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MSC INTERNAL NOTE NO 64-FM-19

PROJECT GEMINI

PRELIMINARY STUDY OF ACHIEVING ORBIT USING SPACECRAFT PROPULSION CAPABILITY

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July 1, 1964

[redacted]

N70-75820
(ACCESSION NUMBER) (THRU)
19 none
(PAGES) (CODE)
TMX 65267 (CATEGORY)
(NASA CR OR TMX OR AD NUMBER)
FACILITY FORM 602

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SUMMARY

This paper offers a brief discussion of the present Gemini abort philosophy in the region just prior to insertion. Aborts in this flight regime are known as Mode IV aborts. Specifically the paper is an attempt to: (1) propose a Mode IV boundary, (2) indicate insertion conditions for 1.5 revolutions resulting from an abort in this mode, and (3) present two methods for determining in real time the required incremental velocity (ΔV) to be added via the OAMS to obtain 1.5 orbits.

INTRODUCTION

The two-man Gemini spacecraft, designed for rendezvous and long duration missions will generally carry from 350 to 700 pounds of maneuvering (OAMS) fuel (depending on the particular mission). In the event of a GLV shutdown between conditions to land in the last Atlantic recovery area and insertion, the OAMS fuel may be used to obtain 1.5 revolutions (to facilitate water recovery). For this discussion, Mode IV is defined as those SECO conditions that would result in the Gemini spacecraft having exactly 1.5 revolution capability (V_2, γ_2 and h_2) after the two aft OAMS thrusters were burned (at 0, 0, 0) for a fixed time.

DISCUSSION AND RESULTS

Figure 1 presents the applicable portion of the launch trajectory. For this study, the initial launch azimuth was 72 degrees and the spacecraft weight was 6700 pounds.

In the event of an early GLV shutdown, figures 2 and 3 indicate the SECO boundary conditions which begin the Mode IV region. To determine this boundary two 84 pound OAMS thrusters were burned at 0°, 0°, 0° attitude for 400 seconds (nozzle lifetime). The dashed lines on figure 3 require more than the 400 second burn time, but are still within fuel limits. The off nominal flight-path angles were considered to be at the same altitudes as the nominal trajectory. The Smithsonian No. 2 atmosphere was used to determine this boundary; whereas, the Mode III boundaries shown were determined with the 59 atmosphere ($\approx$ 17 fps difference).

It is shown in figures 4 through 7 that insertion conditions (for 1.5 revolutions), resulting from Mode IV aborts are radically different from SECO conditions. These changes are due to the earth's gravitation attraction, an inherent thrust addition from the GLV (about 100 feet per second velocity increase in 20 seconds) due to tail-off, and the slow addition of velocity during OAMS burn ($\approx$.8 feet per second per second)

Because of the changes after SECO, as evidenced in the above figures, the value of the Mode IV boundary line (capability line) is somewhat reduced on a SECO plot. However, this line may be used similarly to the Mercury GO-NO/GO line to establish when the launch trajectory reaches conditions that permit an alternative to landing beyond the last Atlantic recovery area. Figure 8 shows that for a nominal trajectory, the 1.5 capability

is reached just before conditions to hit the last recovery area short of Africa (3400 nautical miles). Procedures covering the small area between the West African Coast line and Mode IV boundary line will be discussed in another paper covering Mode III aborts.

If a premature engine cutoff occurs after Mode IV boundary is reached as defined in figure 2 (inside 3σ altitude limits), the pilot must be informed of the ΔV (incremental velocity) that he must add with the OAMS. Figure 3 shows how the required ΔV varies with SECO V and γ. At the boundary, a 331 feet per second increment takes 400 seconds to add. To utilize the latest velocity and position vector and to include as much of the tail-off effect as possible, a data "smoothing" technique is employed for 13 seconds after engine cutoff. A constant 10 feet per second, to simulate spacecraft separation from the booster, is then added to give the final abort vector (V_I, γ_I and h). It is this vector which is used to determine the required OAMS ΔV (because it includes the tail-off velocity increment, the flight-path angle and altitude changes that occur during tail-off). For discussion purposes this vector is called the SECO +30 vector.

To accomodate this more reliable vector (as compared to the SECO vector) a series of ΔV (to be added) curves for SECO +30 conditions possible from any 3σ trajectory have been determined and are shown in figures 9a, 9b, and 9c. It is observed that the altitudes are for 93, 87 and 82 nautical miles. (For a given V and γ the OAMS ΔV required for 1.5 revolutions at each of these altitudes may be read by interpolation.) Figure 9d can be used to illustrate that the change in required ΔV is non-linear in altitude as well as velocity and flight-path angle. In other words, an early GLV cut-off at nominal altitude with a nonnominal flight-path angle can result in significant altitude changes during tail-off. These altitude changes can cause the OAMS (ΔV required) lines (and/or flight control decision lines) to shift. Therefore, these lines have been determined for the possible altitude extremes and computing techniques devised that include the altitude effects.

Based upon figures 9a, 9b, and 9c two techniques have been developed, each of which may be used in the Real Time Computer determination of ΔV required.

One technique (reference 1) requires considerable storage space (approximately 1000 locations) and may best be used in the ground computer. In general, it works as follows: given V_I, γ_I and h_1 at SECO +30, it interpolates for required ΔV at each of two altitudes, both above and below the given altitude. It then linearly interpolates between these altitudes for required ΔV at the given altitude. In most instances results are conservative (safe) but a small ΔV pad of 5 to 10 feet per second may be necessary to cover extreme conditions (low $-\gamma$'s). The second technique (reference 2) employs curve fit methods which for the most part are within 5 feet per second of the required ΔV. Although this method has not been thoroughly checked, it is estimated that maximum errors of 15 feet per second can be expected. The small storage space required for this method makes it particularly useful for the onboard computer (less than 100 storage locations).

At present, it is not known which of the two methods is most reliable. However, with a small ΔV pad, either one should suffice. (Either method is sufficiently fast.)

It should be pointed out that the only restriction placed upon these ΔV requirements was that following OAMS thrust, the spacecraft achieves 1.5 revolutions. Some of these orbits from nonnominal trajectories are highly irregular (typical orbits indicated on figure 9b) and may violate other spacecraft limitations (i.e. heating or retro capability to hit a prescribed recovery area). Preliminary limits for these conditions are shown in figure 3. Considerable effort is presently being expended to determine these limits more completely.

CONCLUSIONS

Mode IV boundary for a nominal trajectory using two 84 pound aft thrusters for 400 seconds begins at V_I = 25,210 feet per second (Smithsonian No. 2 atmosphere).

The low acceleration obtained via the OAMS as used in Mode IV aborts results in significant changes relative to SECO conditions in velocity, flight-path angle, and altitude.

Two methods for predicting required OAMS ΔV in a Mode IV abort have been developed. Either one should suffice for Real Time Computer logic with a small velocity pad for ground computing. One may be applicable to on-board S/C computing.

