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ORBITAL MECHANICS OF RENDEZVOUS MISSIONS

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ALIBRANDO: The briefing we arranged this afternoon is essentially in response to the questions we had from you. We do request one thing. We would like to restrict it to rendezvous and docking to orbital mechanics. We won't have time to talk about the overall mission. We plan to do that at the overall briefing at T-one day.

Transcripts of the briefing will be available in the newsroom Tuesday morning, and they will be mailed out to all of those people who received press kits. The press kits will be mailed this afternoon for release Wednesday a.m.

That is about it.

Eldon Hall, if you will introduce the participants, we will get on.

HALL: Thank you.

We have broken this briefing up into three main parts. The first part is a technical discussion of the basic phenomena of orbital mechanics. This part will be given by Mr. John Hammersmith, who is our aerospace scientist.

Following this we will have a discussion related specifically to the Gemini 6 mission and how it will be conducted. This part will be given by Mr. Bob Aller, who is chief of mission planning.

To assist us in answering questions in a short panel session following the formal presentation, I have Mr. Ed Harkleroad and Mr. Jim Cooper, who are both with aerospace technology.

In the first session Mr. Hammersmith will get into some of the basic fundamentals. I think it would be well if we could withhold our questions pertaining to this part and keep these questions only to those which require clarification rather than bringing up new subjects or questions that have not been covered by this discussion.

If there are any remaining questions, we will open it up following his discussion before we get into Gemini 6 specifics.

With that, I will introduce Mr. Hammersmith.

HAMMERSMITH: Thank you.

I think that the part that I am to cover here is more in response to questions from the news media than it is pertaining directly to the Gemini rendezvous situation.

I will try to describe and try to talk about a number of fundamental concepts, fundamental definitions, of which you must have an understanding if you are to have an intelligent appreciation of what we are doing, not only in rendezvous but in any space missions.

Many of you have been covering the space field for a long time and are undoubtedly familiar with a great deal of what I am going to talk about. I hope that from time to time you all will be with me and I hope that by the time I am finished you will all be with me also. And if I seem to be talking down to you, please bear with me because the material which I am covering to a great extent is being covered in response to indications of confusion.

As soon as we try to talk about understanding and to my getting an understanding to you, we run into a problem of what is understanding, and I have the problem of how do I start, where do I start, and how deeply shall I go.

In order to understand this material to such a degree as to have a facility with it, to be able to manipulate the material in order to do things, a knowledge of mathematics, of appropriate mathematics, a knowledge of physics, of astronomy, and of quite a bit of engineering is absolutely essential.

I do not think, however, that a knowledge of that type is essential for you to have an intelligent appreciation of what is going on in space in general, and of what we are doing in the Gemini program in particular.

To assist me I have had a number of illustrations specially drawn and I have put up a little 3-dimensional model to which you may wish to refer from time to time.

Many of the terms which we use have been carried over directly from a branch of astronomy known as "celestial mechanics." This concerns quite briefly the study of the motion of bodies in space. Usually these bodies are small, circulating about a body of large mass.

(Slide.)

The case of the Moon about the Earth is such a case; Mars and the Earth about the Sun is such a case.

I have drawn a schematic which shows an orbit about the Earth -- and I must apologize. I set this up for a briefing and was not anticipating all these microphones and cameras. I am going to have to go to the board.

Let us say we have a spacecraft in an orbit about the Earth oriented thusly. If you stretch a sheet, an imaginary sheet, over the edge of that orbit, you will find that it is perfectly flat, just like a drum head. This is called the orbital plane. It is an imaginary construction and in your imagination it slices through the center of the Earth.

The first thing that astronomers ask themselves, the first types of things they have to grasp in a situation like this, was to come up with a set of nomenclature and of concepts that would enable them to describe the characteristics of such an orbit, to describe its orientation and position, and to describe the position of a body in that orbit with precision. These you will probably hear referred to and have already as parameters -- orbital parameters. Parameter means nothing more than it is a thing that has another name, or is a set of things which help us to describe something.

(Slide.)

The astronomers found that they needed and that it was most convenient to have some plane of reference for such an orbit. For a spacecraft about the surface of the Earth, circling the Earth, the most convenient plane of reference is the equatorial plane, depicted here.

This doesn't look very much different from our orbital plane of our spacecraft except that it is constructed entirely differently. The orbital plane is constructed by putting a sheet, an imaginary sheet, over the edge of the orbit. The equatorial plane is constructed by slicing in an imaginary way about the equatorial line which you see depicted on the globe.

(Slide.)

Putting these two together -- you have heard the word "inclination". The equatorial plane and the plane of the target orbit intersect at the center of the Earth, and since they are both flat, an angle can be measured between them. This angle is called inclination. It is measured in degrees.

A spacecraft of satellite under no other influences than the gravitational attraction of the body that it is circling, will remain fixed in such an orbit in such a plane. Among other things, the inclination will stay the same, or essentially the same, unless the spacecraft thrusts. If the spacecraft attempts to maneuver out of that plane in some fashion, perhaps by pushing itself this way or that (indicating) it will establish itself in a new plane at the end of its thrusting period. That plane will look just like this, but the inclination will have changed. And that is the meaning of the term which you heard and to which we ascribe so much importance during the Gemini 3 mission when we said that we had changed the orbital plane. And that was the significance of that terminology. I think it was largely overlooked because it was not understood.

The point where the orbit of the spacecraft intersects with the plane of reference, in this case the equatorial plane, is called the "node". The term node has no other significance than that. And it is just that simple.

If a spacecraft should be coming in this direction, from north to south, cutting across the reference plane, this node would be called the descending node. If the spacecraft comes down around, back up the other side, this node is called the ascending node.

(Slide.)

Two spacecraft in orbit will establish themselves in planes very much similar to that, and the intersection of those planes is very often called nodes. This situation differs from the one that we were talking about in that neither plane is really a reference plane. And in our rendezvous situations, this angle between the planes of two spacecraft, say between our Gemini spacecraft with the men in it and with our target vehicle, the Agena, this angle will normally be very small and you may hear it referred to as a wedge angle. If you can visualize that, you can see there that this is reminiscent of a wedge.

Let's depart from the 3-dimensional situation for a while and let's see what we can do and what sort of things we need in our nomenclature for a spacecraft or a satellite in one of these planes. From now on for a bit we will be talking in the plane.

(Slide.)

It could be proven mathematically that a spacecraft in orbit about a very large body, a body whose mass is arranged in such a manner that the simplification can be made for purposes of calculation if the mass is concentrated at its center, a spacecraft in an orbit about such a body will be at an orbit such as this which is an ellipse.

An ellipse has a very precise mathematical definition in that not every oval that you see is an ellipse. I would like to speak just a moment about the mathematical theory. No mathematics, but I will talk about the mathematics.

Once a spacecraft is deposited in orbit, or a body such as the Moon is found to be in orbit, then the shape of its orbit from there on is determined solely by the force of gravitation of this central body. This was one of the first applications of Newton's calculus and of his discovery of the law of gravitation. And he married these two ideas and he was delighted to find that he could predict on this very clean conceptual frame of mathematical reference that he could describe very clearly the motion of the Moon about the Earth, and he knew that he had something.

That theory shows, as I have said, that the orbit will be in a plane, that it will either be an ellipse or it will fly away. If it has a lot of energy, for example a comet has a lot of energy, it will come and go and it will not be seen again. I should correct myself slightly. Some comets do return.

The circle is a special case of the ellipse, and for many purposes it is convenient to use circles. For the ellipse the point of closest approach to the body of mass is called the perigee; the point of furthest approach is called the apogee.

These two points in general are known as apsides. And a line can be drawn from here to here which is called the line of apsides, and you may hear reference made to that. That is the significance of that term.

In the case of some bodies which have been studied extensively, such as the Earth, instead of saying apoapsis and periapsis, which are very awkward terms, some kind of a syllable has been attached to make it easy to indicate the orbit, or rather the body about which the orbit is being studied. In the case the "gee" is really a corruption of "geo" for Earth.

Some of you who covered the Apollo may have heard the terms "apolunar" and "perilunar". The time that it takes to go from perigee to perigee may be measured in minutes, hours, days, any convenient time reference. But it is time, and it is called the period.

By far, the dominating force in a case like this is gravity, and I have discussed one form of that gravitational attraction. However, the Earth is not so neatly constructed. Its bulge causes aberrations. It is the bulge of the Earth that causes the orbital plane which I said was motionless to rotate slightly. It causes it to rotate in this manner, backward. The atmosphere of the Earth is very tenuous but extends to very great heights and tends to distort this orbit. Even radiation pressure from the Sun will tend to have an effect upon such an orbit over a period of time.

Those are all natural forces and they are pretty largely out of our control. Sometimes we can contrive things and manipulate them to our advantage, but they are essentially out of our control.

There is one thing that is within our control, and that is our spacecraft is built -- all our spacecraft are built in such a manner that they can thrust. It is this force that is under our control and enables us to change the characteristics of these orbits.

I have built up with this terminology so that when the press kit comes out and you hear your press conferences, these changes will be described in terms such as I have just discussed.

Before we talk about what we can do in this orbital plane, with a spacecraft, I want to talk about something which is very simple but which, because it gets involved with a few other things I am going to talk about later, I want to make certain you have clearly in mind.

(Slide.)

The two concepts that I want to get straight are forward and backward. Forward for the Gemini spacecraft is the direction in which the crew faces. Backward or aft is the direction directly behind them. The thrusters are located in this section. Some of them point forward. When a forward-firing thruster fires, it tends to push the spacecraft backward. And when an aft-firing thruster fires, it tends to push the spacecraft forward. It fires forward, tends to go backward, tends to push backward. Fires aft, tends to push forward.

Are you with me so far?

Now we get confusing.

(Slide.)

The terms forward and backward -- and the reason I belabored that point is that the terms forward and backward have gotten mixed up with the terms "posigrade" and "retrograde."

You will bear in mind always that forward and backward are forward and aft referring to the spacecraft, and are oriented towards it, and the terms posigrade and retrograde are oriented towards the direction of travel. You will have no problem.

If the spacecraft is travelling in this direction (indicating), this is the posigrade direction. If our spacecraft is oriented in its orbit in the way depicted here, and it uses its aft-firing thrusters, the spacecraft will be pushed forward in the posigrade direction.

If that maneuver takes place at perigee in the way in which I have depicted it here, then the orbit that the spacecraft was on, which might be such, will be amplified and the most notable change or the easiest way to note the change will be to say that the apogee has been raised. This, from a fuel standpoint, is the most efficient way to raise apogee, to fire the thrusters at perigee, and to fire them so that you move in a posigrade direction.

(Slide.)

Just to show our versatility, this is the same maneuver done with the spacecraft in another orientation. We are using the forward-firing thrusters to push the spacecraft in a posigrade direction. The consequences of the maneuver have to do with the direction of travel and the direction in which the thrust is made, with respect to the direction of travel. It does not have anything to do with whether the spacecraft is pointed forward or backward. At least not directly. As a matter of fact, the spacecraft could have been pointed sideways.

(Slide.)

Retrograde, a retrograde maneuver, is one in which the thrusters are fired against the direction of motion. They tend to push the spacecraft backward, although there will not be a backward motion. That takes too much energy. If the spacecraft had been on a large orbit such as I got us into on our previous slide, and we were to make a retrograde maneuver, that is, we were to fire the thrusters against the direction of motion, then the apogee would be lowered.

The same type of discussion can be made at apogee. If a firing, if a posigrade firing is made at apogee, that is, the spacecraft fires in such a direction at apogee as to push itself faster in the direction in which it is travelling, then it would be placed in an orbit that would look like this. Perigee would be raised.

The most pronounced retrograde maneuver that we have in our repertoire is the retrorocket firing with which the spacecraft is brought back to earth. In that case this backward section of the spacecraft has been discarded. The spacecraft is reoriented and the firing is so severe that it just comes down like that (indicating).

The retrograde maneuver is so severe that instead of going into a lower orbit, its orbit actually intersects the Earth and it comes home.

Are there any questions about that particular series of points? Apparently, from the word I get, it has caused a lot of trouble.

Is it clear?

QUESTION: I don't quite understand if that rocket is sideways, how firing would make it go farther out or in.

HAMMERSMITH: You are right, because I have just shown the forward-firing thrusters and the aft-firing thrusters. There are thrusters that fire sideways. If it had been sideways, we would have used them and they would then have been firing in the direction or against the direction of travel.

You can see from this sort of behavior that if we are going to catch a target with a spacecraft like this, that even if we had them in the same orbit -- let's say the target was only a little bit ahead -- that it would do little good to fire the thrusters of our manned spacecraft with the crew on board, straight ahead, with the hope of catching. Because this does not act as though this orbit were a track like a road, but rather any firing along the direction of travel tends to cause not a catch-up but tends to push into a higher orbit.

So that if we see our target directly ahead, and even if we know it is in the same orbit we are, it does no good to try to catch him by going right after him. That type of thrusting only puts us into a higher orbit.

So how do we beat this game?

(Slide.)

It so happens that a spacecraft in a low orbit can make one revolution about the Earth faster than a spacecraft in a higher orbit. It has been suggested to me that this is analogous to a race track situation, where if a racer or a horse on a rail is travelling actually at the same speed as the horse or racer next to him, but toward the outside, that the one on the inside has the advantage because he makes the circuit faster. And that effect is present here.

But there is more to it than that, in that that effect does not account for all of the differential.

There is more present here. I toyed with the idea of trying to explain it and I decided against it because I couldn't think of any way to do it without involving some mathematics. Take my word for it.

(Laughter.)

The essential point is that it takes less time for this one to go around than it does for this one to go around (indicating). Keep your eye on that.

(Slide.)

We will make one trip around. What this does, as this one makes one complete circuit, this one hasn't quite made it. This one and this one started at the same time, and we see that the difference in angular position is less.

You will hear this angle referred to as the phase angle. These types of maneuvers are what are called phasing maneuvers or catch-up maneuvers. The rate at which this phasing takes place I think should be obvious by this time. You can control this by varying the difference between the amounts.

This is about all we have to work with when it comes to trying to catch up, and it is not as beneficial as it sounds for the Gemini system because at the altitudes at which we are working, it is not possible to provide a differential time around, or a differential period between the two spacecraft of much better than about one-and-a-half minutes per orbit.

QUESTION: Say that again.

HAMMERSMITH: At the altitudes at which we are constrained to operate with the Gemini system, it is not possible to provide much more of a differential period between the target and the spacecraft -- not much more than about one-and-a-half minutes.

QUESTION: What do you mean by differential in that sense?

HAMMERSMITH: Perhaps I used too big a word to describe it. All I am talking about is the difference in time that it takes to make one complete circuit. And when I said differential I was comparing that time between the two vehicles.

QUESTION: Do you mean the difference in orbital period between the spacecraft and the target narrows by a minute-and-a-half each orbit?

HAMMERSMITH: That is correct.

QUESTION: And you can't catch up any faster than that?

HAMMERSMITH: That is correct.

QUESTION: That is if you did nothing?

HAMMERSMITH: Yes, if you did nothing. Actually, a minute-and-a-half is about a good average. We can vary it. As we come very close here, the time difference will be very small.

There is one contingency type of maneuver which perhaps, since you are getting all around it that I should mention, and that is should we get too badly out of whack, it is possible to send the Agena way out and bring it back, and then circularize again so as to upset this actually very tight phasing relationship. The emphasis in the Gemini program will, however, be on having the men in the spacecraft make the maneuvers, the Agena essentially resting there and only answering and speaking when it is spoken to.

In terms of lift-off and lift-off time -- launch time -- this imposes a very important constraint. One of the major constraints, one of the major problems we have to grapple with is lift-off on time. And I think now you can begin to see one of the problems that we have to grapple with.

If we could launch on time in the sense of coming off the surface of the Earth, going directly to the target, that is, we launch when the target is directly overhead almost, and go right to it, if that is what we call launch on time, then if we launch only 24 minutes late, it takes a whole day to catch up -- 24 hours, 16 orbits.

In terms of duty cycles for the men, in terms of keeping them busy, keeping their attention up. we feel that we don't want to spend much more time than this. And so we have accepted a constraint something on the order of 24 hours at least for the present.

Don't hold me to that 24 hours too tightly, because there are situations where we might differ from this. I am emphasizing here the important central concepts. If I can have you with me all the way through this, I think I will have achieved what I tried to do, and I think you will be in a position to dig into it more deeply if you care to without having to unlearn a lot of things.

Finally, when the phase relationship is approximately what we want it to be, the spacecraft then will thrust, it will actually be pointed so the crew can see the target vehicle. It will thrust using the aft-firing thrusters, make a posigrade maneuver, will go into a transfer orbit. As it travels the target vehicles travel around with it until they meet over here. At that time the spacecraft must make some kind of a maneuver so as to put it in the same orbit right in front of the Agena.

QUESTION: Does that go in front or back of it?

HAMMERSMITH: It will go in front. It seems more natural that it should go behind. There is a long history as to why it goes in front.

I wonder if you would let me beg off. It is quite involved. It has to do with the various engineering design constraints, particularly as they pertain to the target vehicle.

QUESTION: But they will be going forward when they start the transfer orbit?

HAMMERSMITH: That's right.

QUESTION: They will go underneath the Agena and in a sense overtake it, get ahead of it?

HAMMERSMITH: Get ahead of it.

QUESTION: And turn around?

HAMMERSMITH: Turn around.

QUESTION: After they overtake it?

HAMMERSMITH: After they overtake it they will make a posigrade maneuver out here. You see, if they did not do that, they would come back down like this, back to where they started from here, back where they started that maneuver, executed that maneuver. Go around, down like this.

So it is necessary then to make another posigrade maneuver so that they circularize. The timing is very critical. They should be within a mile or so. My colleagues will correct me if that is not true. Ed? Something like a mile or two.

At that point we can afford to waste a little fuel and finish it up optically. This is what happens. At that point you can't tolerate that kind of efficiency to have a man guessing and flying all over the lot because it costs a lot of fuel to maneuver in space. This is a constraint that I did not mention. It is the fact that to make maneuvers in space takes an extremely large amount of fuel compared to what it takes, say, to fly an airplane on similar types of maneuvers near to the Earth.

It costs us fiercely for every pound of fuel that we put up. We do not have that kind of capacity on the Gemini spacecraft and we will not have it on any of our spacecraft for some time to come.

So great emphasis is placed on efficient maneuvers, efficient of fuel, efficient of energy. When they are so close together, then these laws of space mechanics drop our energy requirements down to such a low level that we can afford to be a little wasteful. I might add it is at this point that the men in this thing become really critical.

We know -- we have had a lot of studies -- we know that we can build an unmanned system to do all of this. But when you get to that point right there, trying to do it automatically, or under remote control from the ground, it gets to be a whopping big development problem, and nobody has been willing to tackle it.

It takes advantage of the unique kinds of control capabilities of which men are capable. And if we are going to do this kind of mission, if this kind of mission is important, and we think it is, this is a good reason for having men in the space program or men in space.

I want to start into a more complex phase. Are there any more questions in this area?

QUESTION: I just don't understand your reference to 24 minutes, 24 minutes late, what it means.

HAMMERSMITH: What I am saying is, and the relationship I gave you, which maybe I slipped over too fast, is that for every minute late it takes an hour of catch-up time.

QUESTION: That is without firing? That is simply by virtue of their orbits?

HAMMERSMITH: No matter what you do at the altitudes we are talking about, with this spacecraft, no matter what you do, you can't change that rate by much more. You can't change that time difference by much more than something like a minute-and-a-half.

Mr. Aller, when he talks about the Gemini 6 mission in particular, is going to show some of the possibilities here. But on the average, what I am trying to do is give you a feel for the kind of things we are up against.

QUESTION: You spoke of how essential the men are there. Are they doing their own computing, or is that being done on the ground?

HAMMERSMITH: Mr. Aller will take that up. Essentially, up to the point where they start this transfer orbit, the orbits are being kept track of on the ground. The computing is being done at the central computing facility at the Manned Spacecraft Center near Houston. From here on the on-board radar and the on-board computer will take over and carry out -- tell the crew what types of corrections to make during this transfer orbit, and they will finally take over using entirely the types of visual cues they can get by looking out the window.

QUESTION: Assuming everything goes off on time, Gemini is going to be below and behind the target vehicle, right?

HAMMERSMITH: Yes.

QUESTION: How far below and behind?

HAMMERSMITH: Let's let Bob Aller take that one up.

ALLER: I was going to suggest, many of these questions will be covered later.

HAMMERSMITH: Yes. If it is not the type of thing to clarify what I have covered so far, let it wait. I think it will be covered. We will have a question and answer period after everything.

We have been talking about what happens in the plane of the orbit, what happens when a spacecraft is in orbit about a body like this. It is in a plane.

Let's say we have our target vehicle up there, and we take a look at the situation and we realize that our launch pad is back here on the surface of the Earth, and that that launch pad is rotating like this, making that kind of a pattern, and our target is going around like this (indicating).

(Slide.)

In terms of the big picture, our target in orbit takes about an hour-and-a-half to go around. The launch pad where our men are takes about 24 hours to go around the Earth -- it is going with the Earth -- to go around this point. If we could mark it in space, go around, back, come back around, it takes 24 hours.

For an orbital range such as this one arranged, there are two times when we can conveniently get into the plane of our target, this time and this time (indicating).

I have mentioned that it is very expensive of fuel to fly out of plane, to go up and down, and so the choice that we are practically driven to is that we must launch at such time as our spacecraft on the pad comes into or near that plane of the target.

This imposes the second very important constraint on a rendezvous problem. I mentioned the catch-up business. If you will bear in mind that one of the other constraints has to do with the fact that the launch pad is moving with the Earth, makes a complete circuit once per day, the target is in another kind of path, taking about an hour-and-a-half to make its trip.

If you turn to the ugly side of my model, this is approximately the situation I have depicted. If we lower this somewhat, you see that the two points come very close together, and finally there is a time where there is only one point in the target orbit where the launch pad touches it.

QUESTION: That is per day?

HAMMERSMITH: Per day. And if we go to the extreme case, there is no time. That is, for a pad located as our pads are.

(Slide.)

All Gemini rendezvous missions are arranged in such a manner that the target vehicle is arranged in approximately this position. There are all kinds of games played to give us every last second or minute of launch window time so that this is not arranged exactly so.

Mr. Aller will talk about some of those things that we do. They include such things as steering the launch vehicle as it is launched, of providing some plane change capability to the spacecraft, and you can also play some games with the Agena spacecraft, one of which I mentioned to you.

(Slide.)

Now I would like to talk a minute about the launch azimuth problem. You will hear the term "variable launch" azimuth. If the target is in an orbit such as this, and is on the descending portion of its trip as it comes over the Cape, then we will launch in a southeasterly direction.

(Slide.)

If we happen to be on the other side and it is convenient to launch when the target will be on the ascending portion of its trip, then we will launch in a northeasterly direction.

(Slide.)

And a launch azimuth is simply the angle between true north, measured at the Cape in the horizontal, and the direction in which we actually fly out. Azimuth is actually a general term. Converted into other contexts, it may be measured in other directions than north. For us it is north.

(Slide.)

Let's go back to this. I would like to talk a moment about how we get these odd traces that are on the maps that you are handed out. Have all of you seen these maps with the orbit traces? I am sure all of you have.

That is caused again by the fact that the Earth turns underneath the orbit while the orbit remains relatively fixed in space. For example, if we assume that this line is drawn here as the spacecraft comes over, as it goes around back the Earth will turn and we can draw another line like this, but it will be somewhat behind. Let me illustrate that over here.

Can you all see that bullseye? Let us say we have a pencil extending from the spacecraft to Earth, and we are going to draw a line around the globe as it goes around. As we are drawing that line, the Earth is turning slightly, and I am going to exaggerate this now, come back around, and we have come back behind our launching point, just due to the simple fact that the Earth turned; the plane of the orbit did not.

If you are a mapmaker and you have to get that odd thing onto a flat sheet of paper, you get this kind of picture.

(Slide.)

If you took off in this manner, came back around, by the time you came back these lines represent -- these lines -- the fixed position of the plane of the spacecraft, and the fact that they are separated represents the amount that the Earth has turned underneath and the time it takes to go around and back.

A related problem that has been causing a lot of trouble, and in this case the news media are not alone, it has caused us a lot of confusion because we are beginning to run out of words for all these concepts. I mentioned that the period of the orbit is the time it takes to go from perigee to perigee. It can be reckoned in other ways.

Let's take that, 360 degrees around, from perigee to perigee. Let's call that the orbital period. That is very convenient as long as you are in space. But we require, our tracking network requires, our recovery forces require, a system of reckoning that is tied to the Earth. And this problem of the Earth rotating underneath, and of us keying in much of our work to the Earth's surface, has led us to another type of period in a way, and it is the meridian line at the Cape, as it goes through the Cape.

I think I can explain this best using this globe. Let's take our meridian line at the Cape. Our orbit is somewhat flatter. And let's say that the bracket here is our measuring point in space.

It will not change. Our target vehicle goes around once and that is the orbital period. However, the Earth has turned a small amount and if we are counting revolutions as measured along this meridian line, then it will take us a little bit longer, about six minutes longer, as a matter of fact, to get to that meridian line.

To save confusion we have been calling that a revolution. So we have an orbital period and a period of revolution. When you hear the term "revolution" -- and this is the common one that we use; some of us may slip and say "orbit" -- the normal thing that is released to the press is that period, the period of revolution, the time to go from meridian line through the Cape and back to it.

May I have the lights, please?

I have one other thing by request. This came up too late to make a slide. The term "Delta V", we all use it when we discuss these maneuvers. This symbol Delta is the Greek letter Delta which has been used in the mathematics of differences, to mean a difference, to mean an increment or to mean a decrement. The "V" stands for velocity.

