2. Documentation

a. Reports for IU 205-212 and IU 504-515 (120)

(1) Description

Document Description	Contract Appendix
LVDC Equation Defining Document	A8
Flight Program Level I Performance Prediction	A8
Final Flight Program Documentation and Final Flight Program	A8
Preflight Performance Evaluation Document	A8
Phase III Design and Analysis Report	A9
Final Flight Simulation Completion	A9

(2) Incentive Application

Adjustments to target fee for the delivery of 120 reports defined in (1) above shall be made in accordance with the following:

FIGURE - 80A - DOCUMENTATION INCENTIVES

DOCUMENTATION INCENTIVES (Continued)

Delivery Dates	Maximum Rewards/Penalties Per Day	Per Report	Per System (6 Reports)	Total (120 Reports)
1-5 days prior to target	+$249.00	+$1,245.00	+$7,470.00	+$149,400.00
Target to 5 days late	0	0	0	0
6 to 19 days late	-$249.00	-$1,245.00	-$7,470.00	-$149,400.00

b. Launch Computer Programming (27)

The target dates shall be those dates defined in Appendix 11, "Saturn IB/V Launch Complex Computer Programming", to Exhibit A. Adjustments to target fee for delivery of 27 reports shall be made in accordance with the following:

Delivery Dates	Maximum Rewards/Penalties Per Day	Per System	Total
1-5 days prior to target	+$1,108.00	+$5,540.00	+$149,580.00
Target to 5 days late	0	0	0
6 to 10 days late	-$1,108.00	-$5,540.00	+$149,580.00

FIGURE - 80B - DOCUMENTATION INCENTIVES (CONT)

Mr. LERNER (cont.). reports. Additionally, launch computer programs are incentivized on a per-vehicle basis--plus or minus $5,500 depending upon delivery.

The Switch Selector program is a special situation. (Figure 81) We mentioned earlier that the IBM Owego facility is building Switch Selectors. Our Switch Selectors (in our contract and built by IBM Owego) are also on an incentive program covering both delivery and performance.

In summarizing where we are today, of our original contract of $162 million cost, we have negotiated $10.7 million of directed changes to date. This results in a $172 million estimated cost contract. (Figure 82) We have been directed in a number of changes totaling close to $30 million which are not presently negotiated. Therefore, we are assuming that our target value is $202 million at this time. Based on all changes directed to date, we anticipate that negotiations will increase target fee to approximately $16.2 million. Taking a look at where we are today, beyond target, we feel that in the hardware delivery area, we have earned over $22,800 for the delivery of Instrument Units prior to target. It is still too early to define documentation since most of the documentation is based on S-IU-205; it is too early to determine a plus or minus incentive on documentation. We have slipped our delivery of Switch Selectors. We are presently assuming a loss of $32,800. We feel, at this point in time, we have earned approximately $40,500 of incentive beyond the target. We have every hope of meeting the target. Our goal, of course, is to perform to the maximum extent possible

SWITCH SELECTOR PROGRAM

Incentive Fee Formula

	Maximum Reward/Penalities	
	Per Day	Per Switch Selector
Unit 1 - 21		
1-7 days prior to target	+$248	+$1,736
4 days target period	-0-	-0-
1-14 days late	- 92	- 1,288
Units 22 - 61		
1-7 days prior to target	+$131	+$ 917
4 days target period	-0-	-0-
1-14 days late	- 49	- 686
Units 62 - 78		
1-7 days prior to target	+$ 77	+$ 539
4 days target period	-0-	-0-
1-14 days late	- 29	- 406

FIGURE - 81 - SWITCH SELECTOR INCENTIVES

CONTRACT NAS8-14000

INCENTIVE REPORT

TARGET COST:	
Target - per original contract	$162,000,000
Add: Negotiated Directed Changes	10,748,012
Total Negotiated Contract	$172,748,012
Add: Unnegotiated Directed Changes	29,776,000
Total Contract Cost (Target)	$202,524,012
CONTRACT TARGET FEE:	
Target - per original contract	$ 13,125,000
Add: Negotiated Directed Changes	843,611
Total Negotiated Contract	$ 13,968,611
Add: Unnegotiated Directed Changes	2,322,000
Total Contract Fee (Target)	$ 16,290,611
ESTIMATE OF INCENTIVE EARNED:	
Schedule Incentives	
Hardware	$ 22,852
Documentation	-0-
Switch Selector	(32,398)
Performance Incentives	
IU System Checkout	$ 14,017
Flight	34,606
Switch Selector	1,352
Total Earned	$ 40,529

FIGURE - 82 - INCENTIVE REPORTS

Mr. LERNER (cont.). and to earn as many incentive dollars as we can through excellent performance. It is difficult, at this moment, to portray how we are going to do because 5 weeks ago we thought we were going to earn full incentive on delivery of S-IU-205, and it was just about 5 weeks ago that something happened to the manifold. So, it is quite difficult to say that we are home free and, ask MSFC for payment against incentive earnings. I do not think that it is quite as easy as that.

Mr. WILSON. I do not think we want to place dollar figures for public record. It would be inappropriate to place you in that situation with respect to other contractors. We can delete this from public records.

Mr. STICH. With a few of the editorial comments being "excepted," of course. What we presented here is probably correct in terms that it is in the contract.

Mr. LERNER. I appreciate that.

Mr. WILSON. I might ask you one general question in respect to incentives. How do you identify, down to your first line management, what the incentives are, with respect to the particular area?

Mr. LERNER. Let me answer in two parts. Those incentives that relate specifically to the completion and submission of a report are very easy to take care of. We can find the parties who have the major responsibility in test plans or a test report, give them specific targets, and track them. Those that relate to the completion of the whole Instrument Unit delivery on time, we break down on a basis of a report. We look at what our problems are and

Mr. LERNER (cont.). which we must get to the engineer, purchasing man, and the quality man who is most concerned with delivery of the particular components.

Mr. WILSON. Does he know that you have incentive on this?

Mr. LERNER. He knows. Yes, I spent a significant amount of time preaching the "gospel of incentive" to him.

Mr. WILSON. Does he know specifically what the amount of incentive is?

Mr. LERNER. Yes, we spend time talking to our quality people and manufacturing people. We specifically identify that a particular component, which is in the Instrument Unit, is worth $1,000, et cetera.

Mr. FREITAG. If he makes an incentive for you, does he share it?

Mr. GRACE. The fact of the matter is, we talk about incentive a lot. I am sure that if you went over and questioned one of our people in terms of what incentive is, he really would not know. Let us be frank about it. We tell him we have an incentive contract to get these things out on the schedule we talked about, because that is how we are going to earn our incentives. But, rarely, do our people know what this is--other than in broad terms.

Mr. FREITAG. I do not know what IBM's policy is on this, but are bonuses or anything of this nature tied into the incentive--as far as salary is concerned?

Mr. LERNER. No. Motivation is tremendous whether or not incentives are here. From my standpoint, I have been at other IBM facilities operating under other contracts non-incentivized, CPFF, and many of the faces that we see

Mr. LERNER (cont.). here in Huntsville are the same fellows who worked day and night on some of our other programs. This, in general, concludes my specific presentation on incentives.

Mr. FELTON. Yet, there is no penalty for a system failure, is that right?

Mr. LERNER. No, there is no fee penalty, shall we say, to the IBM Corporation, as such.

Mr. FELTON. How about financially?

Mr. LERNER. No, no specific financial penalty of any kind.

Mr. FELTON. What is the reason behind giving incentive for the system working the way it should, and not being penalized for not working?

Mr. LERNER. I think part of the answer could be that, if a mission is a complete failure, it may very well be difficult to determine what specifically failed so as to assess a responsibility against the stage.

Mr. STICH. There is also the consideration that there is a significant time gap between delivery and actual performance of the mission. During that time gap the question of control over the hardware itself leaves the IBM "umbrella" of control, so to speak. A lot of things can happen to it that we do not have control over.

Mr. FREITAG. Earlier, you said that it could set down there for almost 5 years without affecting its reliability.

Mr. LERNER. Oh, yes, but we do not know what would happen if, unfortunately, a Government employee of another stage, a contract employee, did something to it when we did not know about it.

Mr. GRACE. Let me correct what I think is a misunderstanding. I said that we do not know what would happen if it were down there for 5 years. It is planned that they will be there for something like 2 to 6 months. There is no guarantee that they have a 5 year shelf life, or anything like that.

Mr. WILSON. You were talking about the physical deterioration.

Mr. LERNER. Yes, rather than the actual mishandling of the Instrument Unit.

Mr. FELTON. Would your last minute checkout at the Cape determine if there were anything wrong on it?

Mr. GRACE. Hopefully, yes. The way the total program is set up, the vehicle is not launched unless there is solid confidence that it is ready to go.

Mr. FREITAG. I do not see how this affects your point then?

Mr. STICH. There could be modifications made to the "bird" subsequent to delivery of the Instrument Unit, am I correct?

Mr. EHRHARDT. Changes could be made by other stage contractors.

Mr. GRACE. As a matter of record, many of the vehicle stages have been modified rather extensively, after they have left the manufacturer. Mr. Powell, were you involved in the negotiations?

Mr. POWELL. Mr. Ehrhardt and I were involved in this point.

Mr. GRACE. One of the things that is the ultimate responsibility of whether it goes is not really directly in our hands. That is a NASA total responsibility, since they have the total vehicle responsibility. They certainly look to recommendations from each of the stages, but the ultimate decision as to whether

Mr. GRACE (cont.). one particular system is exactly the way you would like to have it, is theirs. We are not in an overriding position on this.

Mr. POWELL. Another thing that I think ought to be brought out, for those of you who have been involved in this kind of business for many years know that whenever there is failure--unfortunately some programs have had failures--the assets are gone to the bottom of the ocean or some place else. It is not like going to the scene of a plane crash and putting everything together and determining what happened. It is tough to find out what happened. One of the things that you want very badly is an open cooperative attitude to try to find out what happened or went wrong and to gain the benefit from that in the next one. If you have an incentive that forces a man to keep quiet if he knows what is wrong (because he is going "to get nailed" for an incentive loss if he exposes it), you are working against yourself in a program like this. So, that is the reason for the plus, in my opinion, the prime reason for the plus incentive.

Mr. FREITAG. The position is well taken. We do use major incentives. Obviously, the famous dust cover cost of the Martin Company--$25,000 a piece. This just happens to be a number; $25,000 is not half as much as what Martin did inside of that dust cover.

Mr. POWELL. That was a real clean-cut sort of a thing where this inter-relationship makes it more difficult to pinpoint.

Mr. EHRHARDT. As much as I would be reluctant to bring up the GT4 computer affair--there is a good example of what Mr. Grace was referring

Mr. EHRHARDT (cont.) to. We never did, to my knowledge, identify the exact cause of the GT4 glitch. The computer we did get back, in that case, could not be made to fail, and we never knew what happened.

Mr. POWELL. We have guidelines that we had for something essential to flight--it was not done to really penalize anybody. It was done in an effort to tell the contractors, "Look, we know that you are going to do a good job; we expect that out of you because we accepted you as a contractor. What we would like for you to do, if you can, is to put a little more than you would normally plan to put into a flight evaluation or to monitoring what goes to the Cape." If you go back to that set of incentives we showed you for the criteria, you will see that we started from the time the battery is activated. We did this from the standpoint of not only saying, "Well, we had a good mission where good is easy to see. Will we ever have a bad mission?" Sure, we will have those, and it is in the ocean; but, is there something between a perfect mission and a bad mission? How do you evaluate where you stand on a scale? So, we looked at it and asked, "What are we doing with a condition that we start from battery activation and then go completely through the mission itself? What kinds of criteria can we apply in each step?" Well, the only thing that we could see was a motivation to a contractor to take a look at anything that happened. I guess you could say that it was really from a standpoint of motivating him into an evaluation of what was there, using that information to preclude the same thing happening again, if you could at all possibly do it.

Mr. LERNER. Please keep in mind the fact that there are significant numbers of performance incentives that have negative sides to them prior to the vehicle going to the Cape--such things as performance of the vehicle in checkout, whether the vehicle is complete, and the like.

Mr. FREITAG. I can see where it would be helpful to have it there 7 days before the target date. On the other hand, they might not want it there 6 months before that time and have to take care of it down there. How is this situation covered?

Mr. LERNER. At this moment I do not foresee any of the near-term vehicles getting there 6 months before they will be needed. Again, Mr. Grace talked about the MA2 schedule.

Mr. GRACE. If you look at the delivery schedule, it is 7 days. Anything beyond seven days, you do not earn anything more. The maximum fee is earned 7 days ahead. If you deliver them 6 months ahead, I know what will happen. They will say, "Could you find a place to store it? We do not want it yet." So, there is no incentive to delivery except right near when it is wanted or a bit earlier. That gives you a little cushion.

Mr. FREITAG. They are not required for the test period then?

Mr. GRACE. You have to have a signed-off NASA Form 71.

Mr. POWELL. I am glad you said that, Mr. Grace, but this goes back to the same basic philosophy which is used in all systems circuits. When you put this thing on schedule, you are not really saying I want this thing any earlier. If you take an old contract administrator who has been in business for 50 years, he will say, "I do not need to schedule this in because I have

Mr. POWELL (cont.). a clause called non-performance that I can stick him with every time if he does not deliver on time." So they usually say, "Do not incentivize schedules." But, if you look under the whole blanket called "incentives", you will find the real reason for scheduling incentives is to pay the man to plan. Pay him to plan! Do not wait and do something tomorrow that you could do today! I think that is the underlying thing of the whole schedule of incentives in Marshall. Give the man the motivation to lay out his plan and try and track it.

Mr. LERNER. Actually, Mr. Powell, what you are saying here is true. The point is, the incentives that are based on schedule are really calculated to get you there on the day that it is scheduled, as close to that as possible. The maximum fee is earned very quickly ahead of that--within a week. The negative incentive maximum loss is reached in a little longer period than that, but it is all attuned to that point. The thing you have to do is make sure that the day you ask for it is really the day you want it. The incentives constrain it to that.

Mr. STICH. If we were ever running way ahead of schedule, I think we would have a situation equivalent to a "white glove" inspection.

Mr. GRACE. This is true for the Apollo Program, but on Gemini, the real schedule incentive came about when we decided, at the time of incentivization of the contracts, that we were going to change the schedule from the 3-months' schedule later on to a 6 to 8 weeks' cycle. We were going to speed up the entire schedule from the final launch in February or March, of 1967, to September of 1966. This was a distinct effort, across the board, to really speed up the program and to deliver early. In this case, Mr. GRACE (cont.). this has been done. Occasionally, you do want to use this schedule incentive to speed up the program.

Mr. WILSON. When will the new schedule be completed?

Mr. LERNER. The new schedule has not been directed, suggested, or negotiated . This is being considered.

Mr. POWELL. It is being evaluated as an expenditure reduction process.

Mr. GRACE. Actually, Marshall is very actively looking at it right now because we are into July already--almost to August-- and some action has to be taken quickly or some of the savings that we talked about are not going to develop. We are really examining how to do it. It is a little different from Uprated Saturn I and Saturn V, and it is not simply to implement the MA2 schedule. Marshall adjusted it a little to better satisfy what they really think they need. In effect, speaking for Marshall, it is my understanding, that there are people out there who are very diligently trying to get the answer to that question and get a directive as swiftly as possible. That is right, is it not, Mr. Powell? You are involved in it, so you can either deny or confirm what I have just said.

Mr. POWELL. I think that, as we go through this whole presentation, you will see a number of things that you can view back and forth to see where you are going. I think that you have to first consider that there is no gilt-edge guarantee offering any kind of cost savings by shifting the program. You have to weigh those things before you make a move.

Mr. GRACE. I am going to say a few more things in that regard before we quit here today.

Mr. WILSON. In fact, I want to ask one question! What you have here--does this mean that the cost incentive is finally determined after the contract is complete?

Mr. LERNER. Yes. The actual earnings or losses against cost can only be determined after all the costs are in.

Mr. WILSON. Are 55 percent of your incentives really determined after the fact?

Mr. LERNER. Obviously. This gives you an incentive today to work toward the management of the program in such a way that you, at least, reach target in total performance of the program.

Mr. FELTON. Does it mean that you do not receive any incentive till the end?

Mr. LERNER. We would be receiving something like the target fee. Actually speaking, let me put it another way. Under the terms of our contract, we are entitled to bill for fee based upon percentage of completion of performance but not necessarily directly tied to the expenditure of funds.

Mr. STICH. That is against target?

Mr. LERNER. That is correct--against target and nothing against incentives on performance.

Mr. FELTON. Were you not saying that we would give incremental reimbursement against the cost?

Mr. LERNER. Of course, since this is a CPIF contract, we bill our cost and we get 100 percent of our allowable cost reimbursed. We get the fee

Mr. LERNER (cont.). reimbursement on the basis of percentage of completion.

Mr. WILSON. Do you think, Mr. Lerner, that you would have a significantly less costly administrative burden if this contract were not incentivized?

Mr. LERNER. Not significantly. I think the significant portion of the administrative burden relates to that portion of the vehicle that takes a significant number of changes. Changes are small additional contracts, from an administrator's standpoint, in getting a proposal out, putting together a package, understanding it, and negotiating it. One last comment that would be noteworthy here is about the statement of work of this contract. The scope of work for this contract is fairly specific for a program of this magnitude. It is a fairly tight contract. I would say that it is well drawn up. Of course, this makes it easier for both Marshall and for us in determining how we are doing against performance parameters and what constitutes a change. Because it is well written and clearly defined, it takes less time to define whether or not we have a change or whether or not we are within the scope. You do not have to spend time discussing what was really required.

Mr. GRACE. One question came to my mind. If I understand it correctly, what you just said is that we are not going to get any reward or penalty on the 55 percent incentive on cost until 1970. We are going to get paid target fee on that. If we wind up with an overrun, we could get a bill that we owe the Government, or we wind up with a big check due us in 5 years if we underrun?

Mr. LERNER. That is right. Because of the way Mr. Cleary keeps track, I do not think that will happen.

Mr. WILSON. Does Corporate Management review the program--its progress?

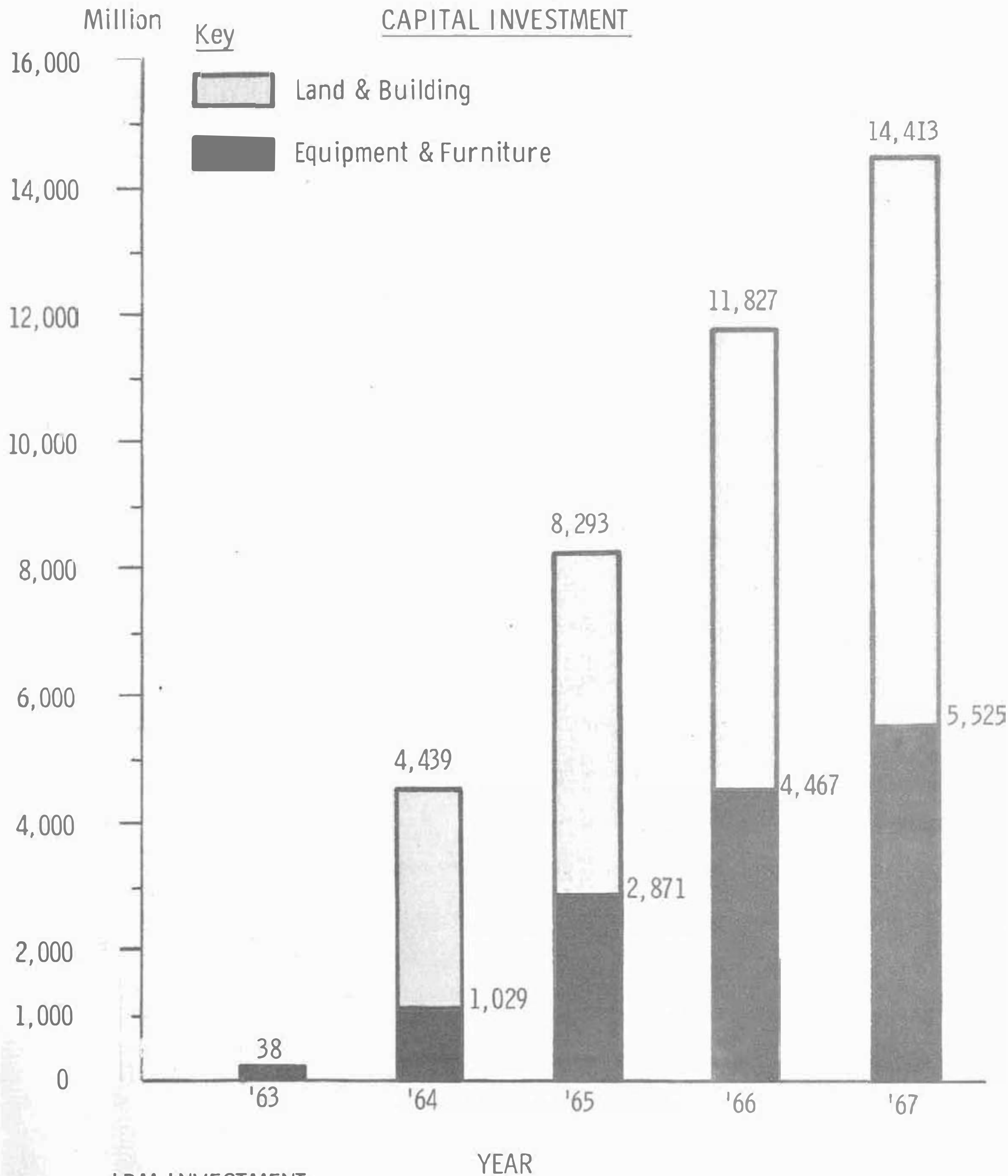
Mr. LERNER. Absolutely, from frequent reports.

Mr. GRACE. Obviously, in terms of my concern, here is the program manager's ability and the philosophy which is probably pretty evident to you. I am committed to get this product out and right, and these incentives are all going to be taken care of by the contracts and financial people when it is all over and done with. Note that on S-IU-202 and 203, which have been delivered and were agreed upon, no payment has been made. So, I don't know how much incentive there is.

COST, MANPOWER, FOLLOW-ON CONSIDERATIONS

COST, MANPOWER, FOLLOW-ON CONSIDERATIONS

Mr. GRACE. Let us go on to the next phase of this. This has to do with the cost, manpower, and investment that we have--I think more of the meat of what you really want to discuss. We talked about capital investment--I think the question was asked earlier--in terms of what we had here. Back in 1963, when we had about 100 people working here, we just had some investments in terms of furniture, fixtures, and a leased facility that we were using. In 1964, with the beginning of our major effort on the Instrument Unit, we did construct some buildings. We invested $4.4 million that year--the yellow referring to land and buildings, the red referring to furniture and fixtures (Figure 83). In 1965, the investment rose to $8.2 million. In 1966, it will be $11.8 million, and by the time we finish this current expansion we are in, it will be $14.4 million--$5.5 million being equipment and furniture and the other $8.9 million being buildings. Obviously, this is a pretty substantial investment, and we have made it in terms of a long haul. We expect to be operating in these Huntsville facilities from now on. That is the basis on which we look at it. We expect to be in the aerospace business quite some time. In the area of manpower, in 1963, we had 130 people working primarily in the Saturn I program and some support in the development of the original Instrument Unit Contract No. 8-5469. Then in 1964, under the present Instrument Unit Contract No. 8-14000, we started a buildup which we are still on. We had 900 people at the end of 1964; 1400 at the end of 1965; and we have about 2,000 at the end of 1966. We actually have more people, but some are



IBM INVESTMENT

FIGURE - 83

Mr. GRACE (cont.). temporary, supplemental, et cetera. We will peak by the end of the first quarter of 1967 to about 2,100. By the end of 1967, we will be down to 1,500 people on the currently defined Instrument Unit program; 906 at the end of 1968; 320 at the end of 1969; and out of business in 1970. That is based on the presently defined contract and schedule.

Mr. WILSON. How many of these people are professional? Are these predominantly engineering types?

Mr. CLEARY. Right now, we have 766 professional and 403 technical. The bulk of the professionals are in engineering. We are categorizing programmers also as professional.

Mr. FELTON. Let us put it another way. Who are the 500 who are going to go this year?

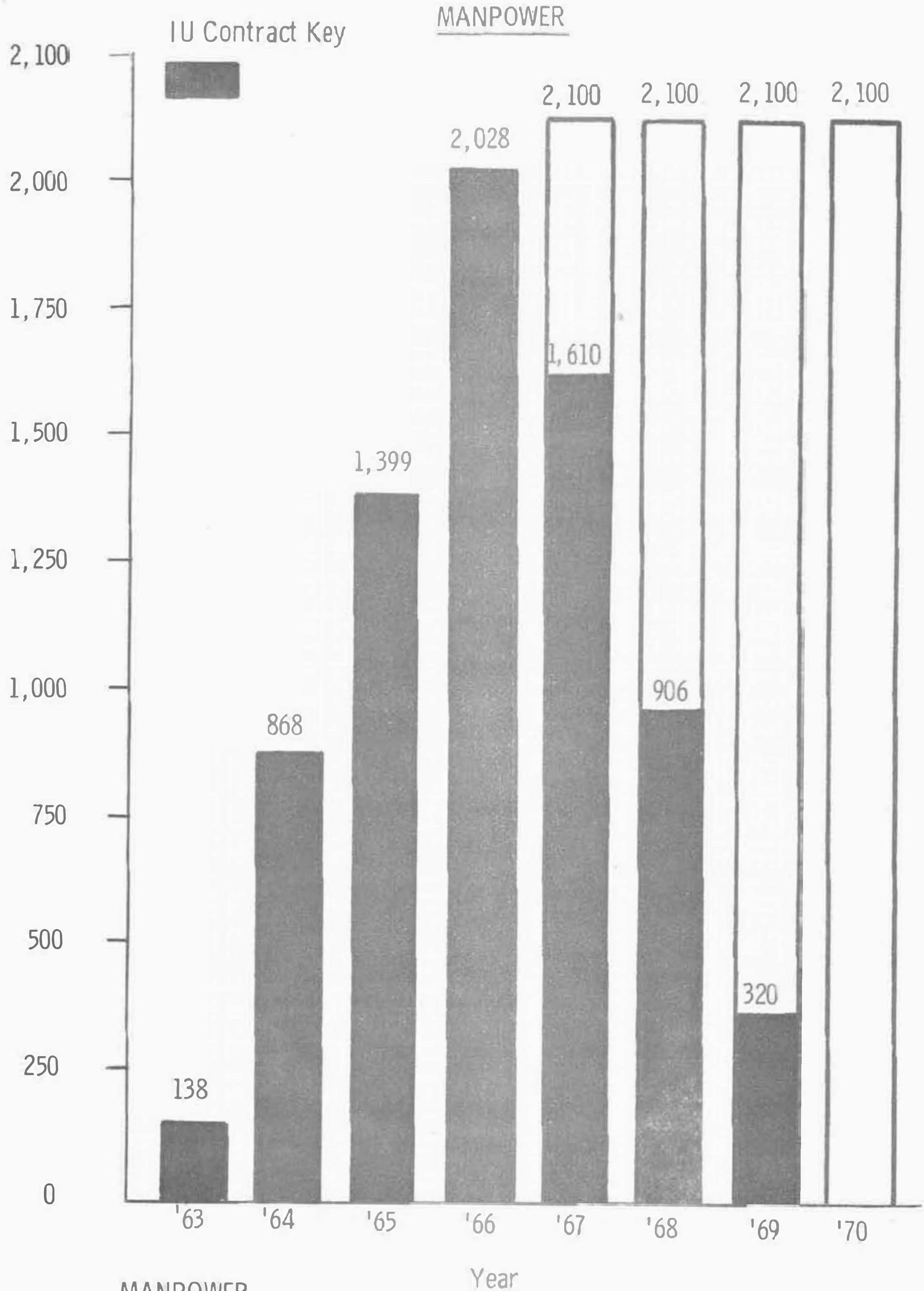
Mr. CLEARY. There are not going to be 500 going this year if things go the way we hope.

Mr. GRACE. If the program goes this way and we don't have some follow-on activity by the end of 1967, these will probably be largely professional people.

Mr. FREITAG. Will they be lost to IBM?

Mr. GRACE. Possibly. We will certainly try not to have that happen. We do not propose that this will go this way. Maybe the best way to answer this is to go on to the manpower chart. (Figure 84) The next chart has to do with the cost and allows me to explain our thoughts on this subject (Figure 85).

Mr. WILSON. Clarifying this--it will be predominately engineering people?



MANPOWER
FIGURE - 84

Mr. GRACE. Predominately. Roughly, professional people. But it will be some reduction across the board because when you get into the latter phases--even though the major thing you have to do is to finish testing and building, et cetera--you are going to have some learning curves.