REFERENCES

1. Memorandum re OAMS 1.5 Orbit Capability by Frank J. Suler dated May 21, 1964.

2. Memorandum re Method for computing ΔV required for a Gemini Mode IV abort by Laurel A. Phillips and Will York dated May 21, 1964.

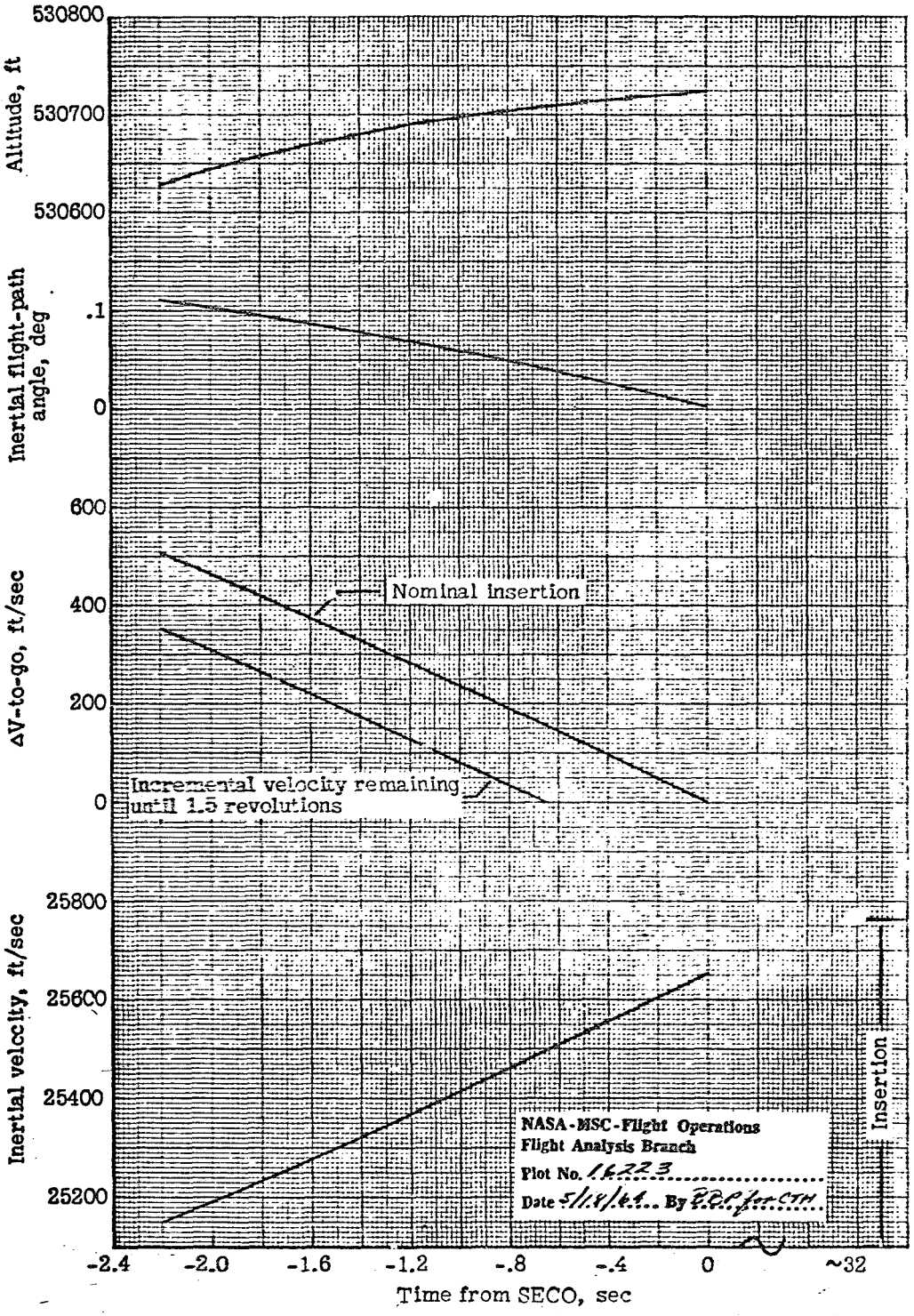


Figure 1. - Nominal launch conditions used for [illegible] simulations.