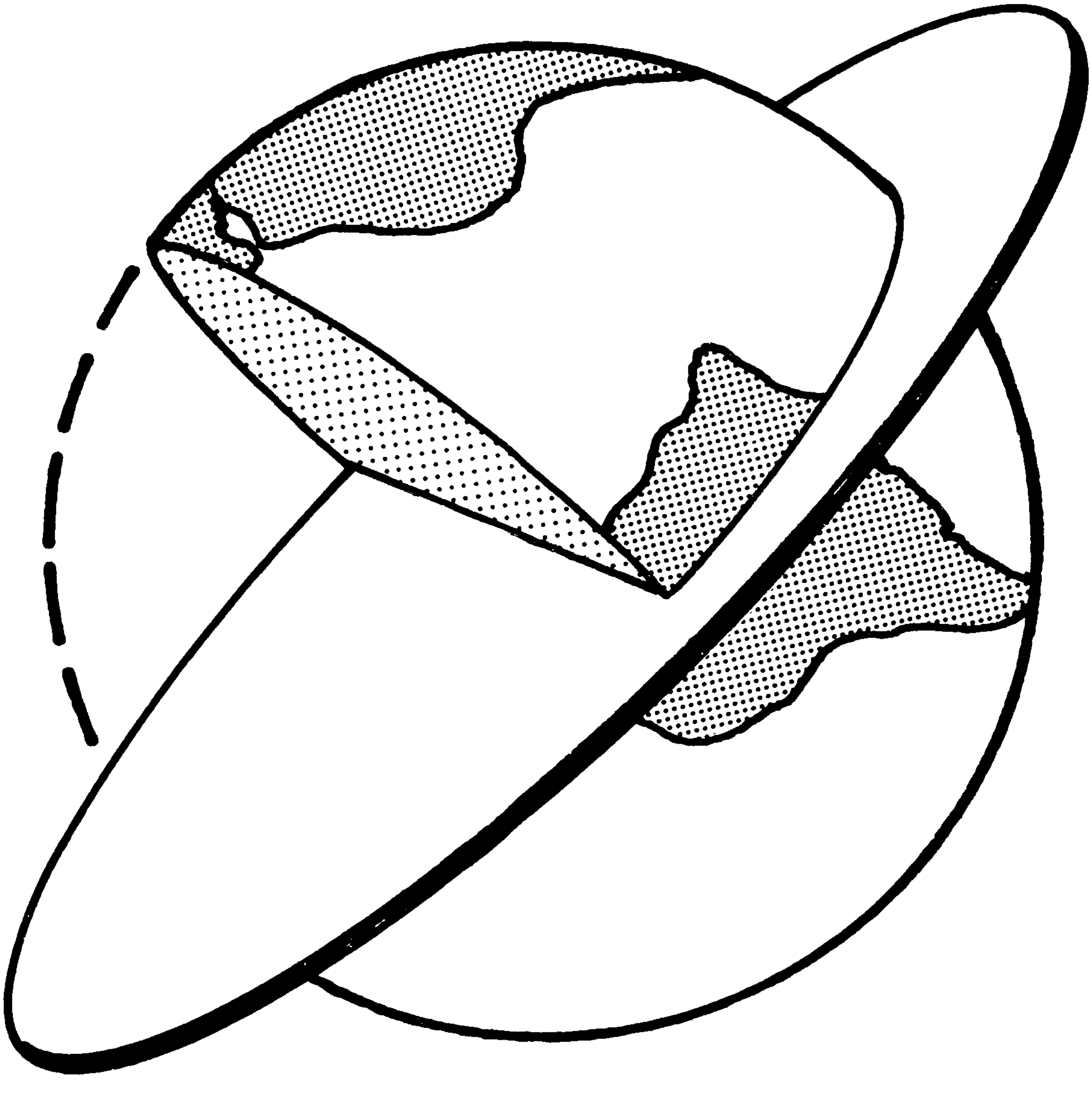
It turns out when we make these kinds of maneuvers or when we study what kinds of maneuvers to make, we find it has become convenient to speak in terms of the change in velocity that is required, the change of velocity that is required for the maneuver.

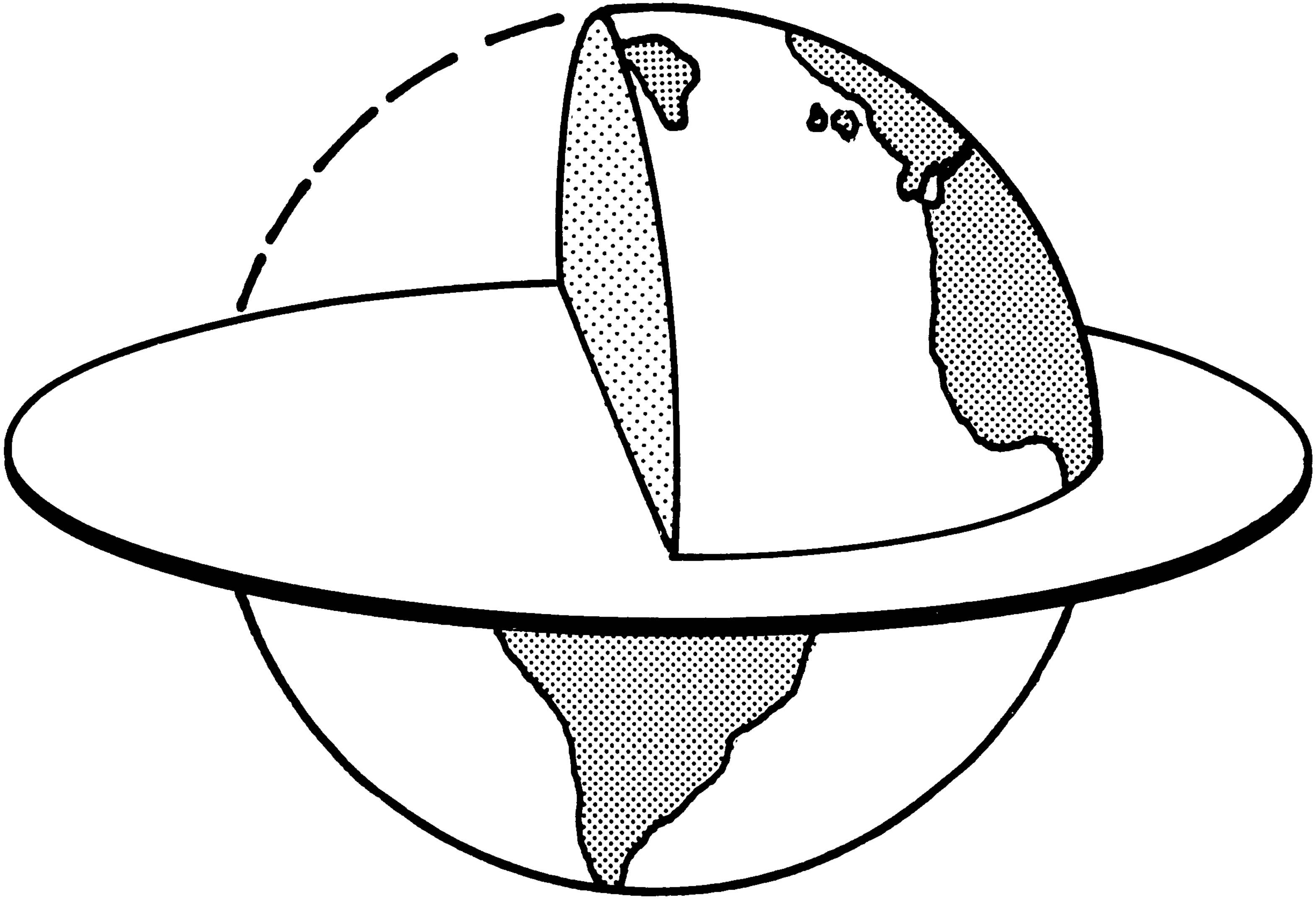
This do-sn't always mean that you will always be able to see a change in velocity; rather, it is a measure of the energy that must be put into this situation by way of the spacecraft thrusters to execute the maneuver.

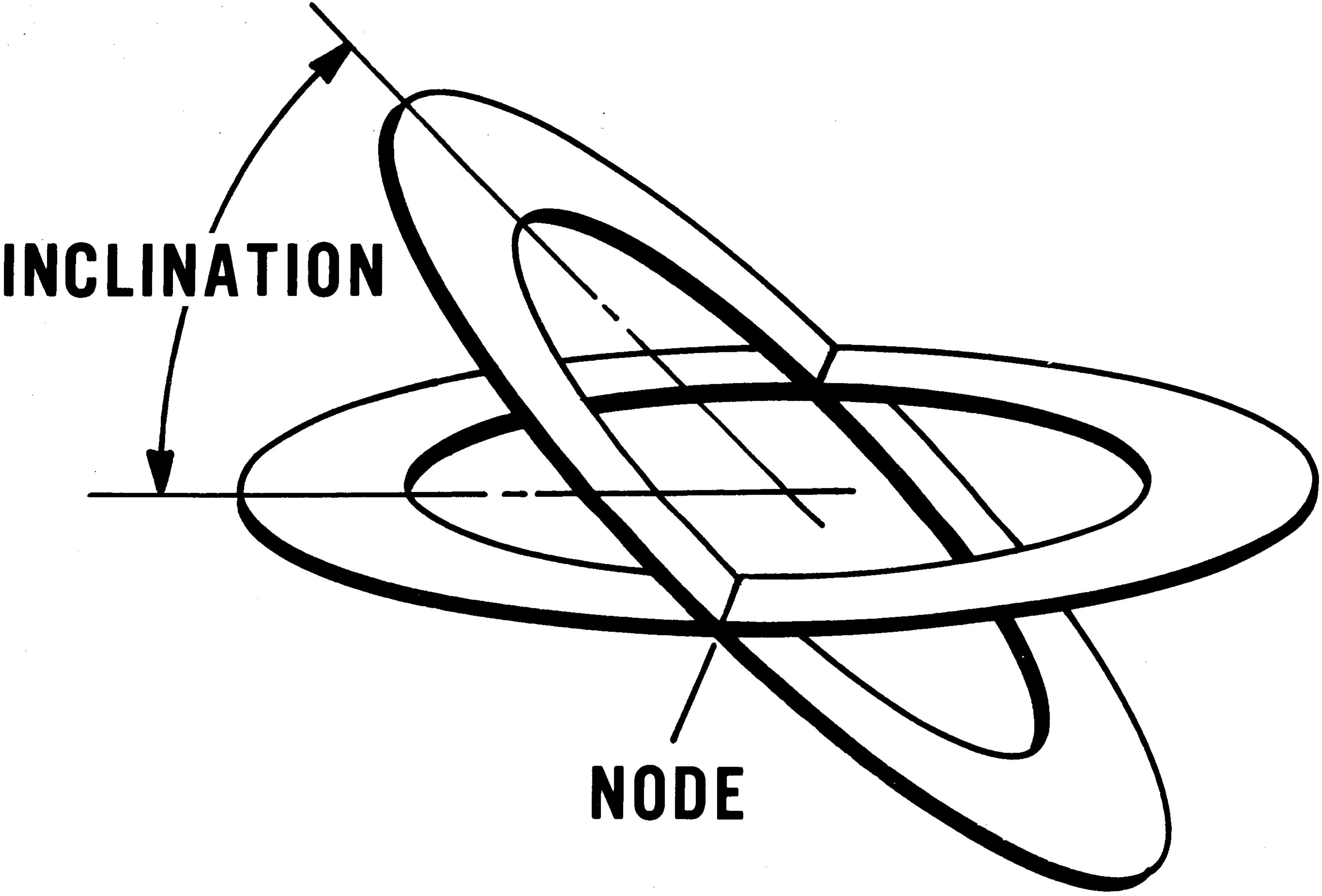
A related concept is the Delta V or the energy potential of the stage, or a spacecraft, and again we use the term Delta V to express the energy capability, and in a sense Delta V is almost saying how many gallons of fuel you have in your gas tank. Except that it is related to the weight of the vehicle. And if as you use up fuel you change the weight of your spacecraft radically, then it is Delta V, the Delta V potential of the remaining fuel changes.

That is about where I thought I would shut off. I hope that I have given you a reasonable, adequate rundown of some of the basic terms, some of the basic concepts.

I would like now to turn the microphone over to Mr. Robert Aller, who will discuss the Gemini 6 mission, the first Gemini rendezvous, and will put some specifics on some of these concepts and will tell you how we have attacked some of these problems in the Gemini 6 mission specifically.



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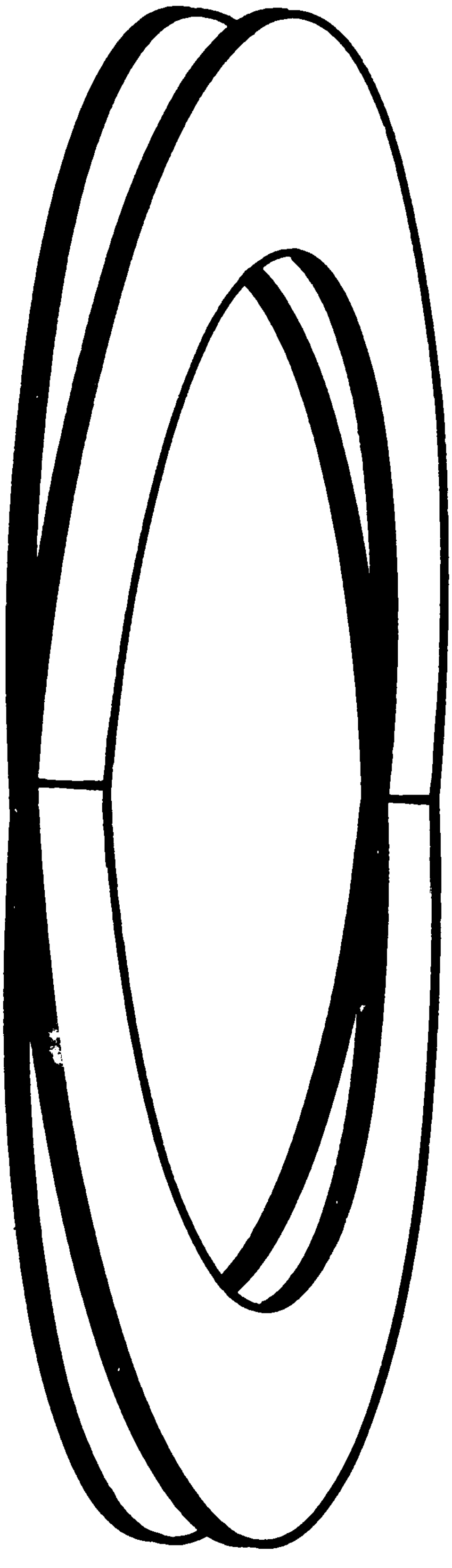

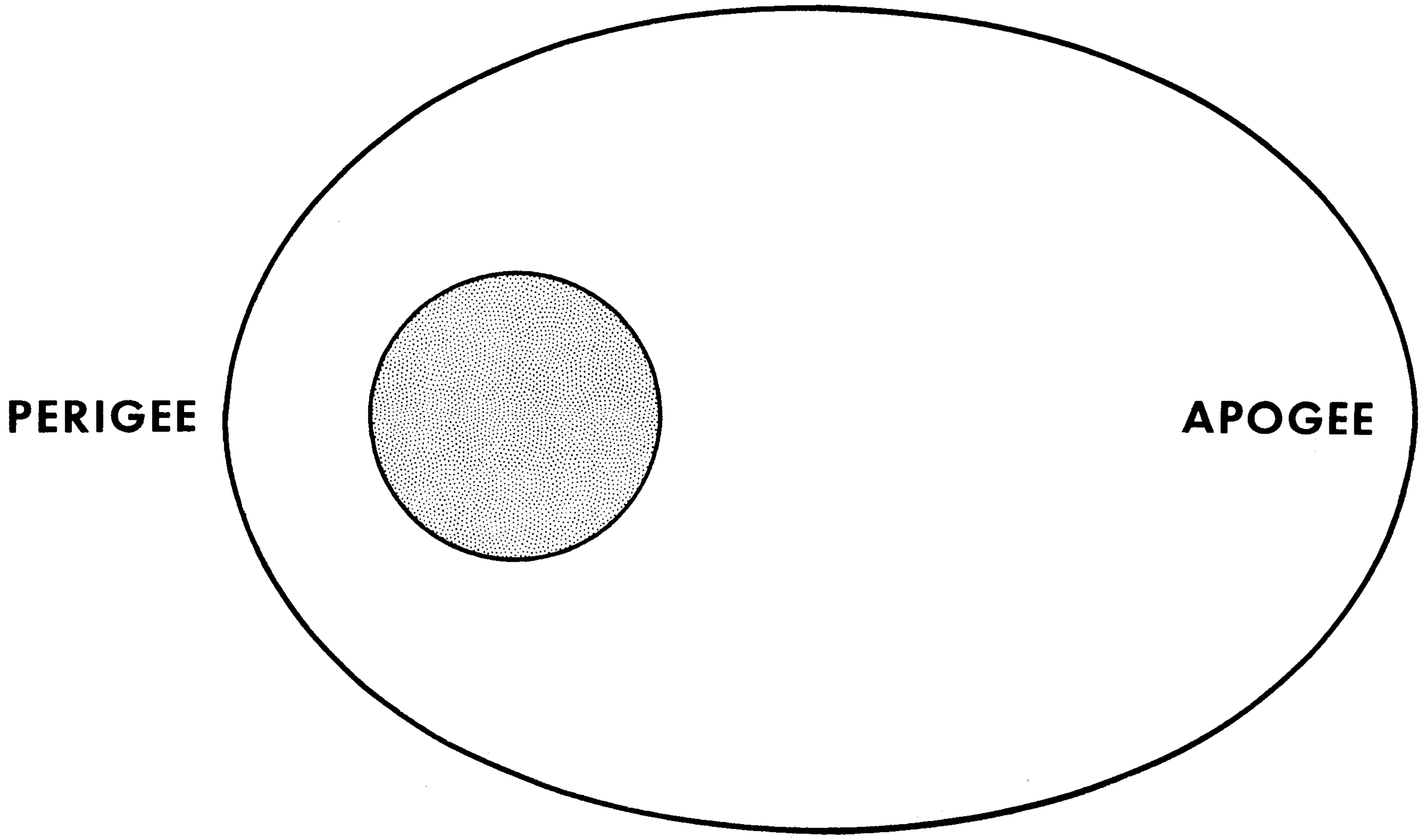
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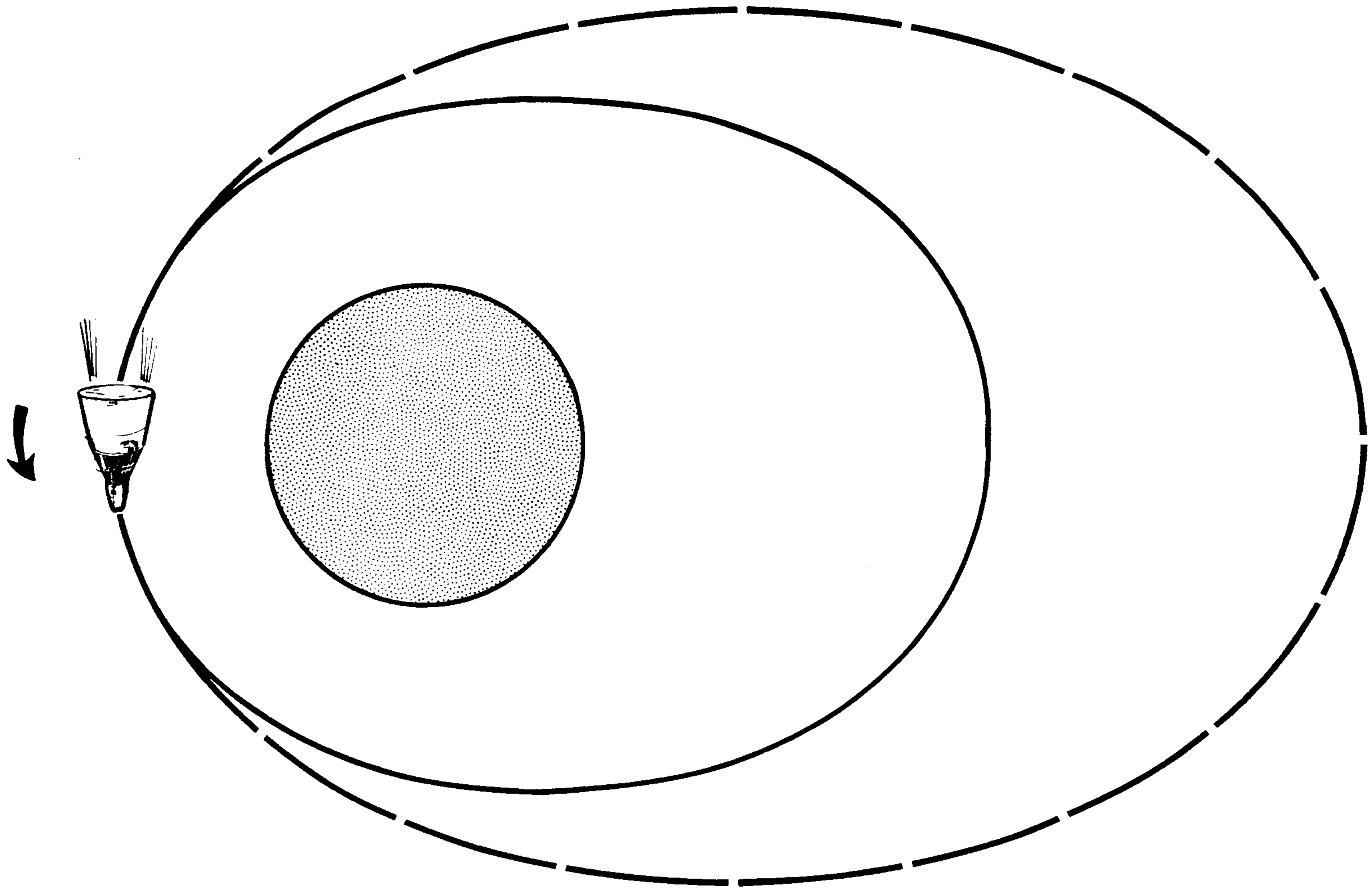
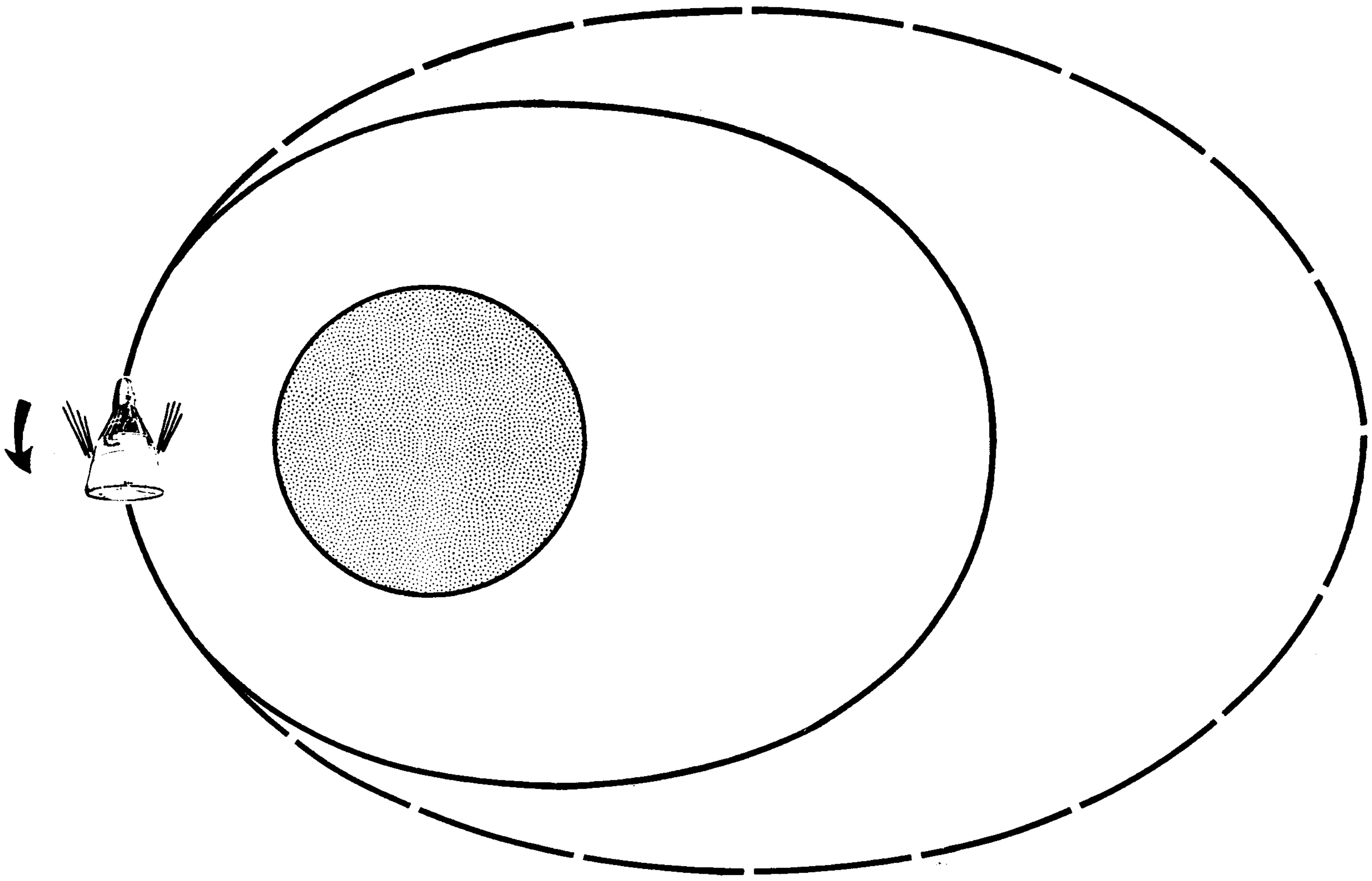