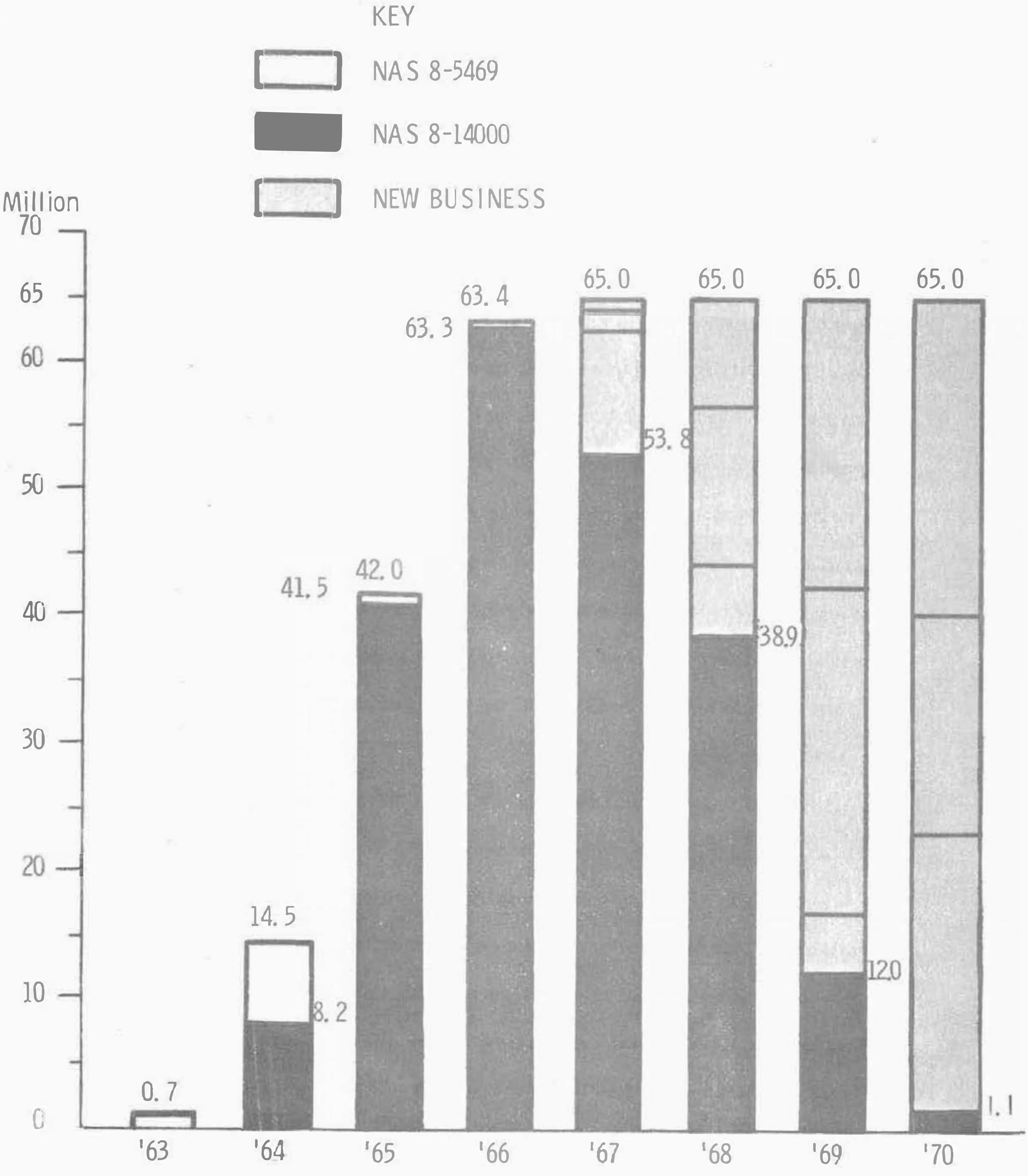
Mr. WILSON. One additional question on the manpower. How much is overhead? You might define what the overhead is to you.

Mr. GRACE. Well, the overhead ratio is about 25 percent. Overhead is personnel and administrative kinds of people--accounting, finance, purchasing, and contracts administration.

Mr. WILSON. Is your management all overhead, or is your first-line supervision direct?

Mr. CLEARY. First-line supervisors in engineering and a couple of other areas--we can say that they spend significant portions of their time giving technical direction and are direct. In the factory and the operations areas, some of it is direct.

Mr. GRACE. Let me elaborate on some of these points. This chart shows the yellow portion as Contract No. 8-5469. (In this discussion, Mr. GRACE refers to specific points on Figure 85.) In 1964, we have the beginning of the major Instrument Unit contract. It is shown here in terms of the present cost picture on that contract. The blue area is new business. I say we built the facility here with the idea that we are going to be operating here permanently. It is recognized, of course, that this depends on a number of factors--whether or not we are successful, we can competitively do business that will be coming up, whether that new business is there, or what have you. But, in terms of



CONTRACT COST

FIGURE - 85

Mr. GRACE (cont.). our planning, that is the way we look at it. With the investment that we have here, it will take about $65 million in annual gross business to justify that kind of investment, and this is what we predicate new business plans on. We have drawn a few lines here to help explain a few things to you. This red is what is currently negotiated on the contract. One of Mr. Lerner's charts had another $30 million which were directed changes to us and which have not been fully negotiated. They are going to take this red to here in this first level so that the work that we have takes 1967 to there. Referring back to the previous chart on manpower (Figure 84), it is going to provide the additional manpower requirements on this contract to that level. We are showing it only on the cost level. It is difficult for us to address cost pictures other than what is finally and firmly negotiated at this point. We fully expect, in terms of the proposals that we have made on these directed changes to us, that they are going to be negotiated somewhere around where we have submitted them. But they do have to be negotiated.

Mr. CLEARY. Also in that line, is the spare parts type of activity which we anticipate required to support that level of activity?

Mr. GRACE. Yes. We have made proposals on many of them, but not on all of them. This is negotiated changes, negotiations on directed changes, and spare parts which will take this up to about this level on the currently defined contract. The next set of lines we are showing here, right down to there, are what we see as being the impact of a follow-on program of 12

Mr. GRACE (cont.). additional Uprated Saturn I's that we have forecast. We have a working chart here that is going to be of interest in answering or raising a few questions (Figure 86). It takes the 12 Uprated Saturn I's, adds 12 more that we were asked to exercise by Marshall, and the 15 Saturn V's--it takes it to the MA2 schedule. These little arrows that you see tie you back to this particular schedule. They are what we call our "F" schedule. On the S-IU-515, there is about a 7-month slip to get to the MA2 schedule. Some of these, like S-IU-206, are only a couple of months. S-IU-502 is only a month and a half. So, the point I was making earlier is that the MA2 schedule does not change much up here, but has a fairly significant effect when you get down to the later portion. If you take a time period, for example, like 1969 which is this cut off here, you can see the additional buys of the Uprated Saturn I's put into that and the MA2 schedule. That is what this particular curve here shows, the additional follow-on which resulted in that kind of cost picture.

Mr. FELTON. Back here, I assume that you are going to approach the point of management and cost reduction to the program. I would like to go back to this chart.

Mr. GRACE. One other think that I have not addressed here in this one. In our thinking and planning here, and in working with Marshall in terms of a rate of Instrument Units or launch vehicles per year, several have been talked about--like 4 or 6 or 8 per year. What we see here is pretty much of an 8-per-year kind of thing.

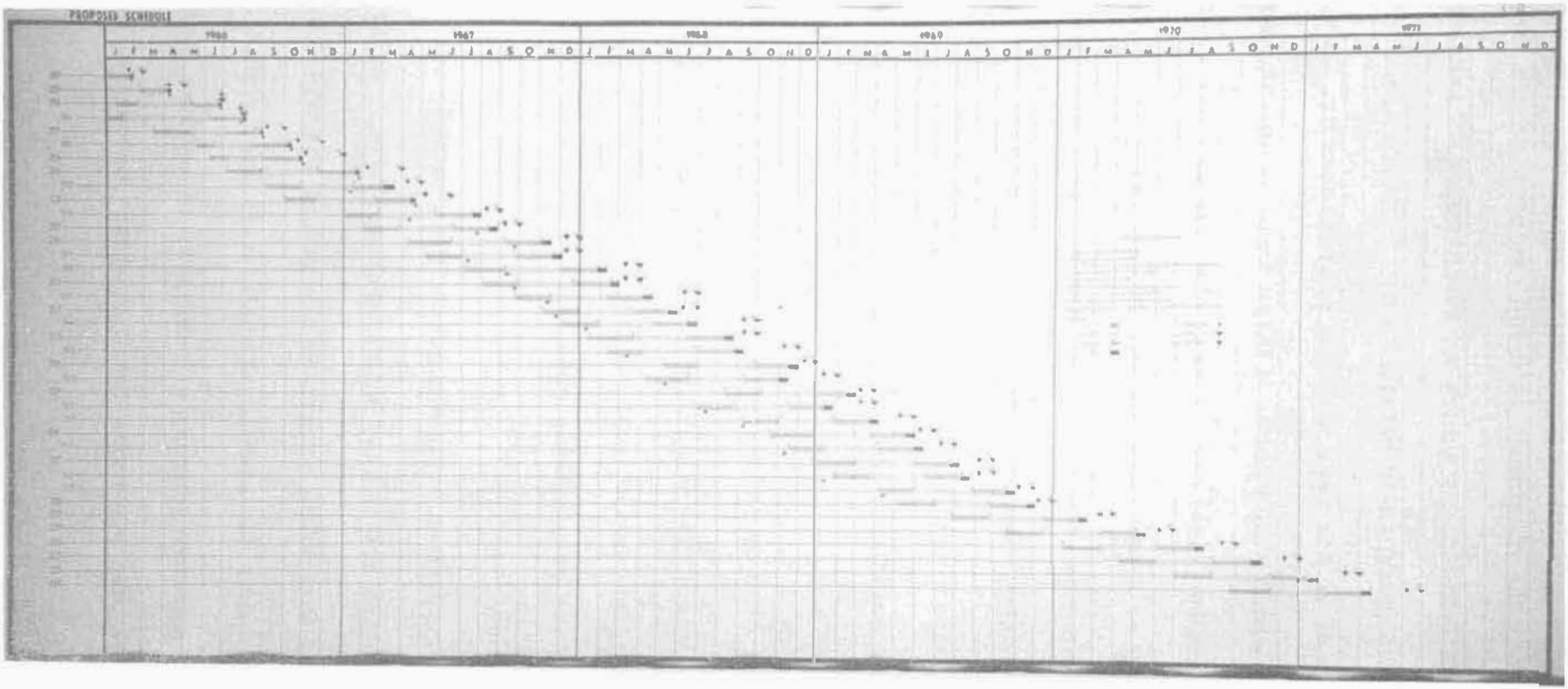


FIGURE - 86

Mr. WILSON. That is the maximum rate you can produce the Units?

Mr. GRACE. In our facility, we figure we can produce 12 per year if they had the right mix--6 Uprated Saturn I's and 6 Saturn V's. We can produce a maximum of 12 per year with our present facility. If we had 8 per year in 1970, which would occur if there were follow-on Saturn V buys, this would stabilize right here to keep the rate at 8 per year. The rate, right now, is 7 or 8 per year, or $65 million per year. We put this in to give you an indication of about $40 million per year when the standard launch vehicles come out. Now the rate is 7 or 8 per year--$65 million a year--which is explained on a learning curve.

Mr. FELTON. How would that $40 million per year rate relate to personnel?

Mr. GRACE. Pretty much equivalently. We figure on a 2100-man facility. We are talking about 1300 or 1400 people involved in this program. Obviously, that means we have to address other areas of new business. We will talk later about what our plans and actions are toward the future.

Mr. FELTON. You are only making Instrument Units here now?

Mr. GRACE. Correct.

Mr. WILSON. Do you plan to bring any other IBM business here?

Mr. GRACE. Our plans are to keep a full workload here, and we are very interested in the way that NASA programs are going, the way AAP is going, and what is the possibility for additional application for the Instrument Unit. We are also looking at other sources of business, in our line, with the Government. Let me give you more detail on this. Basically, this is the

Mr. GRACE (cont.). business currently contracted for, and this is the business we expect to have if the follow-on buys for 12 occur and if we sustain an 8-per-year production. From a planning and management point of view, we have to make sure that we get something in here to provide that kind of business face, or we lose the capability, the people go, and we close the facility. We do not want that to happen. Frankly, we need to maintain this to keep the level and capability together with the Instrument Unit.

Mr. FELTON. What level of effort do you have to maintain the minimum capability?

Mr. GRACE. A minimum capability. We could probably do that on this type of level. That would be a 4-per-year level, and depending upon how much time was available to crank back up, we could get back up there. We would lose a lot of trained professional people.

Mr. WILSON. Would they be lost to IBM or transferred to other facilities?

Mr. GRACE. We hope they would not be lost to IBM. As you know, we try not to lose people. It would be our hope that the business economy throughout the rest of the company would be such we could place people. I know if they are lost here to IBM, they are lost to this program for good. The chances, from the point of view of the individual, to get him to come back to something that had folded up under him, are pretty bad. Whether they go to some other place in IBM is rather immaterial in regard to the Saturn Program. They are gone for good--they might as well have gone to another company. We could probably get key people to come back; we have done it before. We have been very fortunate, so far, in not having to lay off people

Mr. GRACE (cont.). as a result of a cut in business. Like every other Government contractor, we have been faced with it. I was involved in the B70 Program when we received a Christmas present of a termination. We had a 1500-man problem. It was tough to keep from having to lay them off. We had to do some fast and expensive maneuvers in terms of the company and commercial business involved. We were able to weather that storm--it was the worst storm we have had to weather. It would be our hope that we would not have to release people, but there is no guarantee of that. Have I made a clear presentation here?

In the area of cost reduction in FY67, we, like all the other contractors on the Apollo Program, made a number of studies at NASA's request--how we could reduce the cost in FY67 and still meet the program itself. There are a couple of things we say could be done. We recommended that, to reduce the company requirement in FY67, we could take some action that would defer cost out of FY67 to a later time period and go to the MA2 schedule. We are talking about the time period each year where the Uprated Saturn I Program does not buy you very much, in terms of MA2 schedule, but the Saturn V Program does buy you something in the time period until July 1 of 1967. In fact, if you move to this chart, I think I can portray it a little better (Figure 87). This particular point in time, on the S-IU-504 going to the MA2 schedule, is about a 4-month delay. Activities that would have to take place in FY67, in order to meet that schedule, can be shifted

FY67 COST REDUCTION

DEFERRALS	
MA 2 Schedule - IU	$ 1,645
Purchase Commitments - IU	8,900
	$10,545
PROGRAM REDUCTIONS	
MA 2 - IU	$ 1,405
Piece Part Summary	050
Test Procedures	100
	$ 1,555
TOTAL	$12,100

FIGURE - 87 - FY67 COST REDUCTION

Mr. GRACE (cont.) out of FY67 to a later time period and thereby save some funding requirements--but not a great deal. We talk about $1.6 million. The big cost deferral that we proposed was something that the IBM Company could do, and that is in the area of purchase commitments. When you let a purchase order in the present plan, it has to be covered by the Government dollar. It has to be there to pay for that purchase commitment, whether or not the bill is going to come due in that particular time period. What we are saying is--there is a lot of purchase commitments during FY67 that we will cover. We know that they are not coming due until the time period after FY67. On the basis of not requiring funding in the dollar-short situation that NASA is in now, it would be allocated to those particular orders and will be paid a little later.

Mr. FELTON. If you do this, what would your position be in the event of termination?

Mr. LERNER. This would be a risk position.

Mr. FELTON. You could be out $8.9 million?

Mr. CLEARY. No. I do not think we would be out that much.

Mr. GRACE. No, probably if you were terminated, the total amount of claims from your vendors would not be obviously near that high. There would be some portion of it, probably 30 or 40 percent of it.

Mr. FELTON. But they are bills you would not have to pay during this fiscal year.

Mr. LERNER. It is not a question of billing the Government. It is a question of having the amount of funding on the contract. The contract now reads, just as all incrementally funded contracts read, that you are supposed to have enough funding to cover, just in the event of termination, all claims and the like. What we would say is that we would take some risk in this area in order to help this FY67 problem.

Mr. FREITAG. Suppose a problem arises to cause a substantial reduction of NASA funds next year, where funding next year will be just as bad, how does that situation affect you?

Mr. GRACE. Well, this is something that--once you tighten your belt, take a deep breath, and say you are willing to do it--in effect, we are supporting the program like this in terms of the risk.

Mr. CLEARY. It is done only once. It is just a matter of termination liability which you use up once, and it ends that year. When the bill comes due, you have to pay the bills. FY68 has to follow, maybe we can take the same risk for those bills that come due in FY69.

Mr. GRACE. The bills that come due have to be paid. This is a significant thing, in terms of actual reduced costs to the program, as a result of the MA2 schedule. We determine that we could save $1.4 million in that time period by the reduction in premium wages and overtime that would be required to keep on this kind of schedule. Frankly, we did not anticipate the manifold problem then, but it is typical of the kind of thing you have to

Mr. GRACE (cont.). crash through when you are constrained to that kind of schedule.

Mr. WILSON. How much would that problem affect that dollar?

Mr. GRACE. I really do not know. A couple of smaller things--these are some additional things that were part of the program. We were required to provide piece-parts summary information and certain details on test procedures which have gone to $150,000. We felt they were not necessary and could run the program without them. We got together with Marshall and we are in general agreement that the program can run without them--with a slightly greater risk in terms of traceability and things like that. But, we could make that as a net savings with a little over a $1.5 million actual savings to the program for a total of $12.1 million reduction in FY67 funds.

Mr. WILSON. Part of that could be washed out by your manifold problem. Is that correct?

Mr. GRACE. Part of it could, but I do not expect a great deal. We have had to continue a high level of overtime for the month or two that we were in the peak of the manifold thing, but it is going to come down. We are going to make it come down.

Mr. FELTON. If NASA finds themselves in a very successful flight situation--in the Uprated Saturn I and the Saturn V Program--could you refurbish Uprated Saturn I Instrument Units to be used for the Saturn V?

Mr. GRACE. Yes, there is a lot of commonality between these--Launch Vehicle Digital Computers and Data Adapters, Platforms, et cetera.

Mr. WILSON. Supposing, because of continued NASA flight success, NASA does not need all the Instrument Units that you have been contracted for in the total program to date. As you have been building these units fairly early in terms of when they are needed, I assume there would be some increase in cost by terminating the manufacturing of these units.

Mr. FELTON. This schedule here that you show--there is some cost increase associated with it over the MA2 schedule as far as total run-off cost. Is that correct?

Mr. GRACE. Yes, that is correct.

Mr. FREITAG. What are we talking about in terms of dollars?

Mr. GRACE. Well, we did run an exercise about a year ago on what the MA2 schedule would cost relative to this one, and it was $11 to 12 million total additional program cost. Whether that would still be the same would have to be determined.

Mr. WILSON. Let me understand this, does the fact that you get the additional vehicles and you stretch the schedule still increase the total run-off cost of the current Apollo Program by $12 million?

Mr. CLEARY. No, if you stretch down to the MA2 schedule and add the 12 vehicles, you are, in effect, cutting that $12 million cost by $5 or 6 million.

Mr. CLEARY (cont.). We save by stretching out, as opposed to stretching out and adding the 12 units, as opposed to continuing on this schedule and then starting again if you need additional units. We have not really started up.

Mr. WILSON. You do not really know if you save--you know you spend $6 million more even with the additional 12 vehicles.

Mr. CLEARY. Yes.

Mr. FREITAG. Do you know what you might save? You anticipate what you might be able to do.

Mr. GRACE. Well, if you moved something else out onto that floor, you would have to refurbish the floor. You would have to pay to re-train. You would start your training all over again. The learning curve on the building of the Instrument Units would go up. It would start back up again someplace on the curve.

Mr. FELTON. What would it cost to make an Uprated Saturn I Instrument Unit look like a Saturn V Instrument Unit?

Mr. CLEARY. If you had an Uprated Saturn I Unit on hand?

Mr. FELTON. Yes.

Mr. GRACE. Well, it depends on the specific requirements. The telemetry, the measuring unit, et cetera, are different. But the Launch Vehicle Digital Computer and Data Adapter and Platform--the three high cost items--would be the same. The Flight Control Computer would be a new one. It is doubtful whether you could modify that to the Saturn V design.

Mr. WILSON. If you have an already-built Uprated Saturn I, and programmed the Flight Computer, et cetera, and spent that $1 million plus in software, it is obviously almost 100 percent scrap.

Mr. GRACE. I think you have to really separate the software out of the question now and talk just about hardware. Isn't that really what you asked?

Mr. FELTON. I am asking a deliverable item of Uprated Saturn I configuration converted to a Saturn V configuration.

Mr. GRACE. Is it related to launch time?

Mr. WILSON. The launch time is not a factor.

Mr. GRACE. It would seem to me, just off-hand, that you can convert from an Uprated Saturn I to Saturn V Instrument Unit without a great deal of additional cost. Physically, the structure is the same, a lot of the hardware is the same, and a lot of the high priced units are the same. Primarily, it would manifest itself in the different cabling, different distributors--that kind of thing.

Mr. FREITAG. You would be terminating your Saturn V Instrument Unit effort somewhat earlier than the 15 Units that you are talking about now, and there must be termination costs along with this that would wash out some of your savings.

Mr. CLEARY. Again, it depends on how many units would be left to go. Your termination cost is primarily with the event that your hardware left on--how far down the pipe they are on how many units.

Mr. FREITAG. You would have to make the decision fairly early?

Mr. GRACE. Yes. One of the questions that comes up in terms of something like this--regarding the follow-on buy--is how soon do you have to have a go-ahead on something like this? Ordinarily, our requirements are about 18 months ahead of delivery. You must have a go-ahead to get the long lead items on order and delivered. We are talking now about a February 1967 go-ahead, that doesn't mean we incur cost. You must have the authorization to buy the parts. If you authorize somebody to go ahead on parts that far ahead of time, then that kind of tells you what you have committed yourself to if you start considering terminating. Go back to 18 months ahead of time when you ordered something. The supplier has run up some costs starting pretty early. It would still be a pretty good exercise to get an accurate figure to give you a feel.

Mr. POWELL. Actually, the same thing happens fairly early if you were faced with this kind of situation. In fact, it will be late this calendar year to even start.

Mr. GRACE. If you were talking about the kind of activity that you were suggesting here.

Mr. FREITAG. I am interested in what you feel would be the worst sort of situation that could happen to you.

Mr. GRACE. I think that a good rule of thumb, from the point of view of the Instrument Unit, is to figure 18 months ahead of the delivery date, in terms of go-ahead, to get parts on order and activity underway that start incurring cost against that Instrument Unit. Actually, it is not quite that

Mr. GRACE (cont.). simple because we have gone out and ordered a quantity buy for things that are obviously common. If a supplier delivers the whole order on time, your termination costs are based on that--in the particular element.

Mr. WILSON. That brings up a very interesting point. This very thing--buying electronics by the package that the manufacturer makes and hands to you--do you find that a good deal of your subcontractors' work is in this?

Mr. GRACE. Very little. As a matter of fact, we do not want it that way. We want him phased with our need because we might want it changed.

Mr. STICH. We structured our subcontracts specifically to provide for greatest change flexibility and for the stretching out of every occurrence along the slope of our schedule.

Mr. WILSON. This may be costing you money then?

Mr. CLEARY. It saves us money as a result of change activity.

Mr. GRACE. We run analysis in our Purchasing Department constantly. We go to engineering and get their feeling for whether a unit is going to change or not. From this study, we decide whether to buy over this period of time and get a certain price or have them phase out to cover the chance of changes. It is a pretty complicated matter in terms of buying for a program.

Mr. EHRHARDT. In most instances, if we looked at each individual subcontract, we would find that we are actually pushing the capacity of these subcontractors to meet our schedules.

Mr. WILSON. If you start with the S-IU-504 and go down to S-IU-515, you are talking about a time span of 4 to 7 months. That brings up a question. If you look at the $12 million--what is that? Is that the man-power that you sustained from the last S-IU-515 delivery on this schedule versus MA2 or somewhere within that? Pick any lead time item, wipe out the major ones which are really GFE, pick the next one, and largest one. Is it 4 months lead time or is the maximum 7 months? If you equate that somehow, somewhere within that band from S-IU-504 to S-IU-515, there must be a shutdown and start-up cost from some, or a large part of vendors. Let me rephrase that question. What is the $12 million? If you look back at your manpower thing, there are quite a number of people being carried every year. Over a 7-month period of time, what does this equate to?

Mr. FELTON. Neglecting this location's problems associated with IBM in Huntsville, what would happen to the cost of doing the whole job if the Instrument Unit design would be frozen?

Mr. CLEARY. The cost would go down.

Mr. FELTON. Intuitively, you say that.

Mr. GRACE. When you come right down to it, a Chevrolet automobile is a fairly complex piece of equipment. If you made ten per year, it would be pretty expensive. If you make 5 million per year, the cost comes down.

Mr. WILSON. Not saying you are adding any facilities. . .

Mr. GRACE. Make as rapidly as you can at this point, and push all your subs to turn it out en masse.

Mr. CLEARY. And you do mean identical, no measurement different from any other?

Mr. GRACE. Obviously, there is some theoretical maximum rate that you can do on Instrument Units which is limited by your facility. That theoretical maximum rate, figuring 2 months for checkout, is about 6 per year of each kind. So you could do 12 per year. We figure that is reasonable.

Mr. WILSON. The checkout is a limiting factor?

Mr. GRACE. Yes.

Mr. WILSON. For instance, if you built a third checkout facility, you could increase it?

Mr. GRACE. Yes.

Mr. WILSON. Then would it move back? Checkout no longer would be your limiting factor, something else would?

Mr. GRACE. No, probably it would become availability of parts then. Actually, I over-simplified it by saying that checkout is the limiting factor. That is fairly obvious. You take a 2-month checkout phase in two stations-- mathematically that equates to 12 per year. It is not quite as simple as that. There are other factors that determine whether you can do that well or not; one is availability of parts on that schedule. Our experience, to date, would lead us to want to take a little more time to evaluate whether you can actually

Mr. GRACE (cont.) get to 12 per year, based on the availability of parts. We are, frankly, having problems getting the parts at the rate we need them right now. As you know, the Viet Nam situation has created considerable business for many of the people who provides us components, and DOD has a higher priority than NASA.

Mr. FELTON. Has DOD priority effected this?

Mr. GRACE. Not to the point that we cannot make our commitments. Has it affected us? Yes, it has made it much harder for us to get in there and beat our way through. But we are still able to meet all our commitments. When you start addressing something like this (could you go to a faster rate), you have to take that into consideration. Also, just looking at checkout alone, we came out with a maximum of 12 per year when figuring the maximum rate. That is not actually the maximum rate because we could add more people into the checkout station--we could run it around the clock! We could really get more than 12 out per year if we geared it to the maximum human possibility, in terms of the number of people we could physically get in there.

Mr. FELTON. Still, it would not reduce your cost in the next year as far as you can see?

Mr. GRACE. No. I have added this in to get you to understand it more fully. I added a little complication there. I think it nets out that 12 per year is a reasonable maximum rate you could expect. And, if you were talking about

Mr. GRACE (cont.). how fast you could build them, in terms of total program cost, that is about the fastest you could expect.

Mr. WILSON. But your rate of expenditure would be higher than it would be right now?

Mr. GRACE. With your total cost per unit, yes. It probably would be higher because there is a certain sustained level of people that you have tohave to run a program like this. Part of the problem involved, as you well know, is that if you take a program that is ending in early 1969 and you run into 1970, you have that minimum level of personnel that is required to keep you going on the program longer. They are some of the additional costs.

Mr. WILSON. A major point is, you do not checkout with any less people for any longer time. If a checkout takes six months, it is still going to take the same number of people as it does if it takes them 8 weeks.

Mr. FREITAG. They are concerned about your rate of expenditure going into next year. You talk about July 1966 to July 1967. We are trying to get a gauge where you first start to build the last four or five Uprated Saturn I's.

Mr. EHRHARDT. We start fabrication in July 1967.

Mr. WILSON. So you have been buying long lead time prior to this time?

Mr. GRACE. Yes.

Mr. WILSON. Could you simply block out four or five of your last Uprated Saturn I Instrument Units from your schedule, right now, and move them over en masse to a later date--without impacting the initial flight schedule on the Uprated Saturn I and Saturn V?

Mr. CLEARY. Well, effectively, if you go to MA2, you move one complete vehicle into FY67.

Mr. WILSON. You have a domino effect on the last four Uprated Saturn I Vehicles, but you are saying you are to do this with one vehicle.

Mr. GRACE. What you have done is moved the purchase cost of one vehicle from FY67 to FY68.

Mr. WILSON. So it is one complete vehicle.

Mr. GRACE. Yes. Actually, there are a lot of things legislating in favor of this modified schedule--the fact that it is compatible with current program plan. If the schedule on the Instrument Unit Program is consistent with current program planning, it moves activities out of that time period and, thereby, nets out some dollar saving. It does not put in the dramatic kind of thing that you would have to do if you say, "I will take S-IU-209 to S-IU-212, chuck those out, and pick them up at some later date". That throws you back into your supplier base, going back to all those 1500 suppliers and discerning whether you can stretch them out or not. You do that to some extent on the MA2 schedule. On the follow-on buy, you ship those a little later.

Mr. WILSON. Is the Apollo Instrument Unit going to increase the total cost under the schedule?

Mr. GRACE. Total cost?

Mr. WILSON. Yes, cost per unit.

Mr. FELTON. Neglect the 12 vehicles, the total cost.

Mr. GRACE. Yes, the total costs are going to be somewhat greater. At this point in time, we do not think it will be $12 million. A lot of water has gone over the dam since that proposal was prepared. We think it will be less than that, even if you do not consider the follow-on.

Mr. FELTON. How much less?

Mr. WILSON. What was your estimate on that, Mr. Cleary?

Mr. CLEARY. I say around 7 instead of 12.

Mr. GRACE. It would still be a greater price for the total program.

Mr. STICH. Could I ask one question on the $7 million, Mr. Cleary? Is that including all directed changes to date?

Mr. FREITAG. Well, this is something I was not completely clear on--in the directed changes, you really are indicating that directed changes are driving your costs up during the same period?

Mr. CLEARY. When we are referring to directed changes, an awful lot of them are for the procurement of spare parts for the vehicles.

Mr. FREITAG. That $29 some million of unnegotiated... a lot of those are spare parts--how much?