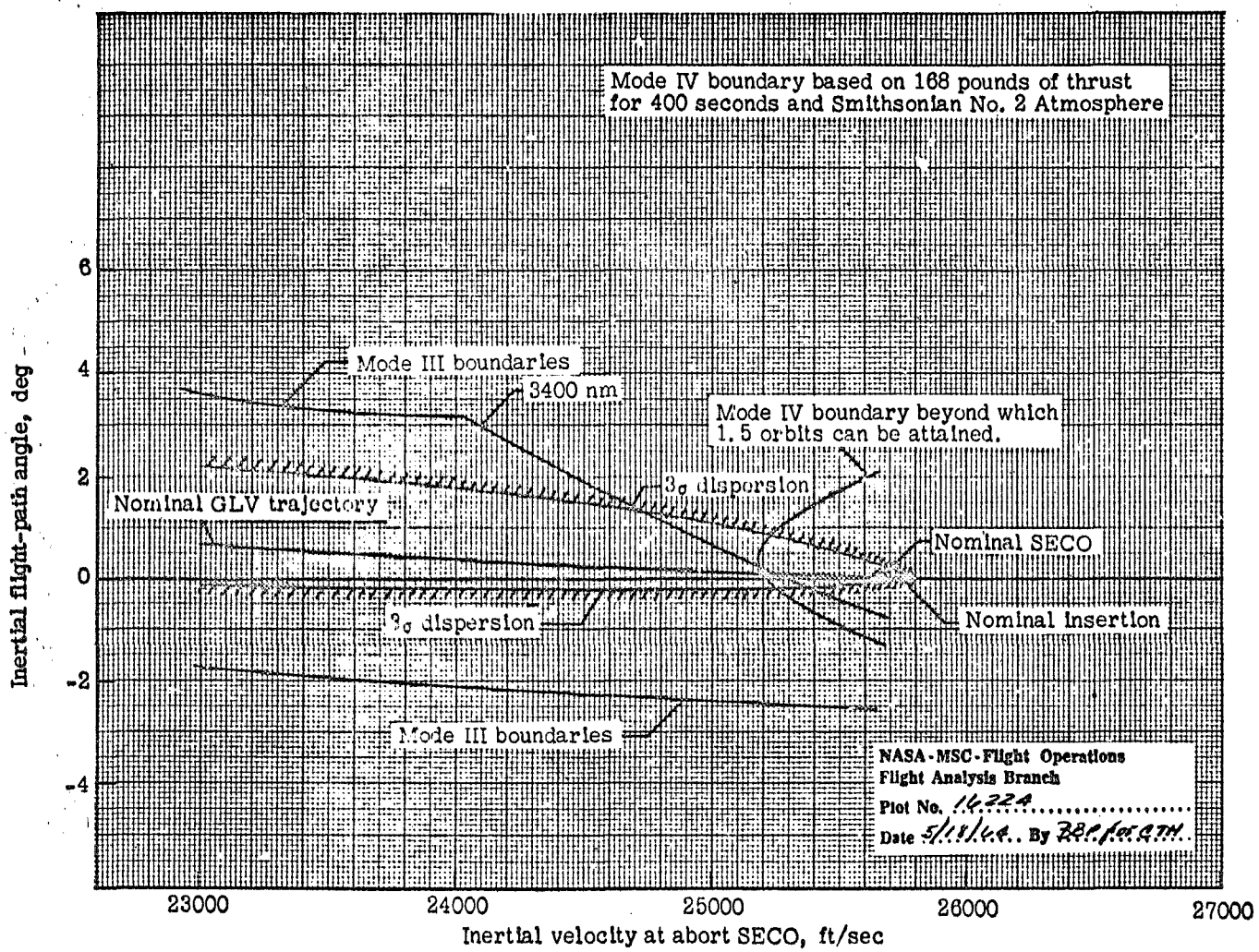


Figure 2. - Relation of Gemini Mode IV abort boundary to expected Mode III boundaries.

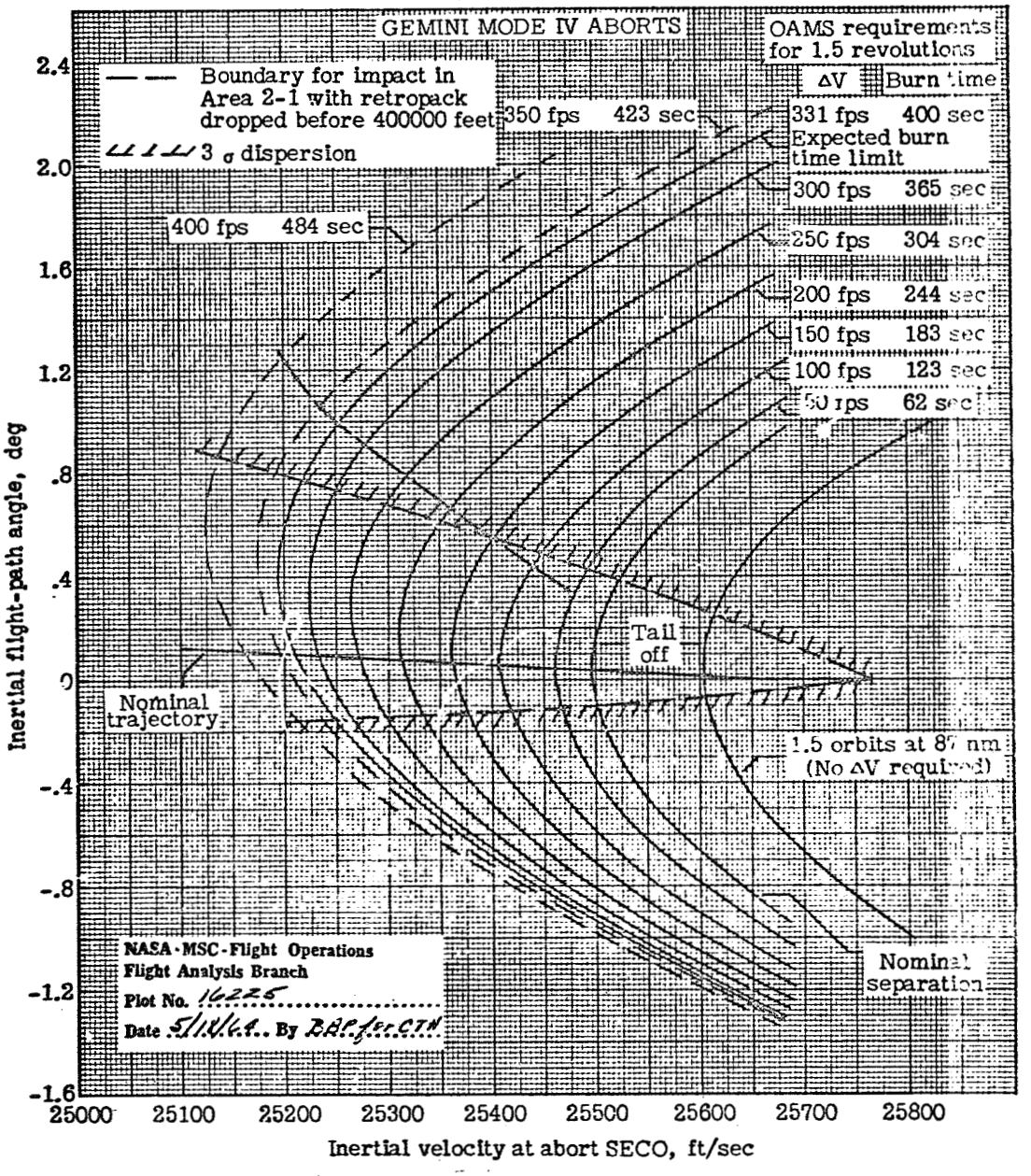


Figure 3. - OAMS ΔV requirements for SECO conditions.