AFT-FIRING, POSIGRADE



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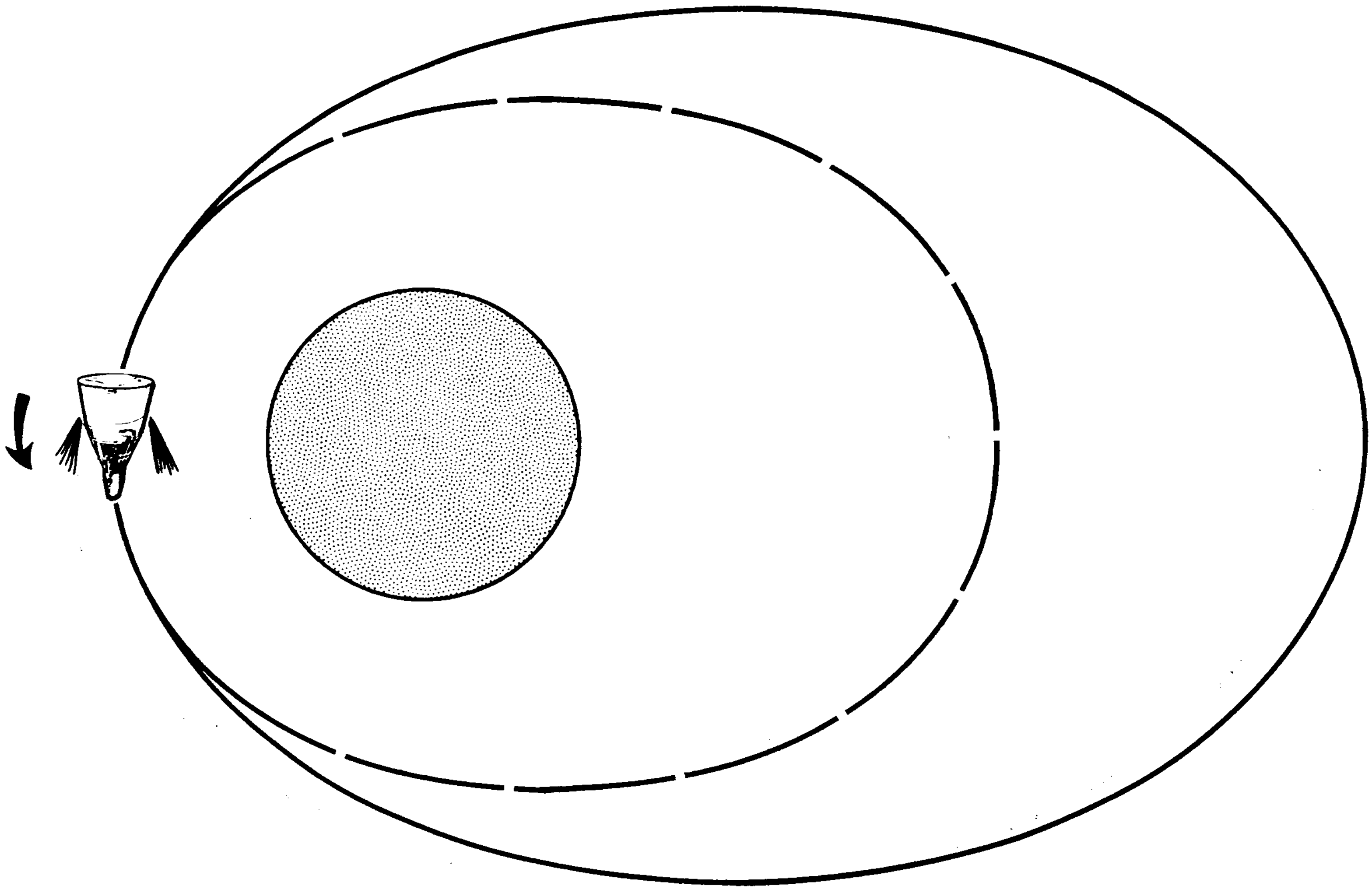

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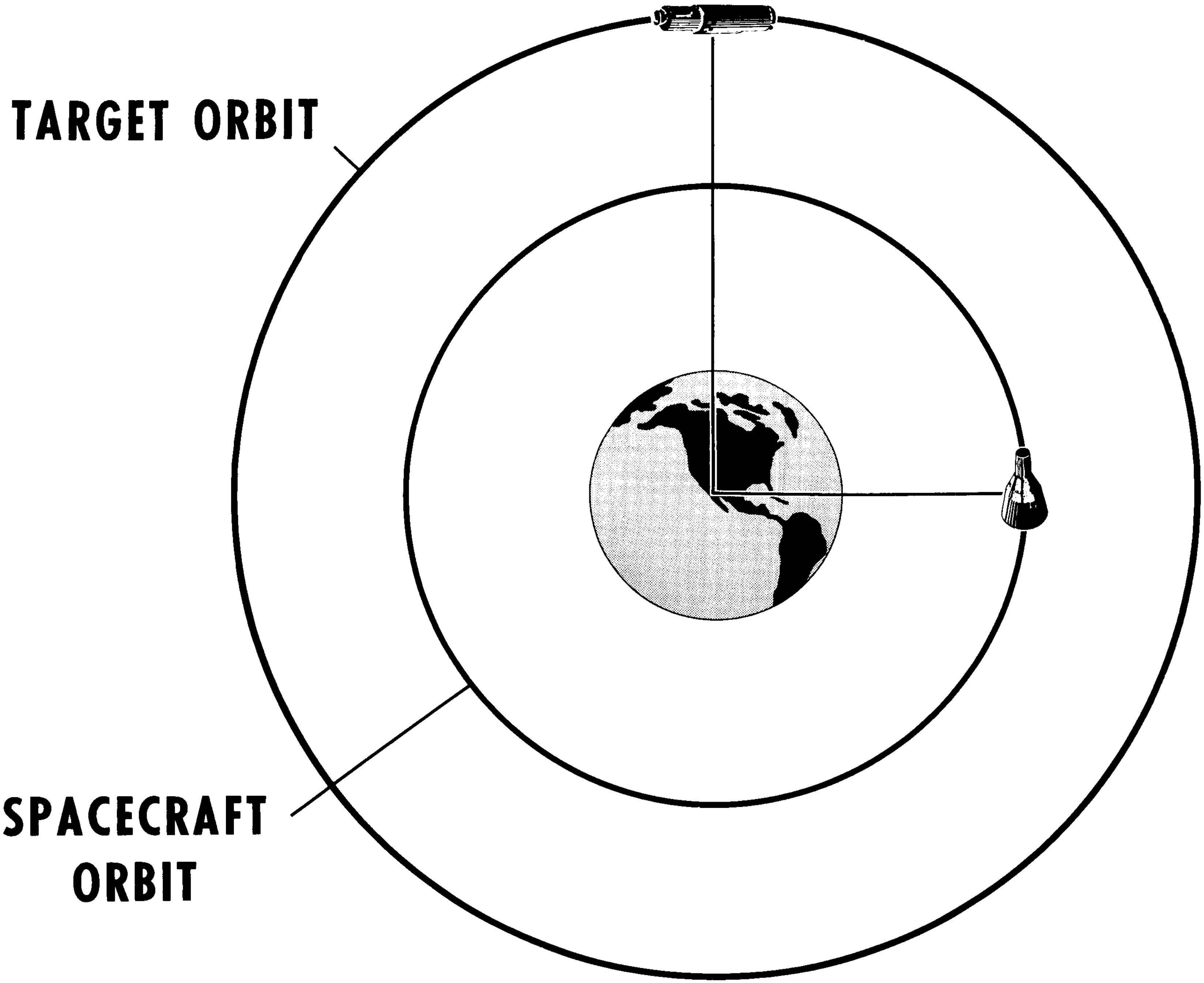
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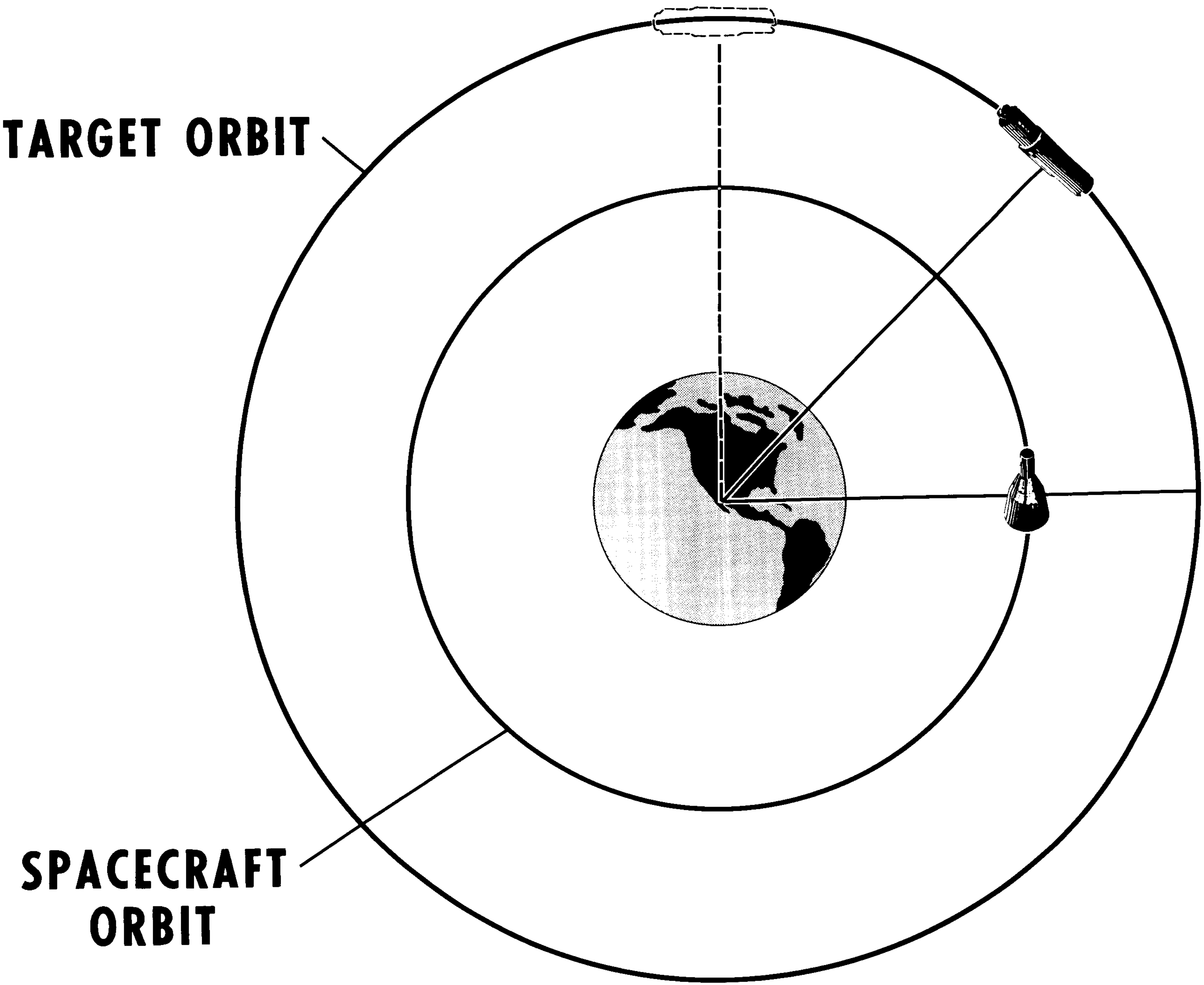
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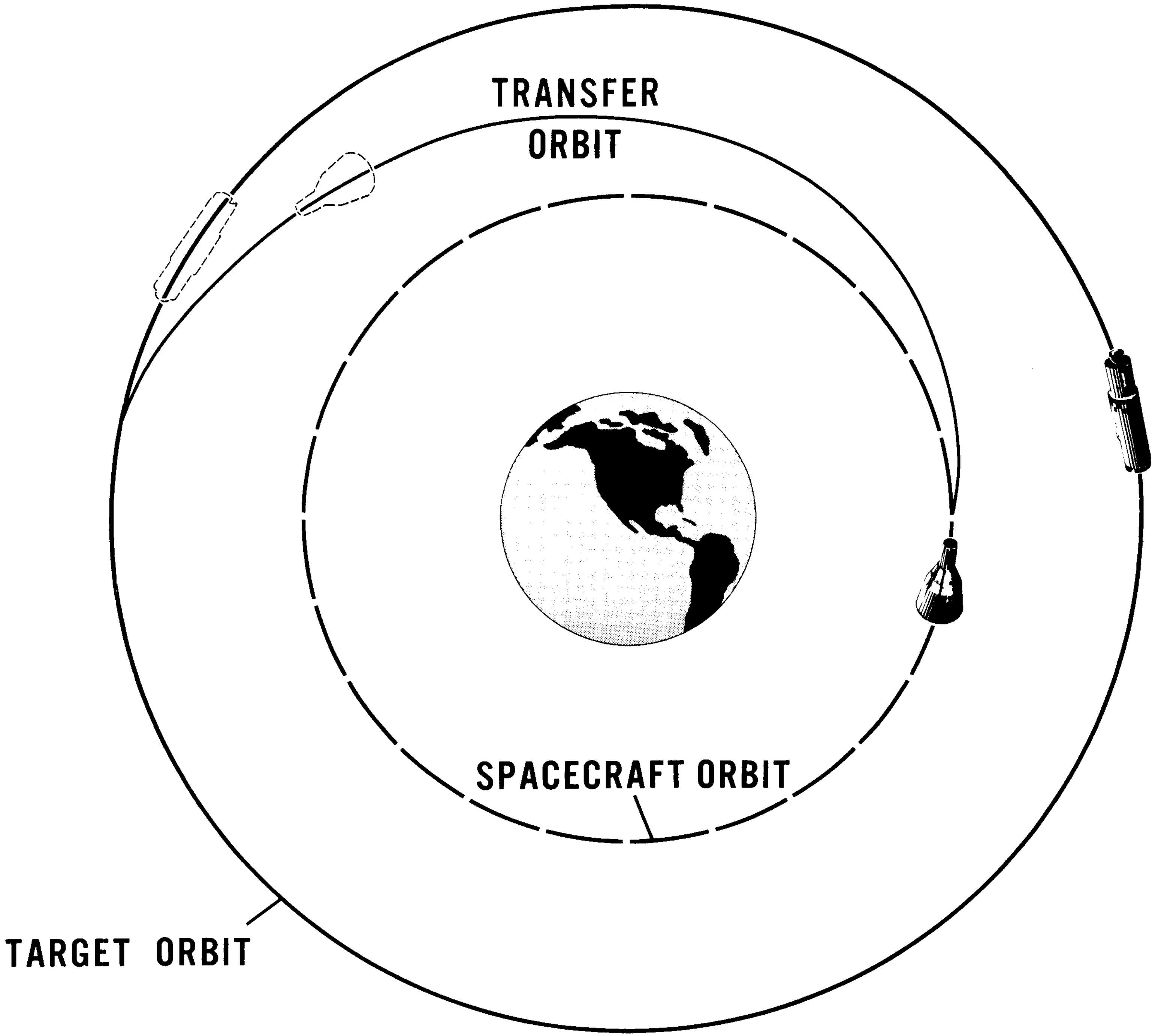
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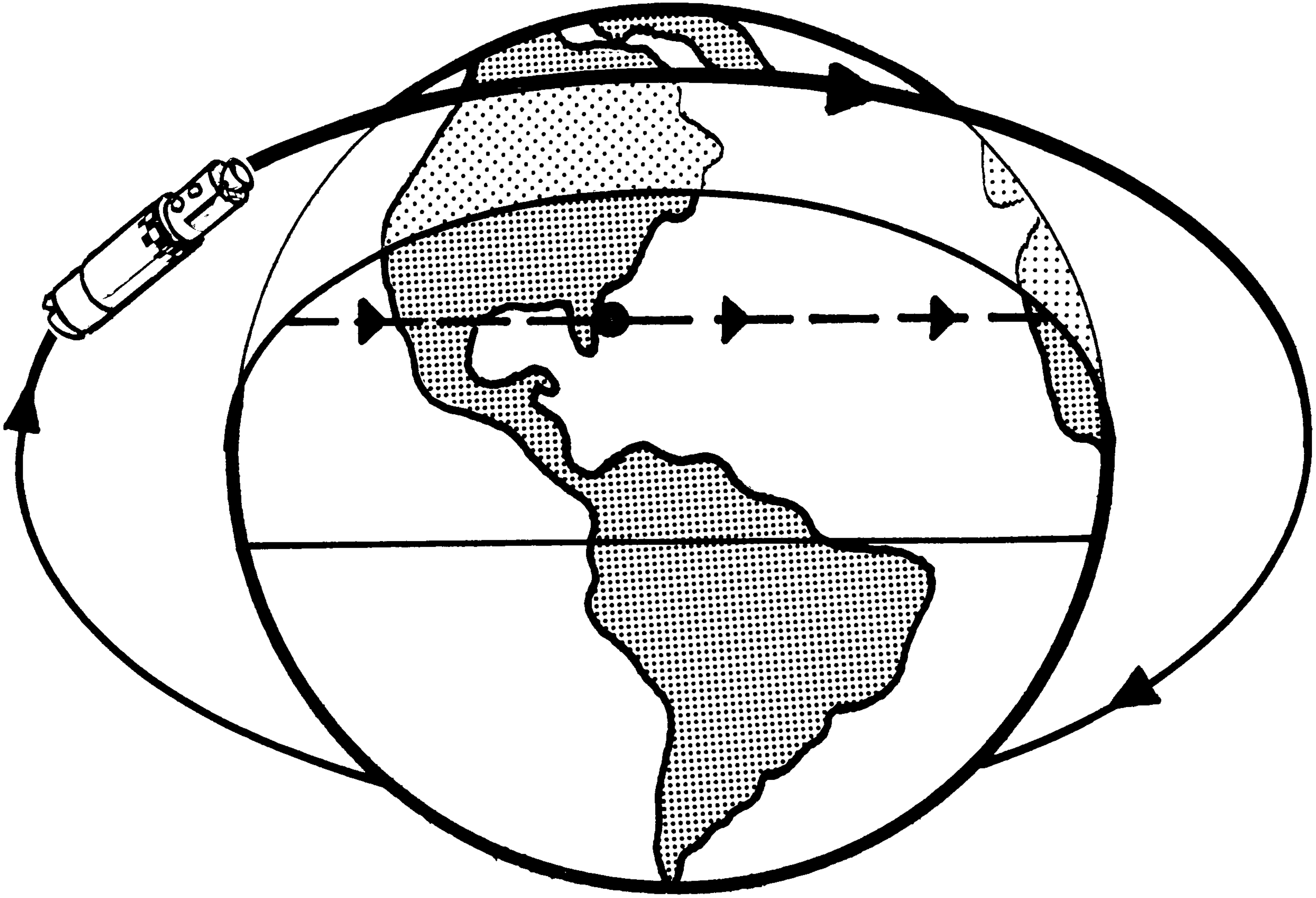

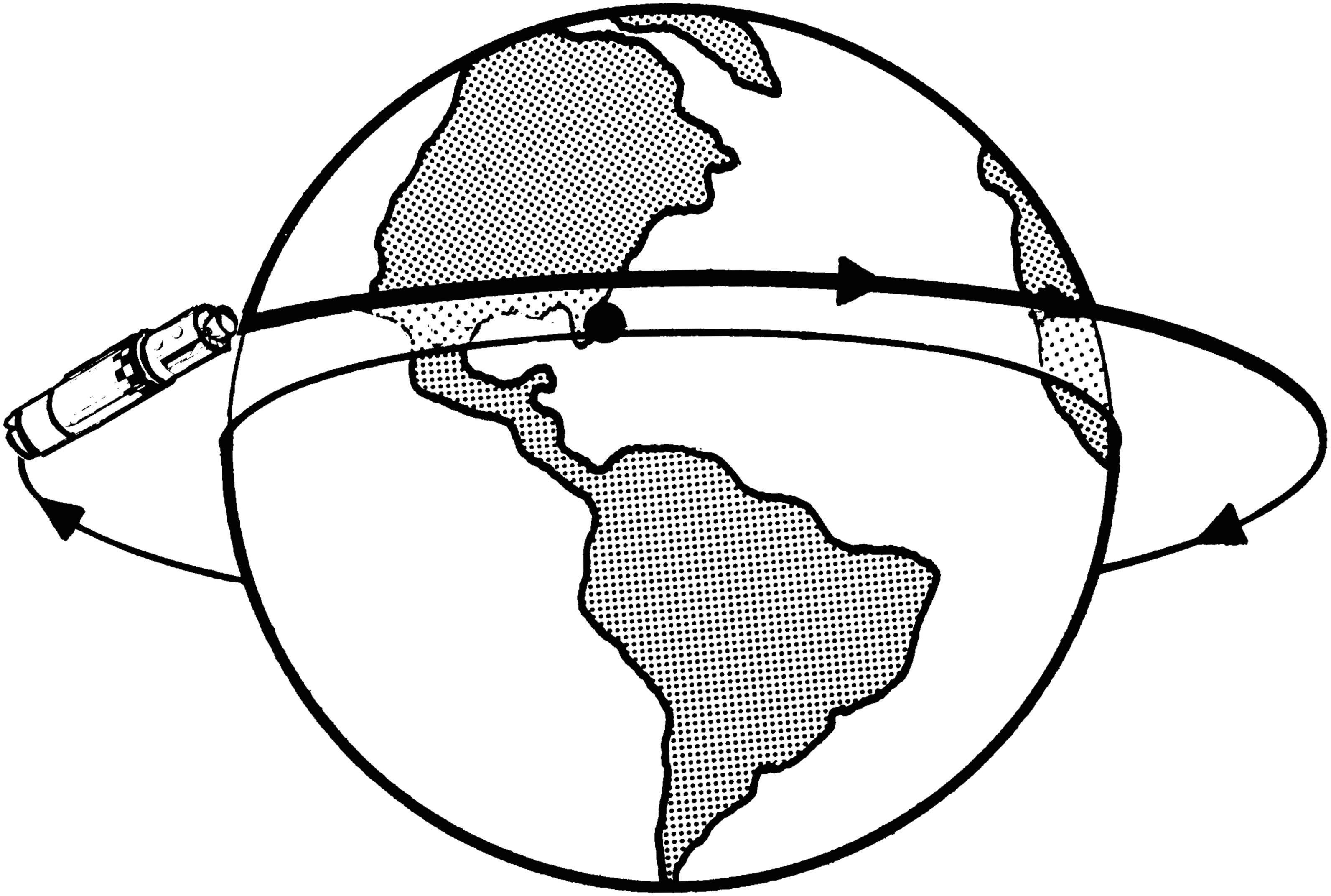

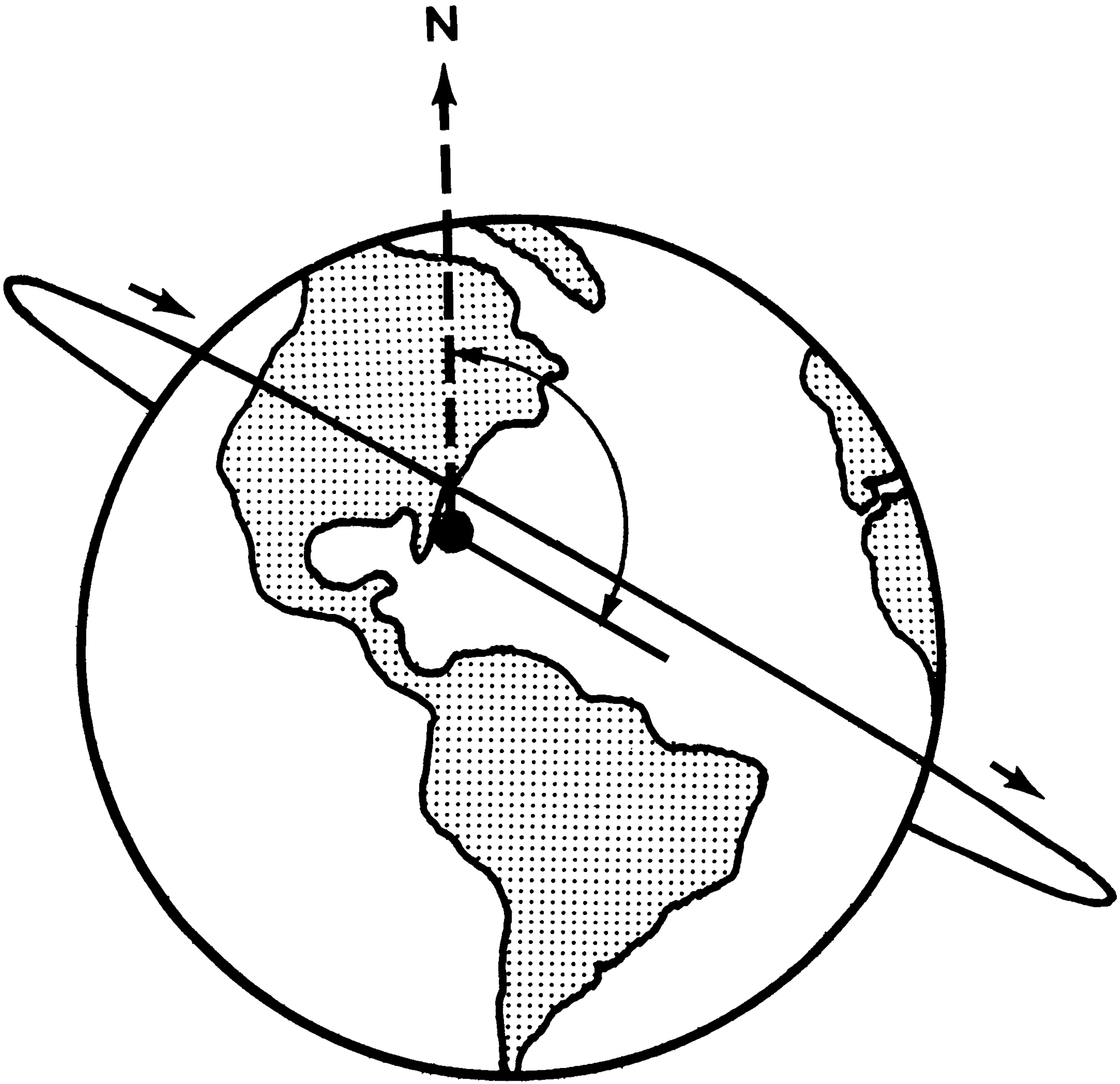
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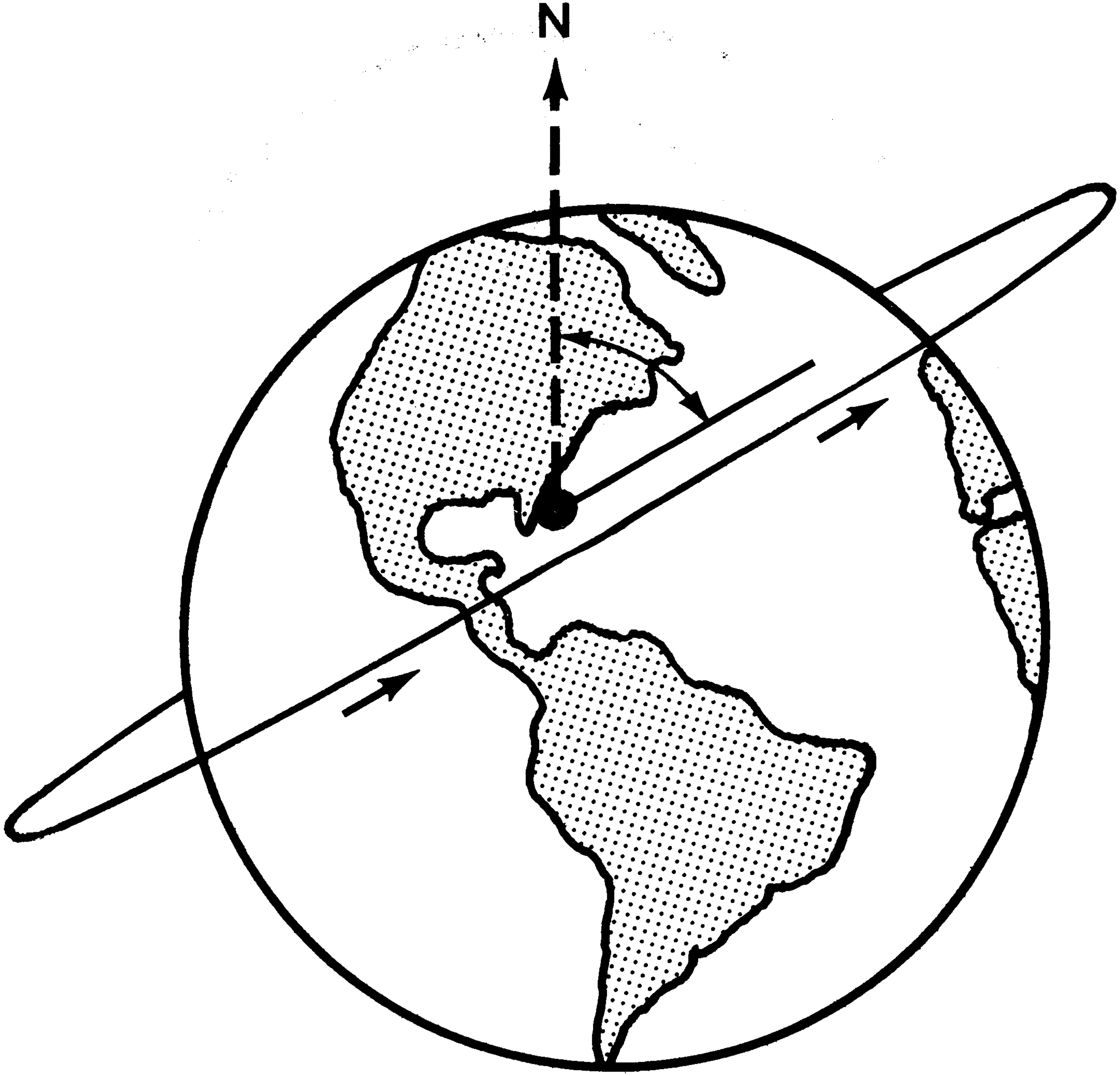