Mr. CLEARY. About $6 million of that $30 million is for spare parts alone. Another significant change that we are taking over is actually not an increase in new total program cost, an increase in the IBM portion, but that is assuming this CEI specification.

Mr. LERNER. That is not in the $29 million?

Mr. CLEARY. No. The biggest portion of that $29 million relates to the configuration management--which in effect is something that I presume you are doing now or someone at Marshall is doing now.

Mr. LERNER. It is being evaluated now, in fact, today. That is a substantial change--$13 million itself.

Mr. FELTON. Let us see, that is $13 million and then $6 million to $7 million for the spare parts. The rest of the change activity is not significant dollars.

Mr. GRACE. It is a large number of changes. Each one of them is carrying a nominal kind of cost, not in the millions.

Mr. FREITAG. I think that the major point of that $29 million is the fact that, when you look at it, the kind of changes that it entails. There is a greater potential for that to grow percentage-wise greater than with the basic contract and stretch-out program. It keeps more personnel on board.

Mr. FELTON. If you have and expect to have a high success on the early flight of the Instrument Unit, do you foresee possible simplification of the Instrument Unit that will, in fact, reduce cost?

Mr. EHRHARDT. There is a planned elimination of certain measurements that are not required operationally. Simplification that would reduce cost is not too likely.

Mr. FELTON. How about savings by relaxation on specifications on subsystems. Do you foresee a possibility in the immediate future?

Mr. GRACE. We have already, I think, done some pretty sensible evaluations of this with Marshall. For example, in the Gas Bearing Heat Exchanger that we talked about, the requirements for class 3 welds which is a specification requirement which is absolutely required as far as Marshall is concerned. It would have probably cost a fortune. We would have eaten up assets to really strive to meet that, yet the yield to that kind of specification is nil. This is the kind of thing we have been able to work out and relax that specification--to be able to deliver a flight worthy product and not incur those costs. We have had enough experience, to date, to anticipate which allows a dollar saving that can be associated with the relaxation of specifications. Mr. Ehrhardt, do you have anything further to add?

Mr. EHRHARDT. I would say that we have saved dollars where we felt there was not a need to meet the original design specifications. We have run tests and convinced ourselves that they could be relaxed. We might consider that as a dollar savings, except we have never put the ECP in. It has never been spent. We have a little trouble saying something was saved. The hardware is essentially designed. We have only two flights under our belt. There are still some unknown things to be resolved and, on that basis, we are not going to be able to go through and say that we now can cut these things back. I think that by late this year or early next year, you have essentially commited yourself for the hardware on the present program.

Mr. WILSON. This follow-on buy, I think you might be more apt to see something like that come up.

Mr. FREITAG. What confidence do you have at this time that you will be able to force your cost breakdown, in the amount that you are talking about or more, for the year?

Mr. GRACE. I still feel confident that we can do what we said here--I say FY67. We are talking about this kind of a program reduction, based on reduced premium expenses and overtime. Frankly, we had expected to be able to cut back on the overtime by now and would have, to some extent, if it had not been for the manifold problem.

Mr. CLEARY. If we can get an agreement to that kind of schedule, I think we will still be able to do that in a month or so. So, most of this saving will actually result.

Now, based on the fact that we felt there was no opportunity to effect a cost saving until late in August anyhow, the direction to the MA2 schedule really has to be received within about 30 days. Otherwise, you start eating up that $3 million--the $1.4 million which is a pure reduction and the other which is a deferral. Obviously, you do not use the whole $3 million up but...

Mr. GRACE. On the other corollary, if it is, we are confident that we have what we should with the exception of what it is costing us on the manifold.

Mr. FREITAG. In essence, you are saying that your answer to Phillips and Mueller, last June--when they came through--was that with the present work force, you did not see how you could get any people off the job and still do the job that you have on contract.

Mr. GRACE. We did not see a reduction in people--we saw a reduction in overtime.

Mr. FREITAG. Only in overtime and not in piece-parts?

Mr. GRACE. That is right. If there is no basic reduction, you do not have a basic reduction of effort to do this job.

Mr. FREITAG. I see. With what you have written in the contract, there is not a major cost reduction of the effort on the present contract. I see that there are $9 million to $10 million in deferrals, not expenses.

Mr. LERNER. The specific two lower requirements, piece-part summary and test procedures, will actually be changes, and we will ask for less work in those areas (Figure 87).

Mr. GRACE. It is hard to see how you can reduce effort (cost) if you do not reduce scope, unless you way over-estimated the thing.

Mr. POWELL. I would like to ask a question in order to get that purchase commitment into prospective. How many dollars would be due in FY67--how many vouchers would you have to pay yearly?

Mr. CLEARY. You are saying, as I understand it, not paying--this was the commitment of funds by Marshall to protect in event of termination.

Mr. POWELL. How many actual dollars of that $8 million would be outlayed? This is a philosophical thing, Mr. Grace, we go by a 30-day basis. We do not fully cover unfilled orders or we have not. It makes certain exceptions and what you are saying when you place a purchase order, you want full coverage recognized. That would not necessarily mean that you are going to actually pay out $8 million or $9 million in FY-67.

Mr. CLEARY. That is correct.

Mr. POWELL. But, you say, one of those purchase orders or a number of them will come in for payment in that particular time frame.

Mr. CLEARY. That is not true.

Mr. LERNER. That is the open amount at the end of the year.

Mr. LERNER. What we are really saying, Mr. Powell, is that under the terms of an incrementally funded contract, right now the way the contract is written, we should be funded for enough to cover us in the event of a termination. In the event of a termination, part of the $8.9 million will immediately become due.

Mr. POWELL. None of that $8.9 million will be paid.

Mr. CLEARY. Not an outlay at all?

Mr. STICH. If you read the limitation of the Government's obligation in incremental funding clauses of the contract, you find that unless the contract reflects sufficient funding to cover the contractor's commitments, he technically would be in a position, if you terminated, that he would not have given you the notice that the 85 percent point that would be required. Hence, he would be in a risk position between the funds that you had on the contract and the amount of termination claims that would exceed the 85 percent point. Do you follow the logic?

Mr. CLEARY. We will pay the suppliers between $16 to $18 million. In FY67, we will also bill those payments to Marshall. But that is not included and has nothing to do with the termination conditions. That figure represents

Mr. CLEARY (cont.). a juggling with the amount of funding you are obligated under the limitation of government obligation and incremental funding provisions of the contract.

Mr. GRACE. We have one last chart here. (Figure 88) Throughout the Company we have what we call the IBM Effectiveness Program. This is represented by a Big E with a square around it. Obviously, as a company, we are in a pretty competitive arena these days with real capable competitors, good products, and good service. Throughout the company, we are doing a lot of things to reduce cost. In the particular environment we are in down here, we have additional motivation in terms of the Government's interest in cost savings and our desire for participation in that. In terms of our effectiveness program, we have what we call the RED X Program (REDuced eXpenses) and all those things you would ordinarily have--you know the suggestion plan where you pay people for their money-saving ideas. We put an awful lot of effort into the procurement analysis which goes through some of the things I have alluded to earlier. Manned Flight Awareness, which we associate specifically to this particular contract. We recognize people for the contributions that save money and still get the job done right the first time. Under our IBM effectiveness program, we lump all of these activities which are ordinarily associated with any business. We have a system that we use in control of cost impact--Management Planning and Control System (MPACS). Under this system, reports come weekly and monthly to the line managers. They tell them exactly what they are doing against their budget

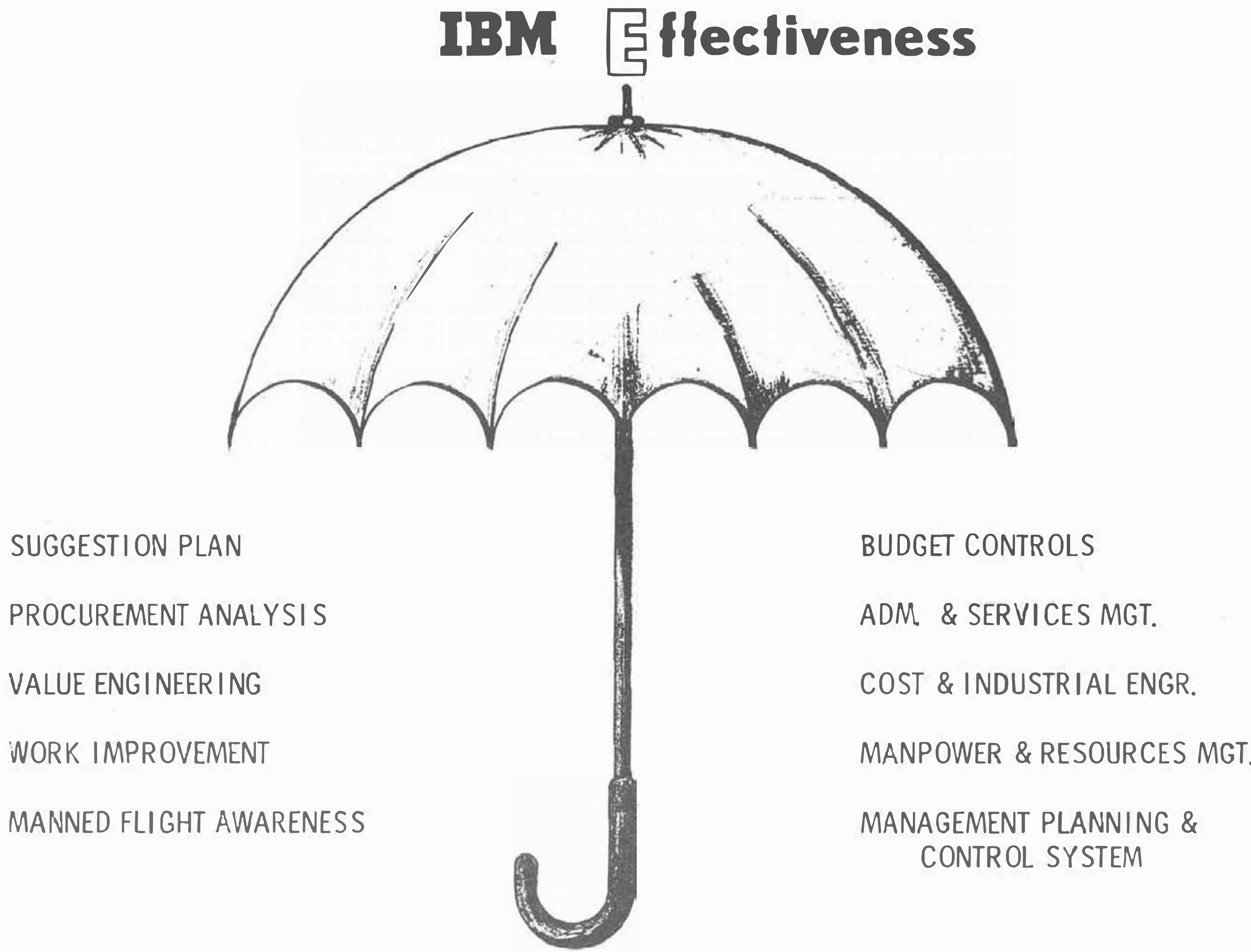


FIGURE - 88- COST EFFECTIVNESS PROGRAM

Mr. GRACE (cont.). and give them the opportunity to make decisions that will reduce the cost. This kind of thing is all lumped under what we call the big umbrella, "effectiveness". The whole purpose behind it is to do the job with the least possible cost.

Mr. FREITAG. What is the effectiveness program costing you?

Mr. CLEARY. It is not a program designed to cost, rather to save. So far under the RED X program this year, which is the composite of all of these things, we have recorded savings of a little over $2 million.

Mr. WILSON. No, how much money? How many dollars out of pocket have been saved? Not if you had spent what you would have saved. I appreciate what you are saying, but . . . .

Mr. CLEARY. Some of the real savings are in areas of the suggestion plan where we saved about $50,000 to $60,000.

Mr. WILSON. I realize you can not evaluate actual cost and savings.

Mr. CLEARY. We have saved a little over $100,000. These are actual ways--we have found a better part than the one we had on order, that type of thing.

Mr. CLEARY. We had one significant one the last couple of months. It concerned the terminal board material that we were using in the Distributors. It was an actual change to the engineering documentation. The estimated savings to the remainder of the program was $200,000 or $300,000.

Mr. FREITAG. These are cost savings!

Mr. CLEARY. Here was an actual item we had out on order. We were going out for more. We had $473,000 for the first 6 months.

Mr. FREITAG. What portion of these type savings does it cost you to administer?

Mr. CLEARY. Well, to administer this, I have one full-time person and part time help from various levels of management, plus, and this is the kind of thing I can not evaluate for you, the time that it takes the people to document it and submit it.

Mr. WILSON. But, I would presume that it is a very, very minute fraction of anyone's time to submit it.

Mr. CLEARY. It is quite significant in savings, even if you discount the things that are perhaps in the future.

Mr. CLEARY. One other area where we have had some really significant savings is in the programming area, both the administrative programming and the scientific programming under Mr. Meadlock. Here people have come up with a revised way to run some of the test programs and substantially reduced the number of computer hours that are needed to check out a particular program. And this has been a real savings.

Mr. GRACE. It is a real savings in cost deferrals of about $200,000, right?

Mr. CLEARY. Yes.

Mr. GRACE. Some of these are cost....

Mr. CLEARY. There is a savings over and beyond what you save out of your pocket immediately. There is one other point on that plan we have recently recommended to NASA, and they are actively pursuing--the advantages to this program of including something in the area of a value engineering program

Mr. CLEARY (cont.). which would allow us more freedom to make suggestions for substitutions and parts like this.

Mr. GRACE. We do not think we have quite enough perspective for getting some kinds of suggestions in the suggestion program. We have, in addition, some other company programs that will allow us to be able to recognize people who were not normally qualified for a suggestion program, like porfessional and management people, and are not usually monetarily rewarded for their suggestions. For example, we had one just yesterday. We had a manager and another fellow who suggested a fixture to handle cable. The other fellow got a pretty interesting award under the suggestion program. The manager who had a lot to do with the idea received a little bit of money-- on the informal award program. We have this kind of thing to stimulate that.

Mr. FREITAG. Where did the award come from?

Mr. CLEARY. As payment either by salary increase or a reward.

Mr. GRACE. Very good. Now, we have been actively engaged in looking at other benefits of the Space Program. The Surveyor Program, under the direction of Dr. Castruccio, originates in the Space Systems Center in Washington. We have some people down here who have been working with Dr. Castruccio who have been particularly interested in improved Instrument Unit applications. This effort has been primarily concerned with our advanced program activities. Dr. Castruccio is well qualified to address the future as we see it. Dr. Castruccio, if you would.

FUTURE APPLICATIONS

FUTURE APPLICATIONS

Dr. CASTRUCCIO. Truly what you have seen today at IBM Huntsville is an example of the build-up of a tremendous capability that we, as a Nation, are gradually accumulating. Popularly, this capability is recognized in terms of weight of payload in orbit. Over the last 7 years, we have increased the weight of payload in orbit by over 10,000 times. It is now within our technological grasp to increase it from 5 to 10 times more. Payload in orbit is, however, not the only dimension of this capability. Another very important facet is the probability of successful launch which has increased from less than 50 percent to an average of 92 percent for all launches. It has been 100 percent on our manned space flights.

The third facet of this capability is that we have now come to understand the earth orbital environment. As the fourth, and most significant capability, we have decreased the cost of total spacecraft payload in orbit from more than $10,000 per pound to approximately $900; and the decrease is still continuing.

The real question today is: what are we going to do with this tremendous capability? There are three possibilities:

- o We could decide to exploit it in the earth-orbital sphere for the benefit of the United States and the World.
- o We could decide to use it to explore further--the moon and the planets.
- o We could do both, in a single well-balanced program.

Today, I would like to give you some data, some facts, on what is involved in the beneficial exploitation of earth-orbital space. These facts

Dr. CASTRUCCIO (cont.). were largely derived through the stimulus of a study funded by the Office of Manned Space Flight of NASA, with specific contributions by Mr. M. J. Raffensperger and Mr. C. A. Huebner.

We had the following objectives:

- o Define what can be done, in what areas, in terms of worthwhile activities.
- o For each area so defined, analyze the prospective program: namely, what equipment, what orbits, what activities, and what additional research is still required between now and the time of flight, to make the program highly cost effective?
- o Determine what is the cheapest way--minimum number of space stations--to accomplish this program.

Let me first present the results, and then some of the highlights of the method used to derive them. As regards what we can do in space, 13 areas of useful endeavor were identified. (Figure 89) The 13 areas fall into three groups. The first group includes areas of activity intended toward the improvement of the US and the world's standard of living. As such, they can be associated with tangible dollar benefits. The second group includes scientific applications. These we found impossible to evaluate in dollars and cents.

Mr. WILSON. Can't you put a dollar value on pure science programs?

Dr. CASTRUCCIO. Not in the absolute sense. Nonetheless, these scientific areas are significant because of their promise of expanding scientific knowledge and capabilities.

EARTH-ORIENTED APPLICATIONS

AGRICULTURE/FORESTRY

GEOLOGY/HYDROLOGY

OCEANOGRAPHY

GEOGRAPHY

ATMOSPHERIC SCIENCE

COMMUNICATIONS/NAVIGATION AND TRAFFIC CONTROL

SCIENCE

ASTRONOMY/ASTROPHYSICS

BIOSCIENCE

PHYSICAL SCIENCE

SUPPORT FOR SPACE OPERATIONS

BIOMEDICINE/BEHAVIOR

ADVANCED TECHNOLOGY

EVEA

OPERATIONS TECHNIQUES/ADVANCED MISSION SUB-SYSTEMS

FIGURE - 89

Mr. WILSON. Is there some dollar ground rule that can be used?

Dr. CASTRUCCIO. There are several, but they are all "soft". For one, you can compare the cost of space science disciplines with current corresponding expenditures--Federal, state, and private. Another way, which is very interesting but difficult to implement, is to perform an historical analysis. For instance, what tangible benefits has astronomy generated throughout the centuries in terms of aid to timekeeping, ocean navigation, and insight into nuclear problems?

Mr. FREITAG. Does the same difficulty apply to the social aspect?

Dr. CASTRUCCIO. Right.

Mr. FELTON. In saying that our communication satellites would make the world an English speaking world, how do you put a dollar value on it?

Dr. CASTRUCCIO. You can put a dollar value on the education, based upon at least two historical experiences, the "Salcedo Experiment" in Columbia, and the Department of Interior's experience in Guam. The third group of application areas is aimed at improving our space operational capabilities for two purposes: first, to be able to exploit the beneficial and scientific earth-orbital applications; second to prepare ourselves in the cheapest and most effective way for further exploration of the planets.

This next chart shows the dollar benefits associated with the first group of applications. (Figure 90) What we call "long-term improvements" are the yearly "increases in productivity" or "decreases in losses"--both amounting to an effective increase in GNP (Gross National Profit) or GWP (Gross World Profit)--which could accrue from properly conducted space

Dr. CASTRUCCIO (cont.). activities. Notice that, for the world, the benefits exceed $100 billion per year. For the United States alone, they amount to approximately $35 billion per year. What are the conditions under which we can reap these benefits? Obviously, we can obtain information from space, but we cannot force people to use it. The conditions are, that the people in the United States and the world use the data. We asked our economists how long will it take before people will learn to, or can be educated to, use the data? They estimated from 5 to 15 years after inception of the program.

As regards the program required to accomplish the 13 applications, it can be accomplished by use of one space platform in low altitude, low inclination, one space platform in low altitude, high inclination orbit, to be augmented, perhaps at a later time, by a synchronous-orbit space platform. (Figure 91)

Mr. WILSON. I have one question I would like to ask you, Dr. Castruccio. Do you envision a man populating the station at all times?

Dr. CASTRUCCIO. I envision the man as being invaluable whenever you have elements of research which must be translated into decisions and eventually compiled into routine sequences of action. After this is accomplished, machines can take over. In fact, I envision these manned space stations as giving rise to families of operational, long-term, automatic applications satellites. How did we reach these conclusions? After much consideration, we found that the only effective way to satisfy the study objectives was a

CORE OF CONSTRAINED PROGRAM

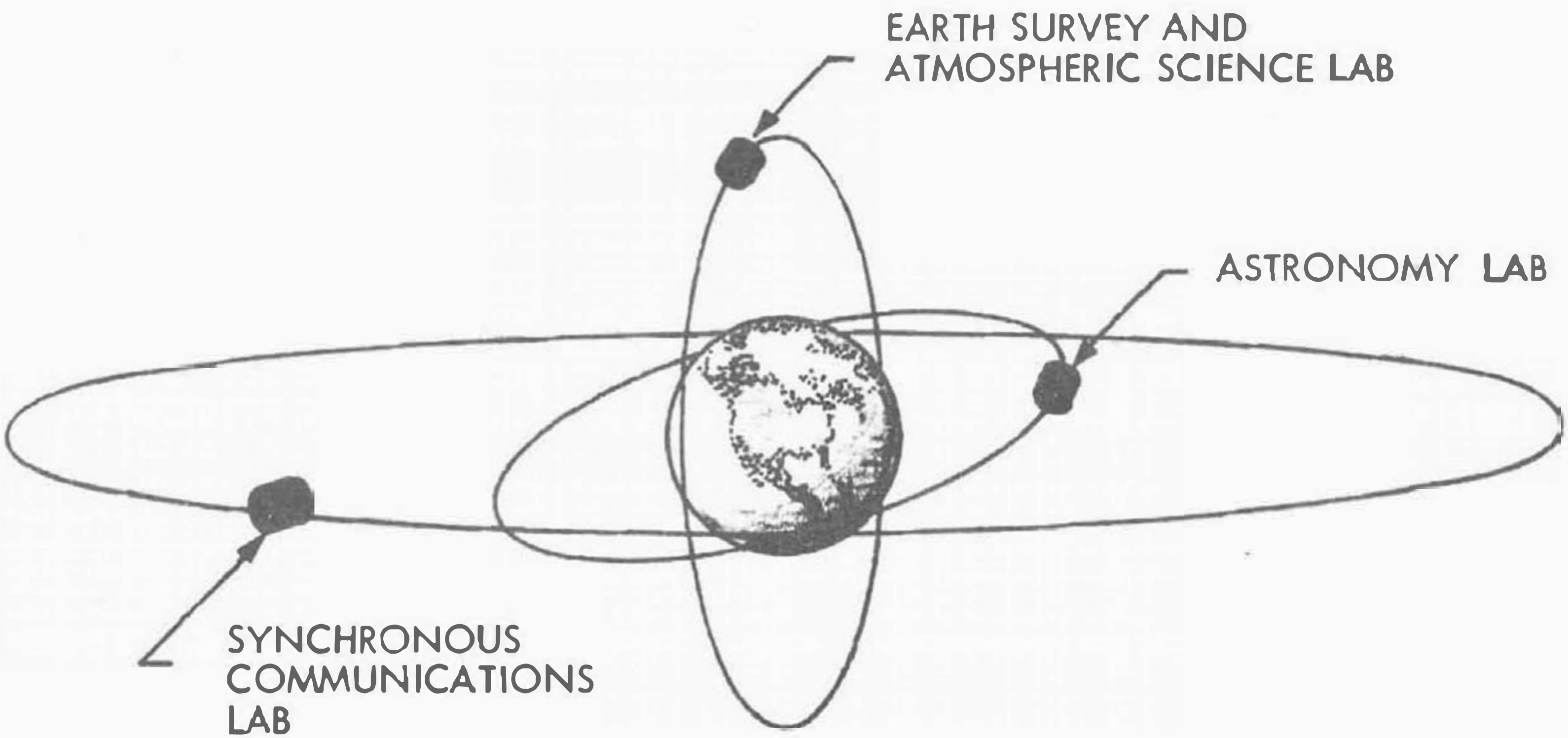


FIGURE - 91

ECONOMIC BENEFITS OF SPACE-BORNE SURVEY SYSTEMS

ESTIMATED ANNUAL BENEFITS - MILLION $

APPLICATION AREA	PRINCIPAL REQUIREMENTS	WORLD EXPENDITURES	WORLD RETURNS	U. S. EXPENDITURES	U. S. RETURNS
AGRICULTURE/FORESTRY	GLOBAL CROP SURVEY CROP YIELD AND DAMAGE SURVEY DETECTION AND LOCATION OF FOREST FIRES WILD LIFE MIGRATION RANGE MANAGEMENT SURVEY ASSESSMENT OF ECOLOGICAL FACTORS	130	11,000	26	840
GEOLOGY/HYDROLOGY	GLOBAL MINERAL AND FUELS SURVEY EARTHQUAKE AND VOLCANO DAMAGE ASSESSMENT DISTRIBUTION OF SOILS, MOISTURE, EROSION PLATTERS WATER POLLUTION SURVEYS AND WARNING FLOOD DAMAGE ASSESSMENT	620	6,000	170	2,500
OCEANOGRAPHY/MARINE TECHNOLOGY	FISHERY SURVEYS HAZARD WARNING TO SHIPPING COASTAL HAZARD WARNING SEA STATE PREDICTION AND TIDAL INUNDATION	800	7,000	350	3,500
GEOGRAPHY	GLOBAL TOPOGRAPHIC MAPPING SYNOPTIC DEMOGRAPHIC SURVEY	33	800	9	100
ATMOSPHERIC SCIENCE AND TECHNOLOGY	WEATHER PREDICTION AND MONITORING AIR POLLUTION SURVEY AND WARNING WARNING OF STORM AND CLIMATIC HAZARDS	1,000	83,000	500	29,500

FIGURE - 90

Dr. CASTRUCCIO (cont.). "top down" approach with the following orderly steps (Figure 92):

- o Analysis of the fundamental problems of each area, leading to clear definition of their objectives.
- o Functional analysis of each objective, in successive levels of increasingly detailed definition, leading to the definition of "Knowledge Requirements" whose satisfaction is necessary to achieve the principal objectives.
- o Derivation, from these Knowledge Requirements, of the four components of the orbital program:
  1. Payload: instrumentation required to satisfy the Knowledge Requirements.
  2. Mission parameters: where to fly, when to fly, and for how long.
  3. Experiments: activities to be performed with the payload instrumentation at the correct time and orbital position, to satisfy the Knowledge Requirements.
  4. Supporting research: including activities such as laboratory research, field verification, and airplane flights, required to maximize the payoff of the space flight program.

It was found that the four components of the orbital program could be derived independently and concurrently from the Knowledge Requirements.

The program so established is an ideal, or "unconstrained" program; it must then be filtered through the practical constraints imposed by spacecraft accommodations capability and programmatic restrictions to derive the optimal

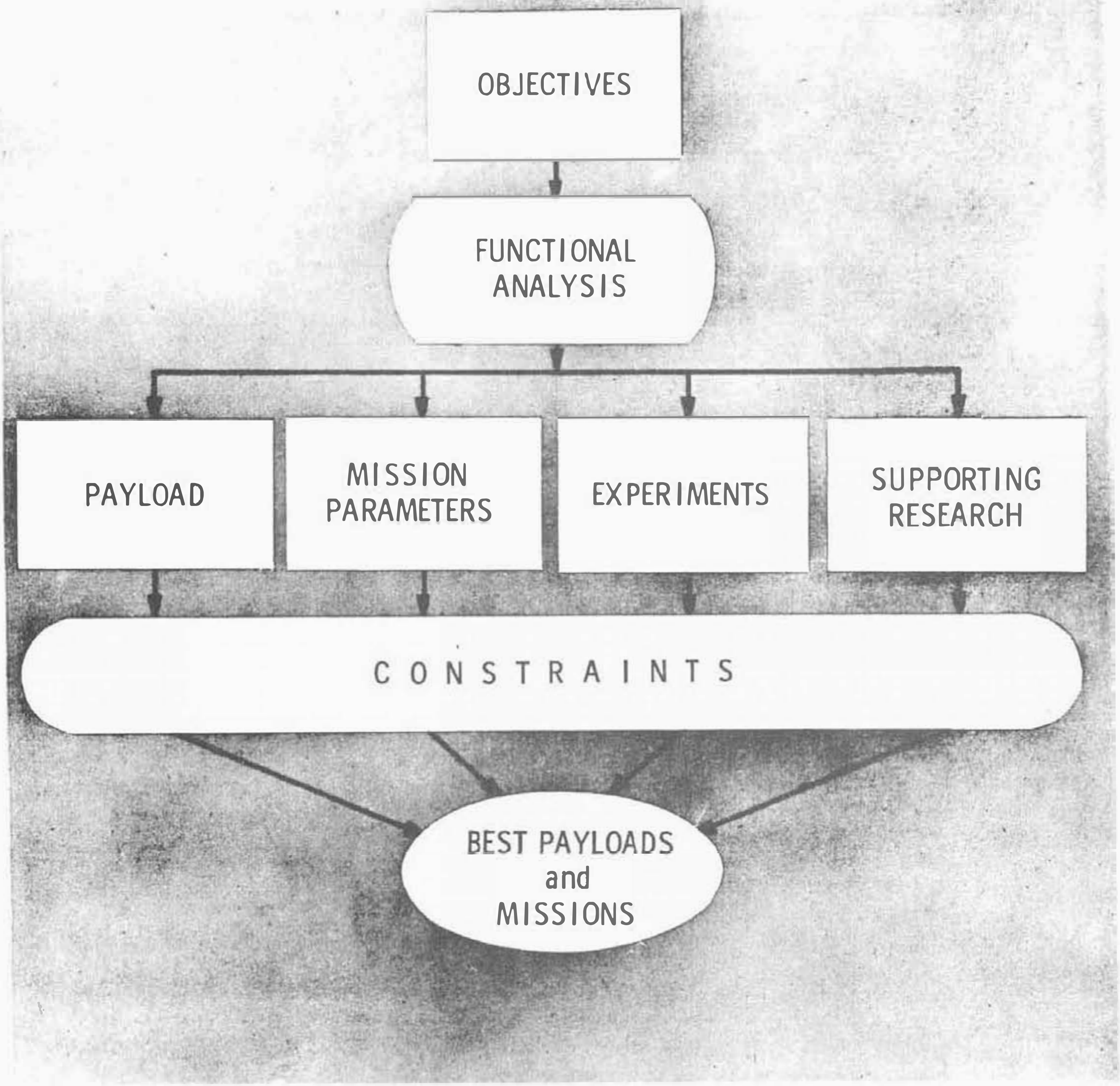

OBJECTIVES
FUNCTIONAL ANALYSIS
PAYLOAD
MISSION PARAMETERS
EXPERIMENTS
SUPPORTING RESEARCH
CONSTRAINTS
BEST PAYLOADS and MISSIONS

FIGURE - 92

Dr. CASTRUCCIO (cont.). program for a particular set of configurations.

