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By Charles E. Foggatt

SUMMARY AND INTRODUCTION

A backup abort procedure for aborts initiated during the TLI burn was presented in reference 1. It was shown that it is operationally feasible to perform a fixed-attitude, fixed-delay-time abort following a premature S-IVB shutdown. Reference 1 and previous analyses of this backup abort procedure were performed assuming an impulsive SPS ΔV. Subsequent analysis has shown that in some cases considerable changes in required ΔV appear when the actual finite burn is simulated. This internal note is intended to provide comparative data on abort ΔV and time from abort to entry for impulsive and finite burn fixed-attitude aborts.

The fixed-attitude abort procedure consists of S-IVB thrust termination followed by immediate separation of the CSM and no attempt to retrieve the LM. The CSM longitudinal axis is then aligned in the orbital plane at a prescribed angle relative to the far horizon (fig. 1). Finally, a constant inertial-attitude SPS burn is initiated to lower perigee and effect a successful CM entry.

SYMBOLS

CM	command module
CSM	command and service modules
h_p	perigee altitude
LM	lunar module
SPS	service propulsion system
T_{AR}	time from abort to entry
TLI	translunar injection
ΔV	velocity increment
ψ	horizon reference angle

ANALYSIS

In this analysis there are three independent variables which define the preabort state of the CSM.

1. The time of S-IVB shutdown which determines the preabort ellipse. In this study shutdown times of 250, 300, and 333.24 (nominal) seconds were considered.

2. The coast time following S-IVB shutdown to the abort point. Times of abort range from 6 to 10 minutes in this study.

3. The angle between the longitudinal axis of the CSM and the far horizon in the plane of motion. This angle is called the horizon reference angle, ψ. Data is presented for values of ψ from $-10°$ to $+10°$. Figure 1 shows the fixed-attitude abort maneuver and the sign convention for ψ.

Following definition of the preabort state, abort trajectories were constructed using the Terra Earth Abort Program (ref. 2).

RESULTS

Under the impulsive ΔV assumption of previous horizon-reference abort studies, the required abort ΔV for nominal entry and subsequent value of T_{AR} were found once the preabort state was defined. However, with the assumption of a finite SPS burn in the current analysis an obvious difference in ΔV and T_{AR} appears. Moreover, for some preabort states which previously resulted in impulsive ΔV abort solutions, no solutions existed in the finite-burn study.

Variation in h_p as a function of SPS burn time is illustrated in figure 2 in which the preabort state is characterized by a nominal S-IVB shutdown and coast-to-abort-initiation time of 10 minutes. As ψ is decreased, the required SPS burn time to lower h_p to the correct value for entry (approximately 20 n. mi. in this case) is reduced. Initially, when ψ is $+10°$ with respect to the far horizon, h_p actually increases during the abort burn and at fuel depletion (585 seconds) has increased to 190 n. mi. from the initial 120-n. mi. value. In an identical situation, the impulsive ΔV simulation found a solution for which the SPS burn time was 460 seconds.

Figures 3, 4, and 5 compare finite-burn and impulsive ΔV simulations following S-IVB shutdowns at 250, 300, and 333.24 seconds, respectively. The preabort ellipses are characterized by eccentricities of 0.618, 0.819, and 0.977. Figures 3(a), 4(a), and 5(a) present the required ΔV for nominal entry as a function of ψ, and figures 3(b), 4(b), and 5(b) show the resulting T_{AR}. As ψ is increased from its minimum value of -10°, the impulsive ΔV required is higher than the finite-burn ΔV until a value of ψ is reached where the impulsive and finite-burn ΔV are equal. This value of ψ, denoted by ψ^*, is a function of the time of abort initiation. For values of ψ greater than ψ^*, the finite-burn ΔV exceeds the impulsive ΔV until a finite-burn solution no longer exists.

In the figures 3(b), 4(b), and 5(b), as ψ is increased from its minimum value of -10°, the resulting T_{AR} of the finite-burn simulation is greater than the T_{AR} of the impulsive burn simulation until the value of ψ is reached where they are equal. This value $\psi = \psi^{**}$ is also a function of the time of S-IVB shutdown to abort initiation. For values of ψ greater than ψ^{**} the T_{AR} of the impulsive ΔV simulations exceeds the T_{AR} of the finite-burn cases.