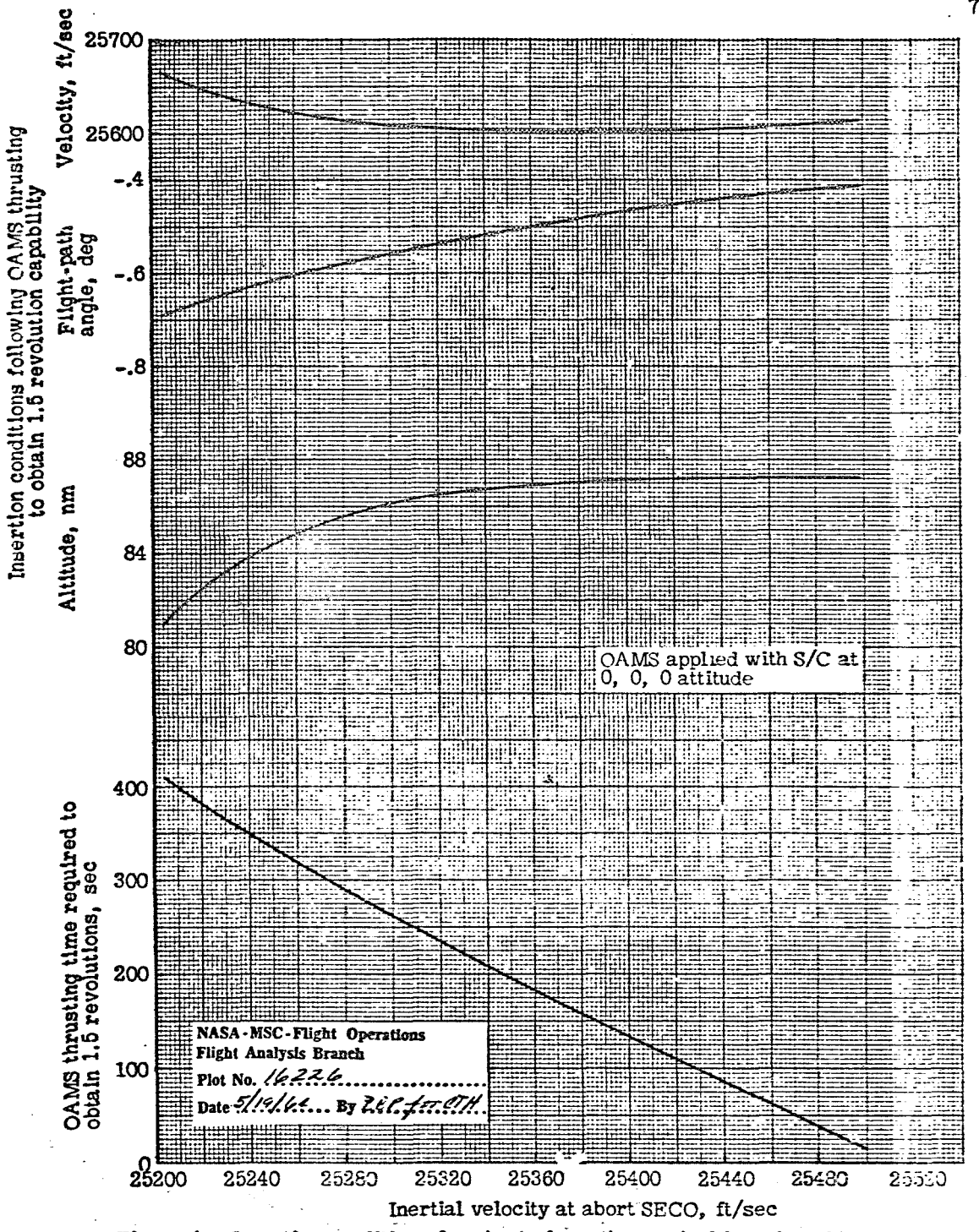


Figure 4. - Insertion conditions for aborts from the nominal launch trajectory.

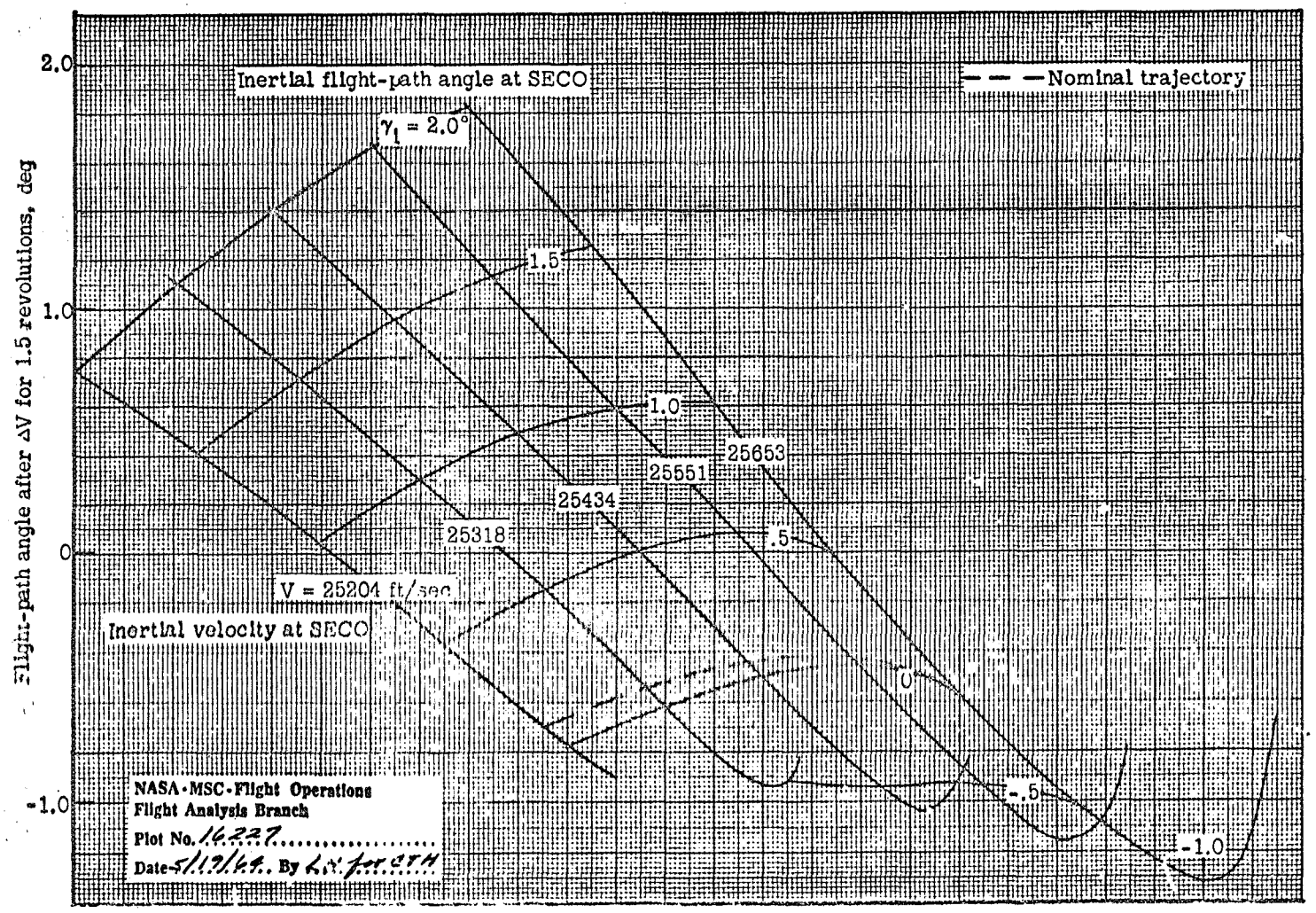


Figure 5. - Inertial flight-path angle at insertion for 1.5 revolutions for non-nominal SECO's (Assuming nominal altitude at SECO).