Let me now describe the application of this approach to a specific area.

Beginning with the Objectives, a major world problem today is the pressure of population upon natural resources. Analysis of this problem leads to the establishment of several earth-oriented scientific/technical areas: agriculture/ forestry, which addresses the pressure upon food resources; geology/hydrology, which addresses pressure upon minerals, fuels, and water resources; oceanography, dealing with the storehouse of the ocean; and geography, which addresses the broad problems of interaction between man and his environment. Let me illustrate the "top down" method of analysis with the problem of population pressure upon food supply.

What is the problem? Two-thirds of the world's people are inadequately fed--60 percent receive less than the normal daily requirement for calories; 80 percent receive less than an adequate supply of proteins; and 60 percent have protein intakes below what nutritionists recognize as the "danger level". (Figure 93) Areas of undernourishment are shown in the next chart. (Figure 94)

Clearly, we have here a major world-wide problem. The question is, is the problem going to stay with us, or will it go away in the future? Population increase in the diet-deficient regions exceeds 2 percent per year, while food output increases only about 1 percent. Clearly, population grows faster than food productivity. Thus the problem will grow worse. The problem could be mitigated by population planning--even so, the need would still exist for

WORLD FOOD CALORIE AND ANIMAL PROTEIN INTAKE

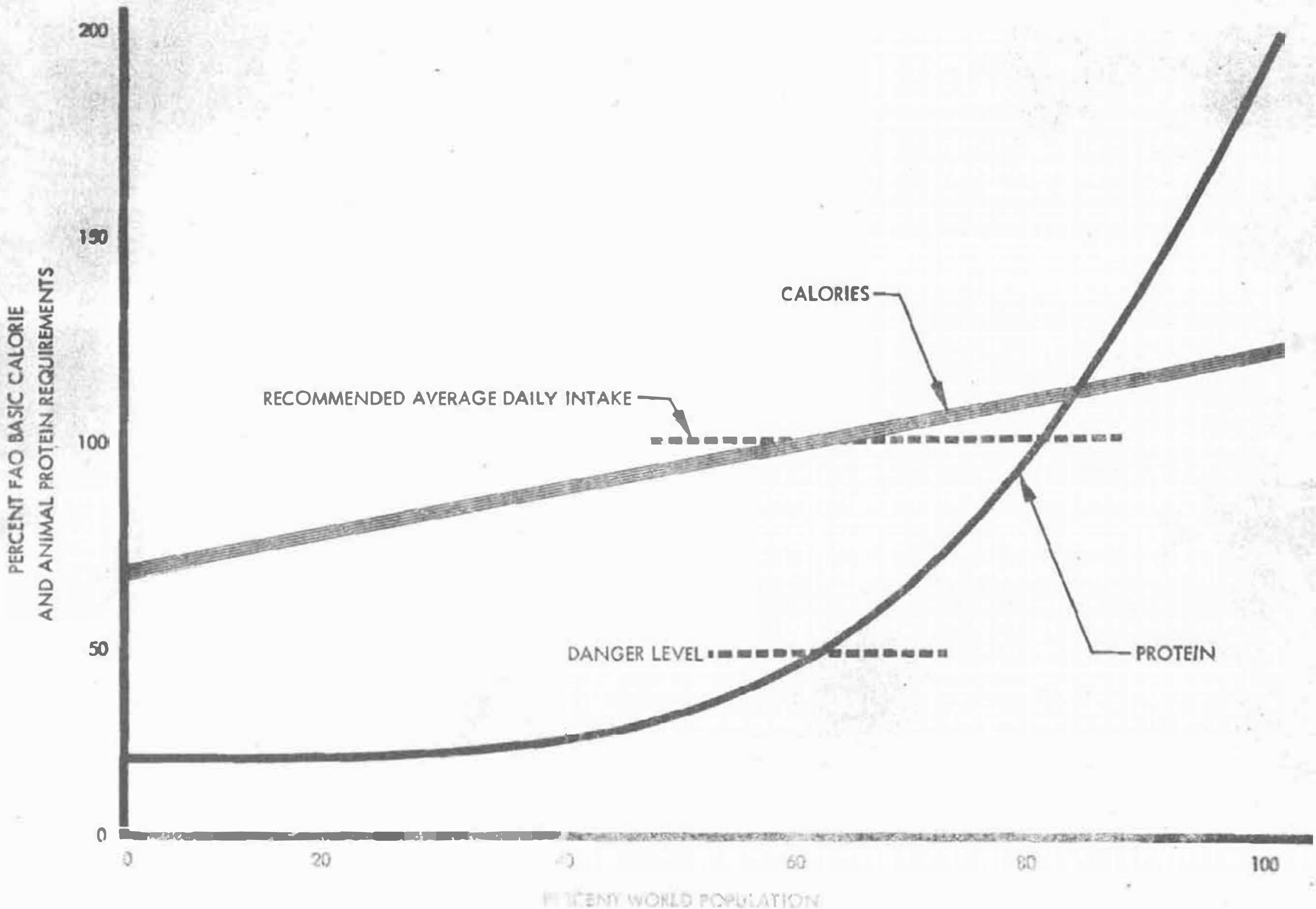


FIGURE - 93

DISTRIBUTION OF WORLD'S FOOD SUPPLY

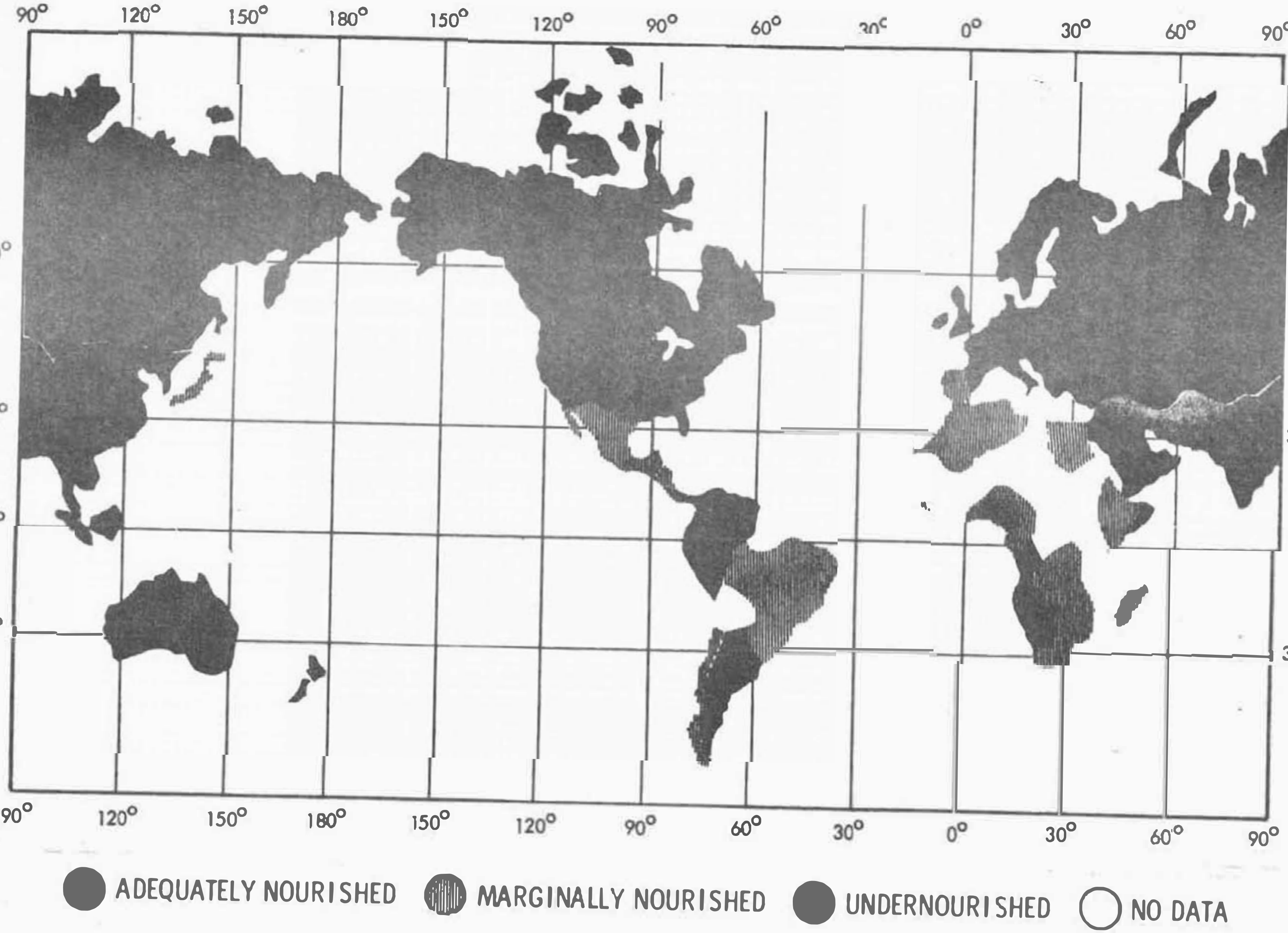


FIGURE - 94

Dr. CASTRUCCIO (cont.). increased food output.

The dimensions of the problem indicate the desirability of further investigating the potential application of space to the area of agriculture/forestry. What can be done about it? There are two principal approaches for the near future: (1) put more land into cultivation; (2) increase productivity of already cultivated land. A third approach involves the development of synthetic foods. Limited experience in this field shows that truly acceptable synthetics must be competitive in taste, smell, and appearance with normal food; this seems to be still quite in the future.

Let us look first at the situation regarding cultivation. (Figure 95)

Of the approximately 36 billion acres comprising the dry land surface of the earth, only 9 percent are currently cultivated. An additional 21 percent is potentially reclaimable: however the cost of the required infrastructure--roads, electricity, irrigation--is large. This favors, as a first measure, consideration of ways and means of increasing the productivity of the currently cultivated 9 percent.

How much can this productivity be practically raised? (Figure 96) This shows that there is considerable room for improvement--the developing regions which possess almost as much cultivated land as the developed countries, actually produce much less per acre.

Mr. WILSON. Why is this?

Dr. CASTRUCCIO. There are at least three major reasons-- (1) lack of know-how, which is perhaps the worst drawback; (2) lack of capital; and (3) less significant than the other two, but still very important--lack of an adequate

UTILIZATION OF THE WORLD'S LAND

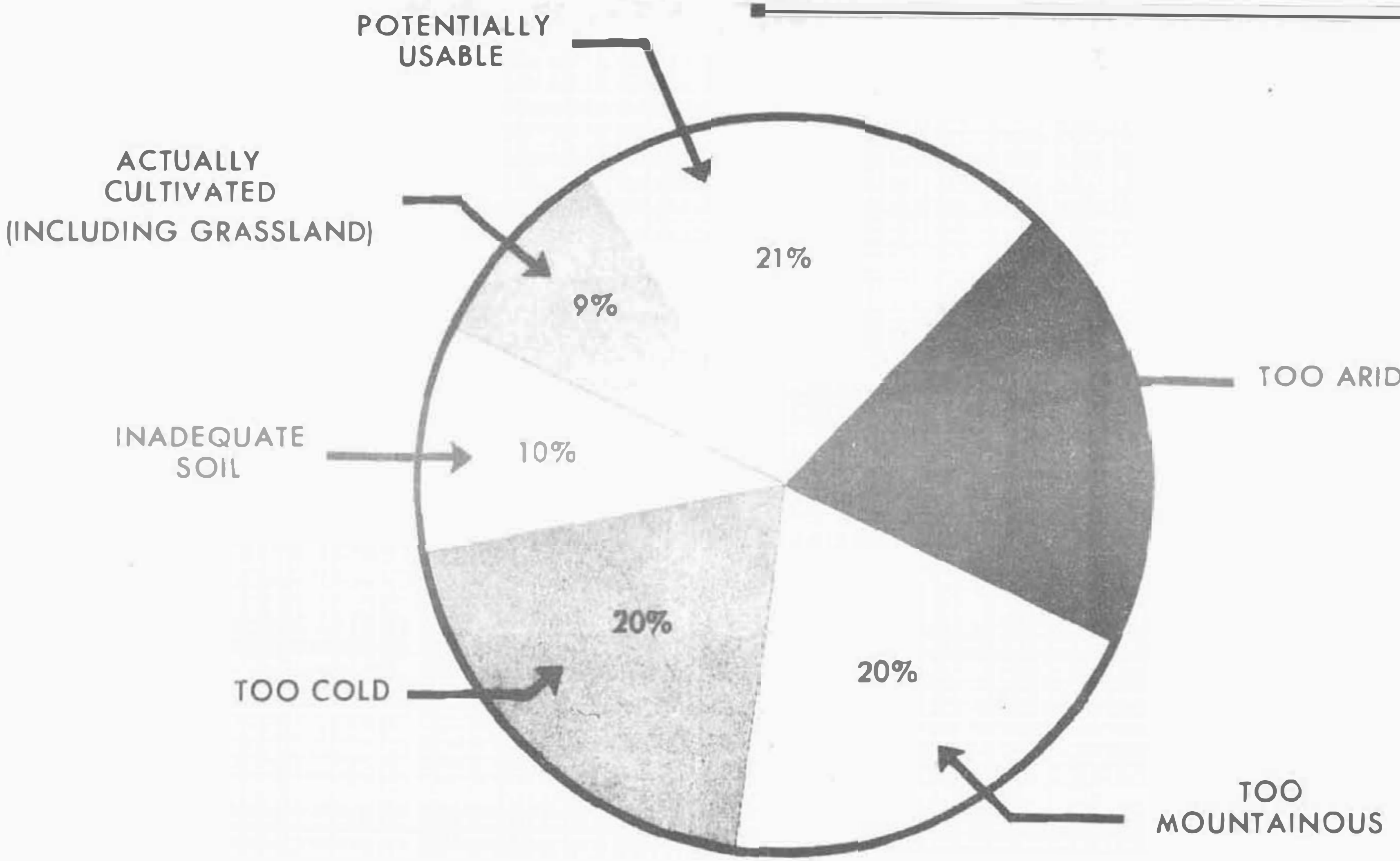


FIGURE - 95

FOOD YIELDS in DEVELOPING COUNTRIES vs DEVELOPED COUNTRIES

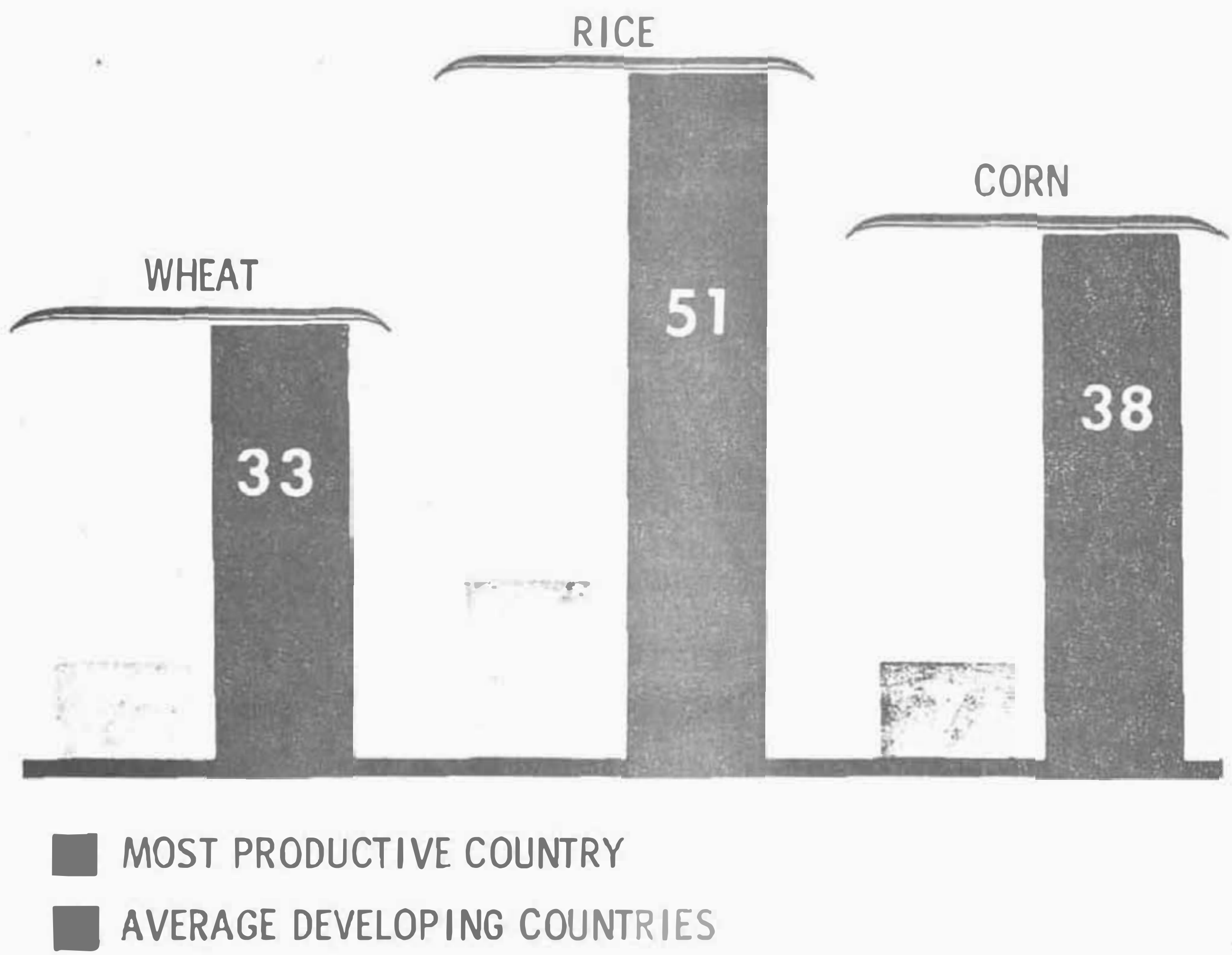


FIGURE - 96

Dr. CASTRUCCIO (cont.). data base for planning of agricultural programs.

What can space do to alleviate these deficiencies?

Education could alleviate the know-how problem; specifically by means of the Broadcast Satellite. We looked at this under "Communications," one of the 13 areas.

World-wide Agricultural Survey could significantly assist in improving the data base, for better planning. Purpose of the survey is threefold:

- o Accurate world-wide inventory
- o Short-term prediction of yield, and eventually,
- o Improved understanding of ecological relationships for long-term yield forecast and global planning.

Let me concentrate now on the feasibility, requirements and value of a space flight program in support of agriculture. (Figure 97)

This depicts the kind of functional analysis which leads to identification of the characteristics of an agricultural space program. It is typical of the analysis required in all the 13 areas of space application. The functional analysis proceeds "from the top down," beginning with the end objective, through successive levels of increasing definition until it uncovers what fundamentally must be known, i.e., the Knowledge Requirements.

In practice, not all Knowledge Requirements are addressable from space. Some are more economically addressed by other means. Others require technologies not yet sufficiently developed.

IDENTIFICATION OF SELECTED KNOWLEDGE REQUIREMENTS FOR AGRICULTURE

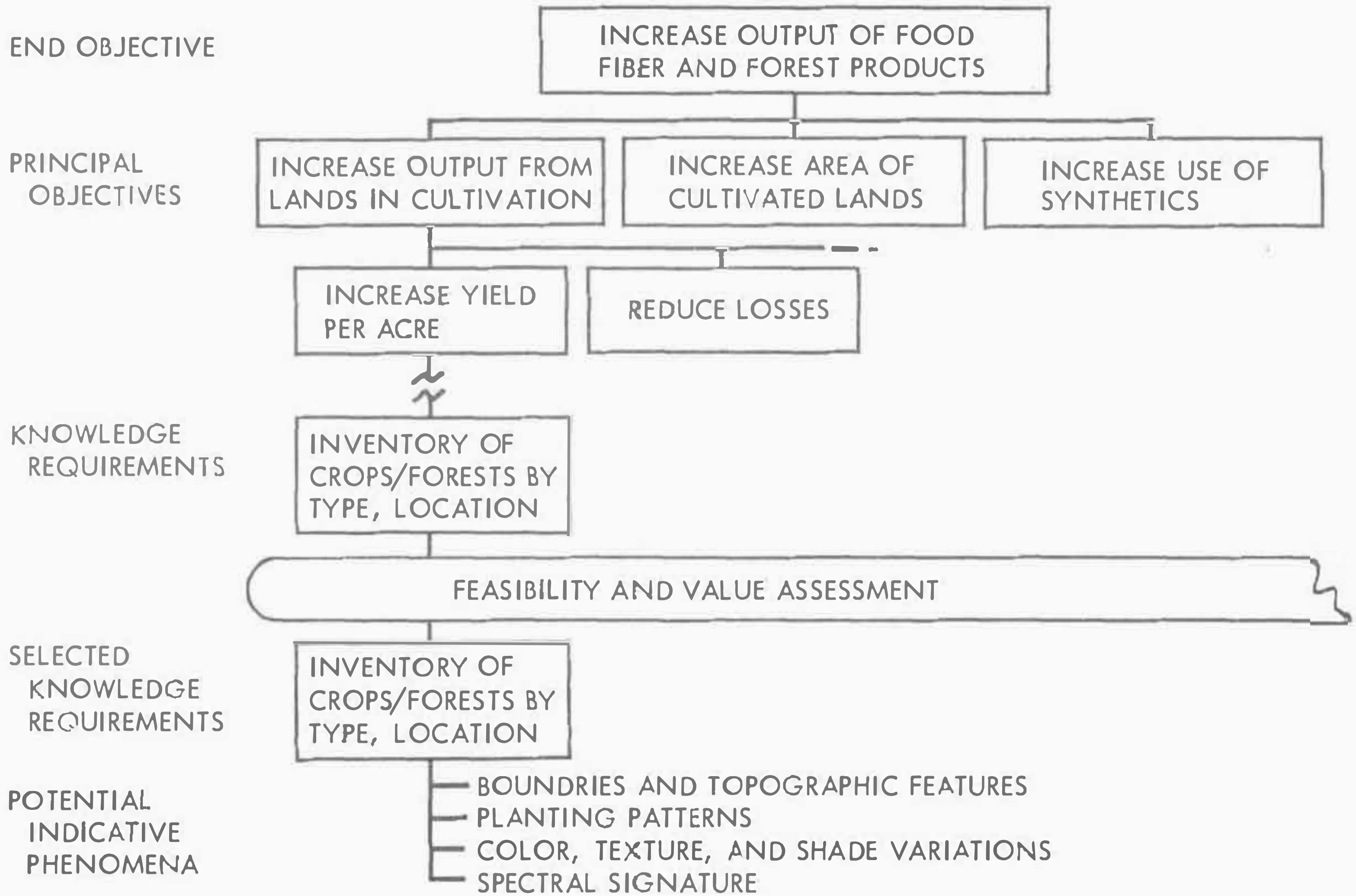


FIGURE - 97

Dr. CASTRUCCIO (cont.).

Filtering the totality of Knowledge Requirements through a "feasibility filter" yields the Selected Knowledge Requirements (SKRs) which can meaningfully be addressed by earth orbital space activities. By this process, the Selected Knowledge Requirements identified for Agriculture/ Forestry survey, were 15 as tabulated in the chart. (Figure 98)

It is from the SKRs that we can logically derive the characteristics of the spaceflight survey program in Agriculture/Forestry. The first step in this process is to derive the instrumentation--the payload--required to satisfy the Selected Knowledge Requirements. This is accomplished as follows.

To each of the 15 SKRs, can be associated "indicative phenomena," i.e., those phenomena whose observation is required to satisfy the SKR.

To each indicative phenomenon can be associated "functional sensor" characteristics:

- o The mode of sensing--how to utilize the electromagnetic energy associated with the indicative phenomenon
- o The spectral band--the region of the spectrum where the indicative phenomenon is best identified
- o The resolution--the spatial accuracy required to garner information of significance from the phenomenon.

This chart shows the typical functional characteristics for two of the SKRs. (Figure 99)

SELECTED KNOWLEDGE REQUIREMENTS, AGRICULTURE/FORESTRY

SKR		
1	INVENTORY	CROPS
2		FORESTS
3		RANGES
4	VIGOR	CROPS
5		FORESTS
6		RANGES
7	AGRICULTURAL METHODS	
8	WILDLIFE MIGRATIONS	
9	INFESTATION	PRESENCE
10		DAMAGE
11	FOREST FIRE	PRESENCE
12		DAMAGE
13	LAND FEATURES	
14	LAND RECLAMATION POTENTIAL	
15	SOIL TYPES	

FIGURE - 98

SKR FUNCTIONAL REQUIREMENTS SUMMARY: AGRICULTURE/FORESTRY

SELECTED KNOWLEDGE REQUIREMENTS	INDICATIVE PHENOMENA	ESTIMATED SENSING REQUIREMENTS		
		MODE	SPECTRAL BAND	RESOLUTION
1 LOCATION AND IDENTIFICATION OF MAJOR CULTIVATED CROPS	A. BOUNDARIES AND TOPOGRAPHIC FEATURES	I P	0.4-3 μ 1 μ	20'-100' 10'
	B. PLANTING PATTERNS	I	0.4-3 μ	5'- 50'
	C. COLOR, TEXTURE, AND CONTRAST	I P	0.4-3 μ 3. -35 GC	20'-100' 10' HT
	D. SPECTRAL SIGNATURE	S	0.4-3 μ	10'- 50'
15 CATALOGING OF SOIL FERTILITY AND ENVIRONMENTAL CHARACTERISTICS	A. COLOR, TONE TEXTURE	I	0.4-3 μ	50'-500'
	B. PHYSIOGRAPHIC, CULTURAL RELATED FEATURES	I	0.4-3 μ	50'-500'
	C. ASSOCIATED VEGETATIVE COVER, TYPE, AND VIGOR	I S	0.4-3 μ 0.4-3 μ	10'-100' 10'-100'
	D. SLOPE, DRAINAGE PATTERN, MOISTURE CONTENT, DIELECTRIC CONSTANT	I R P	0.4-3 μ 0.5-10 GC 0.3-0.6 MC	20'-200' 10'-100' 20'-200'
	E. ENERGY BUDGET	I	3. -14 μ	100'-500'

I = PASSIVE IMAGERY
S = SPECTROSCOPY
R = ILLUMINATED IMAGERY
P = NON-IMAGING REFLECTOMETRY
T = TELEMETRY

FIGURE - 99

Dr. CASTRUCCIO (cont.).

The next chart is a graphic representation of the results of the analysis. (Figure 100) Only 7 SKRs are shown--all were analyzed. Note that the requirements were derived entirely from the phenomena to be observed, independently of the type and location of sensor.

Commonalizing of the approximately 80 sensing requirements imposed by the indicative phenomena, leads to the conclusion that a sensor package operating in four modes and within the bands shown, is required to satisfy all the SKRs. (Figure 101)

The next step in sensor functional sizing is to analyze each of the bands, A through J. As an example, Band A is summarized here. (Figure 102) This band corresponds to optical and near--infrared imagery, obtained with present technology through the techniques of photography. The corresponding sensors are photographic cameras. Their major sizing parameter is the required resolution, shown here for each of the SKRs and indicative phenomena which fall within this band.