In actual practice, if the fixed-attitude abort procedure was to become the backup abort mode during the TLI burn, a standard value of ψ and time of abort from S-IVB shutdown would be established. Figure 6 is a summary of the required abort ΔV as a function of the time of abort from S-IVB shutdown when ψ is 5°. Comparative curves for the finite-burn and impulsive ΔV are shown for S-IVB shutdowns at 250, 300, and 333.24 seconds. As abort initiation is delayed, the abort ΔV decreases in all cases. However, the finite-burn abort ΔV exceeds that of the impulsive simulation, and this difference is larger for the later S-IVB shutdowns. Figure 7 is a plot of the corresponding T_{AR} for these cases. The impulsive and finite-burn T_{AR} values show close agreement for the 250-second S-IVB shutdown but begin to diverge for the later shutdown times.

CONCLUSIONS

The fixed-attitude abort procedure for aborts occurring during TLI remains feasible when analyzed using a finite-burn simulation. However, the previous data generated for the horizon-reference backup abort procedure can be expected to change considerably in some cases when actual finite-burn data is run. The ΔV and T_{AR} may either increase or decrease depending on the value of ψ. Finally, solutions may no longer be possible for larger values of ψ where solutions previously existed, regardless of the SPS burn time.

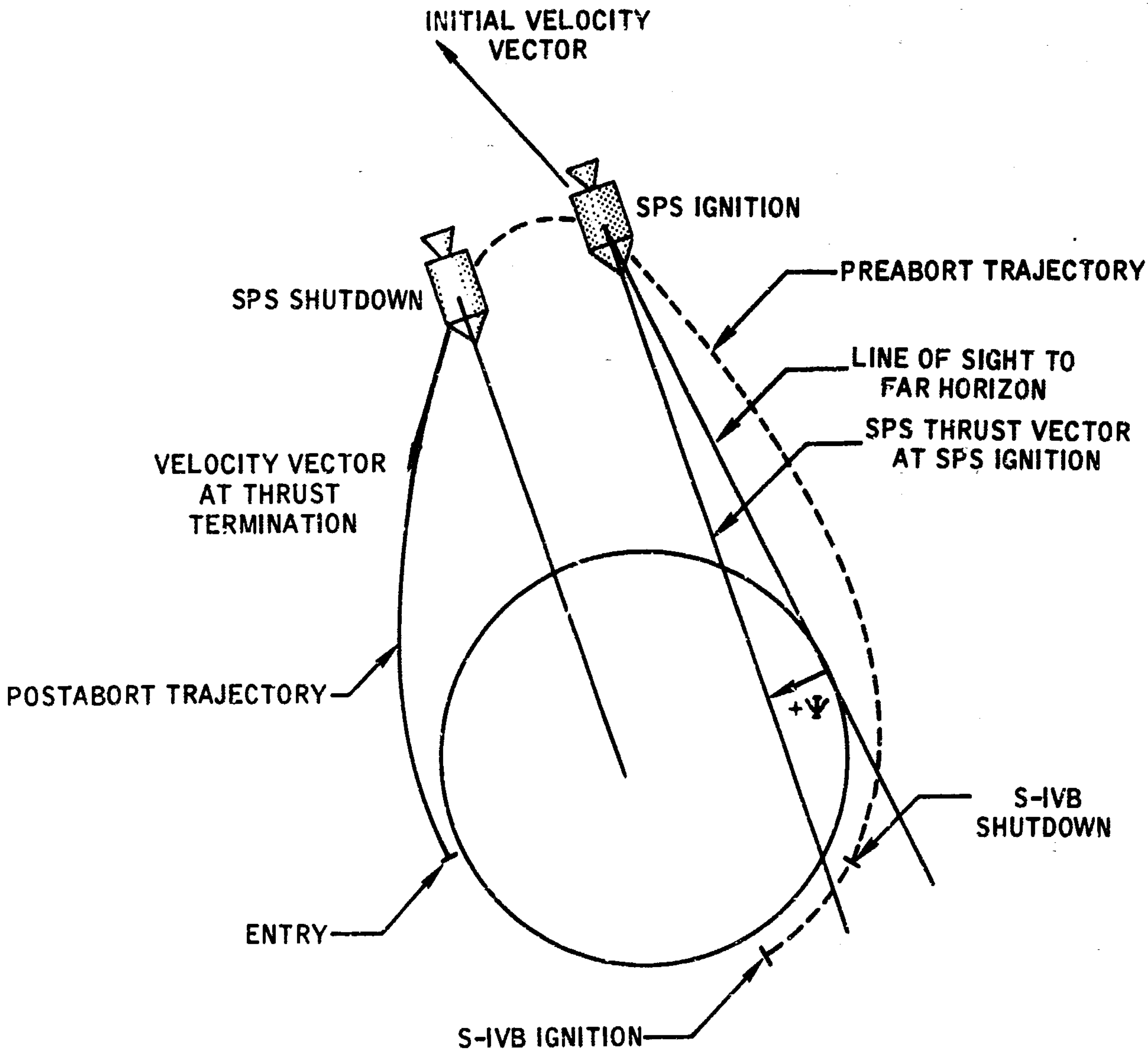


Figure 1.- Representation of fixed-attitude abort maneuver following premature translunar injection shutdown.