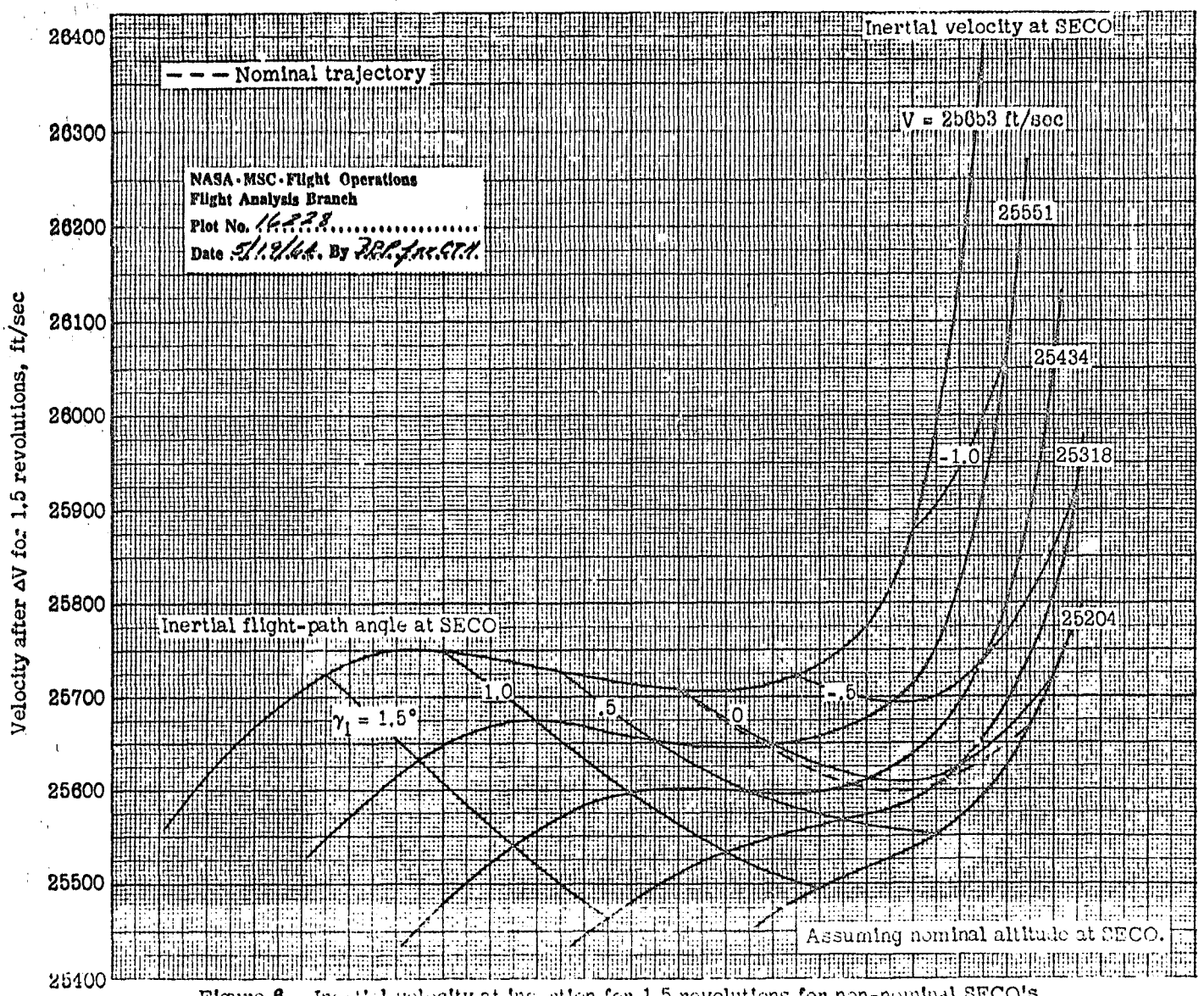


Figure 6. - Inertial velocity at insertion for 1.5 revolutions for non-nominal SECO's.

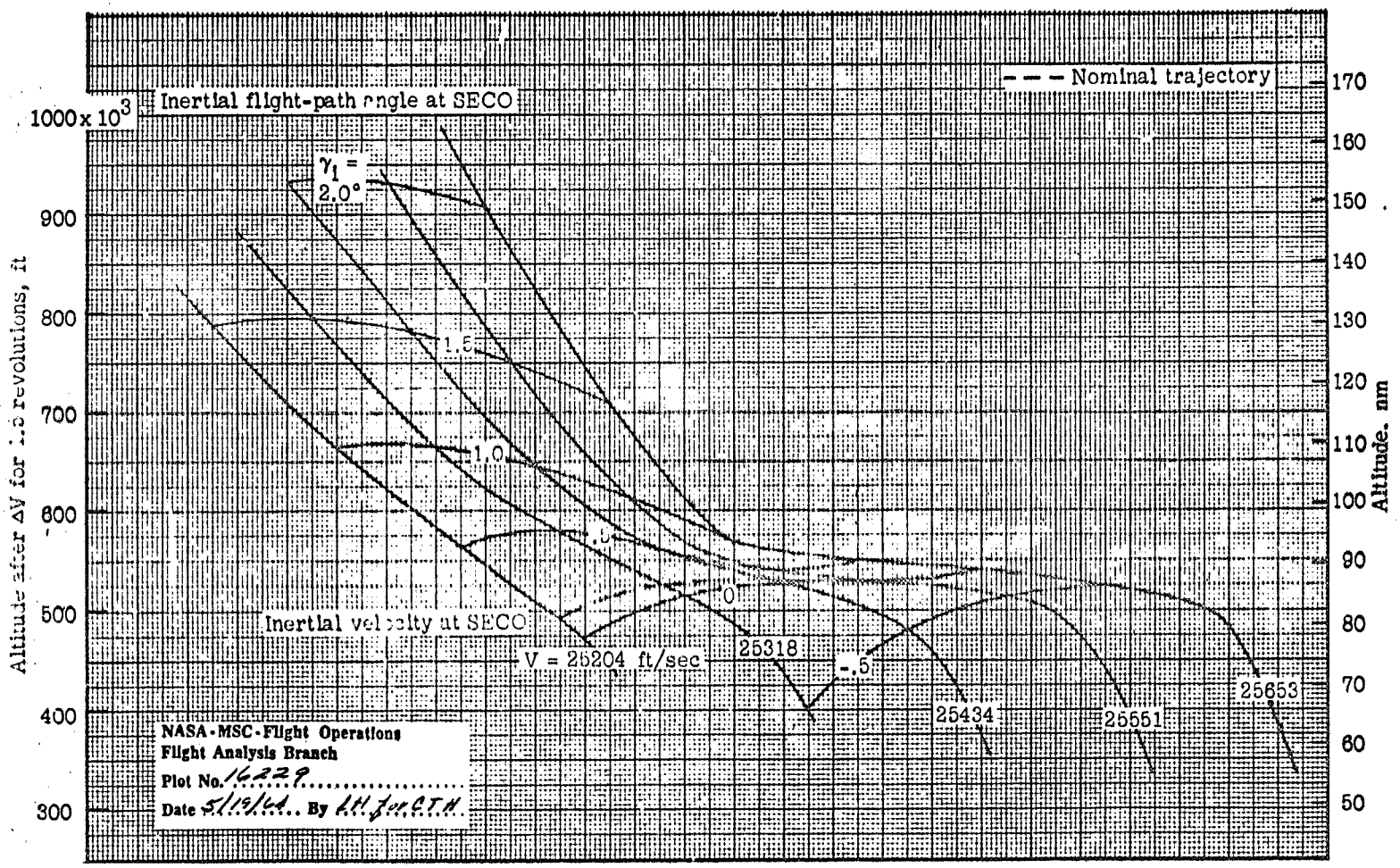


Figure 7. - Altitude of insertion for 1.5 revolutions for non-nominal SECO's (Assuming nominal altitude at SECO).