Now, the required ground resolution is correlated to sensor aperture through the well-known Rayleigh curve. (Figure 103) This curve is degraded by an average factor of 2.5 to take into account a number of practical technical factors such as image-motion compensation, lens degradation and human/photographic interpretation factors. Application of the Rayleigh curve to the resolution requirements yields the required aperture diameters. (Figure 104)

SENSING MODES–AGRICULTURE/FORESTRY

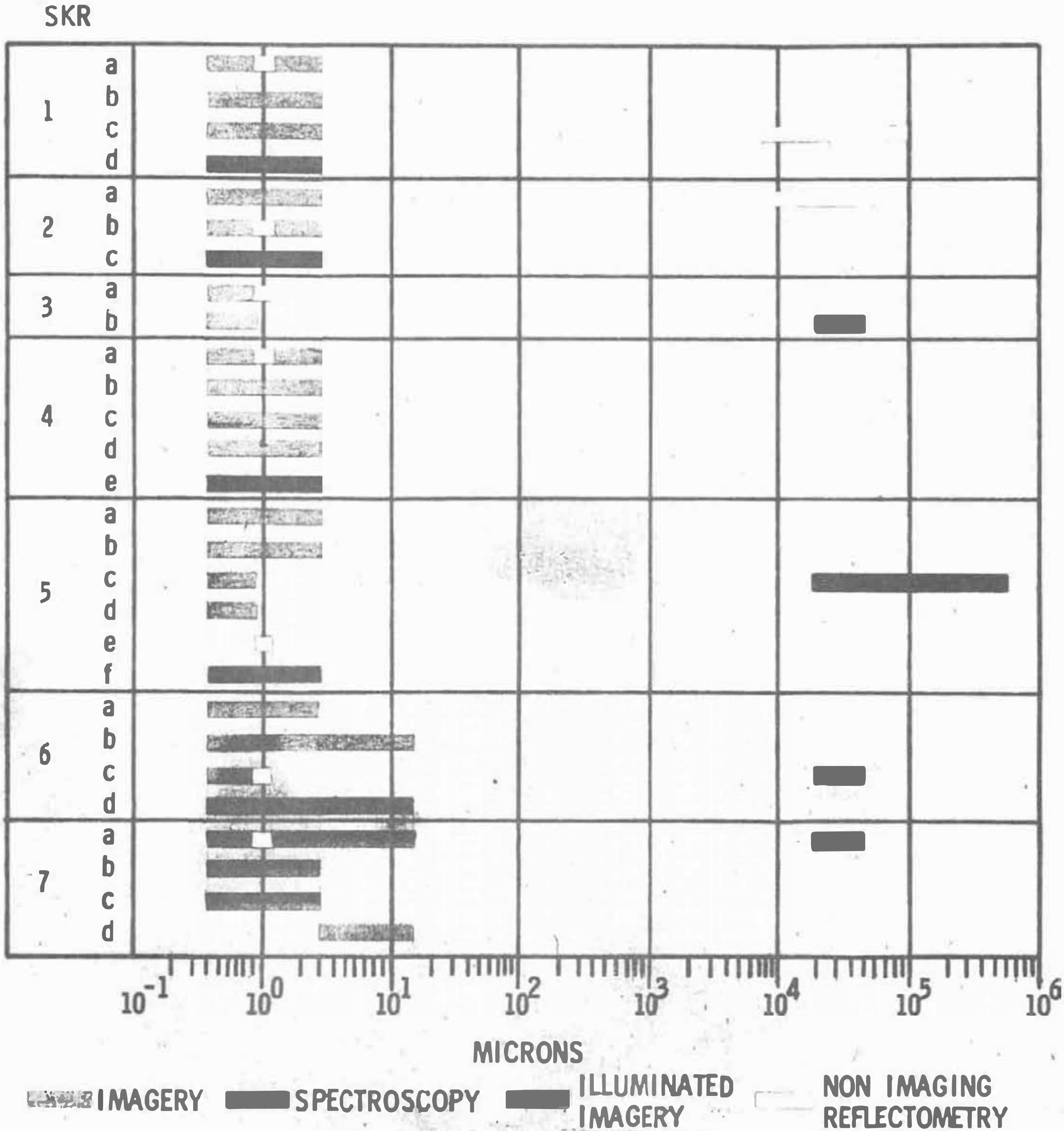


FIGURE - 100

CATEGORIZATION OF SENSING MODES

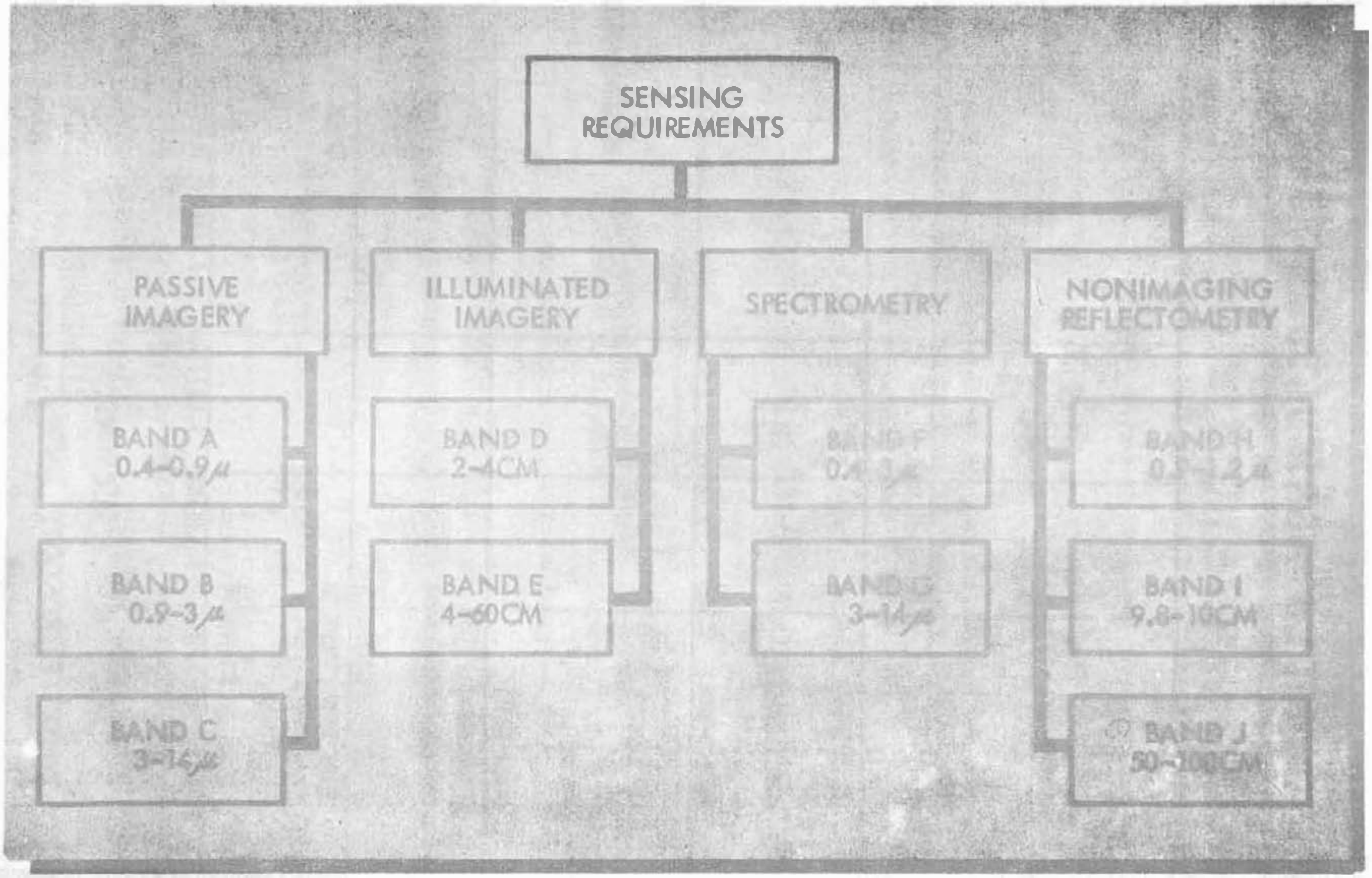


FIGURE - 101

RESOLUTION REQUIREMENTS FOR THE IMAGING MODE, BAND A

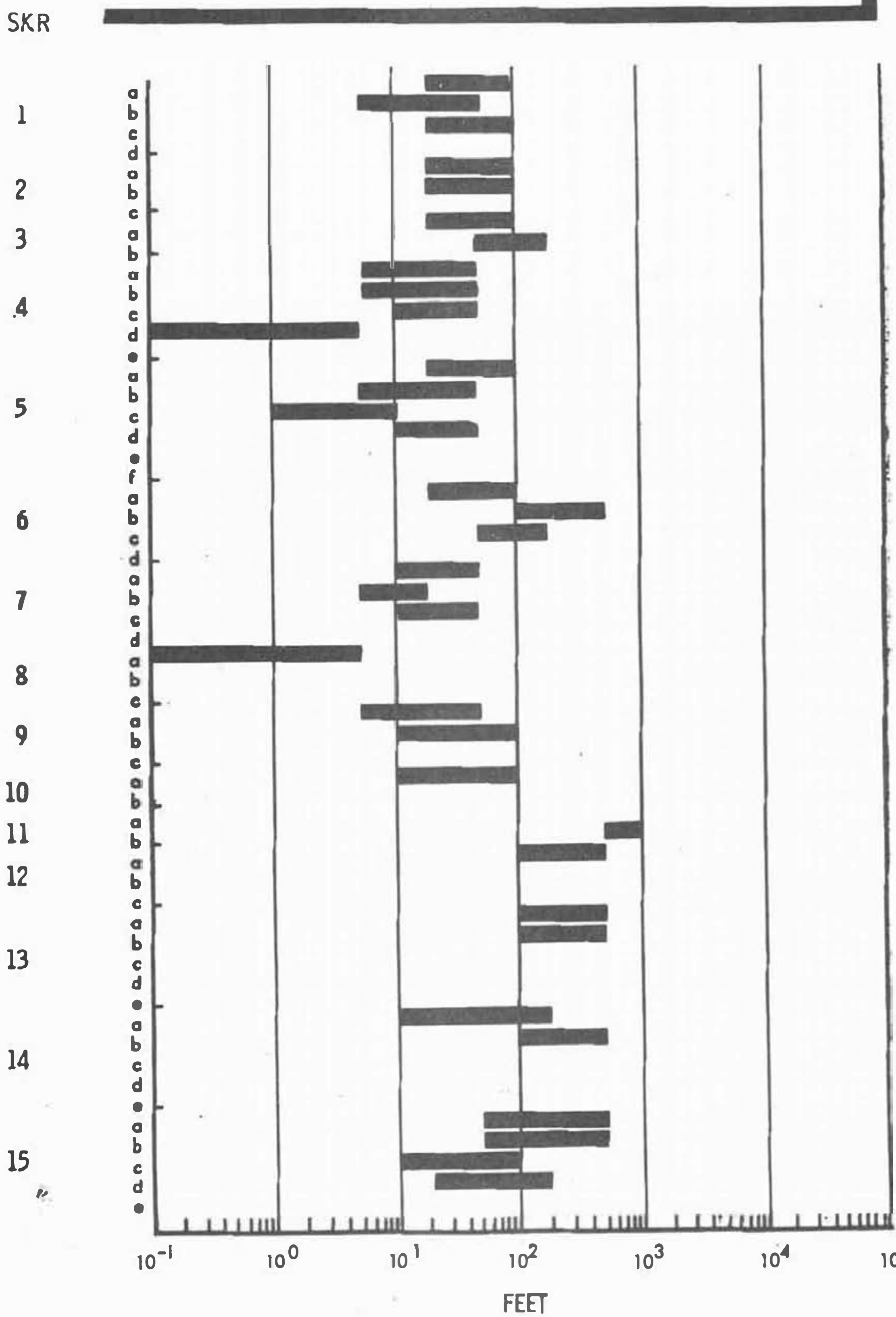


FIGURE - 102

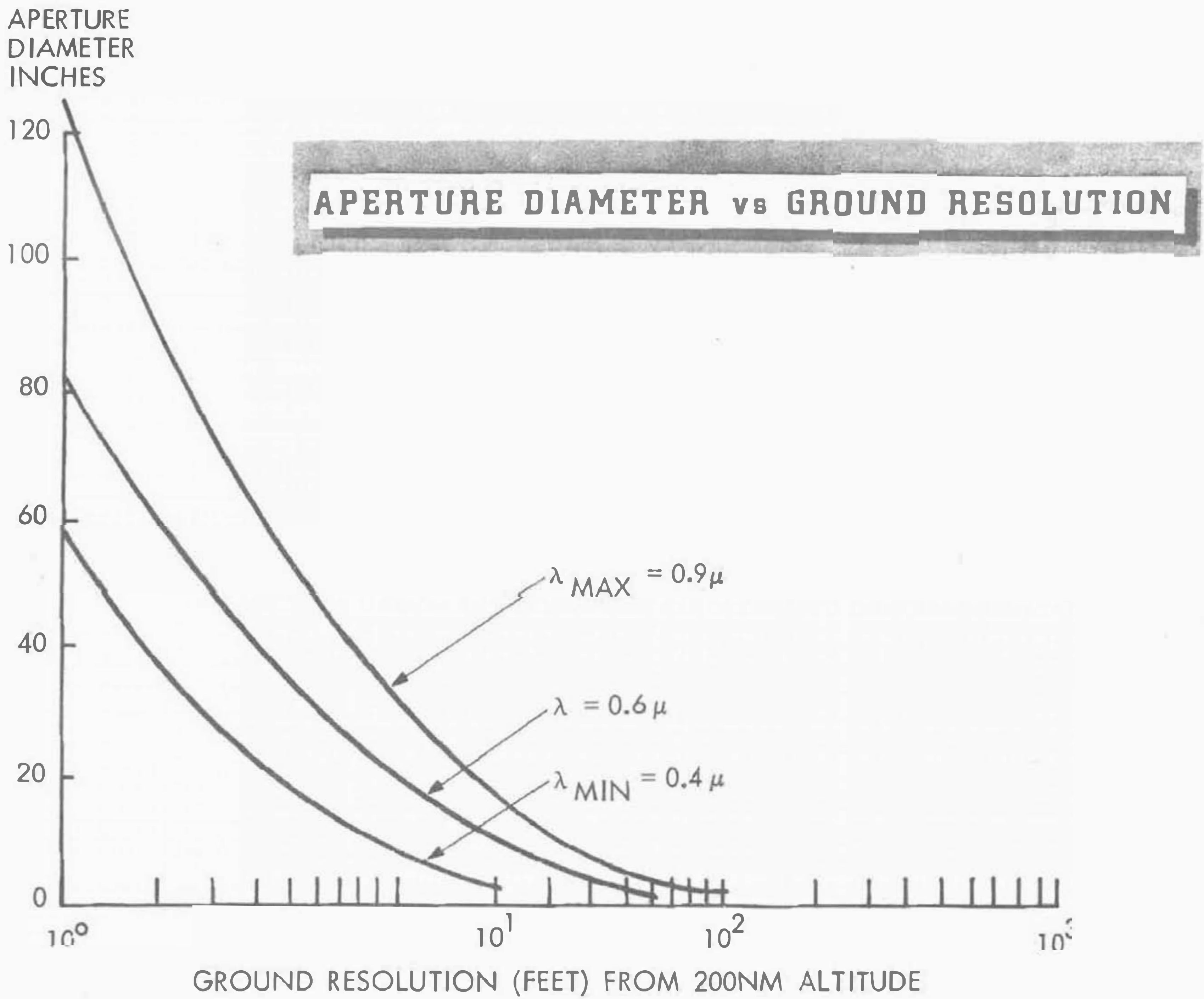

APERTURE DIAMETER vs GROUND RESOLUTION
APERTURE DIAMETER INCHES
120
100
80
60
40
20
0
$\lambda_{MAX} = 0.9\mu$
$\lambda = 0.6\mu$
$\lambda_{MIN} = 0.4\mu$
10^0
10^1
10^2
GROUND RESOLUTION (FEET) FROM 200NM ALTITUDE

FIGURE - 103

APERTURE DIAMETER REQUIREMENTS

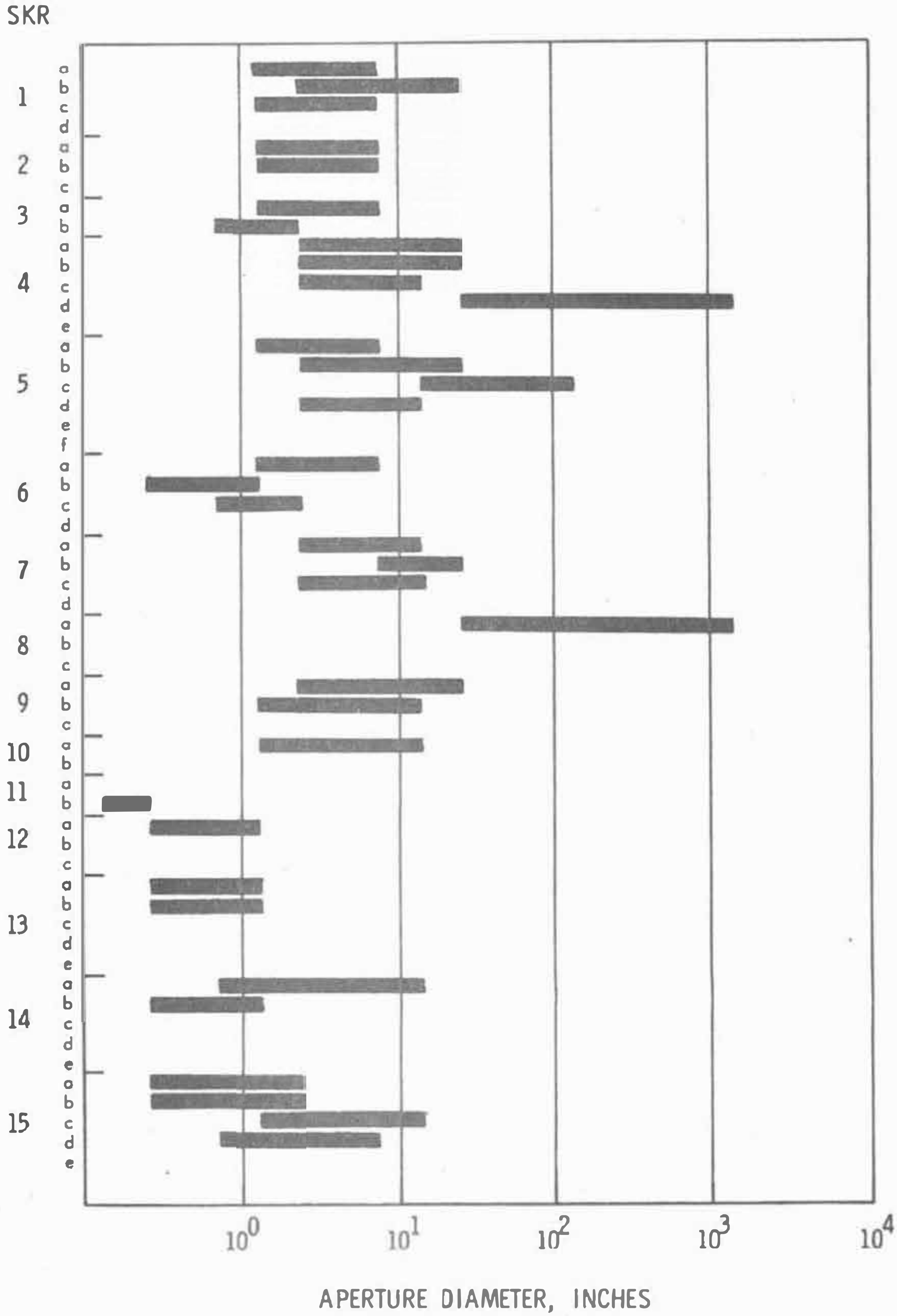


FIGURE - 104

Dr. CASTRUCCIO (cont.).

Although in theory, a single camera of sufficient aperture to satisfy all the requirements....practical tradeoffs between area coverage, practically achievable slewing speeds, and other factors, dictate the engineering selection of a cluster of specialized cameras.

The selected package for the imaging mode, Band A, is shown here. (Figure 105) Note that the 16 inch aperture instrument shares two functions.

Now, following the same procedure that I have illustrated for imaging Band A for the other modes and bands, the complete Agriculture/Forestry equipment package is identified. We found that the total array of sensors weighs about 7,000-10,000 pounds. Some of the equipment needed to meet the SKRs is just in development, but it is significant that the large percentage of SKRs can be addressed with techniques that are very much current state-of-the-art.

Photography is one such technique. Now the questions sometimes arise: (1) can one "see" well enough from high altitude to distinguish the condition of crops, soils and other agricultural phenomena? (2) can this be accomplished from space? The answer to both questions is affirmative. The following photographs, from among many, indicate the potential of agricultural space survey.

This aerial photograph, taken with Ektachrome film, shows soil patterns in the Purdue University Agronomy Farm. (Figure 106) The photo was made in May before the crops attained substantial growth. From such photos the

FIGURE - 105

SENSOR PACKAGE: IMAGING BAND A

GROUND RESOLUTION REQUIREMENT	APERTURE (INCHES)	FOCAL LENGTH (INCHES)	SCALE FACTOR (ALT. = 200 N. M.)	AERIAL COVERAGE (N. M. SQUARE)	DEVELOPMENT STATUS
1	38	960	15,000	1	RESEARCH
5	16	240	60,000	1.7	DEVELOPMENT
10	16	120	120,000	3.5	
20	6	24	600,000	75	OPERATIONAL
50	3	12	1,200,000	150	OPERATIONAL
100	1.2	6	2,400,000	300	OPERATIONAL
500	.63	3.5	4,130,000	558	OPERATIONAL

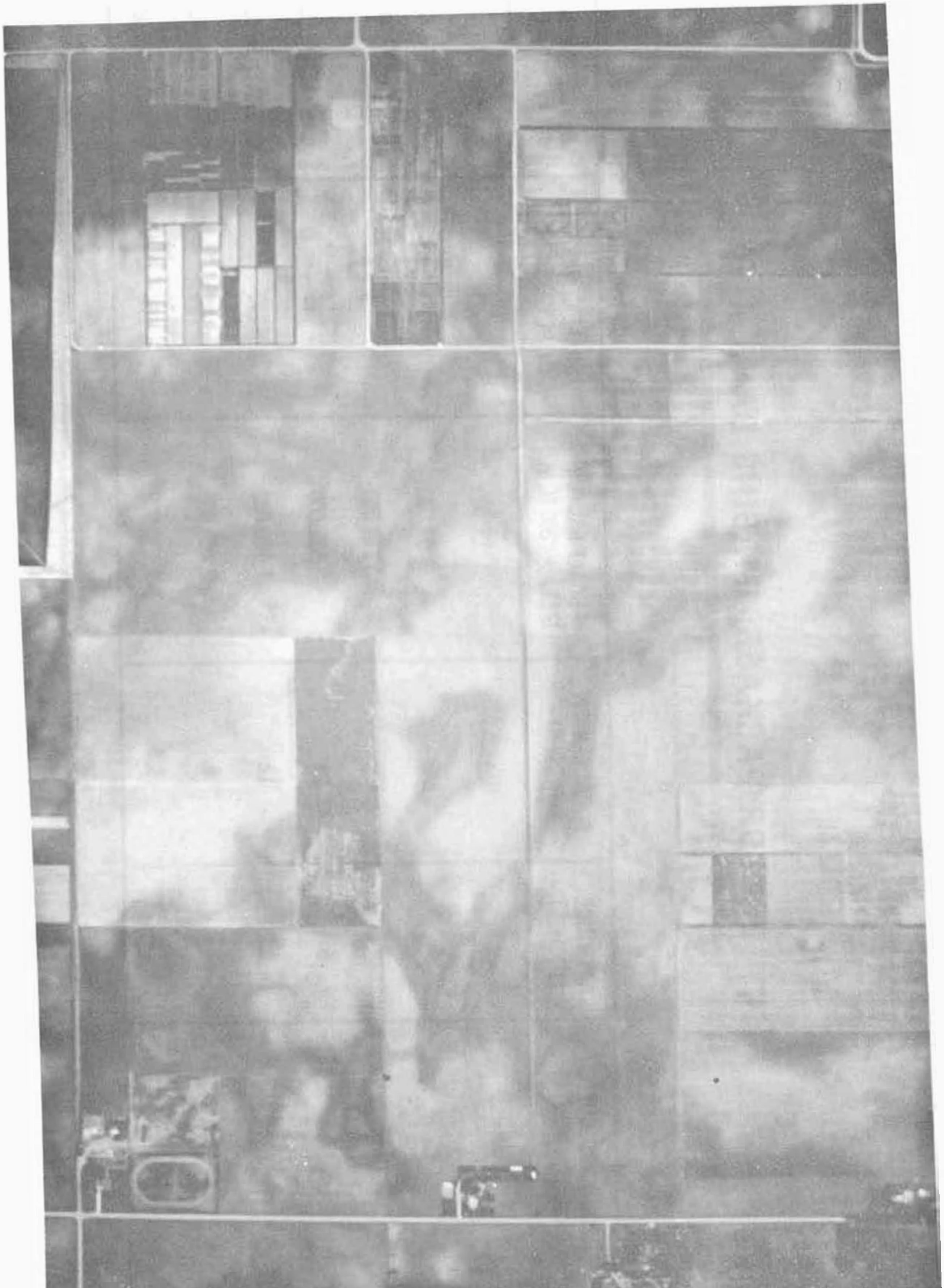


FIGURE - 106

Dr. CASTRUCCIO (cont.). humidity, salinity and other conditions can be inferred.

This photograph of the same fields was taken in July. (Figure 107) The colors are indicative of the crops. The yellow fields are ripening wheat; the dark green fields are alfalfa, oats, and corn. The bright green areas are incomplete cover of soybeans. The point of this and the preceding photo is that, even with conventional photography, significant information can be inferred.

More information can be gleaned from more advanced photo techniques. For example, the color of the crop as viewed in the infrared region has been found to be indicative of crop vigor. In this photograph by the University of Maine of a potato field taken with camouflage detection film, the red areas, which have high reflectance, are healthy potatoes. (Figure 108) The dark areas show blight.

This photograph was taken from Gemini 5 using a Hasselblad camera with Ektachrome film. (Figure 109) It shows the Salton Sea area of California. Clearly visible are areas of cultivation. Each field is approximately 240 acres. Working from this imagery expanded one hundred times, USDA (US Department of Agriculture) scientists are attempting to infer crop vigor and soil salinity.

The point of this and similar photos is that visibility from space is no more difficult than from airplanes, except only, for the geometric scale factor.

Now, with reference again to an earlier chart, let us procede to identify the mission parameters of the spaceflight program, namely where to fly; at

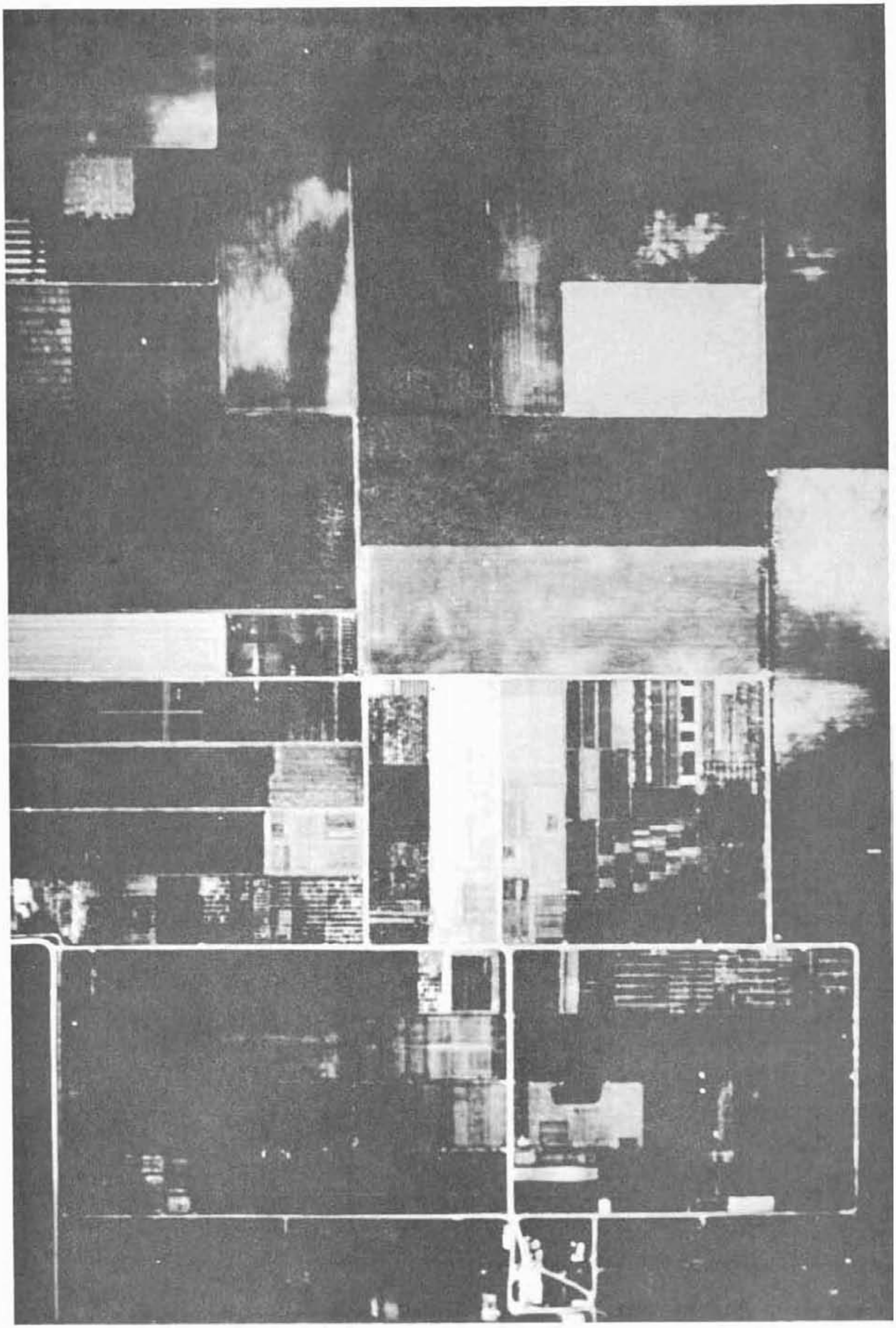


FIGURE - 107

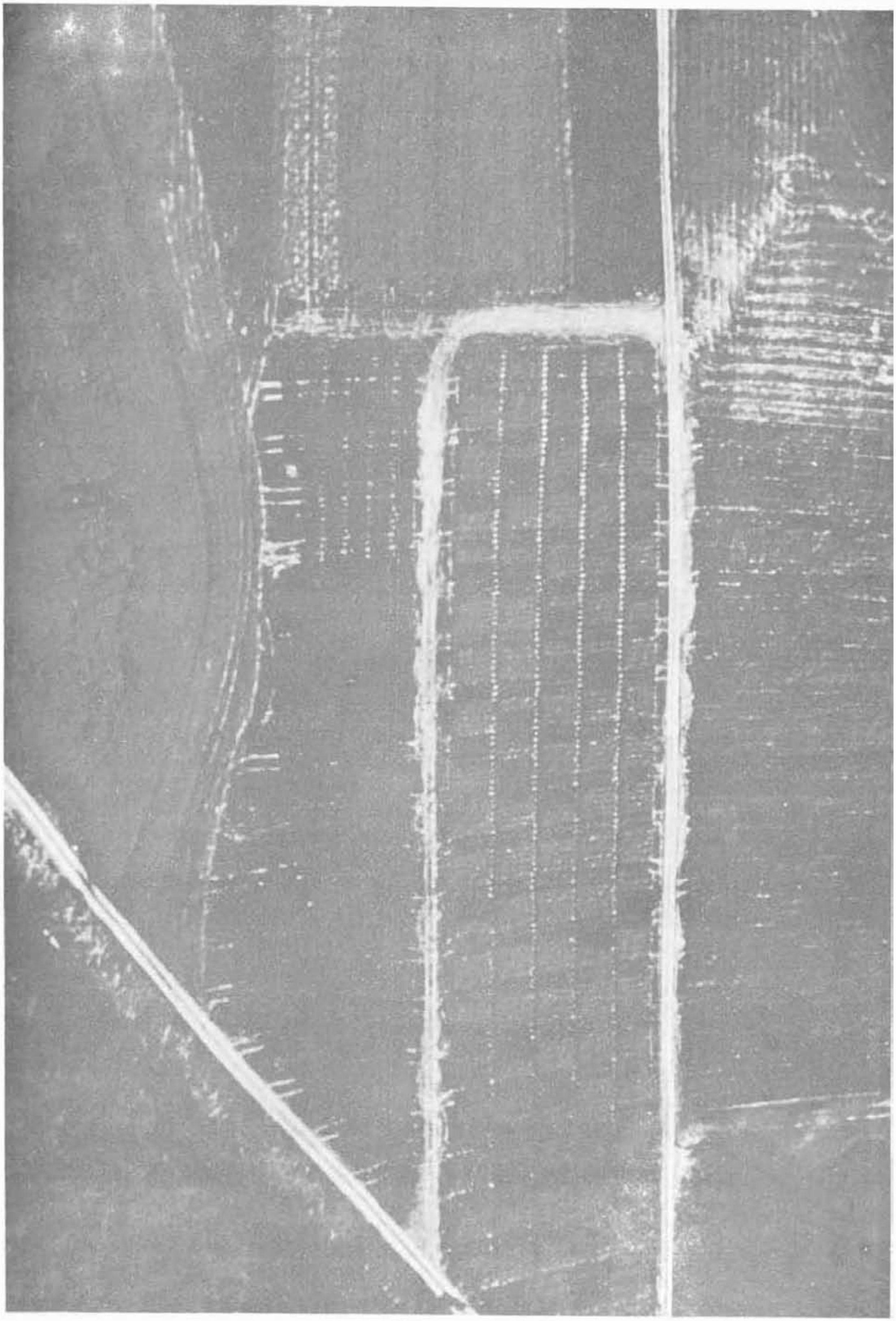


FIGURE - 108

FIGURE - 109

Dr. CASTRUCCIO (cont.). what time, and for how long. (Figure 110)

Consider first the required orbital inclination. This is determined by the location of the observables. Of the 67,000-odd different crops, only a few are significant in solving man's food problem. The ten most important world crops are shown here. (Figure 111)

I would like to note in passing, that the relative importance of the observables, and hence the desired mission parameters, depend upon the composition of the "Club of Nations" cooperating in the survey. For example, for the US alonge, the ten most important crops differ significantly from those for the world at large. (Figure 112)

Once having established what the observables of principal importance are, the next step is to determine where they occur. The areas of interest vary widely depending on the crop. Shown here, is the world distribution of wheat. (Figure 113) Shown here, is the distribution of coffee. (Figure 114)

From plots such as these, the latitude of occurrence of the principal agricultural observables can be determined as shown in this bar chart. (Figure 115) It is qualitatively apparent that flights above $\pm 80^\circ$ latitude have little importance.