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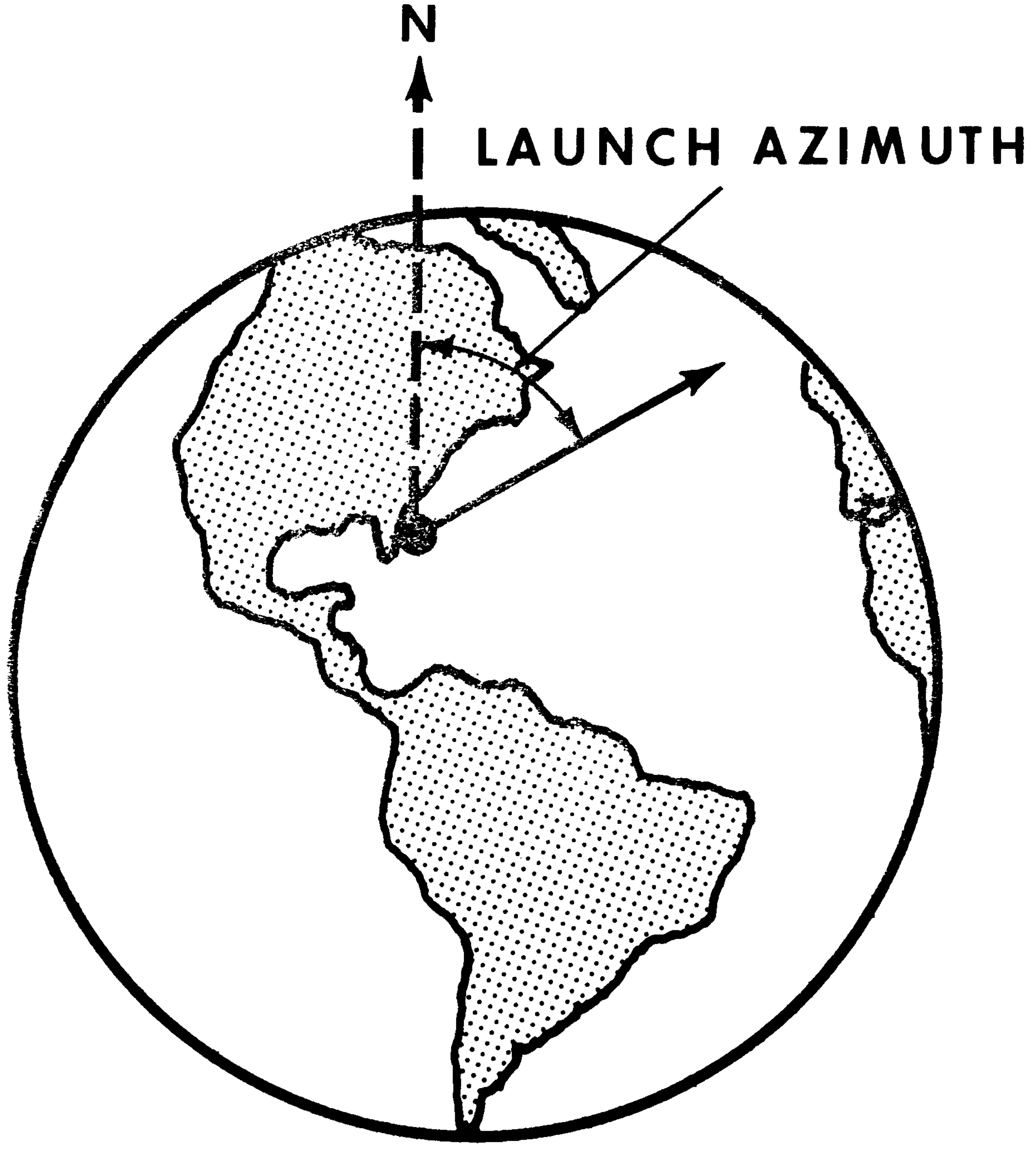
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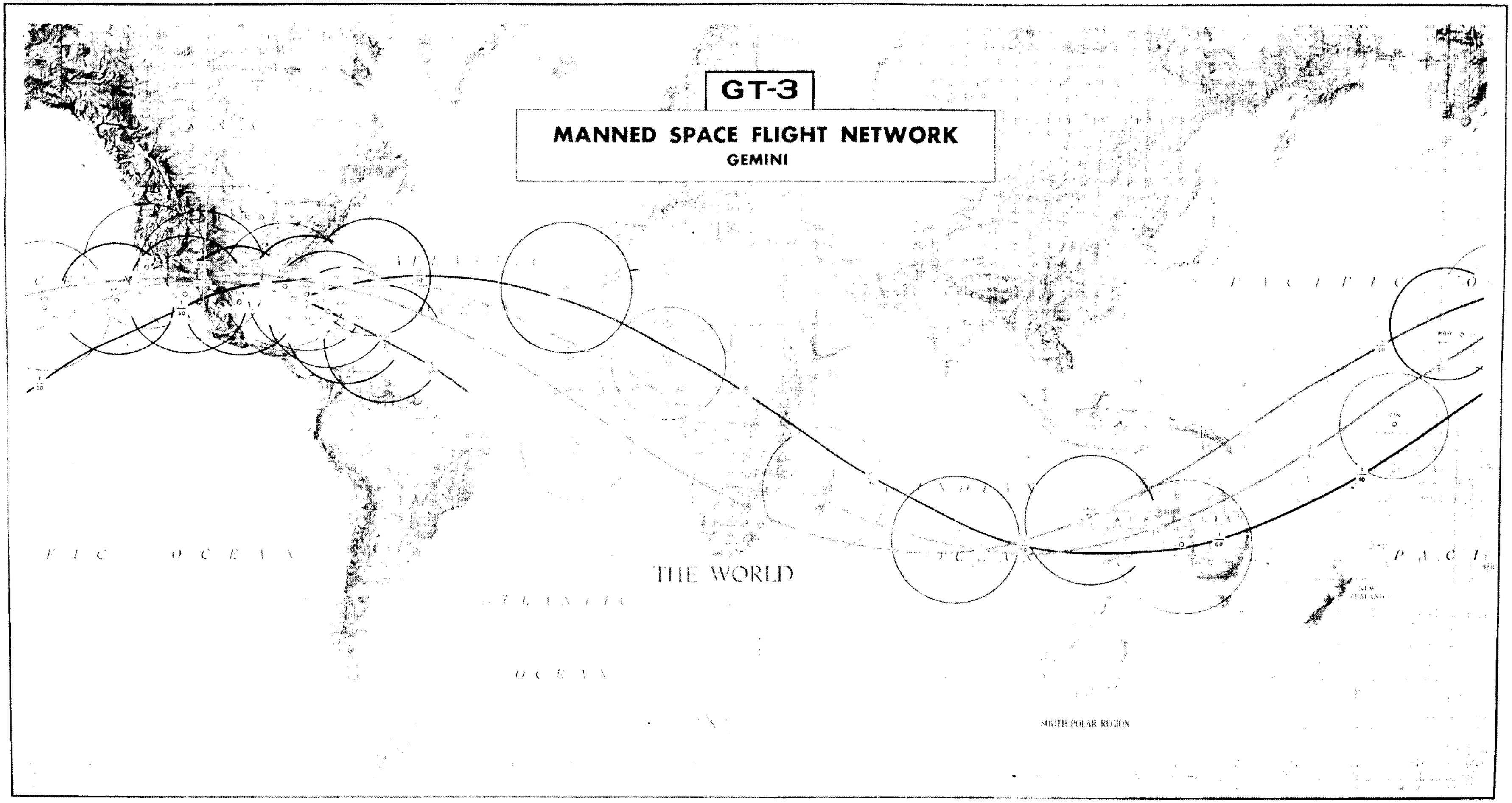
LAUNCH AZIMUTH

GT-3

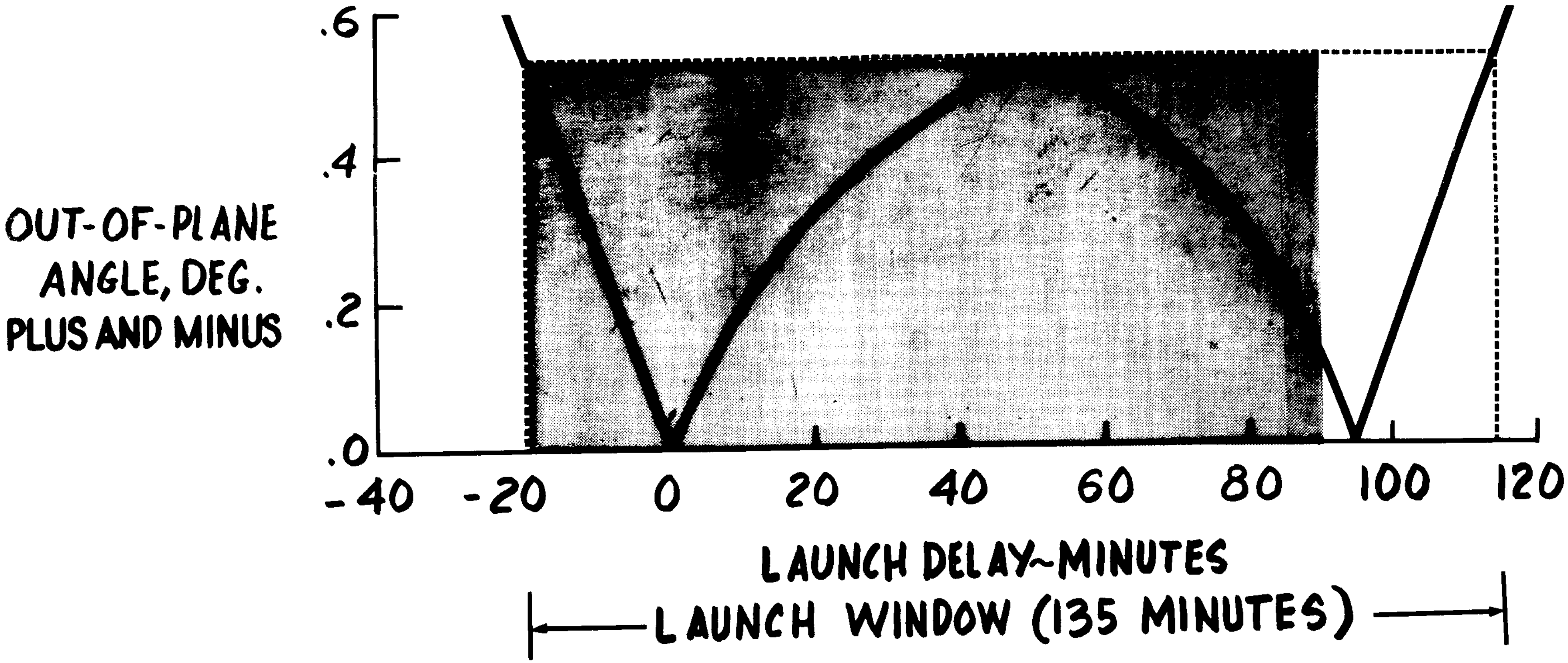
MANNED SPACE FLIGHT NETWORK

GEMINI

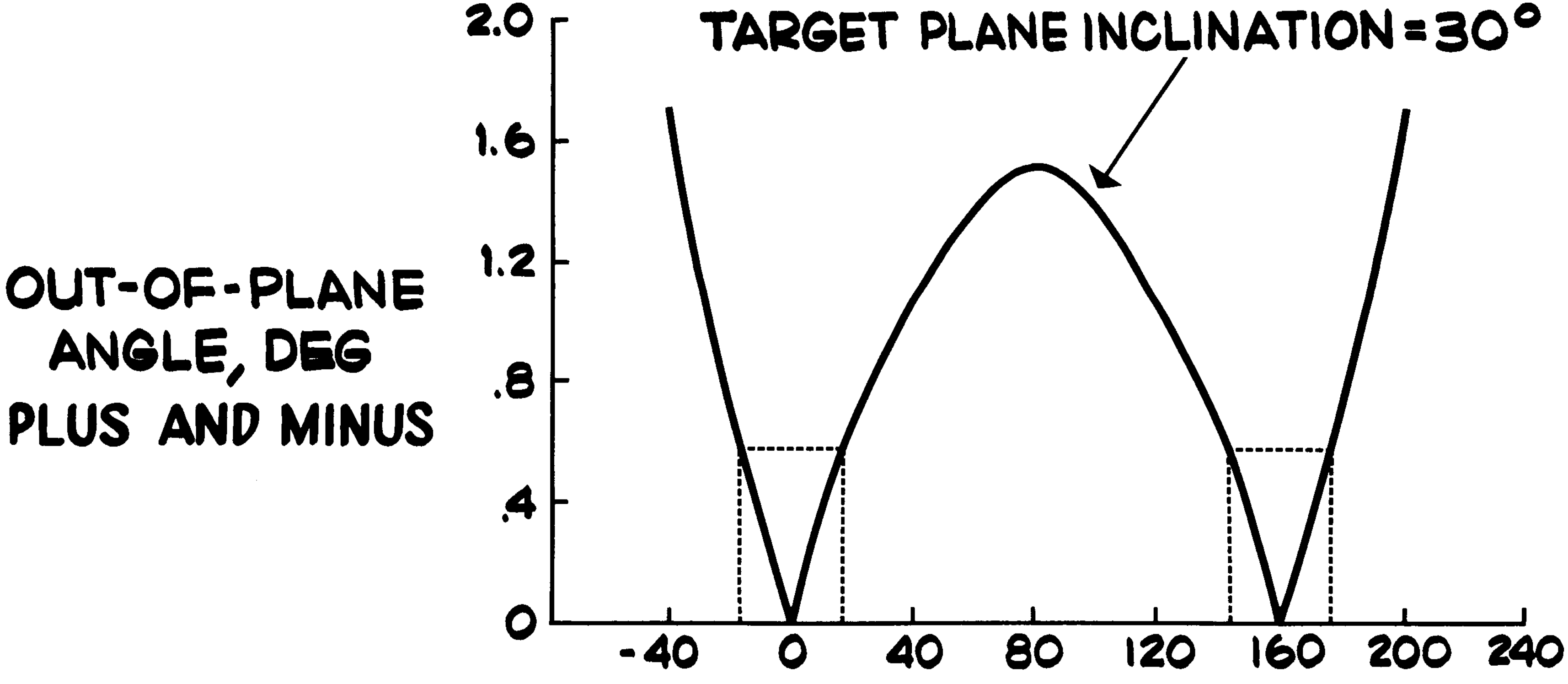


GEMINI PLANE WINDOW

TARGET ORBIT INCLINATION = 28.87°
TARGET ORBIT ALTITUDE = 160 N.M.



PLANE LAUNCH WINDOW VARIATION WITH TARGET PLANE INCLINATION

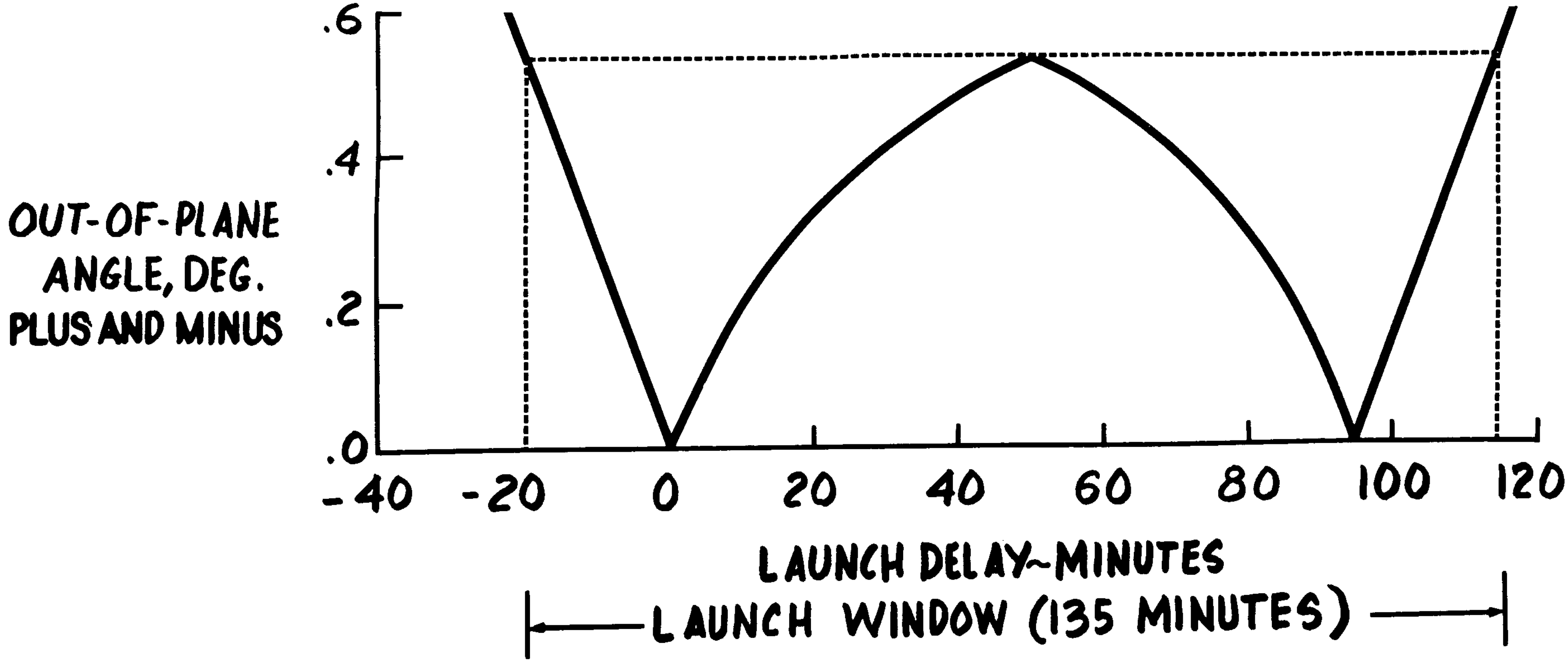


TWO PLANE WINDOWS OF 37 MIN DURATION EACH

GEMINI PLANE WINDOW

TARGET ORBIT INCLINATION = 28.87°

TARGET ORBIT ALTITUDE = 160 N.M.



ALLER: I always appreciate these comments from my boss.

What John Hammersmith has defined for you here, or described for you, I think is what we intended to do. I have heard the comments from the press; the rendezvous is a difficult mission, we are told. What we are trying to do today is to describe to you why we feel it is difficult. My portion of the presentation, hopefully, will describe how we hope to overcome some of the constraints, primarily the time constraints of a rendezvous in space.

The major problems we have, of course, as John described them, are the phase problem and the plane problem. The phase problem is the proper relationship of the spacecraft with the target vehicle. And the plane problem, of course, is being in the plane of the target vehicle.

What we will talk about with the time consraint that we do have is pretty much the nominal mission. I would like for all of you to understand that with the dispersion we anticipate, we do anticipate some dissipation from the nominal.

QUESTION: Will you define what you mean by dispersion?

ALLER: Yes, sir. A dispersion, we speak in terms of probability on dispersions. I guess simply I can say that the systems are built within certain specifications. Each system within a booster, each system within the spacecraft, has certain tolerances, and as long as they remain within these tolerances we feel they are meeting their spec. However, when we combine these tolerances together we can come up with a dispersion. And a dispersion might mean so much velocity off at insertion, so much flight path angle, or the direction in relation to local horizontal, so much dispersion in altitude at insertion, or at one of our maneuvers.

QUESTION: It is a departure of some sort is what you want?

ALLER: From the nominal, that is correct. And we anticipate this and expect this.

I might point out, we have it on every mission. We have nominally several thousand feet off at insertion -- two and three thousand feet; a few feet off at delta V. These are within specifications of the systems.

So we will be talking about the nominal mission. I will run through briefly what I hope to cover. I will go a little bit into mission design and criteria for this particular mission, a criterion by which we selected the profile we have come up with. Then I will talk in some detail about the launch phase, what I have defined as the mid-rendezvous phase or the mid portion of the mission, and then the terminal rendezvous phase, touch briefly on the crew backup procedures that we have developed, and then just wrap up the mission for the remainder of the two-day flight.

(Slide.)

Our design criteria for a successful rendezvous isn't as obvious as it may appear at first. We could have had various criteria. We could have had energy criteria, a time criteria, the amount of fuel we want to use. We could have constrained the point at which we hope to rendezvous. For instance, we could have attempted to rendezvous at first apogee, or on the first orbit. However, because this is the first go-around and we do realize it is a most difficult feat, we have hopefully designed the mission around a high probability criterion.

A high probability, as indicated, is flexibility. Flexibility means that we can deviate from the nominal and still perform a successful mission with the least amount of complexity.

The dispersions I have gone through very briefly, we feel the profiles we have generated allow reasonable dispersions and allow our overcoming these dispersions with the spacecraft systems and launch vehicle systems, et cetera.

Terminal phase is the final portion of the mission. I had better not say the most critical portion. A most critical portion of the mission. We hope to define a mission or a profile of a mission that would allow us a standard type terminal phase. In other words, anyplace that we initiated our final transfer, regardless of dispersions, we would have a standard maneuver for the astronauts to perform, and we have come up with this.

Finally, we wanted a rendezvous that we could provide backup to, backup coming from the astronauts themselves with some on-board calculations and comparisons. The profile that I will describe provides this capability.

I will touch briefly on the types of rendezvous missions.

(Slide.)

Of course, there are innumerable types available. The ones that we concentrated on, as I have indicated here, are the tangential rendezvous at first apogee, and what we term the coelliptical. Very briefly, the tangential type of rendezvous is simply launching the spacecraft into an orbit that is tangent to the target orbit at some point.

This is the Earth target orbit. This is the Agena going around the Earth. The tangential type of rendezvous would be launching directly into this type of orbit (indicating). We are tangent at one point and that would be the rendezvous point eventually.

The second one, the rendezvous at first apogee, is to time your launch so that you could rendezvous the first time you arrive at this point. It is very constraining in fuel, on-board fuel capability. It allows very little flexibility in maneuvering as does the normal tangential.

The coelliptical maneuver is the one we have concentrated on and the one we will fly for Gemini 6. Coelliptical, as described by Mr. Hammersmith, we launch into an orbit that is inside the target orbit. It is coelliptical to the target orbit.