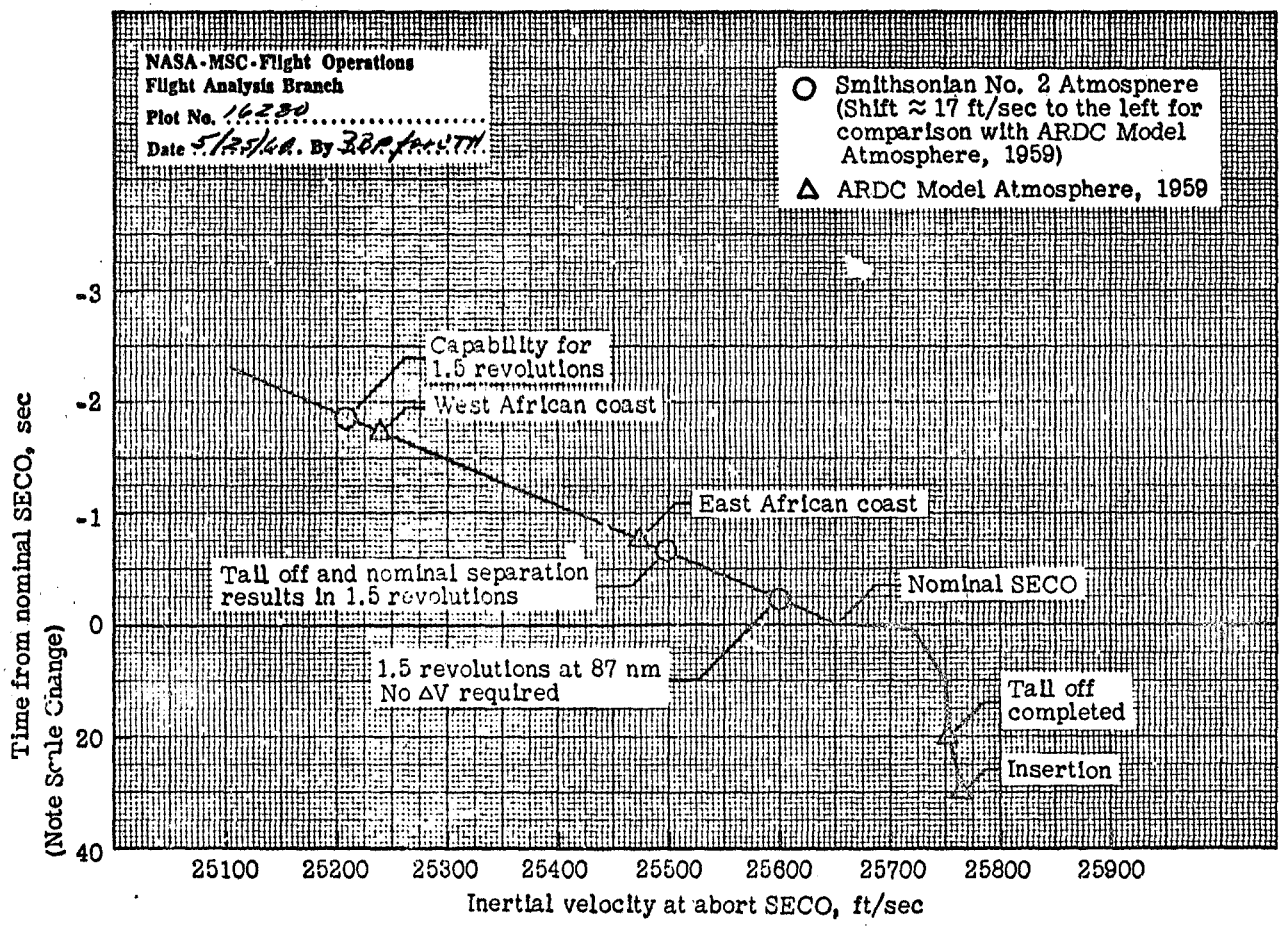
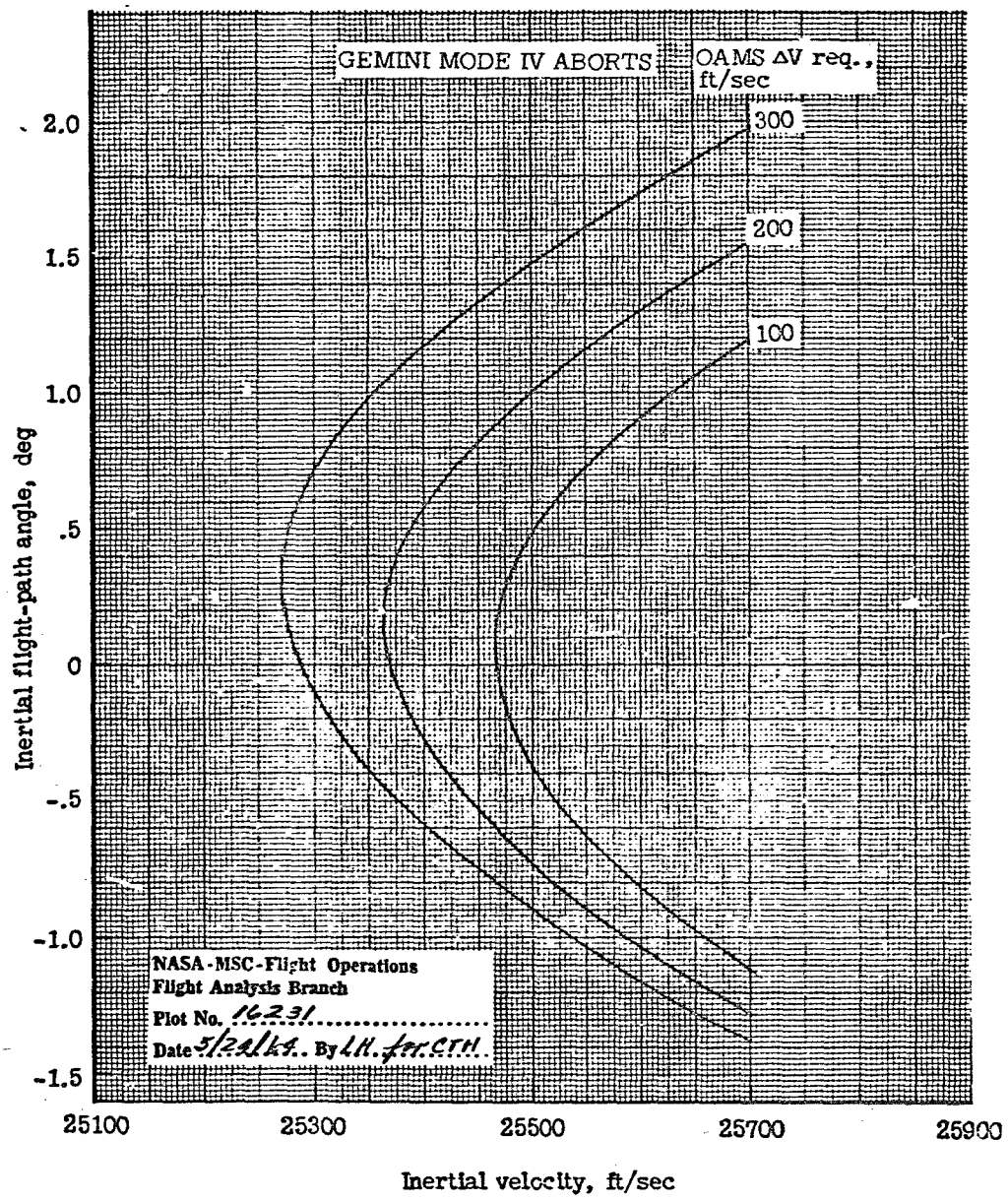