The latitude of occurrence affects the orbit inclination. A quantitative measure of the latitude of importance is obtained by plotting the dollar output of agricultural and forestry products. (Figure 116) The most productive regions lie within the latitude band 45° to 65° latitude. Essentially, all the

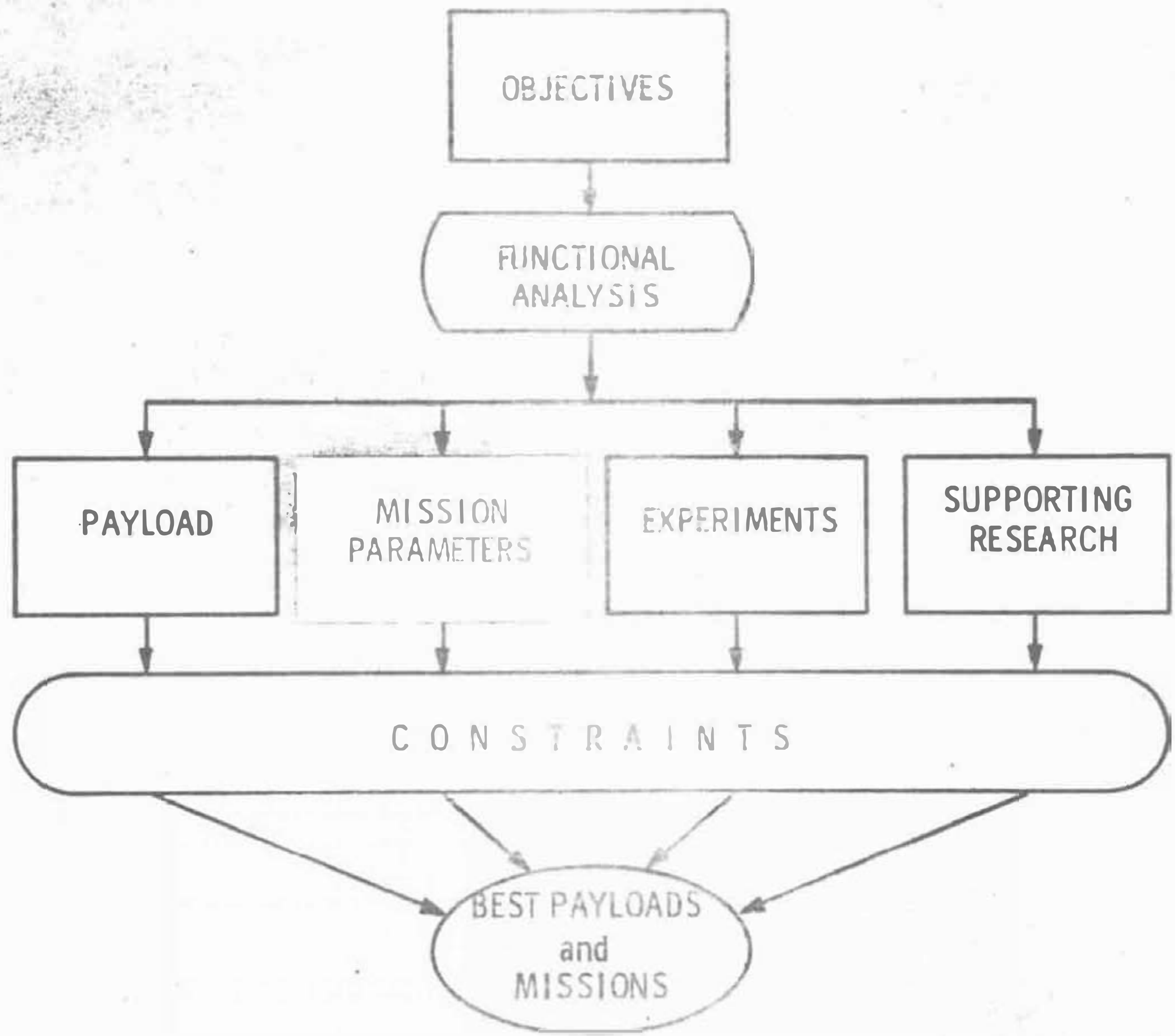

OBJECTIVES
FUNCTIONAL ANALYSIS
PAYLOAD
MISSION PARAMETERS
EXPERIMENTS
SUPPORTING RESEARCH
CONSTRAINTS
BEST PAYLOADS and MISSIONS

FIGURE - 110

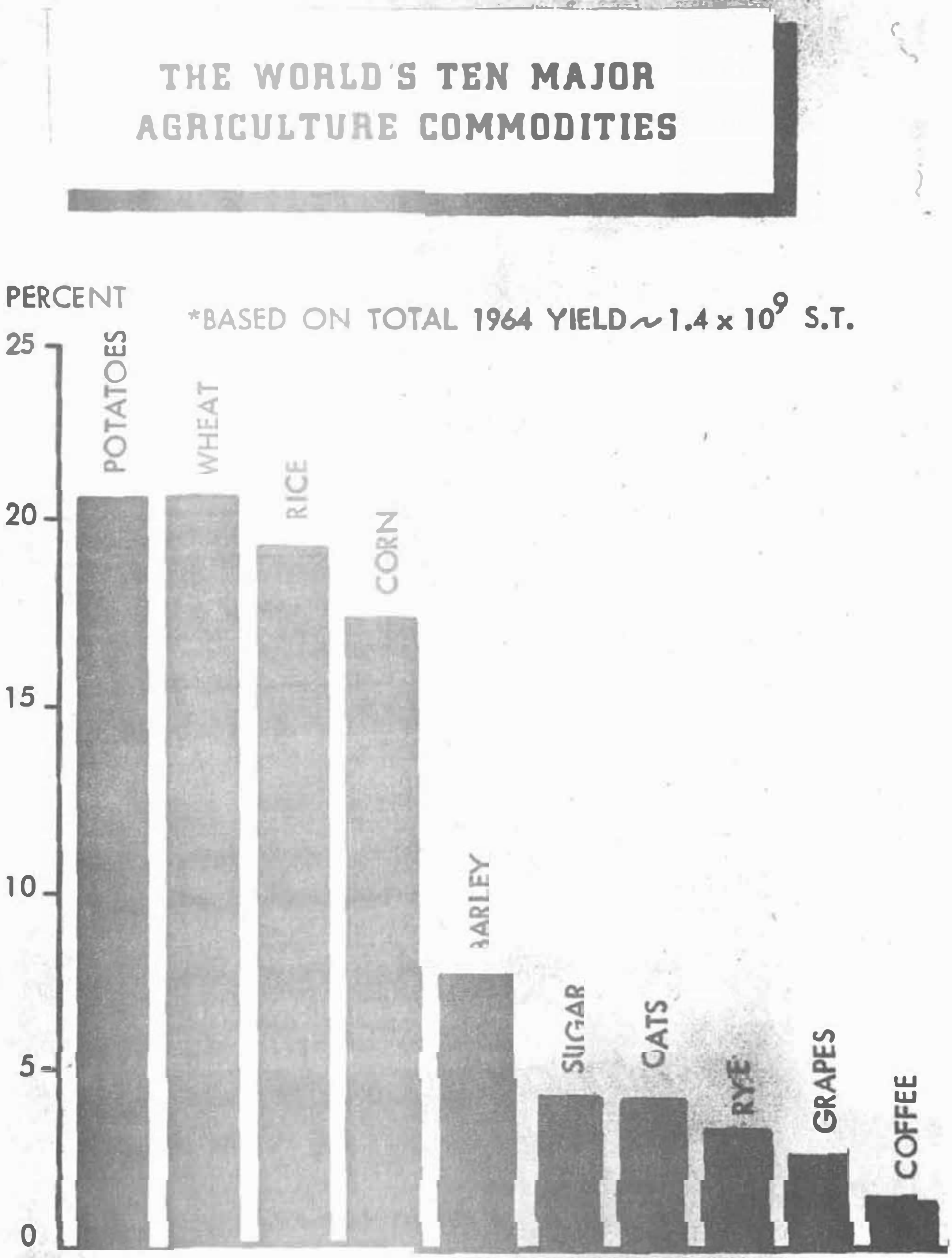

THE WORLD'S TEN MAJOR AGRICULTURE COMMODITIES
PERCENT
*BASED ON TOTAL 1964 YIELD ~ 1.4 x 10^9 S.T.
25
20
15
10
5
0
POTATOES
WHEAT
RICE
CORN
BARLEY
SUGAR
OATS
RYE
GRAPES
COFFEE

FIGURE - 111

U.S. PRODUCTION OF THE WORLD'S TEN MAJOR AGRICULTURE COMMODITIES

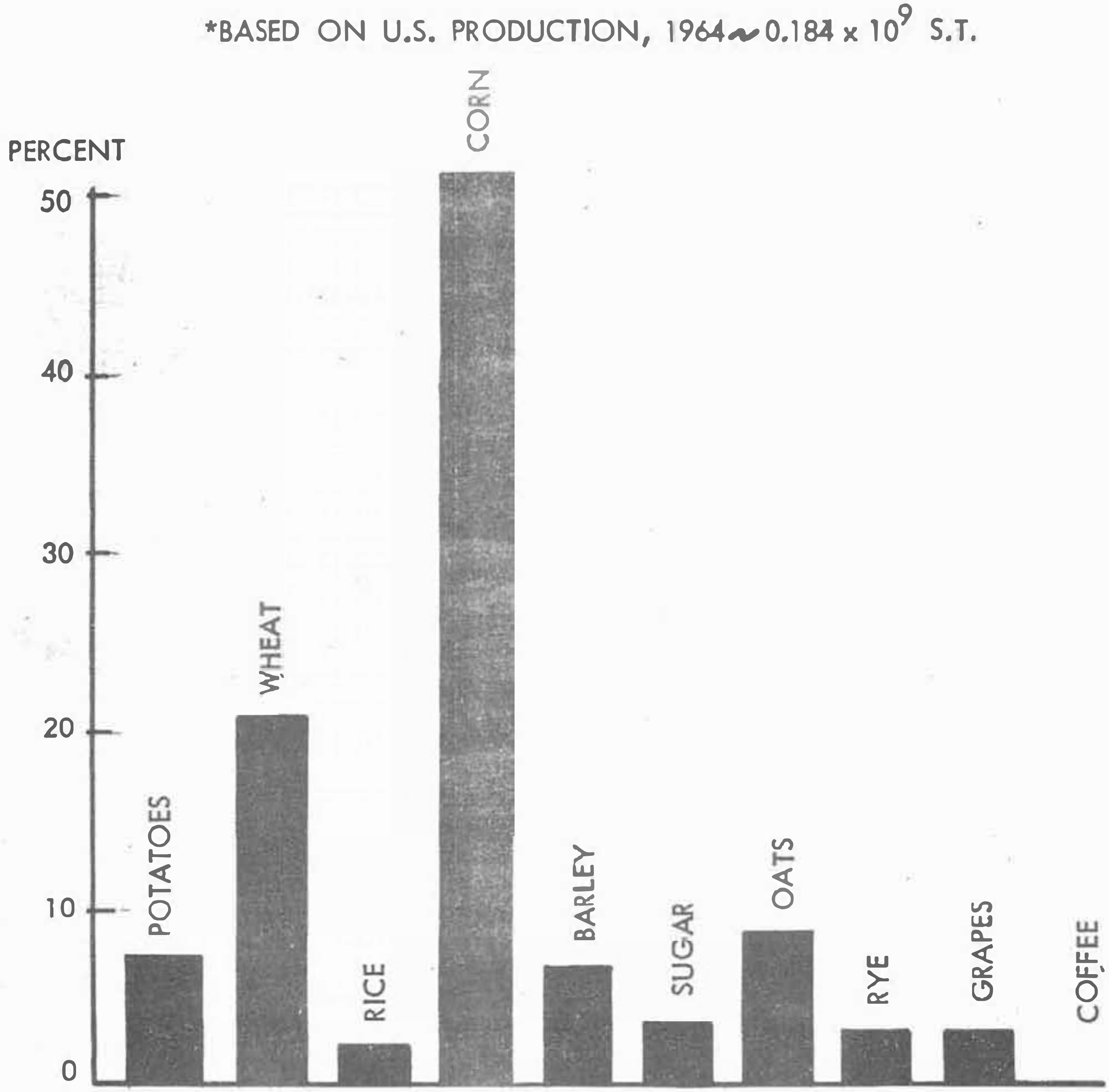


FIGURE - 112

WORLD WHEAT ACREAGE

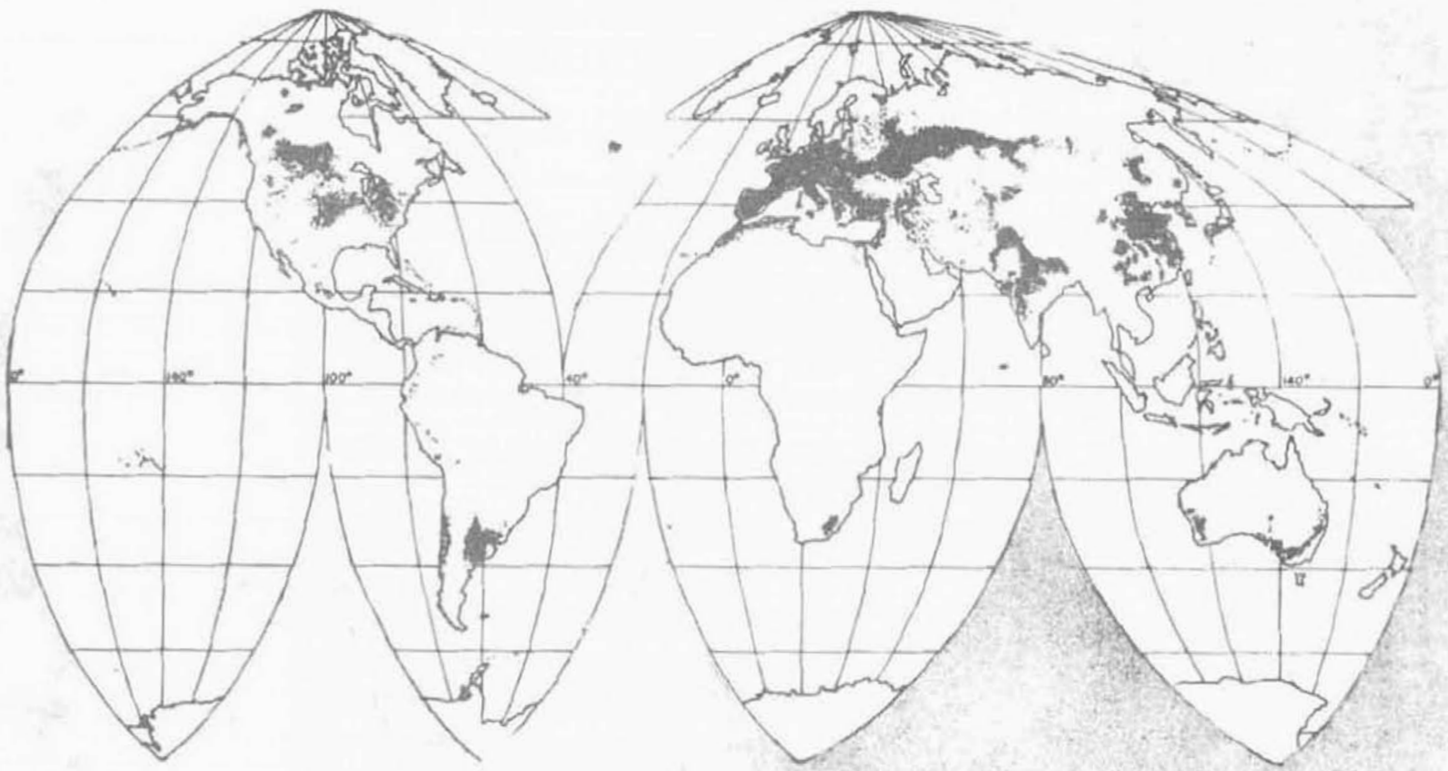


FIGURE - 113

MAJOR WORLD COFFEE-PRODUCING REGIONS

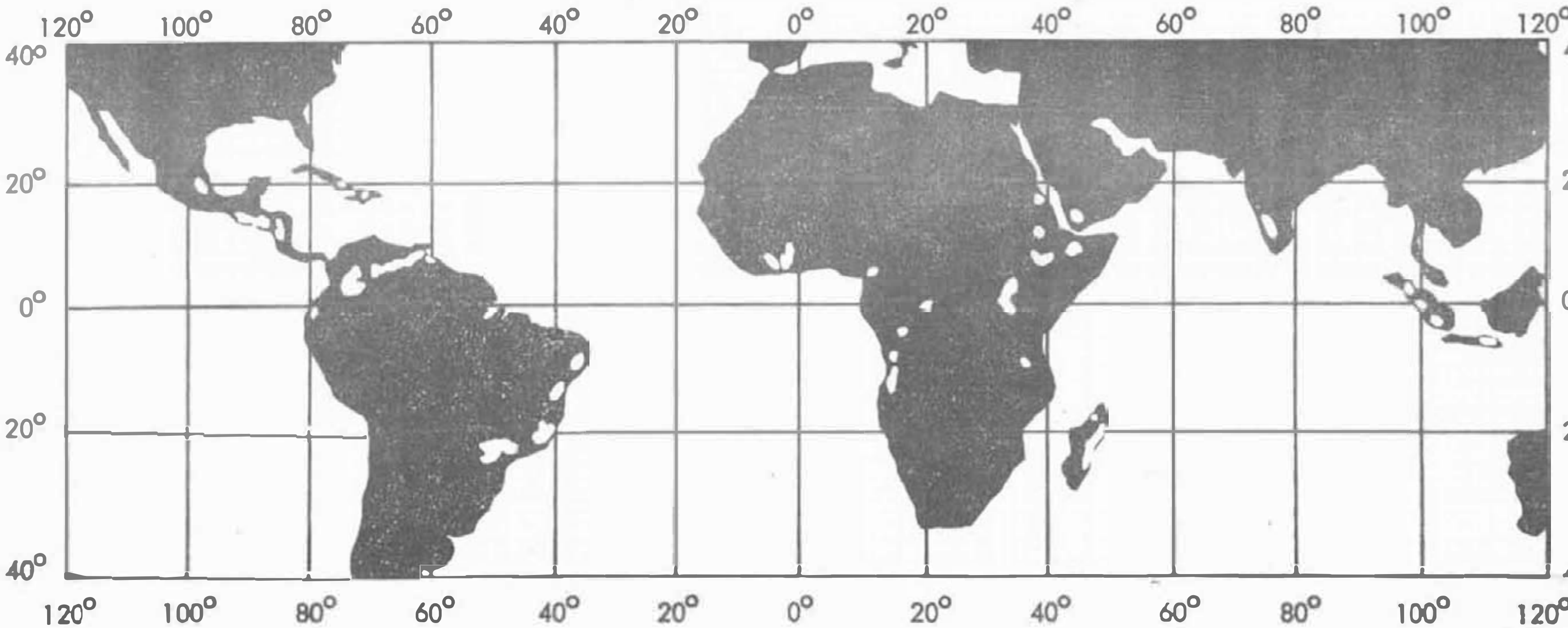


FIGURE - 114

A/F OBSERVABLES AS A FUNCTION OF LATITUDE

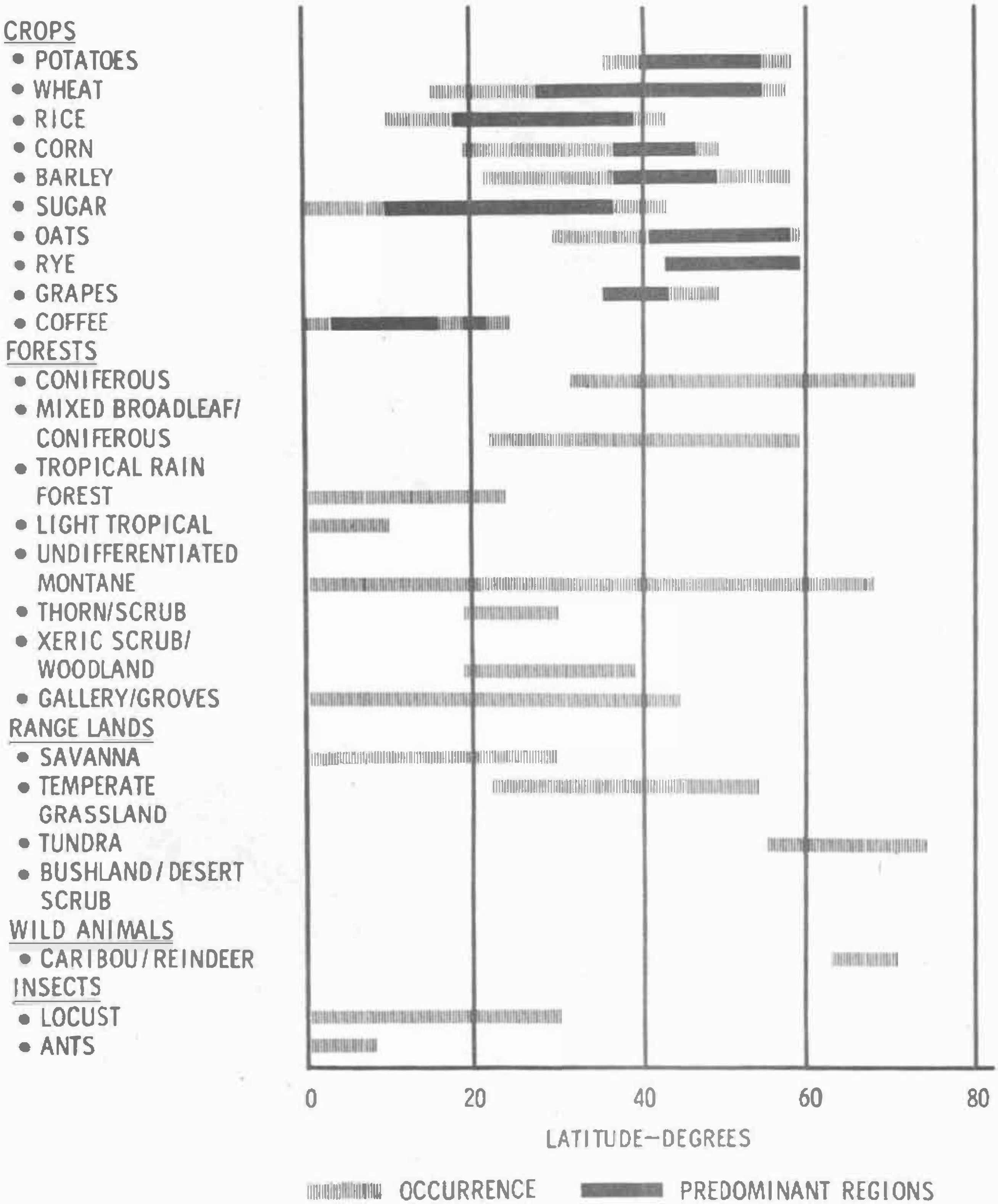


FIGURE - 115

CUMULATIVE AGRICULTURE/FORESTRY VALUE VS LATITUDE

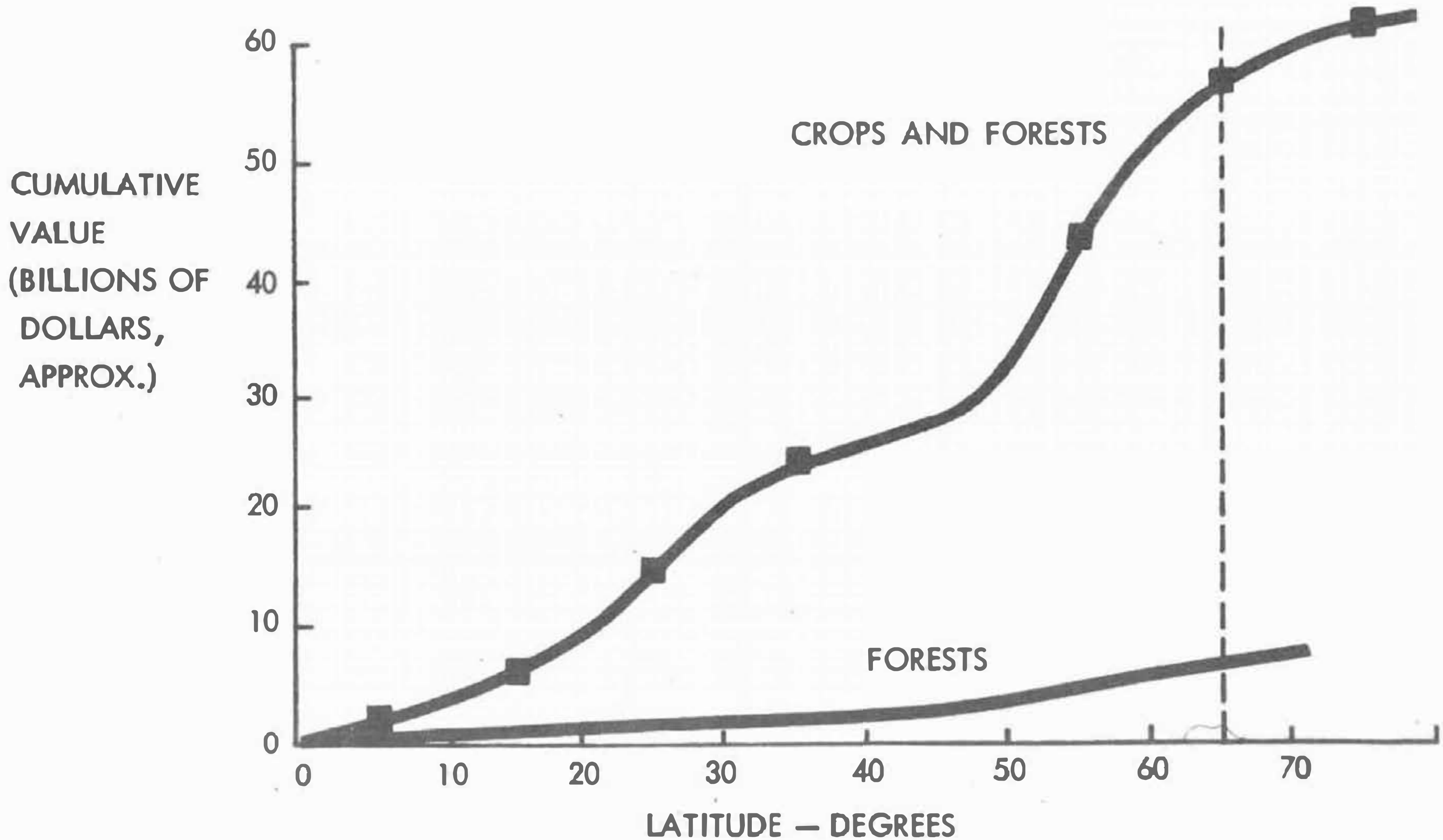


FIGURE - 116

Dr. CASTRUCCIO (cont.). output occurs below $\pm 75^{o}$ latitude. Thus, orbit inclinations of 65^{o}, or even a little less, are probably satisfactory.