Touching briefly on the final statement, say day versus consecutive day launches, we studied briefly the type of mission where we would launch the Agena one day and then launch the spacecraft on the following day, and we very quickly found that our probability of a successful mission, our prime criteria, was higher if we would count down both vehicles simultaneously. The purpose I think, or the reason, the rationale behind this, is fairly obvious. The countdown is a very critical portion of the mission. If we reach any hold while we are counting down the Agena, we can call the same type of hold on the spacecraft, and we can hold the spacecraft until the Agena is ready, or vice versa. And then when we launch the Agena, only ninety minutes or one hundred millutes before we launch the spacecraft, we have just that Delta T in time, or that time lapse in which we need to make up for any problem on the Agena launch or any hold in the spacecraft.

I will touch very briefly on the mission itself. I would like to add that my little pitch here will be summarized with a nine-minute movie that I think will give you a pretty good idea of what the mission looks like, the nominal mission. We are going to launch on the 25th at 1000 Eastern Standard Time the Atlas-Agena.

At 1141 Eastern Standard Time we launch the Gemini-Titan, about 100 minutes later.

We will effect the rendezvous about five hours and forty minutes after spacecraft launch at 1721 Eastern Standard Time on the 25th.

At 0600 on the 26th we plan to separate from the Agena. That is about eighteen hours into the mission.

At 0950 on the 27th, the second day, we will retrofire and we will land at 1027 in the Eastern Atlantic. That is on the 30th revolution, approximately 46 hours and 40 minutes after liftoff.

QUESTION: Will you give those hours again, please?

ALLER: Starting with which one?

QUESTION: All of them.

ALLER: Could I hold this until our question and answer -- well, if it is convenient now, I will go through it again.

1000 EST, Atlas-Agena.

1141 EST, Gemini-Titan.

1721 EST, rendezvous and dock.

0600, separate from the Agena. This is on the 26th.

0950 on the 27th, retrofire. And 1027, landing.

Because you are jotting these down I will emphasize, this is a real-time mission. And we plan to fly it in real time. That is why one of our criteria is flexibility. As you know, any of you who followed the Gemini 5 mission, we do a lot of planning in real time to allow for any problems or dispersion. These times are the ultimate or the nominal times.

If I may, I will launch into the launch window, or launch phase, to more correctly say.

(Slide.)

Again let me emphasize the two major problems we are trying to solve in rendezvous is plane and phase. One of the most critical times we can solve this problem is at the instant of launch.

There are several techniques we could employ to solve this problem: In the on-time launch, a variable azimuth launch -- what we call yaw steering of the Atlas-Agena and the Gemini-Titan -- and the on-board spacecraft and Agena capabilities. As I get into it you will see that we are using all of these capabilities to solve our problem and reduce somewhat the constraints of this critical launch time, critical orbit determination, critical orbit definition.

We feel we have taken maximum advantage of the spacecraft systems as well as the launch vehicle systems to enable us to do this. The desired condition we are looking for, as Mr. Hammersmith described, at launch of course, is to have the Agena -- very briefly we have launched the Agena about one hundred minutes earlier. We want the Agena to be back over the Cape properly placed, relationship-wise, phase-wise we call it, when we launch the Gemini, and in addition to that we want to be able to launch the Gemini into that plane. And it is a critically-timed operation.

This first chart -- I will apologize, but I think I can talk better from over here; for one reason, I can see it -- this first chart describes both Atlas yaw steering as well as Gemini-Titan yaw steering. I will go into the Agena first and try to describe why we are yaw-steering the Atlas-Agena.

You can ignore everything on this but the dotted orbit at this time and the solid orbit, and of course the Earth is rotating.

To solve the phase problem, we need to have an orbit with exactly the right period so that the period of the Agena when it traverses the Earth will come back and be right at the right place at the right time. We have other constraints, such as attitude limitations, drag limitations, et cetera, such that if we launched into this dotted orbit, which would be an orbit in which we had no yaw steering, this plane would pass over the Cape represented by this line at a time in which the spacecraft in that orbit would be improperly placed, which means the spacecraft would be not at the right place in relation to the Cape to launch the Gemini. In this case I think it would be ahead.

Therefore, if we can delay the time the spacecraft would be behind, it would be that far behind in this orbit at the time the launch pad came through that plane. Therefore, if we can delay the plane's passage over the Cape, we can effect a wider launch window. And to delay that passage of the plane we simply rotate the plane by doglegging or providing yaw steering, which effectively moves this plane four degrees to the east, and when the Earth rotates then, or when the spacecraft goes around the Earth, it has a longer period of time to pass over the Cape while the target vehicle is in the proper position in that orbit.

Effectively it works out to be about sixteen minutes of launch window yaw-steering the Atlas-Agena provides.

Another technique that is employed to provide a wider launch window is variable launch azimuth. Mr. Hammersmith described this briefly also, and I think it is fairly clear on this particular chart that at this point we are right in plane. That would be a perfect launch time. This would be a perfect launch time.

However, if we have a variable azimuth, we can parallel at least the plane at any point between here and here. At this point you can see we would be inserting just a little bit north of east. At this point we would be inserting a little bit south of east. And this is what a variable launch azimuth allows us to do.

Basically, as you know, the Gemini-Titan is launched and then it is rolled to its azimuth, and the azimuths we are using for Gemini 6 are from about 80° to 105°. We therefore have this flexibility to launch on any of these azimuths, and we use this flexibility.

The other thing --

QUESTION: How much would this widen the launch window?

ALLER: We don't put a figure on the launch azimuth to widen the launch window. You can't describe sixteen minutes here, nine minutes here, four minutes here, in relation to the azimuth itself. We can say that we have a 25-minute window on which, if we launch, we will require no spacecraft maneuvers, to put us in the plane of the Agena. However, if I may delay that just a little bit, when we get into the very complex picture, I must admit, of the launch window, I think you can see the relationship of azimuth and why you can't relate it to number of minutes available.

The other capability that we have utilized on 6 is yaw steering again, the Gemini-Titan when we launch. Previously I was talking about yaw steering of the Atlas-Agena. We

c8

are now talking about the Titan vehicle. This is shown right here in two examples. Whereas, if we launched at this point, if we had no yaw steering, we would go into a plane, depicted by the dotted line. By yaw steering or bending the Titan trajectory into the plane of the Agena, we can launch directly into the plane, even though our time is not the optimum. The optimum time for that launch would have been right here.

QUESTION: Why couldn't you have achieved the same orbit that you achieve with the yaw steering without yaw steering?

ALLER: You could. The yaw steering prevents us having to use either the Agena or the spacecraft to accomplish this. What we are trying to do by using Gemini -- Titan, I should say -- yaw steering, we are saving the fuel we have aboard the spacecraft for the critical maneuver, the mid-course maneuver and the terminal phase maneuver. We have some 636 feet per second available -- 670 feet per second available. We want to save this for once we are in orbit. Therefore, we use yaw steering.

We are out of plane here. The only way we can launch at this time and be in this plane is to steer into that plane. It is not correct to call it doglegging, but that effectively is what it is. You launch at one azimuth and then you bend around.

QUESTION: This is because of the physical location on Earth of your launch pad?

ALLER: You are very much constrained by your launch pad. You have to launch, your launch windows determine when you are relatively close to that particular orbit. When the launch pad comes under your orbit, this is your launch window. In this case, two hours and twenty minutes is represented in the first day from about here on. On the four consecutive days the window runs from about here to here (indicating).

QUESTION: What is the four degrees slewing east? What did you start with and what did you get?

c9

ALLER: That is what we call a biased launch azimuth.

QUESTION: What is the launch azimuth?

ALLER: You mean the numbers?

QUESTION: Yes.

ALLER: The numbers that we are using on the Atlas, we are biased from 83.7 to 85,7. And on the GLV -- I failed to note them, but I can look them up real fast. It is about, I believe, four degrees bias.

Do you have that number real fast, Ed?

The nominal azimuth is close to 95, and I believe we are biasing it at about 92. If you will bear with me, I think I can find it for you real quickly.

We are biasing from 94.9 to 92.8.

QUESTION: On the launch azimuth, is there a specific limitation you place on it due to safety considerations?

ALLER: Would you repeat that?

QUESTION: Is your launch azimuth, the direction in which you can launch, do you set a specific limitation due to safety considerations?

ALLER: Yes, sir. That 105° cutoff point is defined by Range Safety at Cape Kennedy. This is to prevent the constraining factor of the islands and the South American continent. The launch capability of the Titan is greater than 105°. But it is cut off there because of range safety considerations.

QUESTION: Maybe I missed it. Maybe you are just about to get to it. How long do you have to launch?

ALLER: I am just about to get there.

c10

I have described hopefully here to you the condition of Atlas steering, and Titan steering, and variable azimuth. The other condition I mentioned is the on-time launch. If we were insured of an on-time launch we wouldn't need any of these.

(Slide.)

This is the chart, the thing, that I was talking about.

(Laughter.)

It is a very complex chart. I have broken some pieces of it out on another chart that I will call up in just a minute. However, briefly I will describe what I have here, which is the same-day launch capability described on this line, what we call first day, second day, third day, and fourth day.

The little shadow boxes indicate when we are in phase, not in plane necessarily, but in phase, which means that the target is in the proper relationship to the Cape, that at our natural catch-up phase we can rendezvous with it. This represents just the time scale.

This "W" curve, as we call it, represents the amount of payload capability, simply the amount of energy we use from the Titan to provide the yaw steering capability. These two points, the low points on the curve, represent this type of situation, where we have no yaw steering necessary. We are in plane.

The maximum represents the maximum out of plane, in the parallel plane condition.

This line represents our bias launch azimuth, depending on which time in this particular period you launch. If you pick out, just as an example, a first-day launch, for a fourth apogee rendezvous, you would have this situation. You would use this much yaw steering and launch on a biased azimuth of about 82°, it looks like.

This scale represents the out-of-plane condition because the plane has now passed over the Cape and we are in this position over here, and we are in an out-of-plane condition. It represents how many Delta V is required to resolve that out-of-plane capability.

Earlier we talked about yaw steering. We have a total capability on the spacecraft of about 670 feet per second, which would put us right here. We are in this plane very quickly. However, if we use the spacecraft capability we would have nothing left to perform the rendezvous.

In this particular portion of the window we will use the Agena to resolve that out-of-plane condition. We have a total on-board Agena capability of about 4750 feet per second.

QUESTION: You are talking about fourth-day rendezvous. When you are mentioning this do you mean fourth day after Gemini is launched, or fourth day after Agena is launched, before Gemini can be launched?

ALLER: Down here (indicating)?

QUESTION: Yes.

ALLER: Let me go into that just a little bit.

Our nominal mission is to launch on the same day that we launch the Agena -- 100 minutes later. The criteria we have established allow us to launch on five consecutive days. And if for some reason we would delay the spacecraft liftoff clear through the launch window, approximately 22 hours later we could pick it up right here -- 22 hours later from this point. We could pick up the launch on the next day, hopefully getting off, if we have a problem holding us two days, we could pick up the launch window at this point. We have basically five days, once we have launched the Agena, to get the spacecraft off and perform rendezvous.

QUESTION: Are you taking into consideration the possible refueling of the Titan rocket, that you might not be able to launch within 24 hours?

ALLER: We are taking that into consideration.

The only constraint -- not the only constraint, but a major constraint -- if we are far enough down in the count of the spacecraft that we reach the point where we have the second pre-valve opening in the Titan system, then we will miss, I believe it is, the third day of the launch window because we have to replace these pre-valves. This requires more than the turn-around time permits for a second-day launch.

If we reach this point in the countdown -- and I don't have that figure, the number of minutes before we open the pre-valves -- if we reach that point and then scrub, we would miss this particular day on which we would lift off.

QUESTION: Do the five days refer to the lifetime of the Agena in orbit?

ALLER: The five days refer to the expected lifetime of the Agena, not the lifetime in orbit.

The systems, the beacons, the attitude control capability, this type of thing.

QUESTION: Would you repeat the number for the Agena that you gave a few minutes ago?

ALLER: 4750 feet per second on-board capability. That is for more than one firing of the Agena. The Agena has a capability of more than one firing. Multiple firings in orbit. And the amount of fuel you have depends on whether you burn one big burn or several smaller burns.

QUESTION: Could it be said that if you got the Agena up, and you had a problem with the Gemini, you have five days from the time you put the Agena up to still carry out your rendezvous; but after five days you can't act?

ALLER: The Agena system was built to provide this five-day window. If we were to arrive at a hypothetical situation that we decide we couldn't get off until the sixth day, I think a real time decision would be necessary. We would monitor the Agena to see if the systems are still operating properly, and a decision at that time would be made as to whether we could launch the sixth or seventh day. This would wholly depend on the situation at that time.

QUESTION: I thought it took a full day to recycle the Titan.

ALLER: It takes nineteen hours from turn-around, is what has been developed by the Cape test and evaluation people, to allow us this capability. We have reduced the turn-around time to nineteen hours. This period, as I pointed out, from scrubbing at this point to picking up the launch at this point, is about 22 hours, and the turn-around time is nineteen hours.

QUESTION: One more thing, if I may. I can't see the small numbers from here. What is the maximum window, taking everything into consideration, on the 25th?

ALLER: Two hours and twenty minutes.

QUESTION: You can't fire after 1225, then?

ALLER: Is that the number? 1140 and two hours and twenty minutes is 1400, isn't it?

QUESTION: On the total window, is that both or what?

ALLER: The launch window we are using for these purposes is defined as the time we have to get the spacecraft off once the Agena is in orbit. It is up there going around. We have a window, we have to launch.

(Slide.)

This chart is a breakout of the same-day launch of this particular chart. The shaded area represents this shaded box, and this shaded area is represented here. Hopefully it is a little bit clearer than that launch window display. The end number down here refers to what apogee we would attempt rendezvous, with a liftoff corresponding to a particular time down here.

QUESTION: You said two hours and twenty minutes. Is that counting from your 1141 or counting from your --

ALLER: That is counting from the 1141. If you subtract 100 from 240, it is about 140, or two hours and twenty minutes.

Again let me say that this is under a given set of circumstances. There are maneuvers -- there could be maneuvers required because of an off-nominal Agena orbit that would significantly reduce this number.

What we tried to depict here, then, is the first 25-minute pane of the launch window. In this period of time, any time we launch in this 25 minutes we will require no plane change of the spacecraft or the Agena if we have zero dispersions. Basically what we are saying is the major plane change necessary for launching different than the nominal situation will be accomplished in yaw steering. If we launch in this period, we are going to have to accomplish the plane change with the Agena.

If we delay another orbit basically, another ninety minutes, we will be back in phase again, but we will still require a plane change.

Phase means the relationship of the target to the pad, and plane means the relationship of the plane the target is in.

At this point is about the 4750 I was talking about on the Agena capability. (Indicating)

Very briefly to point out another constraint we have here, and that is the way Mr. Hammersmith described we accomplish the catch-up, we accomplish this by a difference in the period of the two orbits. And of course, for every hundred seconds delay we delay the -- the natural catch-up will be delayed about one orbit. That is a "rule of thumb" kind of thing. It means if we miss liftoff by a hundred seconds, we must rendezvous on the fifth orbit. That is not quite true on Gemini 6, however. We have another constraint that I will point out in just a moment.

When we reach this period of time we are going to attempt to rendezvous not past the sixteenth orbit. That means if we would delay our liftoff down into this area, the natural catch-up rate would carry us out past the sixteenth orbit. The natural catch-up rate of the two orbits as they are, the Agena at 161 and the spacecraft at 87 and 146. So what we do in here is to put the Agena into what we call a dwell orbit. Mr. Hammersmith touched on this.

We will boost the Agena into a higher orbit; therefore, it has a longer period, and we will increase the relative catch-up between the two orbits. Then we bring the Agena back down to its 161 and perform the rendezvous at near the sixteenth apogee. That takes place in this period. If we delay long enough to get back into this window, the phase is proper again.

These are complex charts. The launch window is pretty complex. I don't want to spend too much time on that. If you have questions, perhaps I can answer them later.

There was one point that I didn't bring up in the criteria for selection of the orbits of the mission, and that was astronaut safety.

(Slide.)

This was, of course, as has always been with our manned spacecraft flight, the prime criteria.

This is just to indicate the delays that I mentioned earlier, and I will point out that if we delay over two hundred seconds from our nominal liftoff time here, instead of delaying it in sequence for fifth, sixth, seventh, on up to sixteenth, we decided to meet our prime criteria of maximum probability, that we would like to perform in rendezvous, or at least portions of the catch-up or mid-course rendezvous where we have maximum tracking. And of course, as you know, this tracking is when the orbit passes over the United States.

They cycle around about every fifteen or sixteen orbits. So if we delay past two hundred seconds, we are going to delay our rendezvous to the sixteenth orbit. We are not going to delay our launch. In other words, if we were delayed down to this point, comparable to an eighth-apogee rendezvous, we would launch at this point but time our catch up so that we would rendezvous on sixteen.

When I get into the mid-rendezvous phase you will see how we can time our catch-up or how we can control the catch-up rate.

QUESTION: If there is no delay in the orbits --

ALLER: If there is no delay, we will rendezvous near the fourth apogee.

Now that that is cleared up, I will go into the mid-rendezvous phase.

(Laughter.)

QUESTION: You say if there is no delay you would rendezvous near the fourth apogee, but you are talking about timing your rendezvous when you have maximum tracking, which is over the U.S., but your apogee will always be there, over Australia.

ALLER: I phrased that improperly. Providing maximum tracking of the orbits, so that before they rendezvous we know exactly what orbits they are in. We are not, as you pointed out, tracking it at the point they rendezvous or the point they initiate. That is a very good point.

(Slide.)

The mid-rendezvous phase, as I have defined it, begins with insertion and ends at the initialization of the terminal phase, and I will define "terminal phase" later. That is the final transfer.

We have drawn up three basic charts, one of which is an orbital description, looking down on the co-plane orbits of the target and the spacecraft; another depicts the altitude variation of the two vehicles versus time; and the third depicts the range differential for time. There was a question earlier on this particular area.

I might point out that one of the key features of the mid-rendezvous is the fact that ground is controlling these particular maneuvers. As was pointed out by Mr. Hammersmith, the ground controls in the earlier portion of the mission on the mid-rendezvous phase, and the on-board controls the terminal phase. The astronauts rely solely on the spacecraft -- primarily on the spacecraft for the final phase.

I will describe each of these maneuvers and show you the variance on the three charts.

We insert at this point. You can see at insertion the relative relationship of the target Agena and the spacecraft. Lagging by about 16.5°, our catch-up rate is 6.7° per revolution. We are launching into an orbit that has a 87 nautical miles perigee and 146 nautical miles apogee. We launch into this orbit, the inside circle here.

The Agena has previously, 100 minutes previously, been launched into a 161 circular orbit.

On this chart, this depicts the Agena liftoff, to 161 circular, and 100 minutes later the spacecraft liftoff inserting at 87 nautical miles with an apogee at 146.

You can see at insertion we are lagging by about 1040 nautical miles.

Our first maneuver that is nominally allowed for is at our second perigee, which is back over the Cape. We have gone around in this orbit one time. We now perform a very small nominal maneuver of about one foot per second to allow for any dispersion or any decay due to drag. This is to control, as Mr. Hammersmith pointed out, to control this point we maneuver at this point. So we are controlling this 146 nautical miles altitude with that maneuver. We are looking for a differential of fifteen nautical miles all the way around when we get over here. We are maintaining that at

146 with that small maneuver. That is shown right here, the second perigee.

We then go around the orbit another half orbit to the second apogee and perform a maneuver there of about 53.5 feet per second. We call it the phase adjustment maneuver. It raises perigee from 87 nautical miles to about 117 nautical miles. You can see that is depicted here.

As we pointed out, you perform the maneuvers at apogee, and you control perigee. You pull your perigee up to about 117 nautical miles.

The reason we call this phase adjustment -- we are lagging 410 nautical miles. The angle is shown here as 6.4°. This is the relationship at that maneuver.

The reason we call it phase adjustment, this is the maneuver that we perform to control at what apogee we are going to rendezvous. And you can see the longer we stay in the smaller orbit, the faster we are going to catch up. By putting ourselves into a larger orbit we reduce the catch-up rate.

We perform our phase adjustment at the second apogee. The next major maneuver will be what we call circularization. We then travel around the orbit one time.

I might point out, before there are any questions, plane change, if required, this means that if our yaw steering, or whatever technique we use, did not allow for the total plane change necessary, any dispersions in this would be performed at this point by the spacecraft. That is at the first common node after the second apogee, where the planes would cross.

Then we go around one more orbit and we are back.

I will now jump over to this diagram. This represents second apogee. We go around one more time and we circularize the third apogee, and we put ourselves into a co-elliptical or co-circular orbit, 146 at all points, and the target is at 161.

We reduce our angle at this point two degrees and our catch-up rate is 2.3° per revolution. You can see if we stay on this orbit more than one orbit, we are going to pass the target. We have a rate of 2.3, so we will go clear around and end up at fourth apogee slightly ahead of the target vehicle.

QUESTION: What is the lag in nautical miles at end?

ALLER: The lag in nautical miles in circularization is I think about 140. The scale is not too accurate at this point. I think if you are really looking for some exact figures, we can give them to you later, for the exact lag distance.

QUESTION: Straight-line distance?

ALLER: That is line-of-sight distance. However, until we get to the point of total phase initialization down here, which begins the terminal phase, the line of sight is basically a horizontal maneuver.

When we say "line of sight", by the way, I had better explain that. We normally orient ourselves to the local horizontal, local to the Earth horizontal. That is, our line of sight is four degrees, or ten degrees at this (indicating). If line of sight were twenty-seven degrees, it would be about like that in relation to this position. Our line of sight at circularization is about four degrees.

QUESTION: Would you point out on that chart where the 140 nautical mile lag is?

ALLER: Yes, sir. We are lagging at this point by about 140 nautical miles (indicating). Remember the radius of the earth is about 4,000 miles. This represents 146 miles and this represents 15 miles (indicating). So the relative angle here is way off. You can't relate angle to your position here.

QUESTION: I realize that.

ALLER: The line of sight here would be out about like this.

QUESTION: I still am not clear when you say 140 nautical mile lag. You are referring to the distance between the spacecraft and the Agena?

ALLER: Yes, sir.

QUESTION: Could you just take the pointer and point out that line of distance between the two?

ALLER: Right where my finger is. That distance is about 140 miles.

QUESTION: From your index finger to the thumb?

ALLER: From the spacecraft to the target.

QUESTION: Thank you very much.

QUESTION: Are those both apogees?

ALLER: This is an apogee of the spacecraft. There is really not an apogee on the circular orbit.

QUESTION: On the third apogee you are putting Gemini into a circular orbit, too?

ALLER: We are putting Gemini into a circular, 146 nautical mile orbit.

QUESTION: The third apogee?

ALLER: Yes.

QUESTION: What does that burn?

ALLER: That burn is about 52.4 feet per second.

QUESTION: In other words, you have both of them in a circular orbit?

ALLER: Yes, sir.

QUESTION: When you talk about lag greater than a thousand miles, are you talking about -- well, say the phase angle was 180 degrees on the other side of the Earth. How are you measuring lag distance? Right through the center of the Earth?

ALLER: Line of sight.

QUESTION: But the Earth --

ALLER: It would be hard to relate to that kind of lag. But our lag angle is a line-of-sight distance.

QUESTION: So it would be in effect through the center of the Earth?

ALLER: It would be in that particular instance, yes.

I have a relative chart for our terminal phase that shows this line-of-sight distance. It actually takes into account the differential in heights as well as the range differential.

QUESTION: One question on the lag again. Am I correct in remembering that you said it will be a lag of 140 miles at insertion?

ALLER: No, sir. It is a log of 1040 miles at insertion. I think that lag distance is pretty well represented on this third chart. This is the range from the spacecraft to the Agena along this axis. This is time into the mission, rendezvousing at about 5 hours 20 minutes. At the various maneuvers you can see here what the range is. At circularization it is about 140 miles; at insertion it is 1040 miles.

QUESTION: Why don't you shoot for a circular orbit with the Gemini from the beginning as you did with the Agena?

ALLER: The reason we don't do that is the very reason we call this phase adjust, because it doesn't provide us the flexibility of controlling our difference in period.

We can perform maneuvers that vary this distance anywhere in between 146 and 87.

QUESTION: You want an egg-shaped orbit?

ALLER: We want an elliptical orbit to control our catch-up rate. And I might point out an example. If we don't lift off on time, we would leave ourselves in this kind of an orbit. Because the catch-up rate is greater and we would stay in there for a maximum amount of time, and our circularization instead of being about 50, would be closer to 100. And we would bring the perigee all the way from the minimum up to the maximum, 146, because the longer we stay in this type of orbit, the faster we are going to catch up. So if we are late, we want to catch up very fast, as fast as we can.

QUESTION: Did you say the altitude difference there at circularization is about 15 miles?

ALLER: Yes, sir. This is 161, and this is 146, nautical.

QUESTION: According to this chart you are putting Gemini into circular orbit about 3 hours 45 minutes after launch?

ALLER: We are circularizing about 3 hours 45 minutes. That is third apogee.

Could I go on? We do have a question and answer period later. And maybe we can pick up some of these.

One thing I didn't mention, and touched on very briefly, is that if we get out of that 25 minute phase window I described to you, we are then going to take this orbit, the Agena orbit, and make it very large. That is what we call a dwell maneuver. This allows the spacecraft in its orbit to catch up with the Agena in its larger orbit much faster.

We will then bring the Agena back down to a circular orbit and circularize the spacecraft to that orbit, and we have basically the same mission we had before. This is again an example of what we think the flexibility we have on the mission. We call this a dwell maneuver, to put the Agena into a larger orbit and it is dwelling there while the spacecraft is catching up.

QUESTION: That is the first 25 minutes?

ALLER: That is after the first 25 minutes.

(Slide.)

This is my "clear up the picture" chart.

(Laughter.)