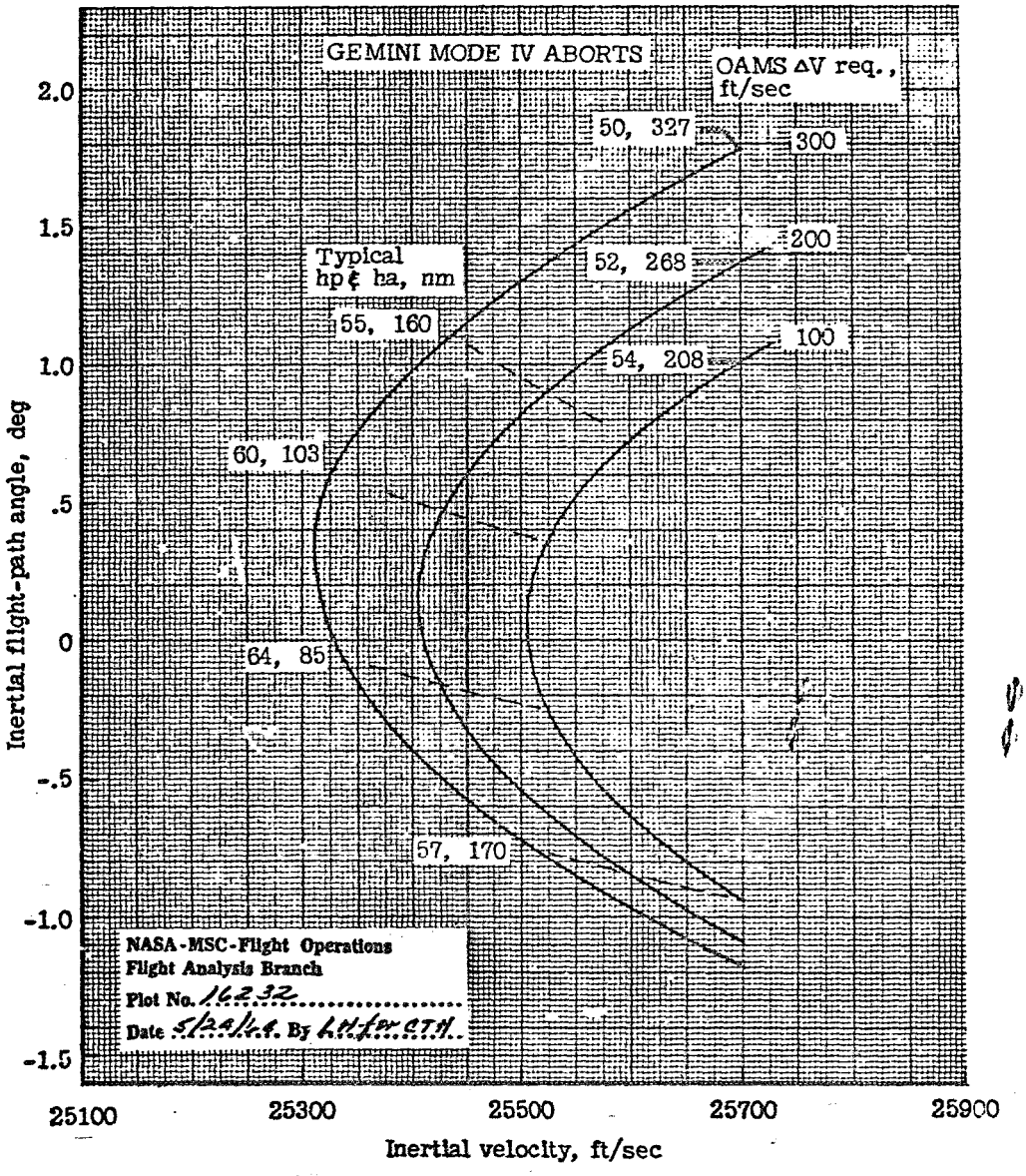