The timing of space survey flights is determined by the growth cycle of the observables. (Figure 117) Since harvest times vary throughout the world, as shown here, observations are required the year round, either through many short flights or preferably through a continuous flight. For a precursor Agriculture/Forestry space survey program with a limited number of flights, the best season is prior to harvest of maximum number of crops--June to August. An important consideration, is the time of flight required, as a function of comprehensiveness of survey.

Shown in the next chart are the swath widths corresponding to selected sensors of the imaging type, Band A, shown previously. (Figure 118) Note that the swath width is not too strongly affected by altitude.

To follow the reasoning let us concentrate on the 6 inch focal length sensor, which yields a swath of 300 n.m. from 200 n.m. altitude.

The next step is to determine the "positional opportunities"--the number of times, during a given flight period, within which a given point on the earth's surface falls within the field of view of the sensors. The next curves are constructed for polar orbit; the positional opportunities are those at the equator. (Figure 119) For the example selected, 300 n.m. swath width, 20 opportunities at the equator occur for 45-day flights, taking no consideration of the day-night cycle or the weather. The number of opportunities increases with latitude; thus, for example, over England (approximately 60^{o} N. latitude), approximately 40 opportunities would be available. The number of oppor-

WHEAT HARVESTING SEASONS FOR SELECTED COUNTRIES

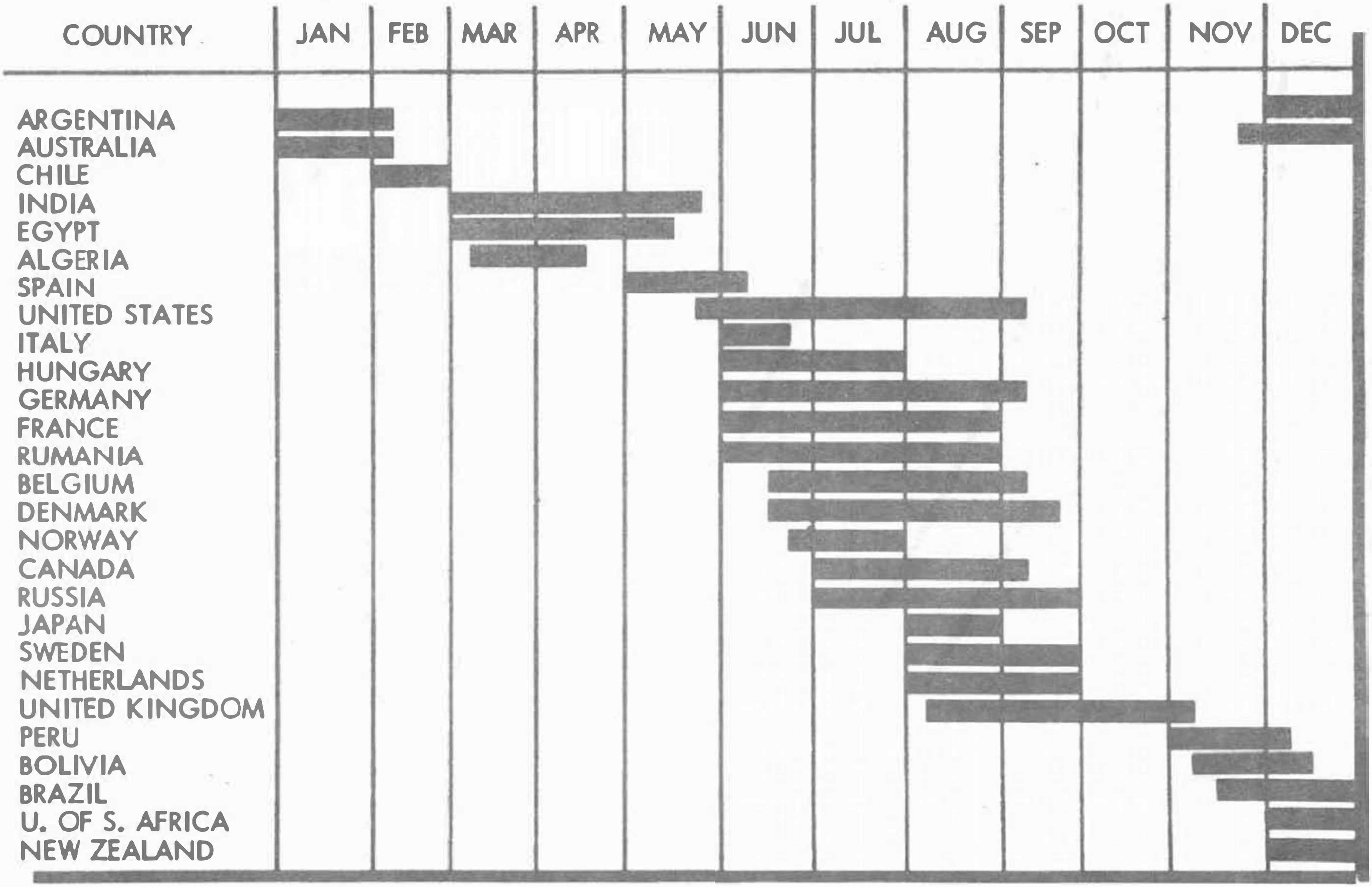


FIGURE - 117

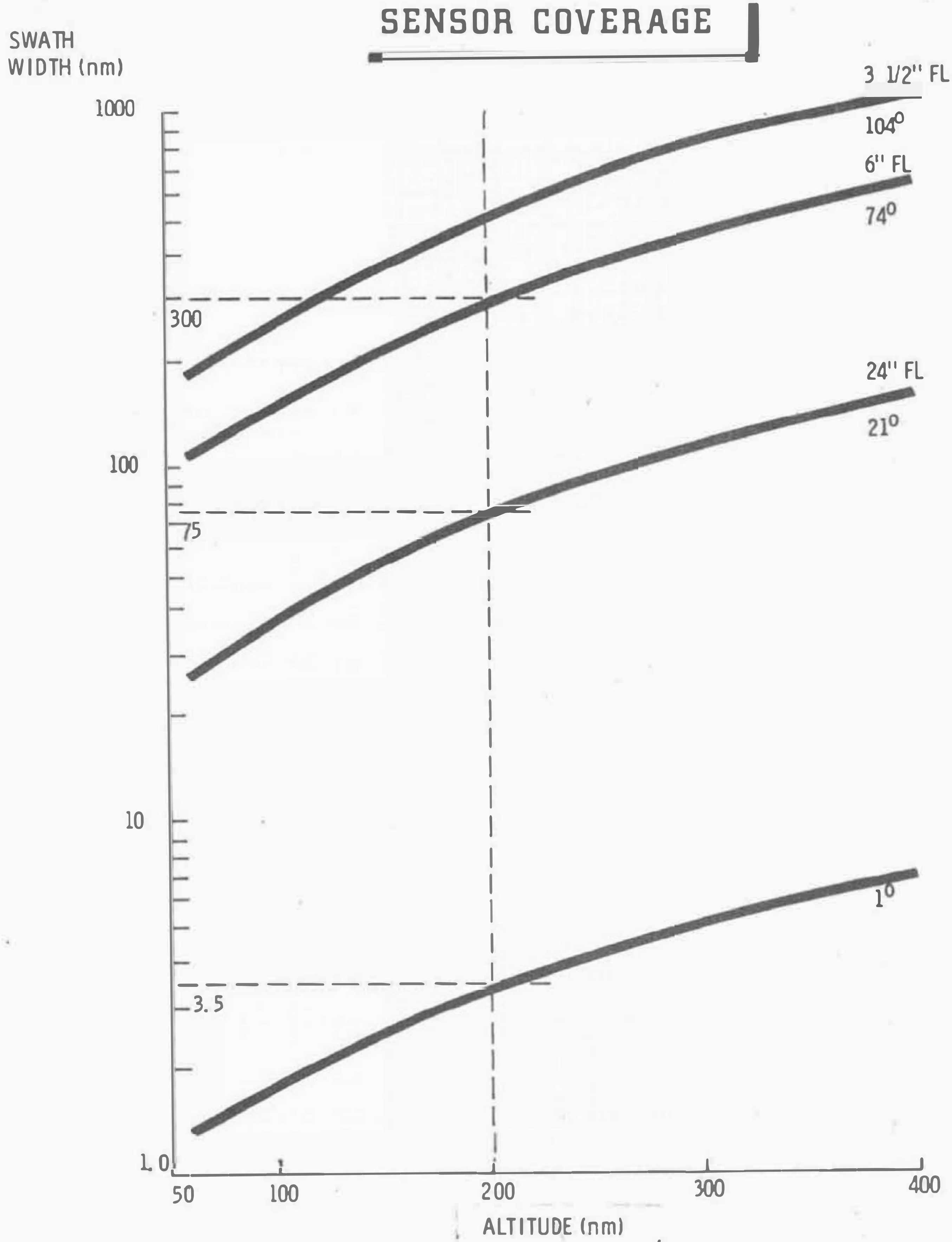

SENSOR COVERAGE
SWATH WIDTH (nm)
1000
100
10
1.0
300
75
3.5
3 1/2" FL
104°
6" FL
74°
24" FL
21°
1°
50
100
200
300
400
ALTITUDE (nm)

FIGURE - 118

UNCONSTRAINED OBSERVATIONAL OPPORTUNITIES

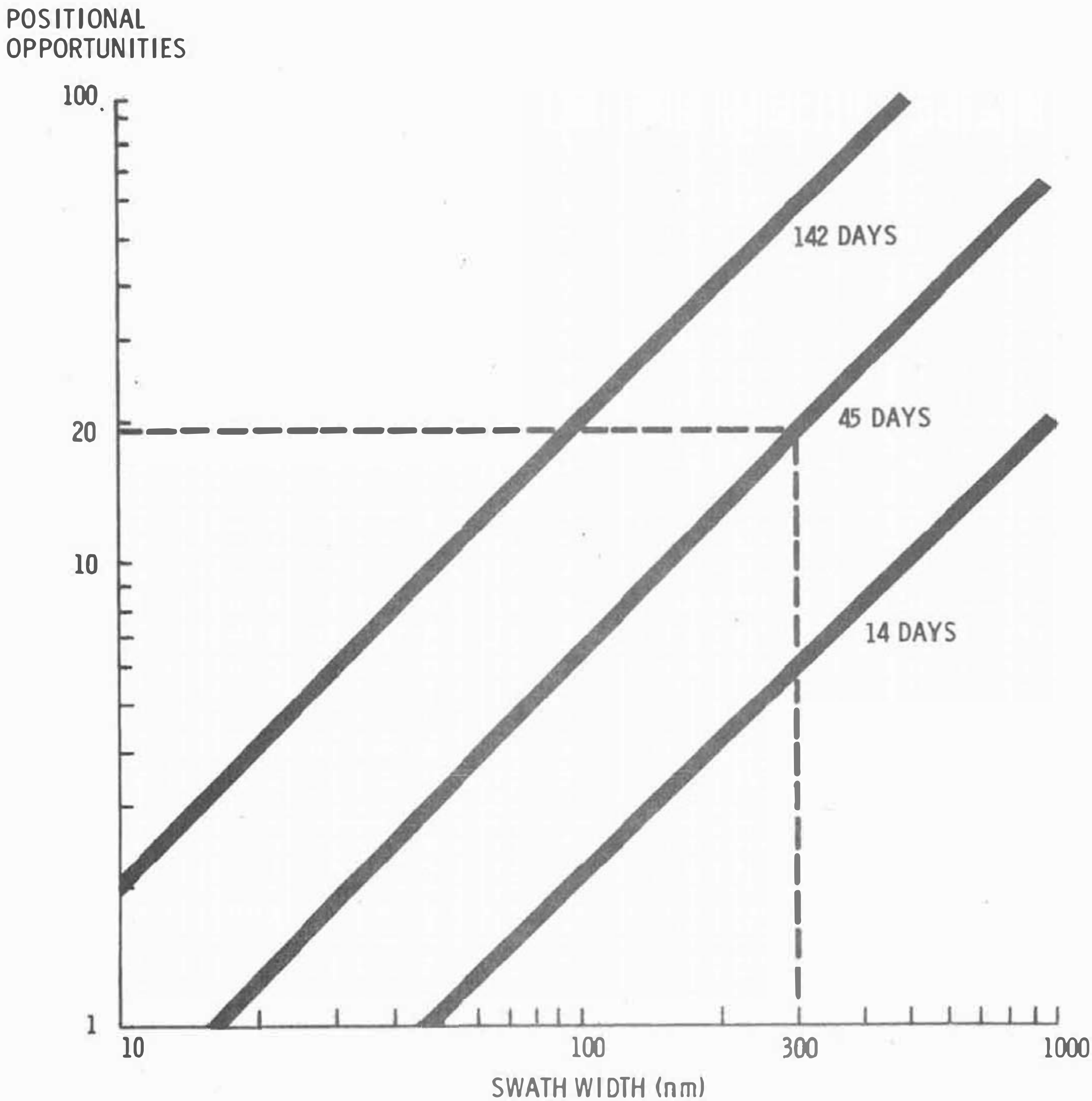


FIGURE - 119

Dr. CASTRUCCIO (cont.). tunities also increases approximately inversely with the inclination; thus, lower inclinations yield even higher opportunities. Let us focus, as an example, upon the number of 40 opportunities. The number of opportunities is diminished by weather, by the day-night cycle, and by man-made haze.

Shown here are the iso-probability curves of light cloud cover, less than 3/10. (Figure 120) This amount of cloud cover is reported by ESSA (Environmental Science Services Administration) as being adequate for taking spot photography; note that for cartography, clearer weather is required.

Concentrating again upon England, in this same chart, we notice that the iso-probability curves range from 10 to 20 percent. Taking 15 percent as an average, the 40 opportunities available in a 45-day mission for 300 n.m. swath width, are reduced to approximately 6 opportunities.

These must further be diminished by the day-night cycle. Exact computation of the diminishment is rather complex, but for our purposes here, it can be assumed to average year-round at approximately another 50 percent. Hence, for the example cited, approximately 3 opportunities would be available during a 45-day mission.

The next chart is a composite of the previously mentioned factors. The day-night cycle and weather, yields on a world-wide basis, an "average available time" of 9 percent. (Figure 121) For the conditions of the example cited, namely 300 n.m. swath width and 45-day duration, this yields almost complete (93 percent) coverage of the earth's surface.

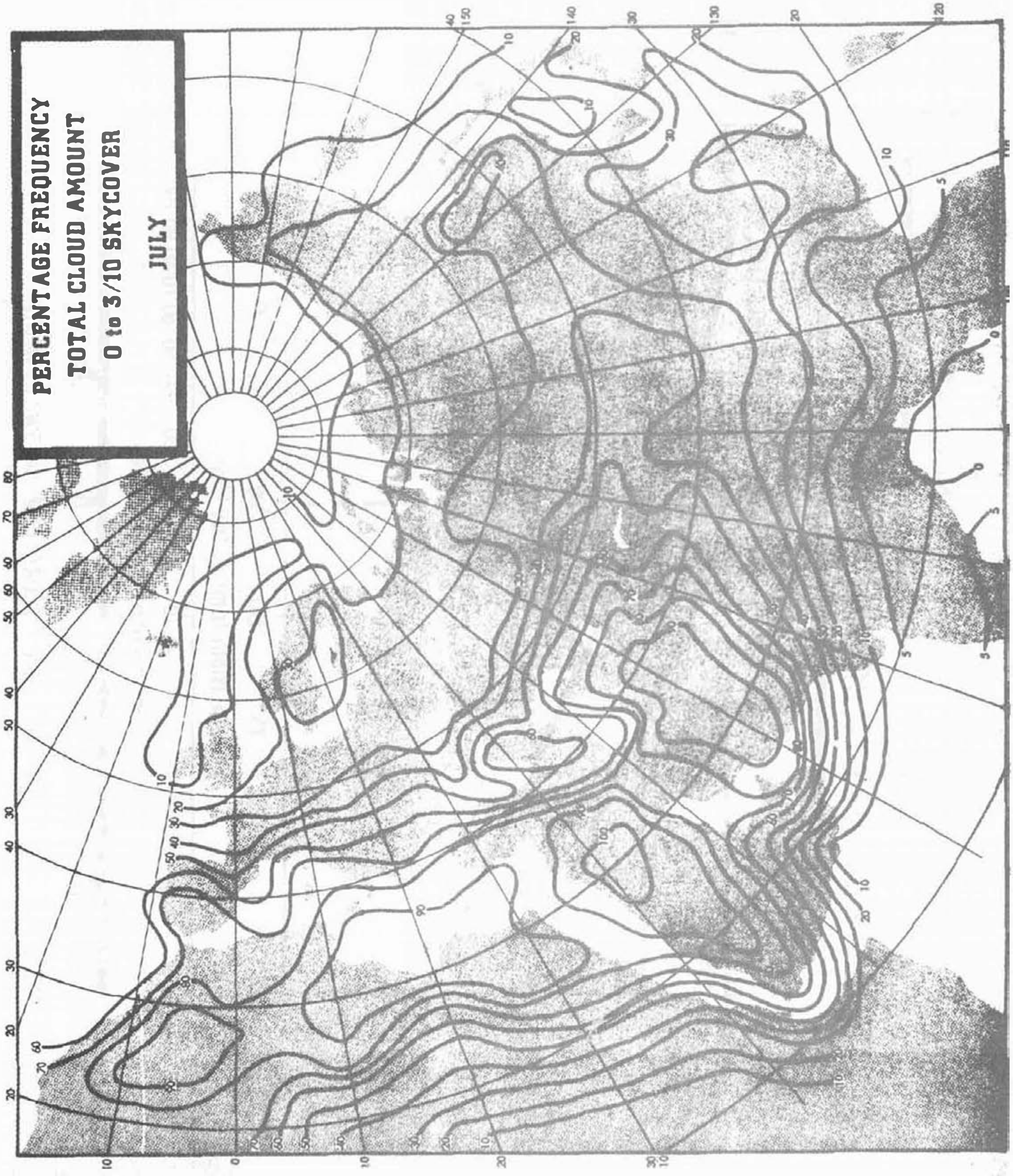

PERCENTAGE FREQUENCY
TOTAL CLOUD AMOUNT
0 to 3/10 SKYCOVER
JULY

FIGURE - 120

WORLD PHOTO COMPLETION CONSTRAINED BY WEATHER AND ILLUMINATION

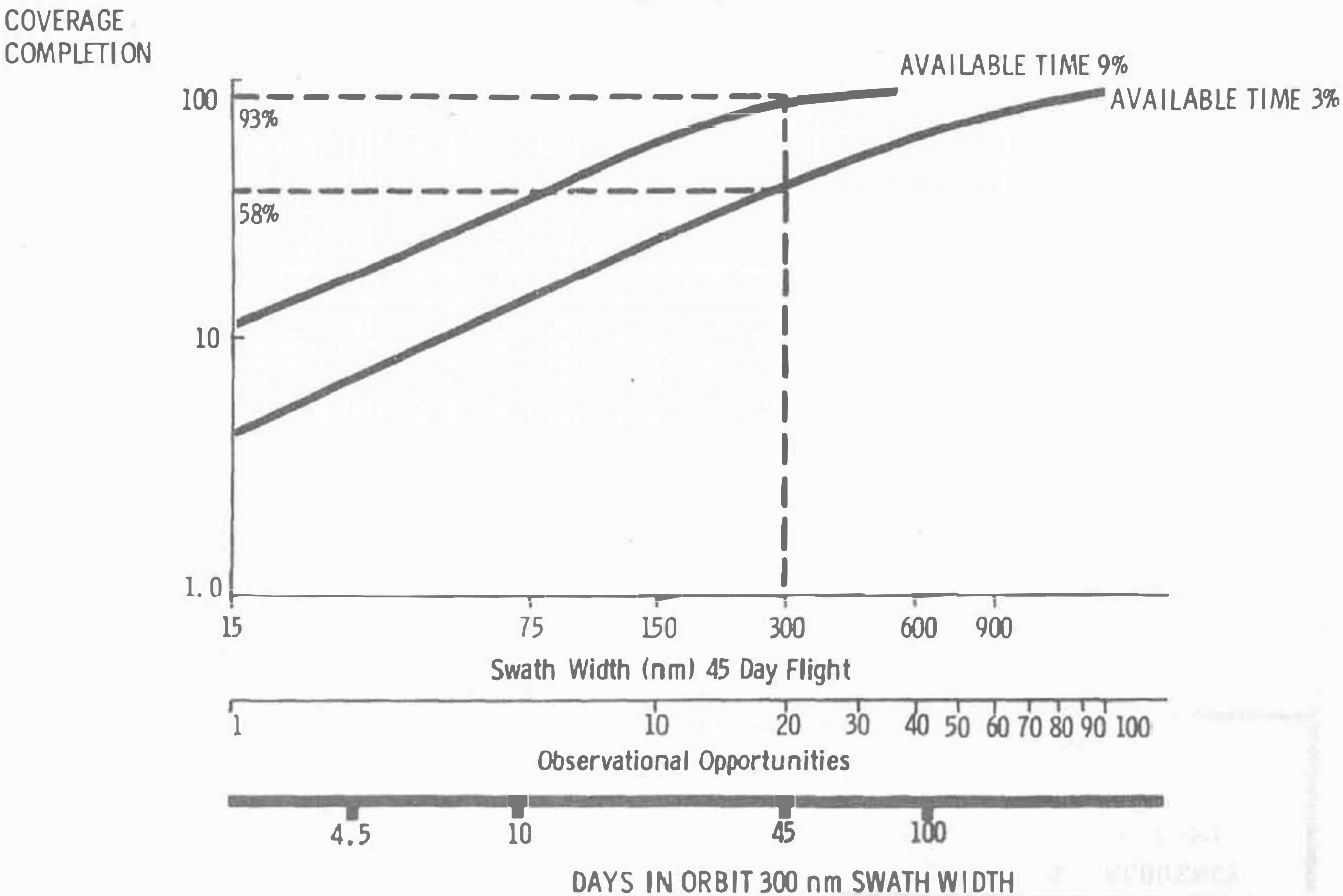


FIGURE - 121

Dr. CASTRUCCIO (cont.).

In practice, particularly over developed nations, the presence of man-made or man-induced haze further cuts the available time by a factor of 3. Thus, over developed regions, a flight time of 45-days with 300 n.m. swath width would only allow coverage of 58 percent . Conversely, under these conditions, coverage of 90 percent would entail a flight time between 120 and 150 days. These considerations thus make a strong case for long-duration missions.

Let me now turn to the orbital activities.... so-called experiments. Again with reference to our previous chart, the functional analysis of end objectives provides a logical basis for fitting individual experiments into a cohesive experiment program. (Figure 122) Moreover, it identifies "holes" in the experiment program to which additional effort can be directed.

Individual experiments can be conceptually visualized as contributing to the SKRs. (Figure 123) This chart depicts the relative importance of the 15 SKRs identified for Agriculture/Forestry and shows how each of 12 experiments (which were defined in detail during the study) contribute to these objectives.

Finally, let me say a word about supporting research. (Figure 124) Again, its requirements derive from the functional analysis. Prior to performing the orbital experiments, a supporting research program must be conducted to maximize their return. This involves laboratory and field research and testing of prospective techniques in aircraft. For Agriculture/

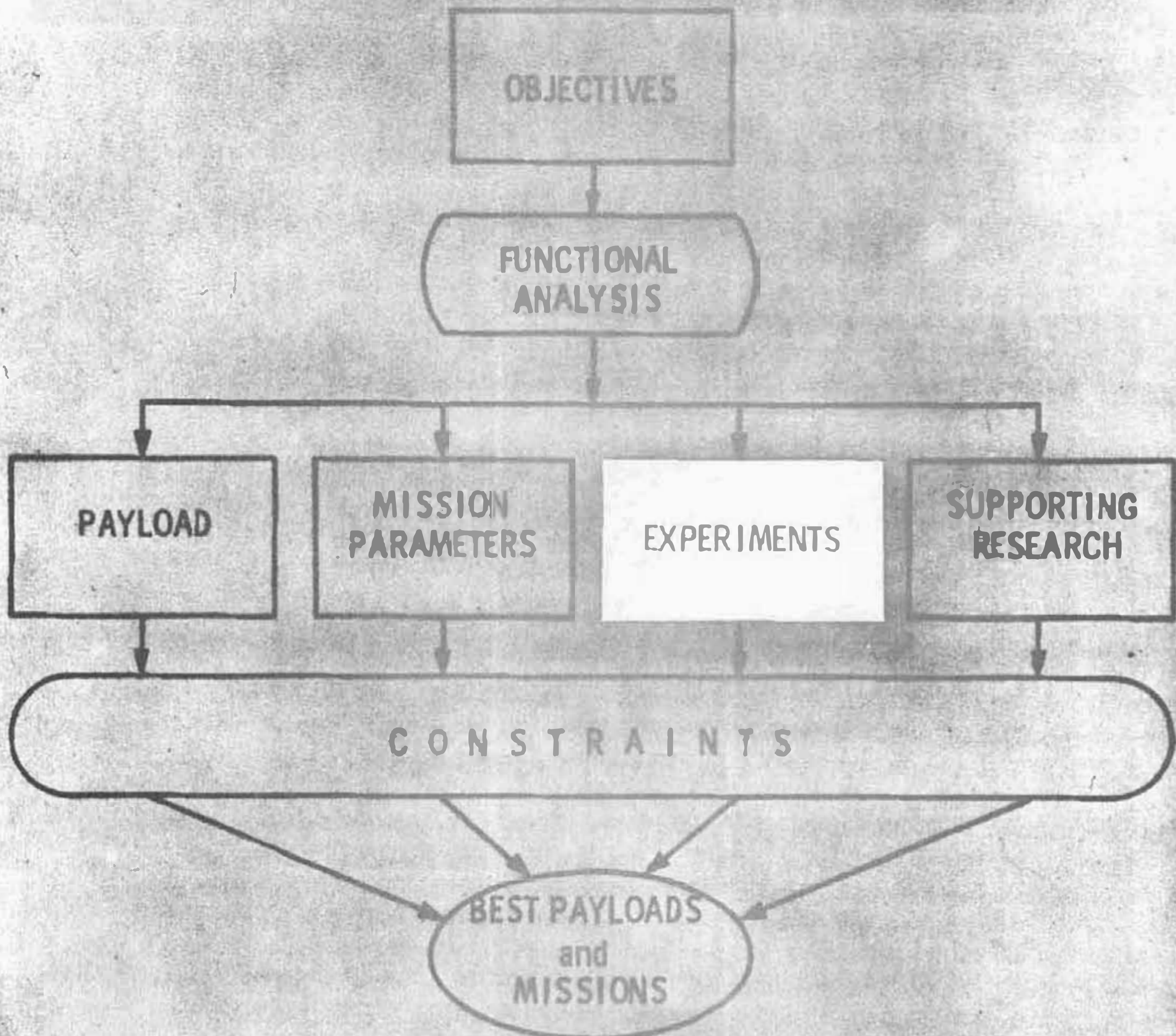

OBJECTIVES
FUNCTIONAL ANALYSIS
PAYLOAD
MISSION PARAMETERS
EXPERIMENTS
SUPPORTING RESEARCH
CONSTRAINTS
BEST PAYLOADS and MISSIONS