The only chart I didn't have was to show where these maneuvers were being performed in geographic relationship, and I won't dwell on it. But you can see very quickly by perusing it yourself why these maneuvers are going to be performed. For instance, phase adjustment, co-elliptic, you can see the apogee for this orbit is about over the Indian Ocean. The perigee, our first height adjust, is very nearly over close to the Cape.

You always insert close to the perigee. You can see from this chart also that our terminal phase initiation is going to be just off the coast of South America. And our braking or velocity match will again be over the Indian Ocean.

I think that is about all I will cover on that chart.

QUESTION: Where, literally, will be rendezvous after three-and-a-half orbits?

ALLER: Rendezvous, near the fourth apogee, will occur right in here.

QUESTION: Where is that?

ALLER: This is over the Indian Ocean. Is this Java?

QUESTION: Malaysia.

QUESTION: Are you going to stick a tracking ship under that point?

ALLER: No. This is the point I think that the gentleman brought up before. We won't have tracking capability at the instant of rendezvous. We have maximum tracking back at these points to set up the orbits, so we know exactly what they are.

The coastal sentry Quebec, tracking ship, I believe is about in this area. I am not certain of the exact coordinates. I believe it is setting about in here.

We have another tracking ship here at terminal phase initiation, with the Rose Knot Victor, which will pick up this maneuver right off the coast of South America.

QUESTION: To make clear, if you are after the 25 minute and you do enlarge the Agena orbit, when you do return it to a circular orbit the Gemini will already have been put in orbit, will it not?

ALLER: No, it will not, because the logic we use in the rendezvous computations always allow for circularization of the maneuver, the last orbit before rendezvous. I don't want to get into that because that is very detailed.

Really, what we are setting up as the exact rendezvous point is when you circularize. When you circularize you set up the 146 circular orbit, one orbit before rendezvous. So we would bring the Agena back down, then circularize the spacecraft.

(Slide.)

The terminal phase is from the initiation of the final transfer maneuver, roughly at this point, to what we call braking or velocity match.

Before I get into the various maneuvers before the terminal phase, I would like to jump back very quickly to the criteria we selected, and the terminal phase was a very important portion of it.

(Slide.)

We selected a terminal phase of 130 degree transfer. By that we mean from the time we initiate our transfer orbit to the time we brake, the Agena target vehicle will have travelled 130 degrees of a planned circular path. That is what is termed the 130-degree transfer.

You can rendezvous at 180 degrees. In fact, the optimum from an energy standpoint is to initiate at this point and rendezvous at this point (indicating). Our criteria for selecting the terminal phase as you can see are greatly dependent on this initiation. What does the crew use as a cue? They could use time; they could use range; they could use minimum Delta V, which would be a 180° transfer.

We selected a relative angle. The reason we did it permits the crew on line of sight to point the spacecraft at the line of target, and initiate their maneuver along the line of sight and maintain radar lock by this method, and the Delta V or thrusting is directly toward the target at that point.

That was the criteria for selecting the 130° transfer. We are performing the transfer in darkness, nominally, as you can see. That was another criteria, to maintain a constant launching condition, and we optimized the final inertial line of sight as we approach the initial braking maneuver. By this we mean the crew can set up their target in the windows and detect any movement of the target against the celestial background. Our type of transfer permits this constant inertial line of sight.

QUESTION: Does that mean that the whole maneuver takes place in the dark?

ALLER: The whole maneuver nominally takes place in the dark condition; that is right.

QUESTION: Including hook-up and everything?

ALLER: Pardon me? No, this is braking. This is the terminal phase termination. We then go into docking.

QUESTION: That is in daylight?

ALLER: That is in daylight. You recall, of course, the target vehicle has lights on it, flashing lights and running lights.

Another criteria was this differential altitude, and here we are talking about the 15 miles nautical miles difference between the two orbits. We wanted it close enough so that the crew could see the target and far enough away that it was rather insensitive to dispersions.

QUESTION: How far along in that terminal phase maneuver do you calculate they will get visual contact?

ALLER: At initiation they are only 34 miles away. They should be able to see the flashing lights at that point, and before. They should have visual contact about five or ten minutes before they get into darkness.

(Slide.)

I will go back to the other two slides and go through the terminal phase. It has four basic maneuvers: initiation, two mid-course corrections, and braking or velocity. The function of these is to transfer ourselves into this outside orbit at this point, match the velocity of the orbit at that point. And these are merely vernier corrections that arethe time from the initialization to this maneuver, approximately 12 minutes; from this maneuver to this approximately 12 minutes; and then to the braking is approximately 8 minutes later.

bl 8

The whole maneuver takes about 32 minutes, 20 seconds; total transfer. The initiation, I think we have defined this as about 33 feet per second. The two correction are, as you can see, vernier, small corrections, at about two feet per second each, and the braking maneuver is 43 feet per second.

Let me caution you, the braking maneuver is a posigrade maneuver. The velocity increases in the direction of travel. It is matching the velocity of the target. It is braking in relation to the target. It is the relative distance between the two.

I think you can see pretty clearly the difference in altitude and the range differential during this final phase of the mission.

QUESTION: What is the speed of the Agena at this point, the terminal phase?

ALLER: The speed?

QUESTION: Yes.

ALLER: The speed of the Agena is constant throughout. It is circular at 161, which is about 25,750 feet per second. That is really a top-of-the-head number. It doesn't vary throughout the mission unless we maneuver the Agena, and nominally we don't plan to maneuver the Agena.

QUESTION: That is 17,500 miles an hour?

ALLER: That is about the conversion, yes.

QUESTION: Do you mean the braking maneuver will be firing thrusters in the posigrade direction?

ALLER: That's right.

QUESTION: It is not a thrust in the posigrade direction?

ALLER: I don't know if this is the time to go into this, because it is a little bit confusing.

They are coming around like this (indicating), and the spacecraft will actually approach in this direction. They are both moving this way. It will come up and under and it will match velocity -- it will fire its forward-firing thrusters and match the velocity to push it in this direction, which matches the velocity of the Agena.

That is what we call a velocity match. I will go into the relative motion of the two in just a minute. You can see basically it amounts to this type of approach, up and under.

QUESTION: Do you have to speed the Agena up in order to slow it down?

ALLER: No. We speed the spacecraft up.

QUESTION: I mean the spacecraft.

ALLER: What we are doing is providing enough velocity and energy to stay in this outside orbit. If we didn't perform this maneuver, our trajectory would take us right up and back down to this inner orbit and we would have a 146/161 orbit, basically.

QUESTION: How fast will it be travelling when they rendezvous?

ALLER: Same speed.

QUESTION: 27,000?

ALLER: Whatever is the circular speed at that altitude. I don't have the exact figure in absolute.

QUESTION: So in absolute terms the braking is actually a speed-up for the spacecraft?

ALLER: That is correct. That is why I like the term "velocity match" rather than braking.

QUESTION: It does not get ahead and then slow the Agena speed?

ALLER: It is ahead of the Agena, and matching the speed of the Agena in that orbit. I think there may have been a misconception earlier. The spacecraft pulls ahead of the Agena in orbit.

QUESTION: Bob, isn't it true that for the men in the spacecraft, the apparent motion to them is of the nature of a braking maneuver?

ALLER: That is why it is called braking.

QUESTION: If you look at it on the simulator that they are being trained on, it has the appearance, to them, the appearance to a person looking, that it is being braked. But in a picture like this, they are actually matching velocity, they are putting energy into the orbit.

ALLER: I have a relative plot here that plots the motion of the spacecraft relative to the target. I think that will give you maybe a little better appreciation of that.

(Slide.)

This is a plot of the relative motion of the spacecraft and the target vehicle. You can assume the target vehicle, the Agena, remaining at this point. This is a relative plot now; this is not an actual plot.

QUESTION: Slew the target 90°?

ALLER: Actually, it is going to be moving like this, as was pointed out. It is at this point. Picture the Agena at that point. And then the spacecraft is down here and follows this trajectory in relation to the target. You can see the range at this point is about 34 miles. It is 15 miles below and about 28 miles behind. We initiate, and then the relative distance of the two corrective maneuvers -- and this gives you an appreciation for braking.

You are now actually ahead of the spacecraft and you are approaching it, and you are slowing down your approach velocity in relation to your approach to the target.

QUESTION: How many miles did you say?

ALLER: Fifteen.

This represents the miles below, and this represents the miles behind. Here the crew will be on their backs looking directly at the target, at this point. Then they come up and under. When they are at their braking maneuver, they come back and are facing the target vehicle.

Picture yourself in an airplane. You are flying up, and you will be right on your back at braking. They will then flip over, roll over 180°, and be heads up.

QUESTION: What is the maximum differential on the speed of the two craft?

ALLER: Do you mean in miles per hour?

QUESTION: Yes.

ALLER: Would you permit us to calculate that? I don't have it. We have plots of just about everything, including relative velocity. We just haven't looked it up.

QUESTION: In feet per second?

ALLER: I don't have it.

QUESTION: The way that plot shows, the spacecraft will be coming back to the Agena, literally, and closing the distance?

ALLER: Yes.

QUESTION: Before braking?

ALLER: It pulls ahead -- at this point it is actually ahead of the Agena -- and then comes back towards the Agena.

QUESTION: Before the braking maneuver?

ALLER: This is braking right at this point.

QUESTION: So it is going to be ahead and will come back before braking?

ALLER: It is ahead and will come back right at the Agena and will brake. If you had a perfectly nominal situation the thing would come back -- I will use it this way, even though it is not exactly the way it will be flown -- it will come around and brake in that condition and match velocity from there on.

QUESTION: That plot seems to suggest that it gets ahead and then comes back, by the negative value there, horizontal displacement.

ALLER: No. This is the trajectory. From start you go right up along here, and brake right here.

QUESTION: At the five-minute mark before that, isn't it ahead --

ALLER: It is ahead of the target.

QUESTION: And now seems to go backward?

ALLER: That is right.

QUESTION: Before braking occurs?

ALLER: I see. This is a relative plot. The spacecraft is actually moving forward in its orbit. The Agena is moving forward in its orbit. With this plot we assume the Agena is stationary. By assuming the Agena is stationary at this point, this is what I had hoped to point out earlier, it is stationary and this is the kind of locus you would get with the stationary target.

QUESTION: Will the movie help?

ALLER: The movie will help somewhat.

QUESTION: Some people have to leave, who do want to see the movie. Would you hold the questions?

ALLER: Let's leap on then. Thank you.

(Slide.)

The next items I wanted to touch upon were the crew back-up techniques for rendezvous. I will touch on them since we are kind of pressed for time. The concept is pretty simple. The concept, that is, for back-up.

We are comparing what we think we know are nominal values against what we are getting in real time. And by comparing these to pre-determined limits, we can establish trends from the data points, make hand calculations with computer solutions, compare with pre-determined limits, and then they can make a judgment on the reliability of their on-board solution.

I might say the theory is simple; the technique that they use is very complex and requires Major Stafford to do some mathematical calculations in real time to make this comparison.

I have just shown here an example of one of the plots that they carry with them. This particular plot is what you call a polar plot, and it just gives them a relative feel for how they are in relation to the nominal track. This is on two scales, this kind of a track. This point, the zero point, represents this point -- initiation of terminal phase.

You can see when we get up to about 16 miles from the target we increase the scale a little bit in the plot, and pick it up down here. Basically what they do, they measure their line of sight to the target and their range from the radar, they have a direct readout, and plot themselves along the nominal plot.

This is an example of one. They have many such devices.

(Slide.)

The critical on-board systems, three of the very critical on-board systems for the terminal phase are the computer, radar, and platform.

Again, in our back-up techniques we have developed methods or cues for initiation in this 130° transfer. If we have a failure of one or a combination of these -- I won't go into them -- this gives an example of how they will initiate their transfer if that particular system failed.

(Slide.)

After we perform the rendezvous we are going to perform some four docking and different lighting conditions, both in the command pilot and then the pilot. We are going to perform our four experiments. We are going to maneuver both the spacecraft and the Agena. We will have final separation, recovery, and followed by about three days of exercising what we call the solar portion of the Agena. The Agena will be up there by itself, and we are pretty much going to wring it out.

Now I think we can go ahead with the movie and I think it will summarize the whole mission for you.

(Motion picture presentation.)

QUESTION: After Agena has been launched, and if it becomes necessary to scrub Gemini, what hour would you launch Gemini on the following day?

ALLER: Let me put the copy of the chart we had on the board. Can everybody hear me?

The time for the launch on the first day, or the next day after the Agena launch -- I am looking at a relative time plot now, the one we had on the board -- it occurs about an hour and thirty-five minutes earlier than the window open on the same day. In other words, if it was 1141 on the same day, it would be 1006.

QUESTION: Could you give us the nominal launch windows for each day in the time after Agena liftoff, so we know what to expect?

ALLER: On consecutive days for the time from Agena liftoff, I think this plot gives it pretty clearly. As a matter of fact it is right here, the answer to your question. It is 1010.

If we could have that slide back, it gives it directly. May we have slide 4 again, please.

If you are going to copy them, I can start reading. The window on the same day opens at 1141 Eastern Standard Time. The second day is at 1010 Eastern Standard Time. The third day is at 0825 Eastern Standard Time. The fourth day at 0848 Eastern Standard Time -- I don't think you can read that --

QUESTION: The fourth day?

QUESTION: Only four minutes difference that day?

ALLER: And the last day 0853 Eastern Standard Time.

QUESTION: What was the fourth day?

ALLER: 0848.

QUESTION: What was the fourth day?

ALLER: 0848, Eastern Standard Time.

QUESTION: It goes up again?

ALLER: Yes.

QUESTION: What is the length of the maneuvers?

HARKLEROAD: We still have the 25 minute windows.

ALLER: No, that is wrong. As you see, the windows, this is the window rate here. It is confusing because the shaded area simply represents the area that you have the proper phase relationship -- pardong me, yes, that is correct. The relationship so that you won't have to maneuver the Agena. But we can launch. For instance, on the second day, as we term it here, we can launch from this point -- this is our launch window.

We are properly in phase in this point, this point, and this point. And these times I was reading you right off this chart.

QUESTION: If your launch window on the first day opens at 1141, when does it close, if you are going to reopen at 1010 the next day?

ALLER: It closes, if you are going to reopen, whenever you scrub.

QUESTION: How long would you wait before you decided to scrub, for the next day?

ALLER: It depends on the situation.

QUESTION: What is the maximum time?

ALLER: The maximum time for the first day is from this point to -- at the 240 point here. This is where the two hours and forty minutes launch window would end. The situation can end that you will get to this point and say I will scrub until the next day because I have a problem that I know I won't get fixed by this remaining time. Or you can be in the countdown after you lift off the Agena, you are in the countdown and you can say we had better scrub for the next day because I have a problem in the Agena and we are not going to get it fixed.

QUESTION: Can you give us the maximum windows for each day? The length of the maximum windows?

ALLER: The maximum window, the first day, two hours and twenty minutes.

QUESTION: In other words, if you don't get Gemini off in two hours and twenty minutes after the first day, you wait until the next day?

ALLER: No. If you don't get Gemini off for two hours and twenty minutes from its nominal launch time, you will have to reschedule for another day. And the day you would reschedule for would depend on what the problem is.

HALL: Is it clear that we have a longer launch window on the day following the same day that we launch the Agena?

QUESTION: 228 is just the first day?

HALL: Yes. The second day you have 260 minutes, over a four hour window, if you started at the time when on the first day you were launching the Agena, because on the following day you can launch the spacecraft at the same time you launched the Agena on the first day.

QUESTION: How about the third day?

HALL: On succeeding days you do not have the proper phase relation. Your window doesn't always open up at the same time each day.

QUESTION: We are trying to get it in hours and minutes.

HALL: I would like for you to understand the chart first. On the first day, the same day launch, we are inserting the Agena here. This is where we have the zero plane change. About an hour and a half later when the Agena has gone around once we are at this point, the nominal time when we would want to launch the spacecraft. From that point on, if everything goes right, you have this much of a window remaining on the first day.

On the second day you would be able to launch to get, plane-wise there, at this point. But because you are coming up in a better phase relationship if you wait a little while we certainly wouldn't launch. We would wait until we got to this point when we would be in proper phase. Excuse me, it is down here. Our window would start really on the first day following the Agena launch at this point. From that point on we would have a window to here.

QUESTION: That is 260 minutes?

HALL: It is not 260 minutes from here. It is 260 minutes from here. We would have to take the 260 minus this, or 220 minutes on the first day following.

QUESTION: Even on the first day if you go the full two hours, you have there --

HALL: The two hours is from this point to this point, and you certainly have the Agena catch-up that is necessary, yes, sir, at this point and here.

QUESTION: Would you do that rather than wait to the next day?

HALL: Rather than scrub and try the next day?

QUESTION: Yes.

HALL: That depends on the situation.

HAMMERSMITH: The rulebook is two inches thick covering this situation.

QUESTION: What is the window before you get in the Agena catch-up period after 1141?

HALL: There is a phase window here of about this long, and about 20 minutes. It doesn't require major plane changes to put you in the proper phase relation. After that you need to change the plane. You need to use the Agena to change its orbit in order to avoid the large number of orbits for catch-up.

QUESTION: You said that, the film said that the closing rate was 1.8.

HALL: I think there is a little disagreement between the film and some of the numbers we have here.

QUESTION: I thought he was talking nautical miles and the statute is in statute miles.

HALL: I hope we haven't thoroughly confused you by using nautical miles in this discussion, which our engineers are used to, and the film which was made for public release which deals with statute miles.

QUESTION: What kind of miles are we going to get later on during the flight?

ALIBRANDO: We will convert them to statute in the release we will give you.

QUESTION: Say it is 1.8. Roughly 100 miles an hour. 1.8 miles a minute is roughly 100 miles an hour.

HAMMERSMITH: I am pretty sure the film said 1.8 miles an hour.

QUESTION: 1.8 miles an hour?

HAMMERSMITH: Yes.

QUESTION: I don't understand. The difference is 34 miles, and you are closing in 32 minutes. So it should be about a mile a minute.

QUESTION: I got 1.8 miles a minute.

QUESTION: Is that what you put down, too?

QUESTION: That is what the film said.

HALL: One of the things I would like to explain to you if you would be willing to wait, I think you have seen the closing maneuvers where you have a fixed target, and where the spacecraft comes in and goes like this. It is fairly simple to explain why we get that. If you have some other questions first, we can delay this.

QUESTION: Do you agree that it is a mile a minute?

HALL: It is not constant over the entire closing period because in one case you are closing and in another case you are opening up, and then you come back in.

QUESTION: But it does average.

QUESTION: The word "fixed" is throwing me because the target is moving.

HALL: A plot like this is drawn relative to the target, putting in the target here as though a fixed point even though it is moving around. This is how everything looks relative to the target point.

QUESTION: Let me finish. We are closing at a mile a minute, let's say. We are supposed to end up a mile ahead of the Agena. That is a difference of a minute in time; right? In other words you have to start your terminal maneuver -- what I am thinking of frankly is in terms of a collision. You have to be within a minute of your initiation of the terminal maneuver if you are going to preclude any kind of collision. Is that correct? Is that reasoning correct?

ALLER: I don't think so.

HALL: When we get close to it, we use optical means to avoid a collision.

QUESTION: But when you speed up to slow down --

HALL: This is the point. Here is the orbit that is inside -- here is the target orbit. We have said that everything in this orbit is going faster than those things in this orbit. We have said that to go from this orbit out to this one we have to increase our velocity here. At this point in this orbit we are going faster than we are in this orbit.

We have also said that when we get out to this point we again have to speed up in order to get into this orbit. And yet we have already said that in this orbit we are going slower than we are in this orbit.

What happens is that when we speed up here, as we coast out here we slow up, and we slow up to a point that is slower than what the velocity is in this orbit. So in order to get to this orbit we have to speed up again when we get to this orbit.

What this means is on the way out here we start out considerably faster than what the target is going at in this orbit. At some point here these velocities essentially match.

QUESTION: To keep the Agena from banging into it.

HALL: Right.

QUESTION: There is a closing rate if you don't speed.

HALL: There is a closing rate if you don't speed up. It is about equal to your braking velocity which you gave.

ALLER: Do you want the closing rate at braking? It is 43 feet per second.

QUESTION: So that would be, say, 30 miles an hour.

HALL: Yes.

QUESTION: If one had a collision it would be at roughly 30 miles an hour.

HALL: That's right.

HAMMERSMITH: I was asked a question as I came up here about this collision. I think we ought to say more than we have said, Eldon, and that is that if they get up into this location -- somebody said if they don't speed up there will be a collision. Not so. The only way there can be a collision is if the intercept, the point where the orbits intercept, both spacecraft arrive at the interception point simultaneously right on the button. If the Agena is a little behind, as the spacecraft comes up ahead of it, unless the astronauts do something the spacecraft will start right back down. There will not be a collision from that case.

QUESTION: You are talking about the two orbits coinciding at only one point.

HAMMERSMITH: That's right. Both spacecraft must be there at the same time for there to be a collision. In other words there is a very -- even looking at it this way, there is a very slight chance, very slight chance, of a collision because the timing has to be exact. Otherwise if they don't hit at that point they come apart -- they move apart.

QUESTION: Let me come at this a different way. We have the Agena going say 17,500 miles an hour. We have Gemini going 17,510 miles an hour, or whatever the figures might be.

HALL: It depends on where you are in the orbit. It goes from lower velocity to higher velocity.

QUESTION: We have the Agena and we have the Gemini, and you start to close to dock. At what speed does the Agena slow down or pick up speed?

HALL: The Agena doesn't change its velocity.

QUESTION: How does the Gemini, in miles per hour, slow down or speed up, and finally come together, and how much impact at that point?

HALL: Here you have a higher velocity than what the Agena is doing. Considerably higher. On this type of plot, where this is everything relative to the Agena, which is at this point, we are going faster than the Agena. As it coasts up in this orbit, it slows down. As a matter of fact, we get to a point here where it is ahead of the Agena, as a matter of fact, at some point, as shown by this plot. It is ahead of the Agena.

We get to a point here where actually it starts slowing down and coming this way relative to the Agena, and that is when it comes back here. So that at this point it is ahead, and from here on out it starts approaching the Agena in that way. When you get to here, then you have to use your braking. You make the braking or posigrade maneuver to give it that 40 feet per second.

QUESTION: It slows down 10 miles an hour to do the mating, whatever it is. I want to get this translated.

QUESTION: Don't they actually get to the same speed in that orbit before you start your last braking maneuver?

HALL: No, sir.

HAMMERSMITH: Right here is where they speed up. This is the plot of distance. This is distance in one direction, and this is distance in this direction. The spacecraft is coming up. They are both actually moving this way. This whole coordinate system is moving.

At this point if they don't maneuver so that they take this kind of a relationship, then hold it, they are going to come right back out. That is what you were looking for, I think. They have to do something here to make the motion that way and then hold it.

ALLER: And the difference in velocity at that point is 40 feet per second. The Agena is going faster than the spacecraft by 43 feet per second.

HALL: Otherwise you would start to fall back.

QUESTION: You have to speed up to coast uphill and then step on it.

HAMMERSMITH: This is where this racecourse analogy breaks down. I told you it breaks down.

QUESTION: I want to ask one thing. In the unlikely event of that collision, what would happen?

HALL: At 43 feet per second, if there was an uncontrolled collision, it would be fairly catastrophic. That is obvious.

QUESTION: Would you tumble?

HALL: It would depend entirely on how they came together. This is, as far as we are concerned, impossible, because the astronauts will be able to see this. They will be able to maneuver. As a matter of fact, these orbits are such that the chance of a collision, even if they had made no maneuvers, are almost nil because of the vast size of the space.

QUESTION: In the terminal maneuver will they be seeing the thing for the last 32 minutes?

HALL: They will be seeing it constantly during that period of time.

ALLER: They will maintain radar lock during that time.

QUESTION: I am talking about visible.

HALL: It will be visible to the naked eye.

QUESTION: Could you get me straightened out on the daylight and the dark and the daylight business? Am I correct that about a minute before darkness, just roughly, they will acquire it visually from 34 miles or so?

HALL: Right.

QUESTION: Then they go into darkness where it is dark for some minutes?

HALL: Yes.

QUESTION: Roughly what?

HALL: Dark continuously.

QUESTION: How long will that be?

HARKLEROAD: The darkness cycle is about 38 minutes.

QUESTION: 38 minutes in darkness. And just a few minutes before they dock, they are in sun again?

HALL: Yes.

QUESTION: Is that the way it works?

HARKLEROAD: Yes.

HALL: They will be doing the braking maneuver and going at relatively the same velocity but at some distance away from it while still in darkness. They will maintain that position until they get around in sunlight, and then close in.

QUESTION: And their backs will be in the direction here going and the Sun will be behind them again?

HALL: Yes.

QUESTION: When they started out the Sun was behind them?

HALL: Yes.

QUESTION: Thank God.

HAMMERSMITH: This was one of the important things to worry about. Where was the Sun. Another practical matter that gets in your hair, or in your eyes.

QUESTION: The teminal phase of the rendevouz is the posigrade maneuver, done in the dark side?

HAMMERSMITH: Yes, sir.

QUESTION: The terminal phase of the docking maneuver is the retrograde maneuver and is done in the day side?

HALL: It is relative to the Agena and has to be retrograde. It is just like pulling into a dock. Pulling in and stopping.

QUESTION: It has to be small enough so it won't do anything to the orbit?

HAMMERSMITH: That's right.

HALL: John pointed out earlier that you can't, in order to catch up to something, speed up, because you get out of the orbit. When you are talking about something close in, that no longer holds. You can consider this the same as you are going down the road and want to pull into something.

QUESTION: How do you know that?

HALL: It is entirely a matter of how far around the Earth you go during this period. If you are going only a very small angle around the Earth so that the angle from where the Earth is doesn't change very much, you can forget about the orbital effects and just handle it --

HAMMERSMITH: What I said still holds.

QUESTION: When does this straight line become a curve again? How long have they got?

HALL: Say a tenth of an orbit, which might be five or ten minutes.

QUESTION: They have five or ten minutes to make it?

HALL: Without having to worry about the orbital mechanics aspect of the final docking.