Figure 8. - Gemini near insertion abort summary.



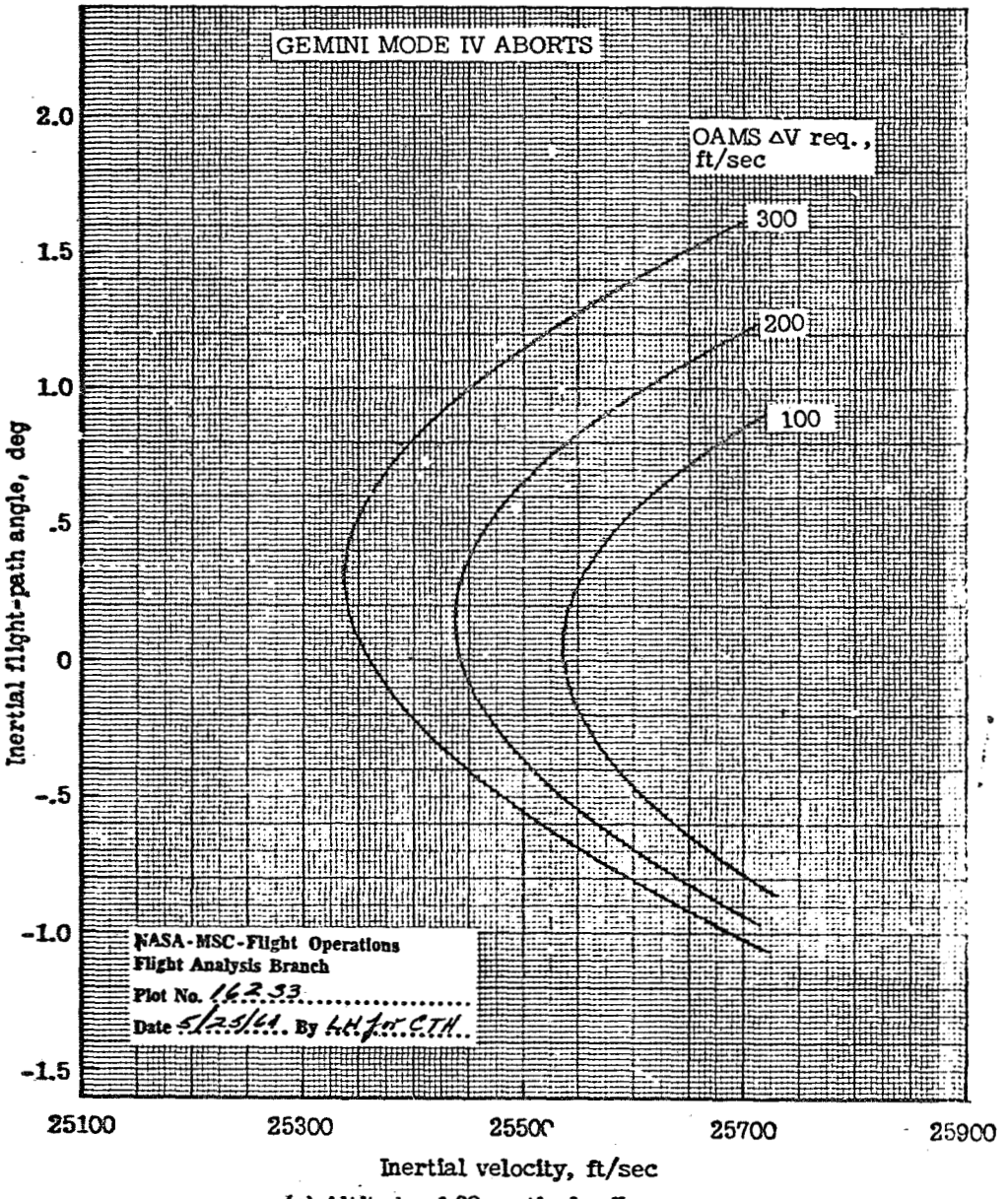
(a) Altitude of 93 nautical miles.

Figure 9. -ΔV required for 1.5 revolutions after nominal separation sequence (84 pound thrusters).



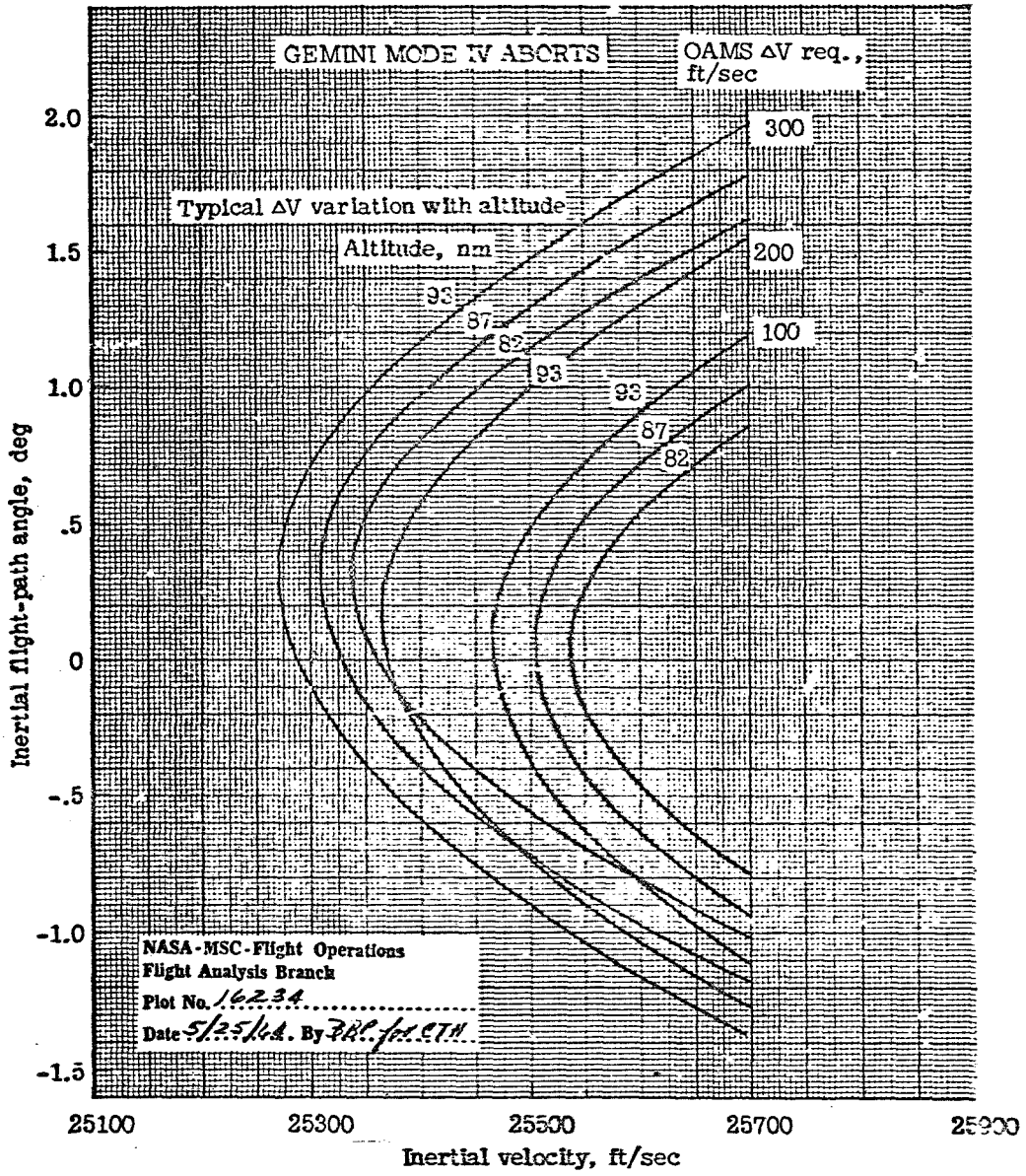
(b) Altitude of 87 nautical miles.

Figure 9. - Continued.



(c) Altitude of 82 nautical miles.

Figure 9. - Continued.



(d) Typical ΔV variation with altitude.

Figure 9. - Concluded.

MSC INTERNAL NOTE NO. 64-FM-22

PROJECT GEMINI

SEPARATION PARAMETER STUDY FOR THE GEMINI MODE I/MODE II ABORT TRANSITION AT 70,000 FEET

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July 15, 1964