FIGURE - 122

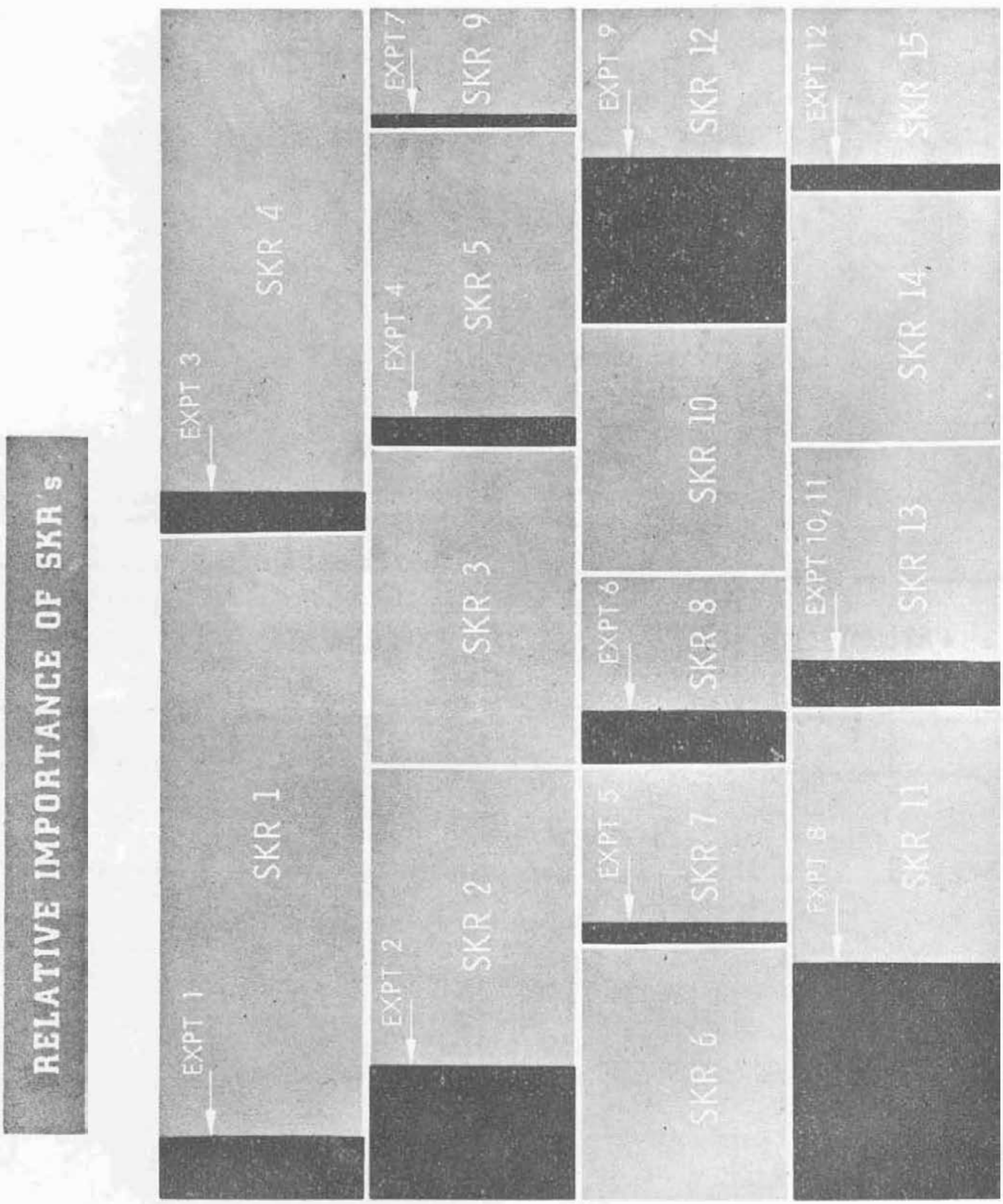
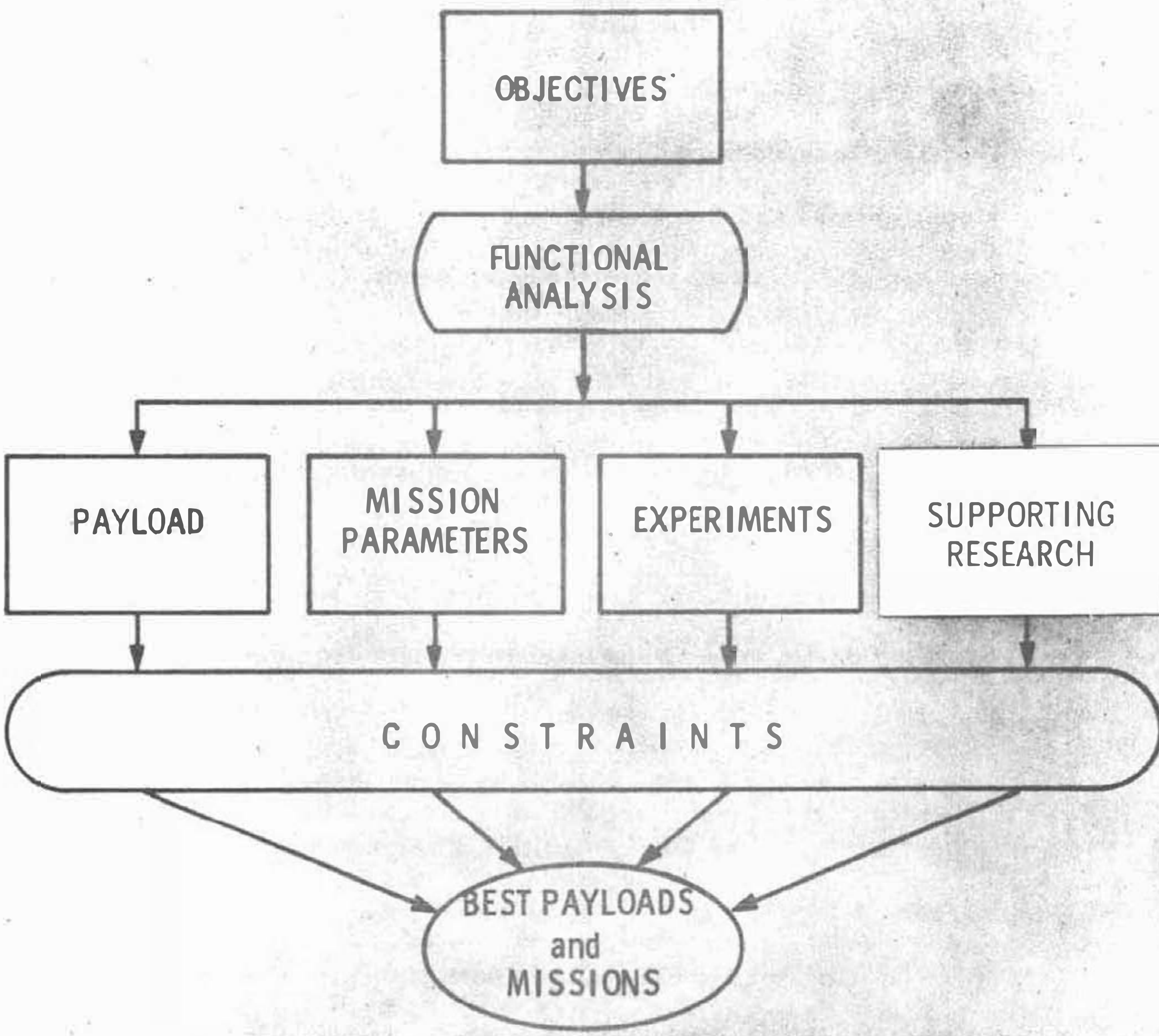

RELATIVE IMPORTANCE OF SKR's
EXPT 1
SKR 1
EXPT 3
SKR 4
EXPT 2
SKR 2
SKR 3
EXPT 4
SKR 5
EXPT7
SKR 9
SKR 6
EXPT 5
SKR 7
EXPT 6
SKR 8
SKR 10
EXPT 9
SKR 12
EXPT 8
SKR 11
EXPT 10,11
SKR 13
SKR 14
EXPT 12
SKR 15

FIGURE - 123



OBJECTIVES
FUNCTIONAL ANALYSIS
PAYLOAD
MISSION PARAMETERS
EXPERIMENTS
SUPPORTING RESEARCH
C O N S T R A I N T S
BEST PAYLOADS and MISSIONS

FIGURE - 124

Dr. CASTRUCCIO (cont.). Forestry, this program is being coordinated for NASA by the USDA.

A significant part of the USDA-directed effort is aimed at developing techniques for recognizing spectral signatures of crops. This technique could conceivably reduce the amount of data required to make agricultural surveys. As yet, unanswered questions are: (1) how stable are the signatures among species and under different lighting, temperature and other conditions, and (2) can the signatures be recognized when they are intermixed, e.g. when two crops are viewed simultaneously? Progress is encouraging. This graph shows the stability of the signature of four different fields of the same crop. (Figure 125)

This chart shows some early results of signature differentiation taking two crops at a time. (Figure 126) Additional research is underway to expand this table to other crops taken in triplets and in higher order combinations.

Another major aspect of the supporting research precursor to orbital flight is the handling of the large quantities of information produced from space survey.

This table indicates typical requirements in terms of number of photo frames to cover various portions of the earth at various scale factors. (Figure 127) I would like to focus attention on the number of frames required to cover the dry land at the smallest scale (1:60,000); this is approximately 1,000,000 frames. Let us remember this number. Let us also remember that this number of frames with current film resolutions and grey scale levels

CONSISTENCY OF SPECTRAL SIGNATURE-SOYBEANS

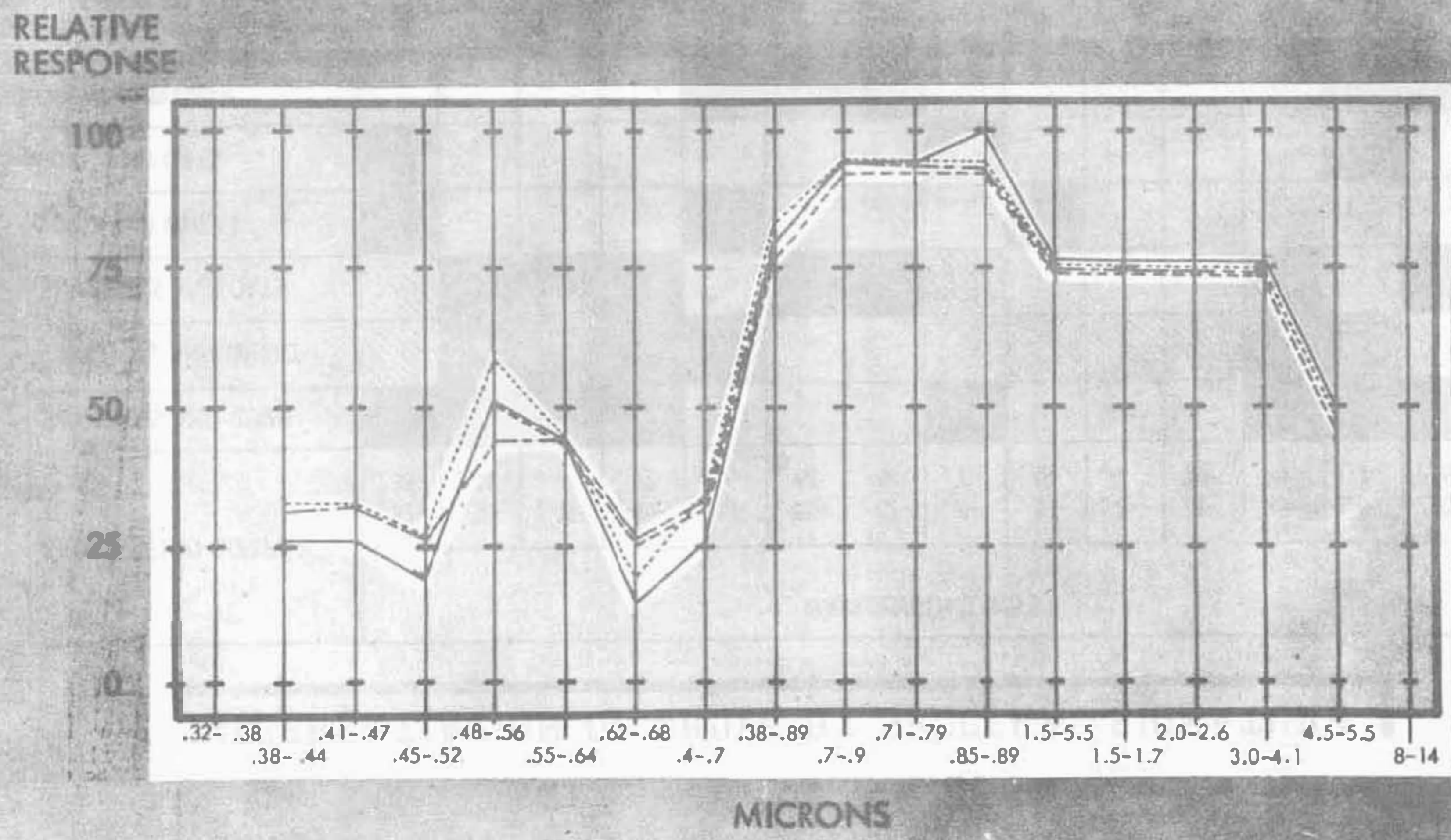


FIGURE - 125

DIFFERENTIATION OF CROPS BY SPECTRAL SIGNATURE

CROPS BEING COMPARED	WAVELENGTH BANDS													
	.32-.38	.38-.44	.44-.47	.45-.52	.48-.56	.55-.64	.62-.68	.4-.7	.38-.89	.7-.9	.71-.79	.85-.89	1.5-1.7	2.0-2.6
SOYBEANS AND CORN	Good	Good	Good	Good	Poor	Poor	Poor	Good	Poor	Poor	Poor	Good	Good	Good
SOYBEANS AND WHEAT	Excellent	Good	Good	Good	Good	Poor	Poor	Poor	Excellent	Excellent	Excellent	Good	Good	Poor
SOYBEANS AND OATS	Excellent	Good	Good	Good	Poor	Good	Good	Excellent	Poor	Poor	Poor	Good	Excellent	Good
CORN AND WHEAT	Good	Poor	Poor	Poor	Good	Poor	Poor	Poor	Good	Excellent	Excellent	Excellent	Poor	Poor
CORN AND OATS	Good	Poor	Poor	Poor	Poor	Poor	Poor	Good	Poor	Poor	Poor	Poor	Good	Poor
WHEAT AND OATS	Poor	Poor	Poor	Poor	Good	Good	Good	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Good

EXCELLENT (hatched)
GOOD (solid)
POOR (blank)

FIGURE - 126

FILM REQUIREMENTS FOR LARGE AREA COVERAGE

PHOTOGRAPHIC SCALE	1:60,000	1:800,000	1:2,400,000
AREA COVERED BY 9" x 9" FILM	73 sq. mi.	13,000 sq. mi.	116,000 sq. mi.
NUMBER OF 9" x 9" FRAMES (NO OVERLAP)			
● CONTINENTAL U. S. (3,022,000 sq. mi.)	41,500	232	26
● EARTH'S SURFACE (197,000,000 sq. mi.)	2,700,000	15,200	1,700
● OCEANS AND SEAS (139,000,000 sq. mi.)	1,900,000	10,700	1,200
● LAND AREAS (58,000,000 sq. mi.)	800,000	4,500	500

FIGURE - 127

Dr. CASTRUCCIO (cont.). amounts to 10^{16} bits.

Note also that the quantity of film decreases inversely proportional to the square of the resolution. Hence, any gain we can make in interpretation at the coarser resolutions, will greatly reduce the number of frames and hence the complexity and magnitude of the data handling system.

The data handling problem has several aspects: (1) How can we get all the data back to the ground? (2) How can we reduce the data, disseminate them, and interpret them on the ground? (3) Can the data load be reduced by raising the astronaut's skills? This table shows the magnitude of the data transmission problem. (Figure 128)

Remembering the figure 10^{16} bits (information content of a complete survey of the world's land area), it is clear that electromagnetic transmission using the most advanced microwave systems would take unreasonably long times: over 3 years of continuous transmissions over a 100mc channel.

As a practical case, consider a spacecraft which could carry say 1,000 pounds of film. This would correspond to about 16,000 frames. In turn, this corresponds to an information content of 16×10^{13} bits, requiring 16×10^{5} seconds or about 18 days continuous transmission. Since, infact, for low altitude satellites the readout time per orbit might be in the order of 10 percent or even less, this corresponds to a transmission time of many months.

Better transmission capability can be expected in the future using lasers. It seems clear that links that can handle up to 10^{10} bits/sec, will be achievable. This is 100 times better than the best radio links and would permit as much

DATA TRANSMISSION PROBLEM

	BANDWIDTH
COMMERCIAL TV	4.25 mc/s
UNIFIED S-BAND	1.25
SGLS	10.0
ADVANCED MICROWAVE SYSTEMS	100 mc
TIME TO TRANSMIT 10^{16} BITS:	
4.25 mc	60 YEARS
100 mc	3.1 YEARS
TIME TO TRANSMIT INFORMATION IN 1000 LBS OF FILM:	
100 mc, Continuous	18 DAYS
100 mc, 1% Duty Factor	180 DAYS

FIGURE - 128

Dr. CASTRUCCIO (cont.). as 10^{16} bits to be transmitted in the order 10 days of continuous transmission; with compaction to perhaps 2-3 days. For practical data loads which are constrained by film supply (say 16,000 frames or 16×10^{13} bits), all the data could be sent down in just 5 hours. Even considering duty factor and the possibility of cloud conditions over readout sites, laser links of the future would appear adequate for transmission.

An alternative to direct transmission which is applicable in the immediate era and which may, even in the long run, be less complex is to return the imagery via return capsules.

A potentially attractive technique for coping with the deluge of data involves on-board screening by the astronaut. Not all the photos taken will be useful or meaningful. If we can eliminate these on the spot, we save film, we help the transmission problem and we also help the ground interpretation system.

Potentially, the astronaut can "filter" the data in two distinct ways: (1) he can be selective in picking the areas to be photographed and the times to take pictures, and (2) he may be able to screen the imagery, culling out the useless imagery.

Let me describe each and point out the possibilities and the problems.

A sampling technique would work as follows. The astronaut would only photograph several ground-truth sites (to serve as a control) and various fields or areas which are known to be representative of the larger area surrounding them. Depending on what is found to be an adequate sampling

Dr. CASTRUCCIO (cont.). rate, the savings in data volume by this technique could be very considerable; a sampling rate of 1 percent certainly seems feasible and perhaps 0.1 percent - 0.01 percent might be useable. This technique would be implemented by an on-board computer which would automatically point the cameras. The astronaut would then evaluate cloud and illumination conditions.

A further reduction in recorded data could be achieved by the astronaut pin-pointing the camera to cover only the very small "sampling" area. By this I mean the following. If the camera were pointed solely by an on-board computer, the error in pointing might be ±5 miles. If the astronaut can recognize his target, he can pin-point the camera to the exact spot. Instead of imaging an 8 mile x 8 mile area on the whole 9" x 9" film, he could use a smaller piece of film covering only the few tens or hundreds of acres to be sampled.

So much for astronaut screening of data. Now let me turn to the possibility of sifting the imagery, after it is taken, by the astronaut. Here the real question is, to what extent will the astronaut be able to interpret the imagery? At first brush, most people familiar with the development of photo interpretation procedures would be very pessimistic. Photo interpretation (PI) is still a very manual operation. The PI process can be represented as shown here. (Figure 129)

To date, computer-assists to the PI have largely been in the area of storage and retrieval of the collateral information needed for interpretation,

IMAGE INTERPRETATION PROCESS

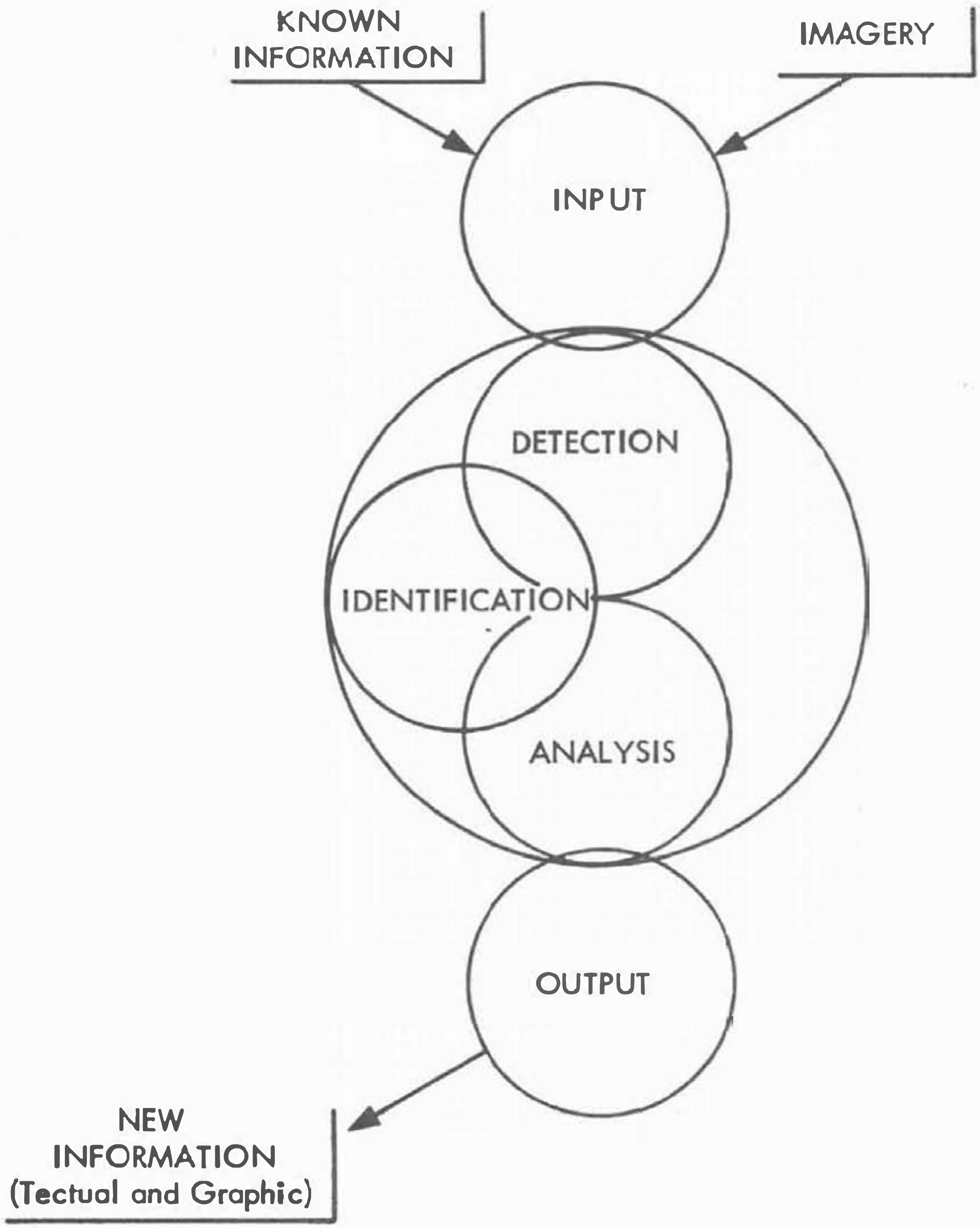


FIGURE - 129

Dr. CASTRUCCIO (cont.). i.e., the library functions. These techniques are quite well advanced and can be used to assist the astronaut in the screening and culling function.

In the areas involving signature identification, significance of images, and detection of images, use of computers is in a very early stage of R&D.

As an example of some of the work in this area, I cite the experience of IBM in automatic map compilation and change detection. Here a computer clearly was able to detect the motion of a truck within two images, each of which was digitized and then correlated. The practical difficulties with automatic change detections are: (1) the vast amounts of storage required and the long operating time (it took the 704 computer several hours), and (2) the ability to differentiate between meaningful changes and natural changes.... example, truck movement vs. wind effects. For these reasons, practical automatic change detections by computers has not yet been realized.

A similar condition applies to automatic interpretation of image significance (target recognition). Techniques for automatic object identification have been under development for over ten years. Yet, even the latest work indicates that much more work remains to be done.

Many workers in the field feel it will be at least 1985 before automatic detection will be practical. Development of improved aerospace computers, plus much R&D, is required before automated interpretation of imagery significance can be expected by an astronaut. Thus, to cull photography in the spacecraft, to select the good pictures for transmission, will have to be done

Dr. CASTRUCCIO (cont.). essentially manually and at a very low rate. Under best conditions, PIs on the ground doing comparable work do perhaps 200 sq. miles per day.

In any event, even if the astronaut can effectively filter the data, the magnitude of the ground handling job is large.

This shows the elements of the ground system that must be incorporated. (Figure 130) It includes:

- o Collection Management--for receiving requirements from users; checking them against an Information System to determine whether information is already on file; and, if not, planning the missions to accomplish the requests.
- o Exploitation Management--for receiving the information; checking it in quasi-real time to determine whether the photography meets acceptable standards and if not to order a repeat observation; and indexing.
- o Information System--the heart of the system, essentially a large library of the photography. Through use of modern data handling equipment, large and efficient libraries of this type have been built.

Our preliminary estimates indicate that the data handling job is a big one, but not an insurmountable one.

This concludes my discussion regarding an effective earth-orbital program of activities. I have given you our views as to its structure and described the method by which we arrived at them.

ELEMENTS OF SURVEY SYSTEM DATA MANAGEMENT

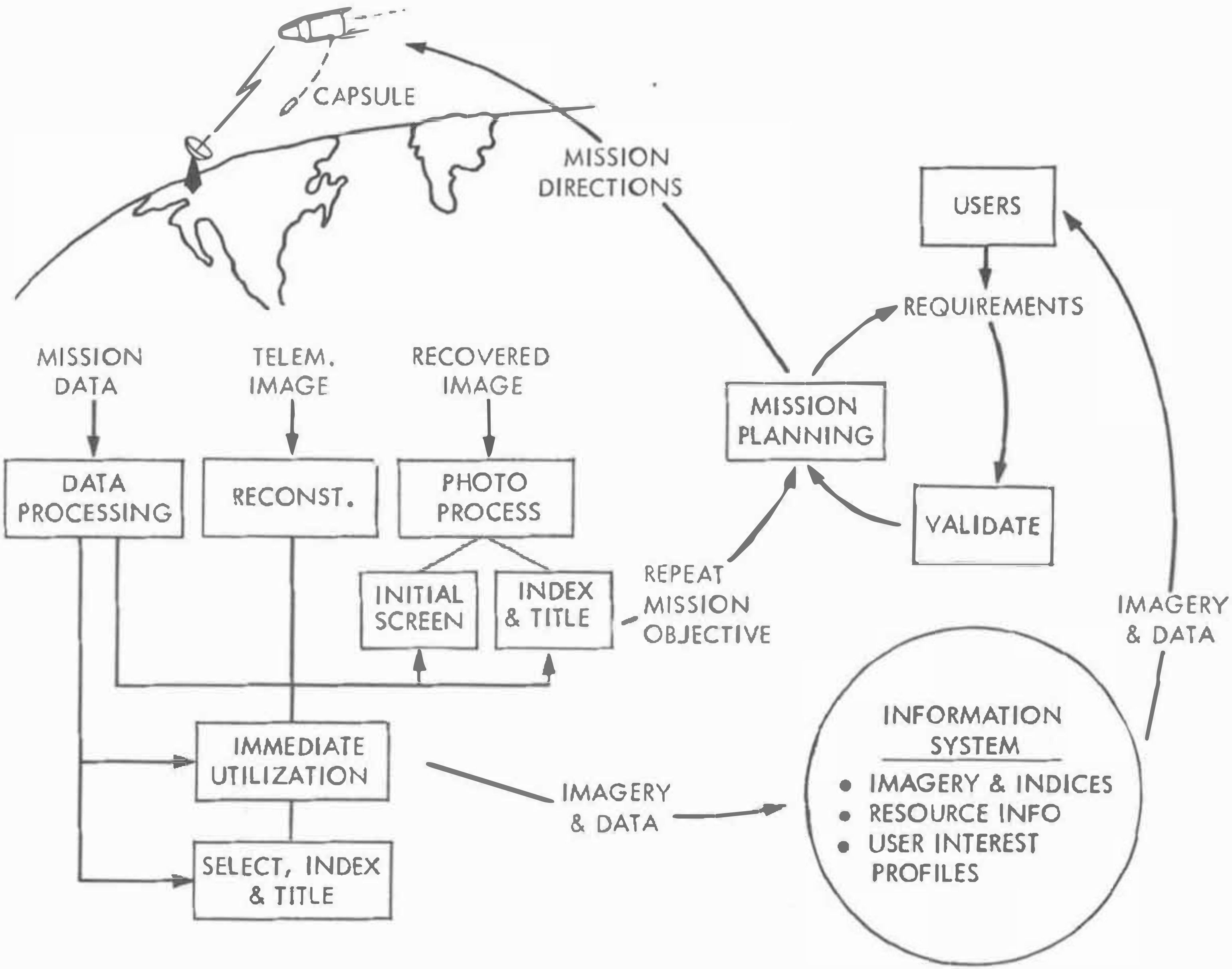


FIGURE - 130

Mr. WILSON. I have one question I would like to ask you, Dr. Castruccio. The systems you envision in this corps of flight, in synchronous orbit or various formations of the pulsive or near-earth orbit, do you envision a man populating the station at all times, or do you....

Dr. CASTRUCCIO. I envision the man doing this. The man is invaluable. Fine enough. He is invaluable when you have elements of research. He invariably translates the elements of research into routine elements. No machine can do this. Maybe in 20 years--not now.

So, conditions may end up sending all this stuff up, correcting all its errors, and being followed by one-man, day in - day out operational capability. There is always the capability for man, and this is how to improve it.

Mr. WILSON. Mr. Grace, I would like to say that I want to thank you and the management of IBM here in Huntsville for a very thorough presentation. I know that the people on the committee appreciate the effort you have expended to give them a good over-view of the Instrument Unit Program in Huntsville.

Mr. GRACE. Thank you, Mr. Wilson. We were too thorough in some things and did not get around to the tour--and I feel badly about that because I am awfully proud of the facility and what is going on here. Maybe you can get back down here.

Mr. WILSON. I get down here occasionally, and I hope that perhaps Mr. Peck and a member of your subcommittee can show us the facility.

Mr. GRACE. We would be delighted.

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