QUESTION: Getting back to the transfer from the inner orbit of the spacecraft to the outer orbit of the Agena, someone said, in describing that, when the spacecraft speeds up in the inner orbit to get into the outer orbit, it first speeds up and then slows down.

HALL: It slows down because it is coasting, just as when we launch something towards the Moon, it goes pretty fast at the beginning. Gravity slows it down as it goes further out. The same thing is happening here.

QUESTION: Does that fact have anything to do with the earlier principle stated, a while ago, that in the larger orbit the vehicle goes more slowly than the smaller orbit?

HALL: It is related to it, but not directly as you put it.

HAMMERSMITH: Let's take an orbit like this. What we are really talking about here is an elliptic orbit. What I was saying was a nice clean situation. The transfer orbit is really an elliptical one. You can't look at this as a velocity thing or as an altitude thing. It is one or the other. Velocity and altitude are combined in a complicated manner. But they combine in such a manner that if the spacecraft does nothing and is in an orbit like this, a thing that we call the energy of the orbit remains constant.

Very generally speaking, if the altitude is low, the velocity will be high. So that in an orbit such as this the velocity reaches a maximum at perigee. As it comes up here, this velocity and altitude begin to have a shifting relationship until out here, at maximum altitude, the velocity is least. And if it just touches an orbit that is circular, right here, this speed is slower for this orbit than it is for one in this orbit because the circular orbit here is a higher energy orbit. Does that help?

QUESTION: One thing, a corollary of that, maybe. Is the velocity least at apogee because, for one reason, of the effect of gravity?

HAMMERSMITH: Gravity and velocity are the things from which you get your energy. This piece of chalk has potential energy with respect to the table, and it loses its energy with respect to the table when it hits. This piece of chalk has kinetic energy because it is moving.

If you combine those two concepts, in spacecraft in an orbit, it has potential energy with respect to the Earth by virtue of its altitude, and it has kinetic energy by virtue of its speed. And the two combined in a complicated way give you an energy constant for an orbit. The energy constant for this orbit is less than the energy constant for this circular orbit.

Therefore when they both touch at the same altitude and they have different energies, the velocity is the thing that has to give in comparing it. So velocity for the spacecraft in this orbit will be less than the velocity for the target when it reaches here.

No?

QUESTION: Yes.

HAMMERSMITH: I feel sorry for this if you have to write it or explain it to somebody else.

QUESTION: This word braking --

HAMMERSMITH: This word braking is unfortunate. I think I said, when I spoke up in the back of the room when the men are in this, these words have a way of creeping in because they are practical in a given situation. When you try to marry all these different situations is when you get this conflict. When you have the big picture here, it is not a braking maneuver. If you are sitting in the spacecraft pushing buttons and watching the Agena, it looks like you are braking.

QUESTION: Does it feel like it? Is this to them seat-of-the-pants flying? Will it feel to them like they are braking?

HAMMERSMITH: No, it will not, because they will be facing --

QUESTION: Facing the Agena?

HAMMERSMITH: They will be facing the Agena like this, and they are going to fire the thrusters this way, which will push them this way. They will pull against their harnesses.

QUESTION: You have a nominal situation right up to rendevouz and for one reason or other you miss rendevouz. Do you have enough fuel left in the Gemini to come back and try it again at a later orbit?

HALL: That depends on how far you miss it. If you miss it by only a small amount, then you have to evaluate the orbits that you end up with and through ground tracking try to correct these orbits with a minimum amount of fuel. If you are close, very nearly in the same orbit to start with, it shouldn't take much fuel to make the correction.

QUESTION: Could the Agena be used to do this, rather than the Gemini itself?

HALL: That would depend on how much velocity it would take in one or the other vehicle. Preferably we would do it with the spacecraft. If it took a large amount of fuel, we would have to use the Agena to make the correction.

QUESTION: In that connection, how much flying time will the spacecraft have on a nominal launch on the 25th? How many orbits can it make, crew, supplies, and all the rest?

HALL: Two-day lifetime.

ALLER: Thirty revolutions.

QUESTION: That is the Gemini spacecraft?

ALLER: That's right. I might say, on this aborted rendevouz, a critical point would be where you abort. If you are up at the braking point, for instance, or your terminal phase initiation, the probability of being able to -- probability of having enough on-board propellant to perform the rendevouz again would be very low. It takes the maximum -- the majority of our on-board systems are used up in the rendevouz attempt.

QUESTION: Geographically speaking, where will the spacecraft be when you initiate transfer? The nominal mission. You are talking about braking over the Indian Ocean. Where will you start transfer?

ALLER: Right off the coast of Brazil.

QUESTION: Initiate transfer?

ALLER: Yes, sir.

QUESTION: You would overtake the Agena over the Indian Ocean?

ALLER: Yes. That is --

QUESTION: Where would the docking occur? Between Australia and Midway?

ALLER: The docking occurs sometime after braking, depending on the dispersions we have at the end of it.

QUESTION: Would you be past Australia then?

HARKLEROAD: They expect to be docked, if everything goes normally, by the time they reach Hawaii.

QUESTION: So you would dock over the Pacific?

ALLER: The velocity match takes place just about due south of India -- Ceylon -- over the Indian Ocean. That particular trace takes you over the islands and I think it is over the Philippines, and I think we can accurately say it is between velocity match at about Hawaii the docking should take place nominally.

QUESTION: The press kit would have this?

ALLER: I planned on it, yes.

QUESTION: When you do dock, is there a linkage between the two ships, that you have them joined together with circuits, things of this nature? Or are you just physically in there?

ALLER: There is an umbilical connection.

QUESTION: Does the press kit cover this?

ALLER: I planned on it, yes.

HAMMERSMITH: It is a hard line, electrical mate, male and female.

QUESTION: Are you going to fire the Agena and use its propulsion after Gemini docks?

ALLER: Not while docked.

QUESTION: You will do that in the three days after Gemini comes in?

ALLER: That's right. There are three systems on the Agena. There is an altitude control system, there is the secondary propulsion system, and a primary propulsion system. We use the attitude control system while docked to control the docked configuration. But we won't fire the secondary propulsion system or the primary propulsion system. After we undock, then we will maneuver with these engines, the thrusters.

QUESTION: Am I correct in concluding from several things that you have said, that after braking, the astronauts have five or ten minutes to dock, and if they miss they probably will not have enough fuel to try again?

HALL: May I correct your statement? The statement was that they would have five or ten minutes to do the docking maneuver. That doesn't mean they have to initiate the docking within that five or ten minutes, because they could stay in these orbits and go all the way around without getting tied up with the orbit mechanics aspects.

QUESTION: But once they start --

HALL: Once they start, if you want to start making maneuvers and you want to do this without getting tied up with the orbital mechanics equations, then you would have to complete the maneuvers in say five or ten minutes.

QUESTION: And if they do not, they won't get another chance, probably?

HALL: They would have another chance.

ALLER: I think there has been some confusion here. The velocity match puts them in the same orbit ideally, and if you dock or you don't dock they should fly around. If you are done braking and you have say a 500 foot separation, they will stay in orbit like that all the way around.

QUESTION: Flying in the same orbit all the way around?

HAMMERSMITH: They may move a little bit, but they will stay within proximity.

ALLER: The docking is actually a very small maneuver, to join up. But unless they perturb this after the velocity match, and they have done it accurately, they will remain in the same orbit, and their relative distance apart stays the same.

QUESTION: They could do this all day long and still dock the next day.

HALL: They have capability to maneuver the spacecraft with their lateral and up and down thrusters so they can even overcome the orbital mechanics aspect if it takes them longer than five or ten minutes. I didn't mean to imply that they had to complete the docking within that time period.

QUESTION: Is this five or ten minutes before they run afoul of Newton?

HALL: That's right. They could still overcome Newton with the thrusters they have on board.

HAMMERSMITH: It takes fuel.

QUESTION: I thought the point was that they didn't have that much.

HALL: The amount of fuel it takes to do the docking is relatively small compared to the amount of fuel it takes to make these major corrections. So that they should have enough fuel to do that, several times.

QUESTION: Why don't they wait for the final docking phase until they come over the United States where there is so much traffic, rather than doing it over the Pacific?

ALLER: Why are they delaying the docking?

QUESTION: Why don't they delay it? Why don't they delay the beginning five or ten minutes?

ALLER: For one thing, the one circumstances we have had of attempting to what we call station-keep, you will recall, was on Gemini IV. This braking maneuver is to put us ideally in the situation I was just describing, where you are in exactly the same orbit. Any dispersion -- as I said earlier, we expect dispersion -- we would be off that nominal situation. We have flown the whole mission, we have performed rendevouz at a certain point, and brake at a certain point, and we hope to dock as soon as we can after that braking point so that any small dispersions we do have won't carry us away from the Agena target.

This is what happened on IV. We had a very small relative dispersion between the two, but we separated faster than we had anticipated, and therefore the whole objective of the mission is to rendevouz and then dock. We feel we should do this as soon as practical. Later we are going to undock and we will dock again.

QUESTION: What differences does it make what country you dock over?

ALLER: It doesn't make any difference. I think his point was that we could watch them dock with our radar and telemetry.

HARKLEROAD: First, that particular track -- on that orbital revolution, on that revolution -- does not pass over the States anyway.

QUESTION: Where does it pass?

HARKLEROAD: It passes over South America. So we would have to wait until the next day.

QUESTION: You are talking about the dispersion drift, as you call it. How rapidly will you redock, and how rapidly do you anticipate redocking, the three subsequent redocking exercises after the two have undocked?

ALLER: Of course once we have docked, we are not worried about dispersion. We have a single orbit, with a single vehicle.

QUESTION: Won't you have some dispersion when you undock?

ALLER: When we undock we will know exactly what that is. If we undock at two feet a second, all we have to do is equalize our relative rate between the two and we will only separate up to about 60 feet I think it is.

HALL: I think the question is, after you separate how long will you wait before you redock.

QUESTION: Will you try to redock as soon as possible?

ALLER: How many minutes will we remain undocked?

QUESTION: Not how many minutes, but will you try to do it as rapidly as possible to prevent dispersions from being made?

ALLER: I can't answer that.

HALL: One of the purposes of the docking exercises, and the redocking, is to give the astronauts some experience at this. If we did it as rapidly as we could, they wouldn't get any experience at station-keeping.

QUESTION: During the whole two hours and twenty minutes window, do you have the capability of launching the whole way through that window, or would you stop for a period of time and then start again?

HALL: You have the period of launching throughout that window. You would have to make Agena maneuvers to correct the phase.

QUESTION: Throughout that window you would launch?

HALL: Yes.

ALLER: You have the capability, but there is a period in there that we would wait.

QUESTION: Could you tell us?

HALL: When you are getting to the point where if you wait a little bit longer, then you don't have to make any phase changes, you would be better off to wait, and simply from a practical standpoint will wait and will not do that.

QUESTION: At 1145 Monday, if there is no launch, we can write a story and say there will be no launch today?

ALLER: 1145?

QUESTION: Yes.

ALLER: No.

QUESTION: If the Agena is not off?

ALLER: If the Agena is not off?

QUESTION: Yes.

ALLER: We have a mission rule that if we don't get the Agena off within two hours of what we plan to, we will scrub both launches. You said if the Agena is not off. Did you mean if the spacecraft is not off?

QUESTION: Right.

QUESTION: If the Agena is up there you have two hours and twenty minutes.

ALLER: The spacecraft window goes from 1141 for two hours and twenty minutes thereafter.

QUESTION: That was confusing me earlier. I was under the impression that you had to get the Agena in orbit by 1141.

ALLER: No. We have several constraints. If we have to delay the Agena launch -- this is the Agena, the first launch -- two hours, we will scrub for that day.

HALL: 12:00 o'clock.

ALIBRANDO: Thank you very much.

(Whereupon, at 5:00 p.m., the briefing was concluded.)

MISSION DESIGN CRITERIA

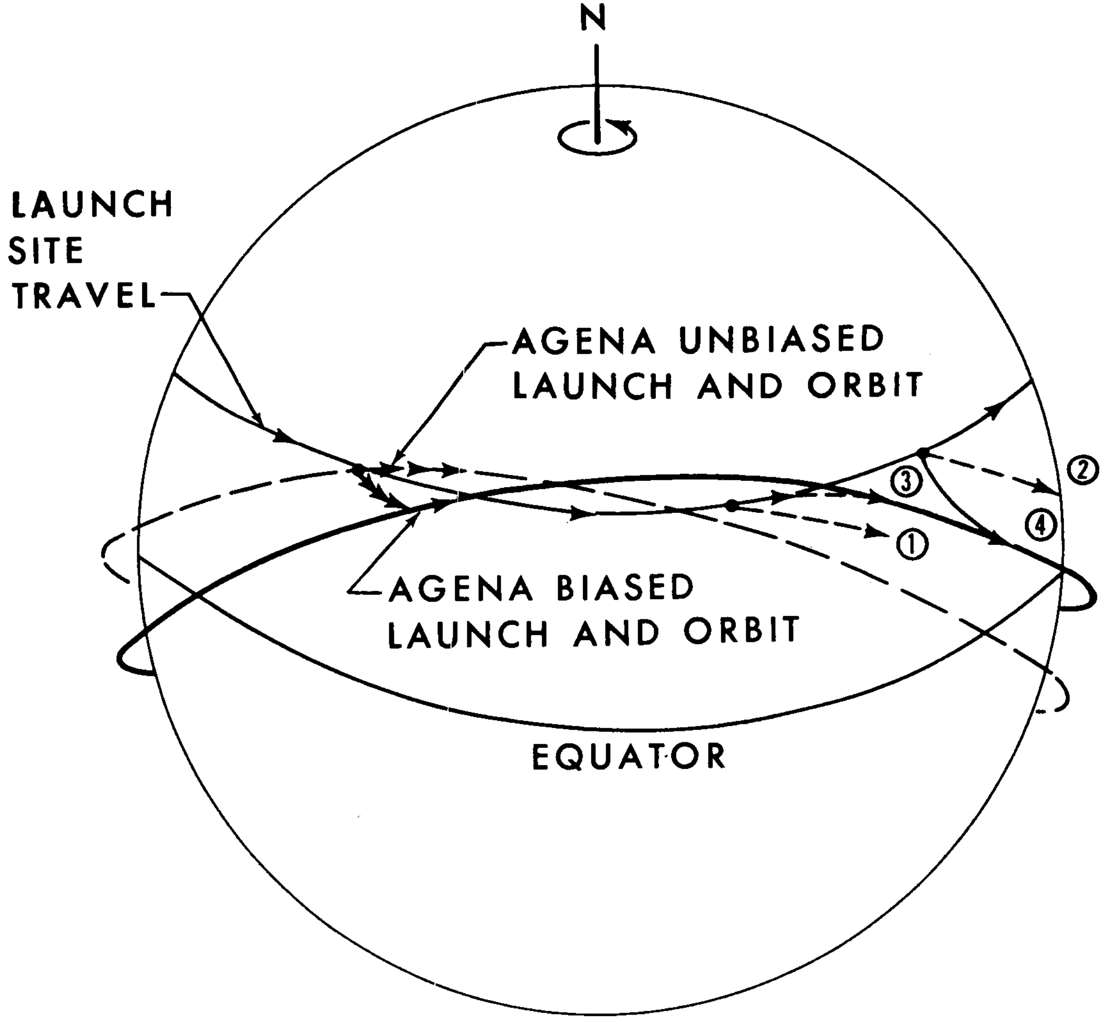
- PROVIDE HIGH SUCCESS PROBABILITY
  - FLEXIBILITY TO DEPART FROM NOMINAL MISSION PROFILE
  - LEAST SENSITIVE TO DISPERSIONS
  - STANDARD TERMINAL PHASE
  - PROVIDE BACK-UP CAPABILITY

RENDEZVOUS MISSION PLANS

- TANGENTIAL — 3-1/2 ORBITS
- RENDEZVOUS AT FIRST APOGEE
- COELLIPTICAL — 3-1/2 ORBITS
- SAME DAY VS. CONSECUTIVE DAY LAUNCHES

NASA-S-65-9548

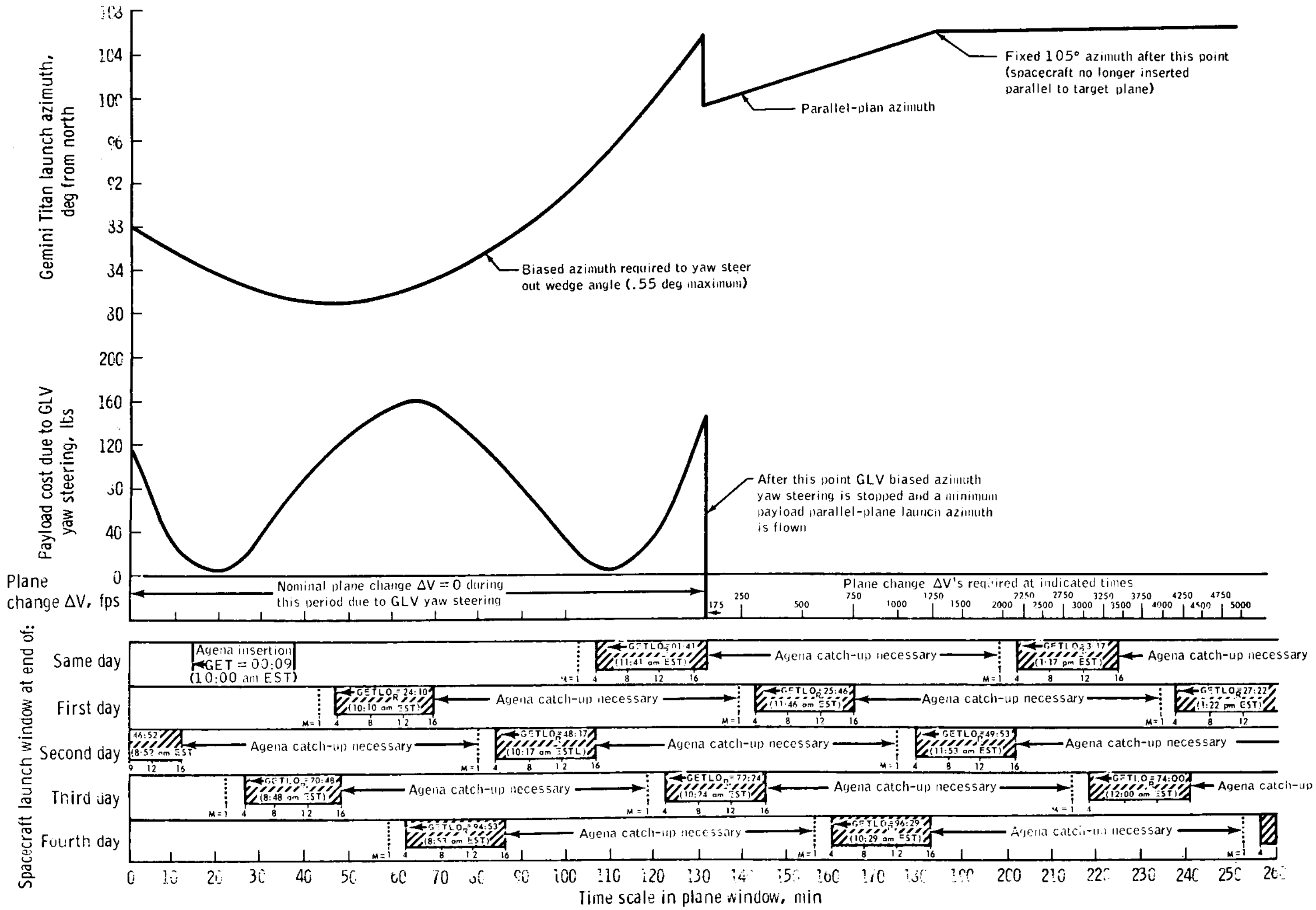
USING 'DOGLEG' LAUNCH TRAJECTORIES



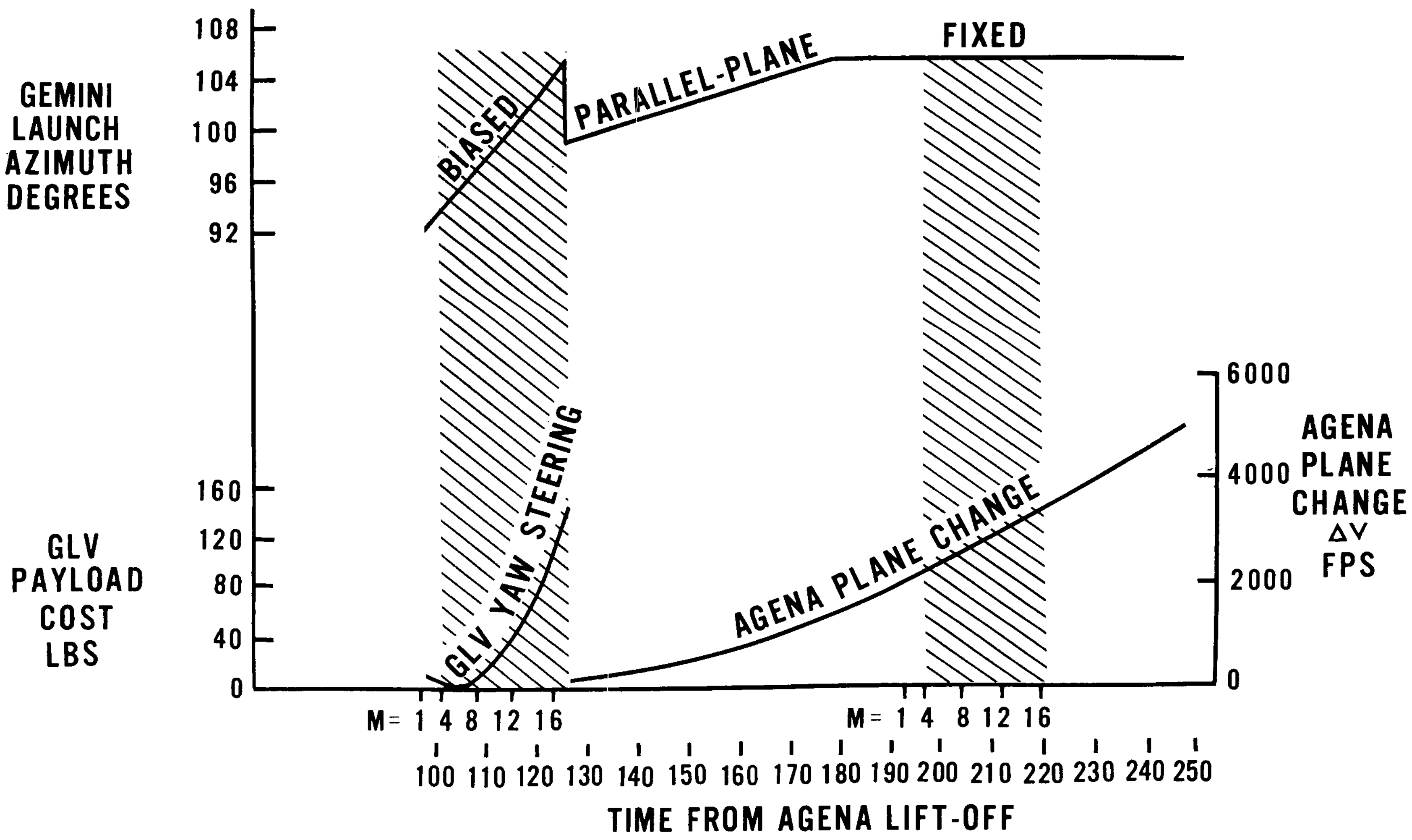
NASA-S-65-9364

65-FM-125

LAUNCH WINDOWS FOR GEMINI VI



GEMINI VI LAUNCH WINDOW



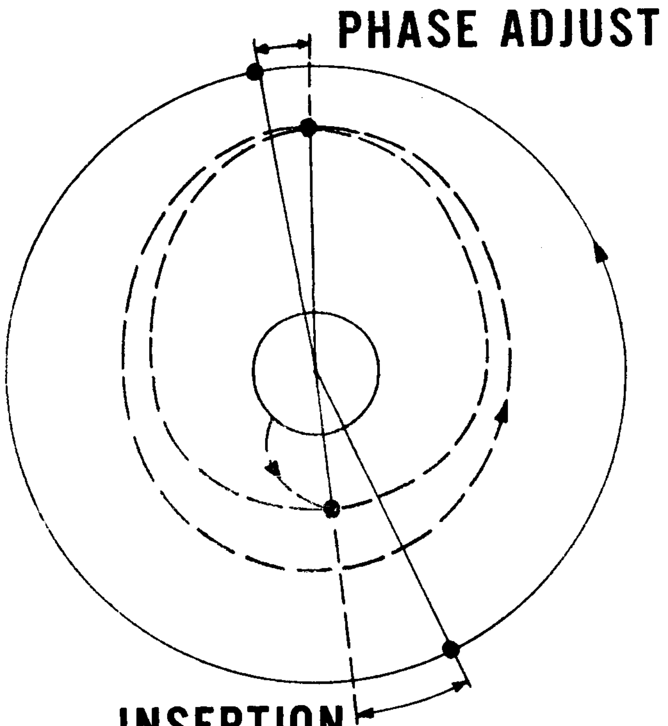
MG65 - 10,853

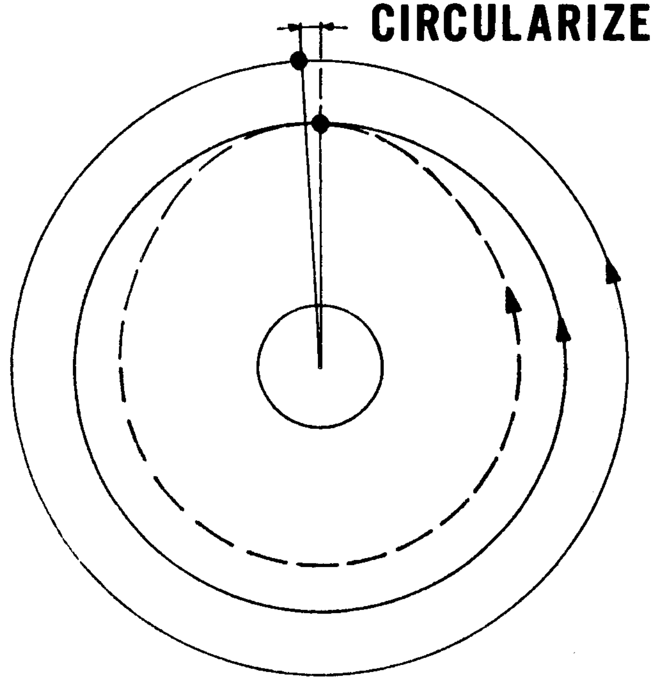
LIFT-OFF DELAYS

DELAY	RENDEZVOUS
100 SEC	5TH ORBIT
200 SEC	6TH ORBIT
OVER 200 SEC	16TH ORBIT

MG5-10, 858

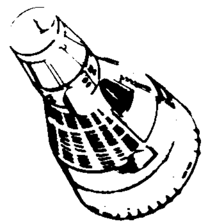
GEMINI-AGENA RENDEZVOUS GEOMETRY



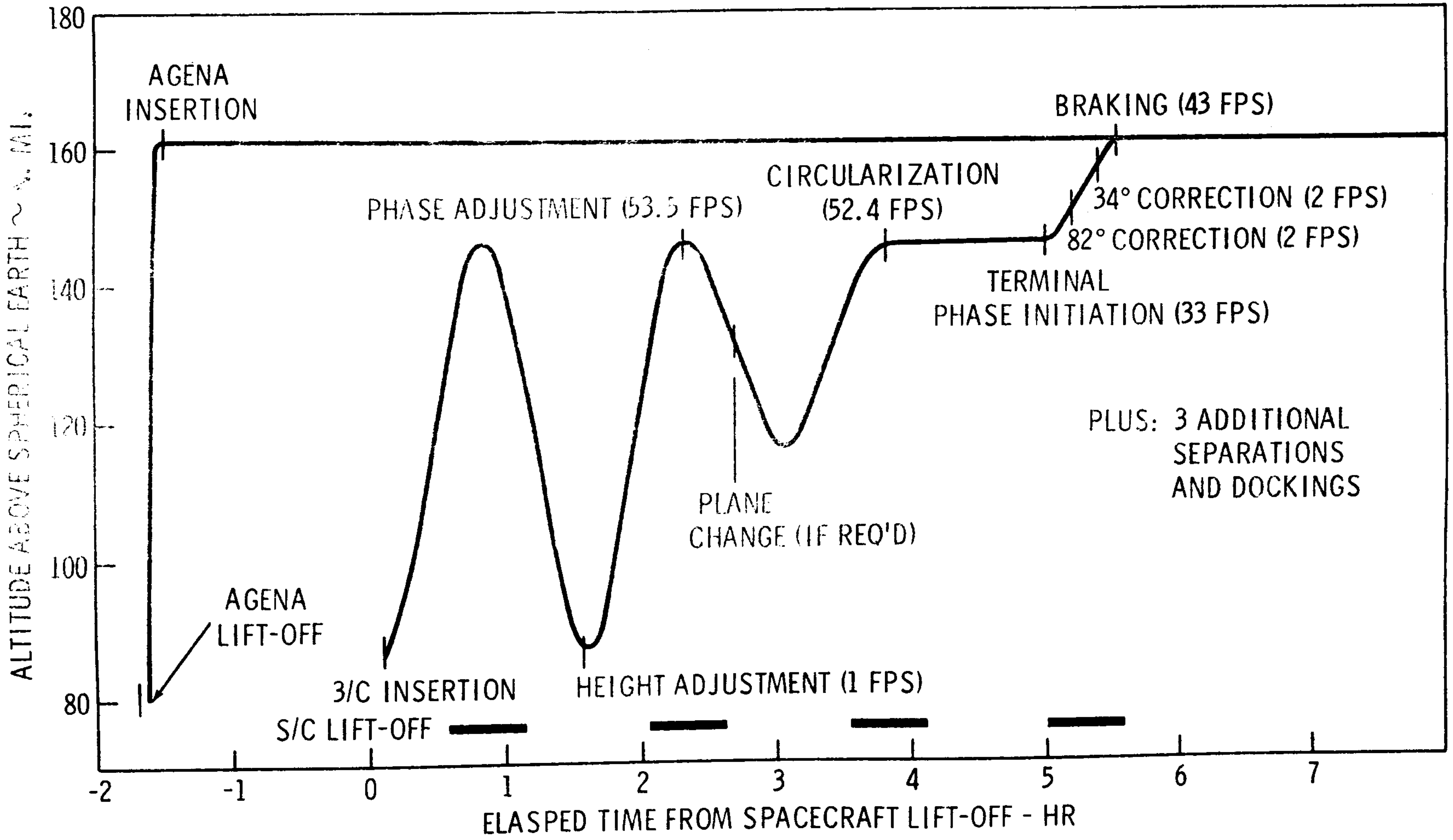


POSITION	TRAIL ANGLE	CATCH-UP RATE
INSERTION	16.5°	6.7°/REV
PHASE ADJUST	6.4°	4.5°/REV
CIRCULARIZE	2.0°	2.3°/REV

MG65 - 10,854

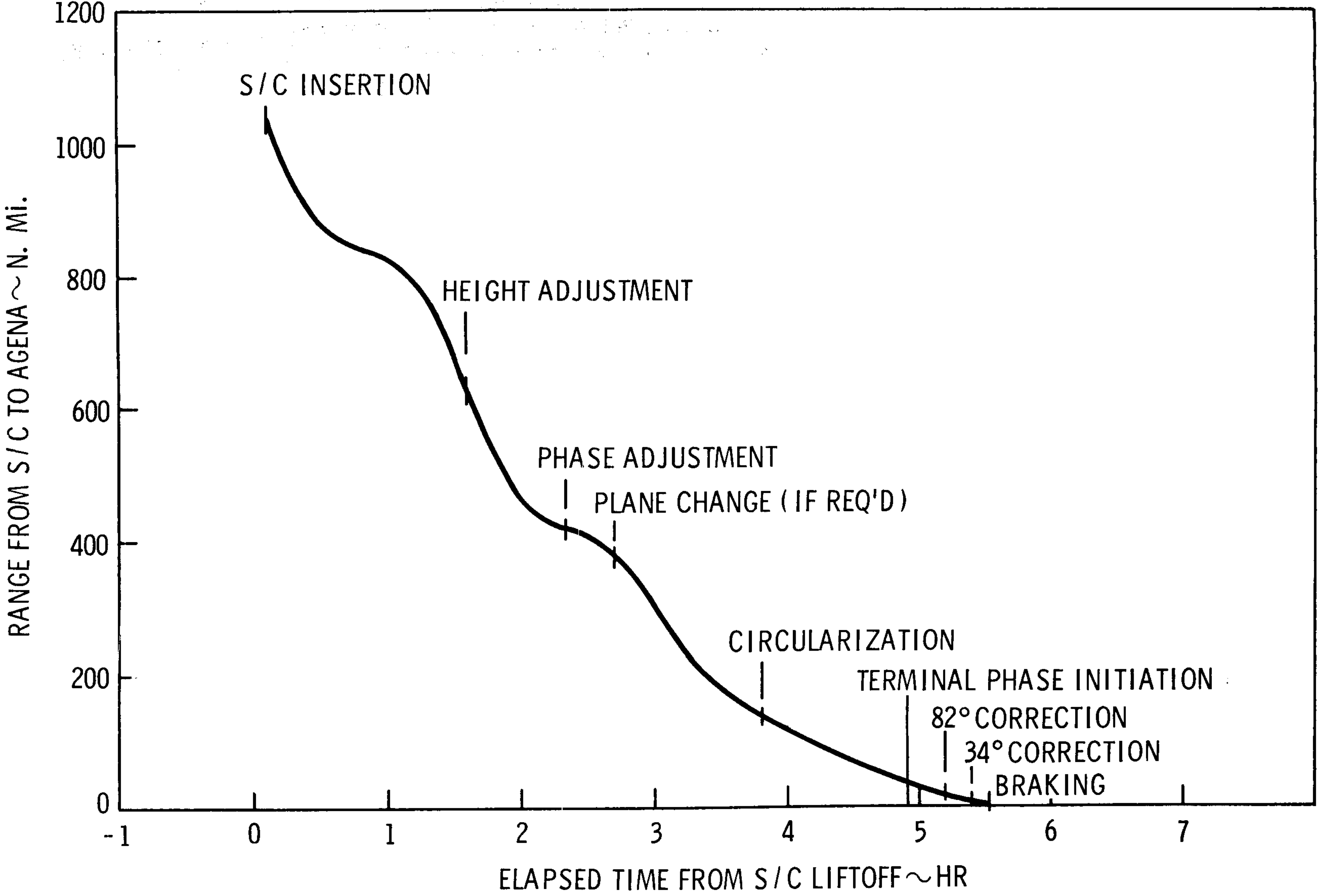


GEMINI VI NOMINAL MISSION PROFILE THROUGH RENDEZVOUS



MG5-10,242

GEMINI VI NOMINAL SPACECRAFT TO TARGET VEHICLE RANGE



MG5-10, 241

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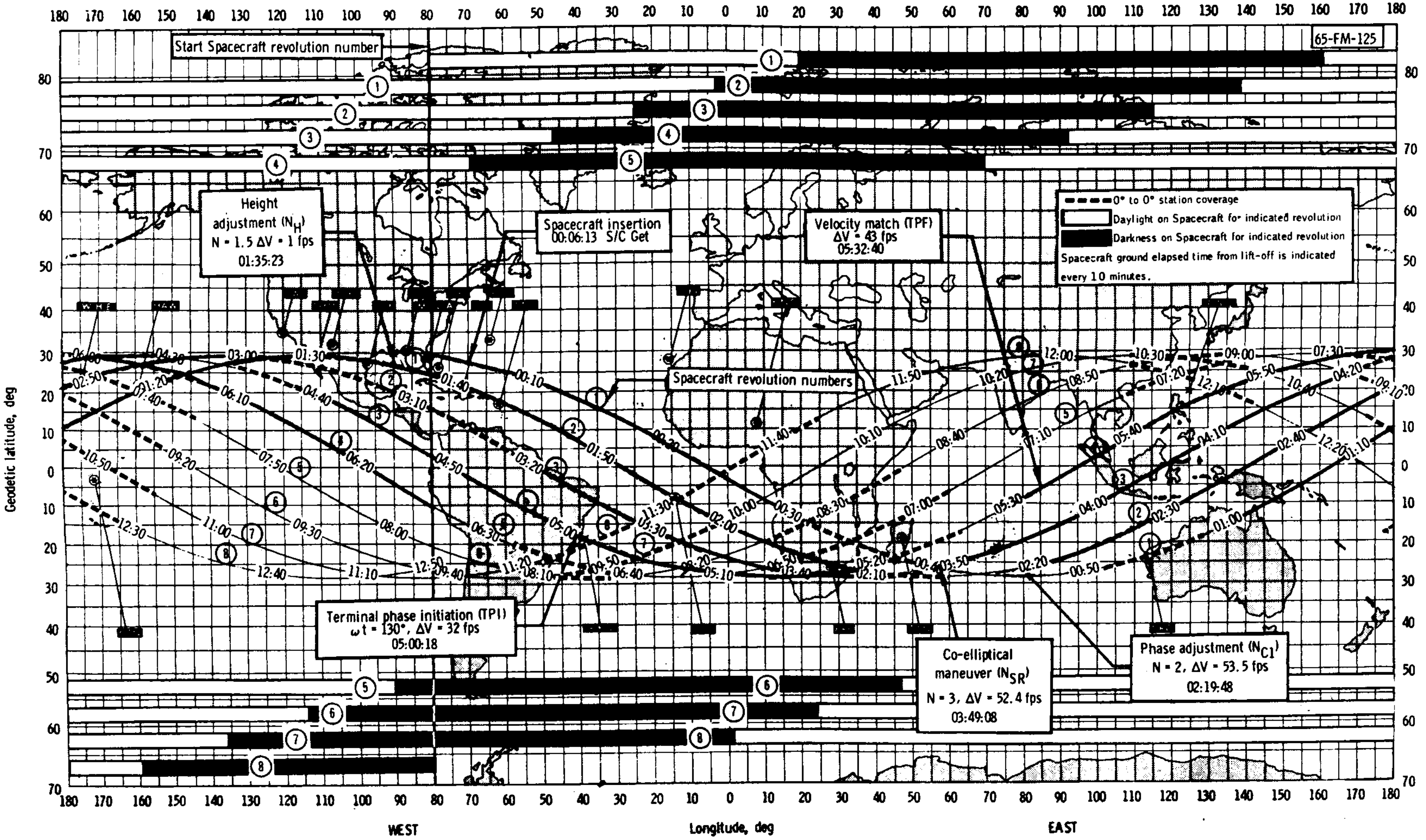
SPACECRAFT ORBITAL GROUND TRACKS FROM INSERTION THROUGH 32 EARTH-FIXED ORBITS

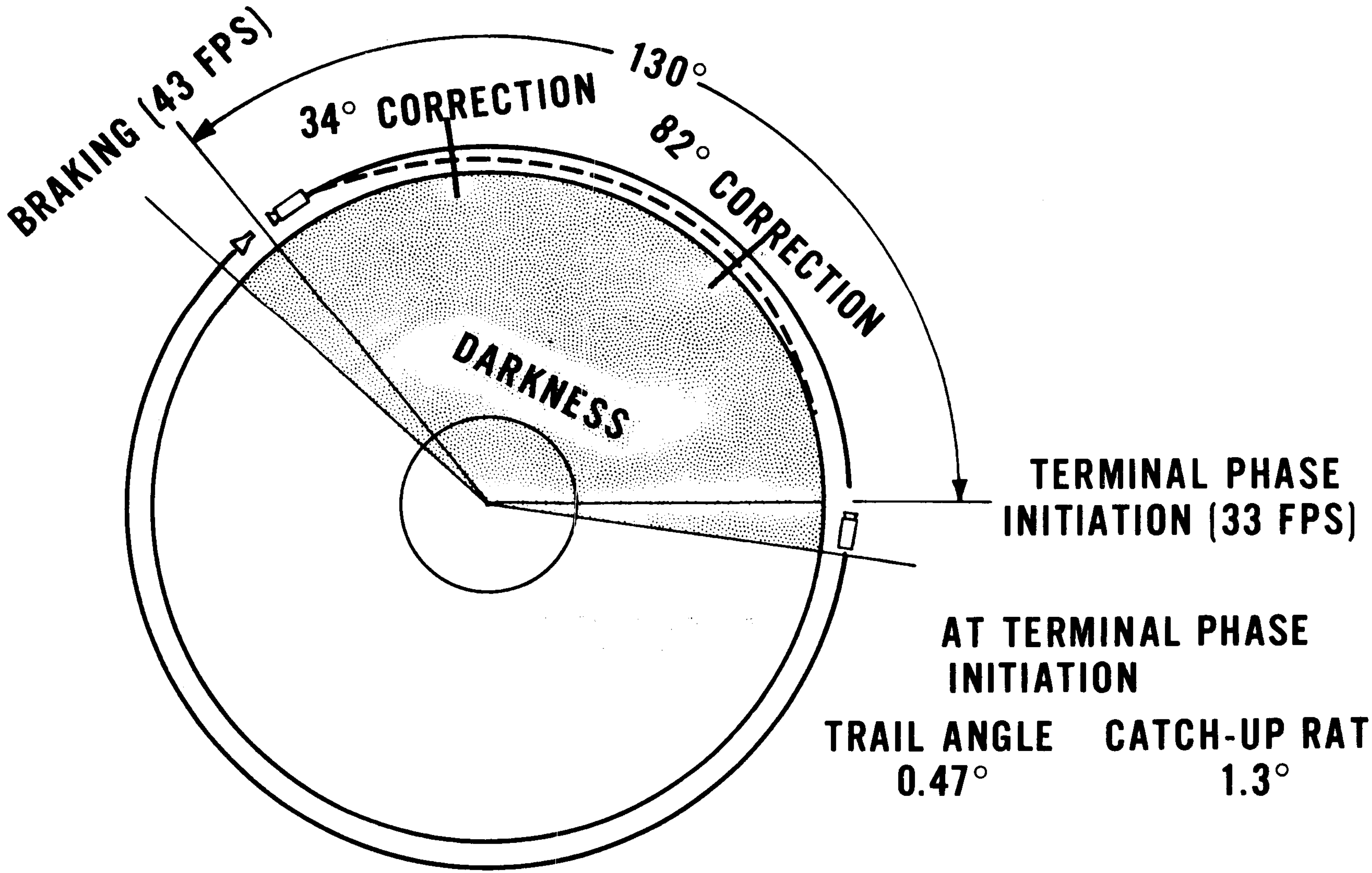
GEMINI TRACKING NETWORK

Revised March 17, 1965



Revolution 1 through 8.

GEMINI 6 TERMINAL PHASE MANEUVER



AT TERMINAL PHASE
INITIATION

TRAIL ANGLE	CATCH-UP RATE
0.47°	1.3°

MG5 - 10,244

INITIATION CUES

- TIME
- RANGE
- ΔV MINIMUM
- RELATIVE ANGLE ←

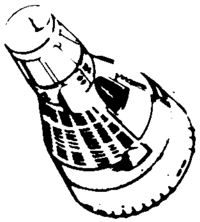
MG 5-10, 859

DIFFERENTIAL ALTITUDE

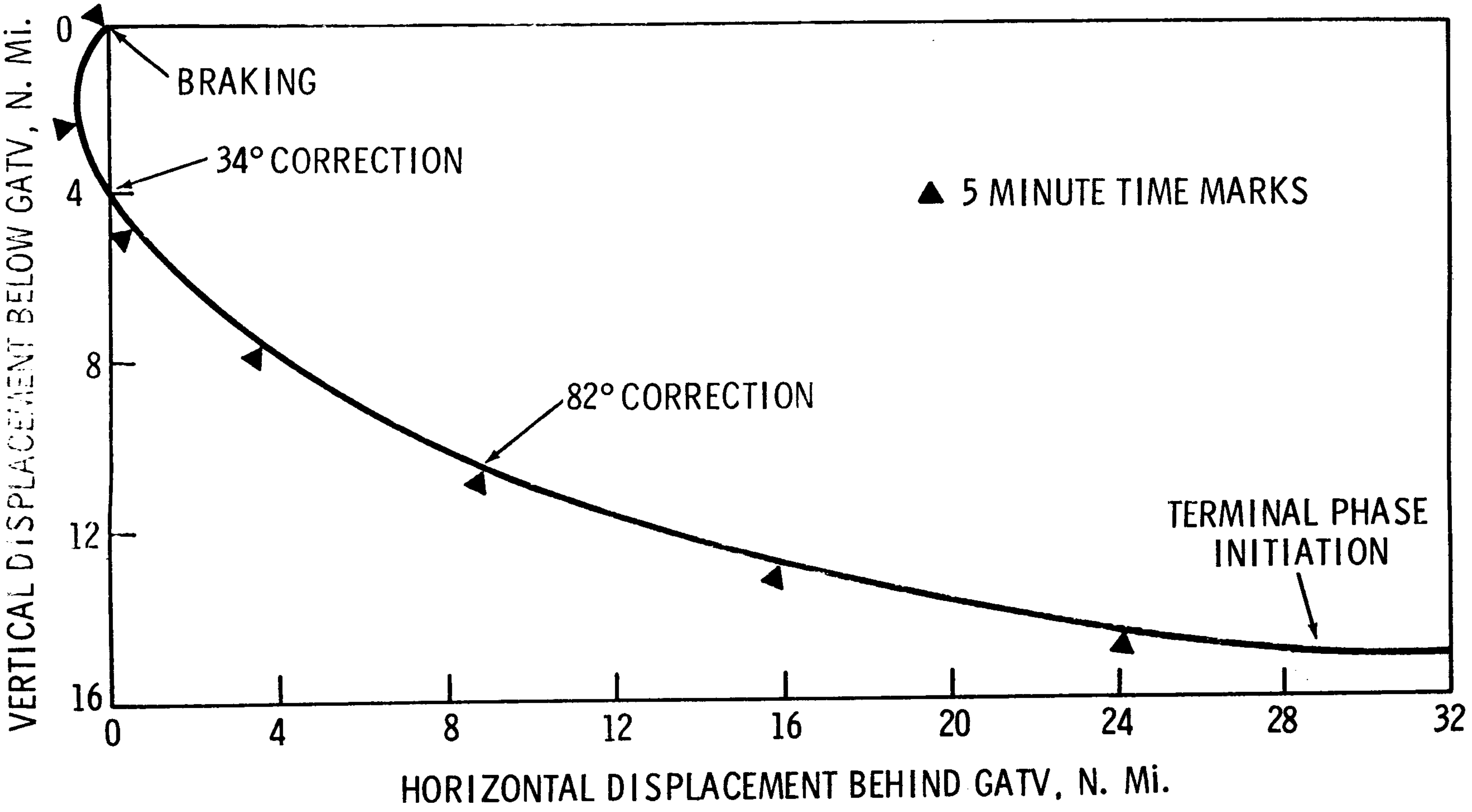
- CLOSE ENOUGH TO SEE TARGET
- NOT TOO CLOSE TO BE SENSITIVE TO SMALL DISPERSIONS

RESULT - 15 NAUTICAL MILE DIFFERENTIAL

MG 5-10,855



GEMINI VI TRAJECTORY RELATIVE TO AGENA

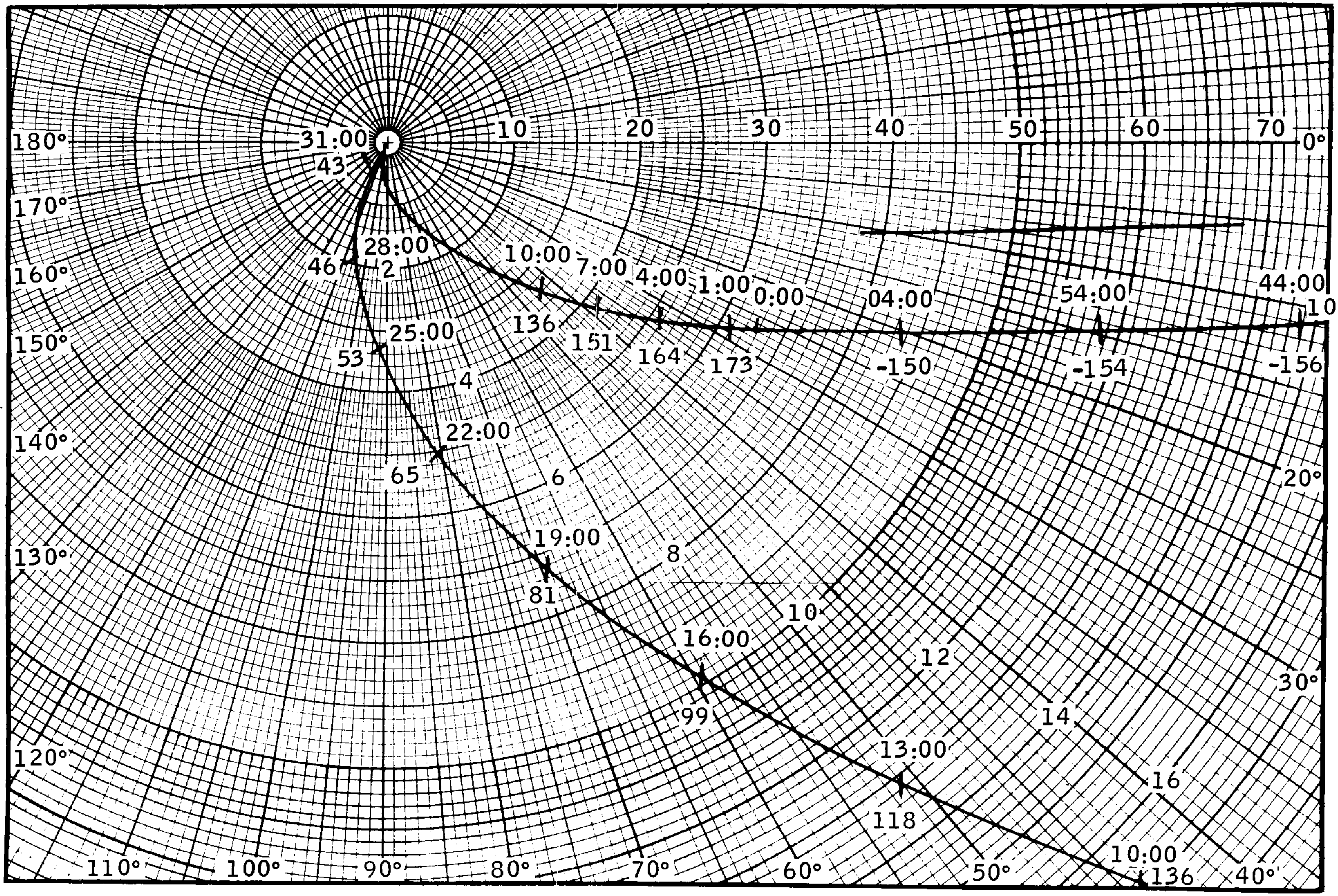


MG5-10, 243

NASA-S-65-9544

GEMINI VI RENDEZVOUS FLIGHT CHARTS

NOMINAL RELATIVE MOTION TRAJECTORY



RENDEZVOUS FAILURE MODES

INITIATION CUES FOR 130° TRANSFER

FAILURE	TRANSFER CUE
COMPUTER	PLATFORM/RADAR ELEV. ANGLE
RADAR	PLATFORM/LINE-OF-SIGHT ELEV. ANGLE
PLATFORM	RADAR RANGE (COMPUTER SMOOTHED)
COMPUTER/RADAR	PLATFORM/LINE-OF-SIGHT ELEV. ANGLE
COMPUTER/PLATFORM	RADAR RANGE (ANALOG)
RADAR/PLATFORM	TIME

POST RENDEZVOUS PLANS

- ADDITIONAL DOCKING PRACTICE
- EXPERIMENTS
- OTHER MANEUVERS
- FINAL SEPARATION
- RECOVERY
- POST RECOVERY AGENA EXERCISES