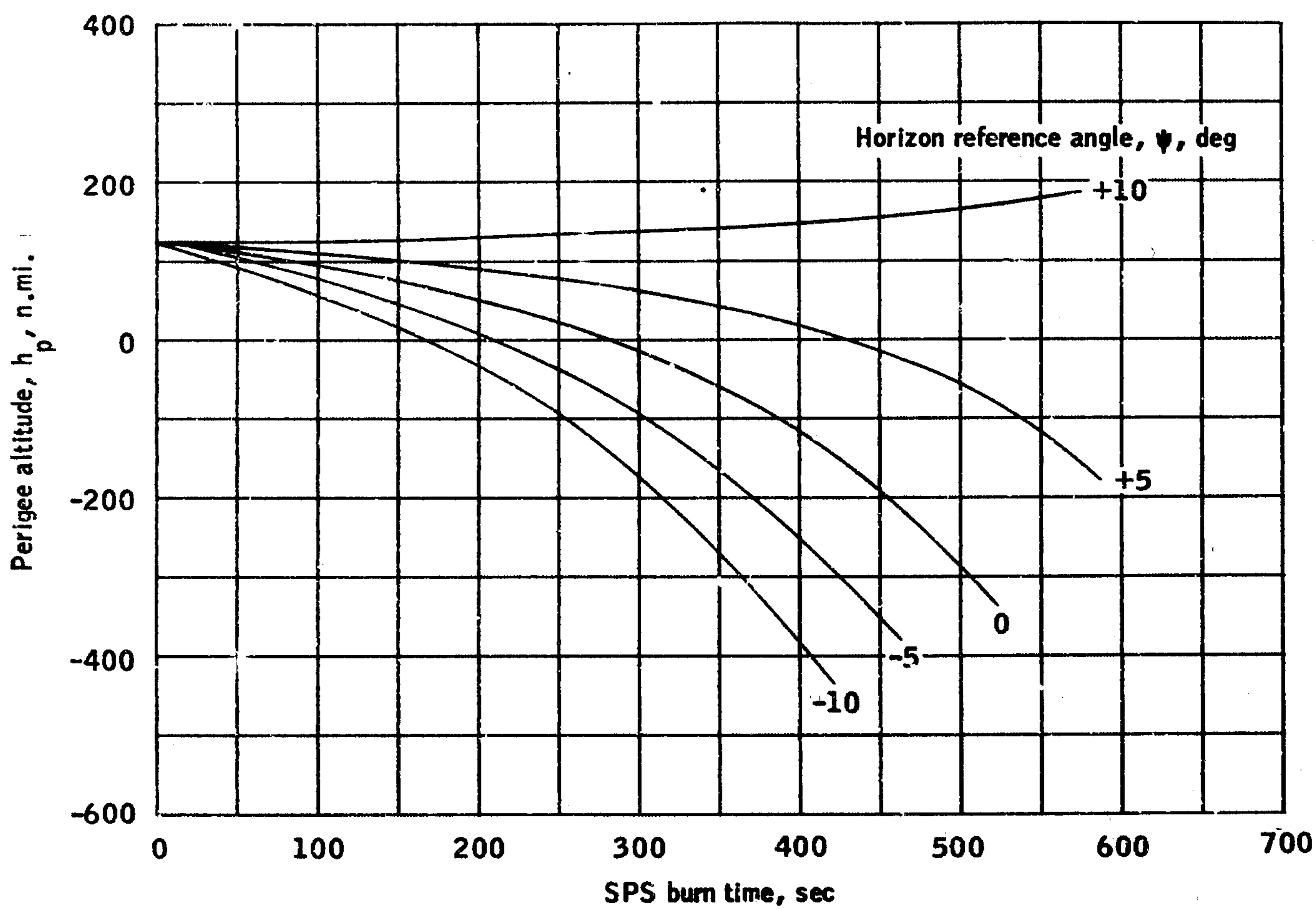
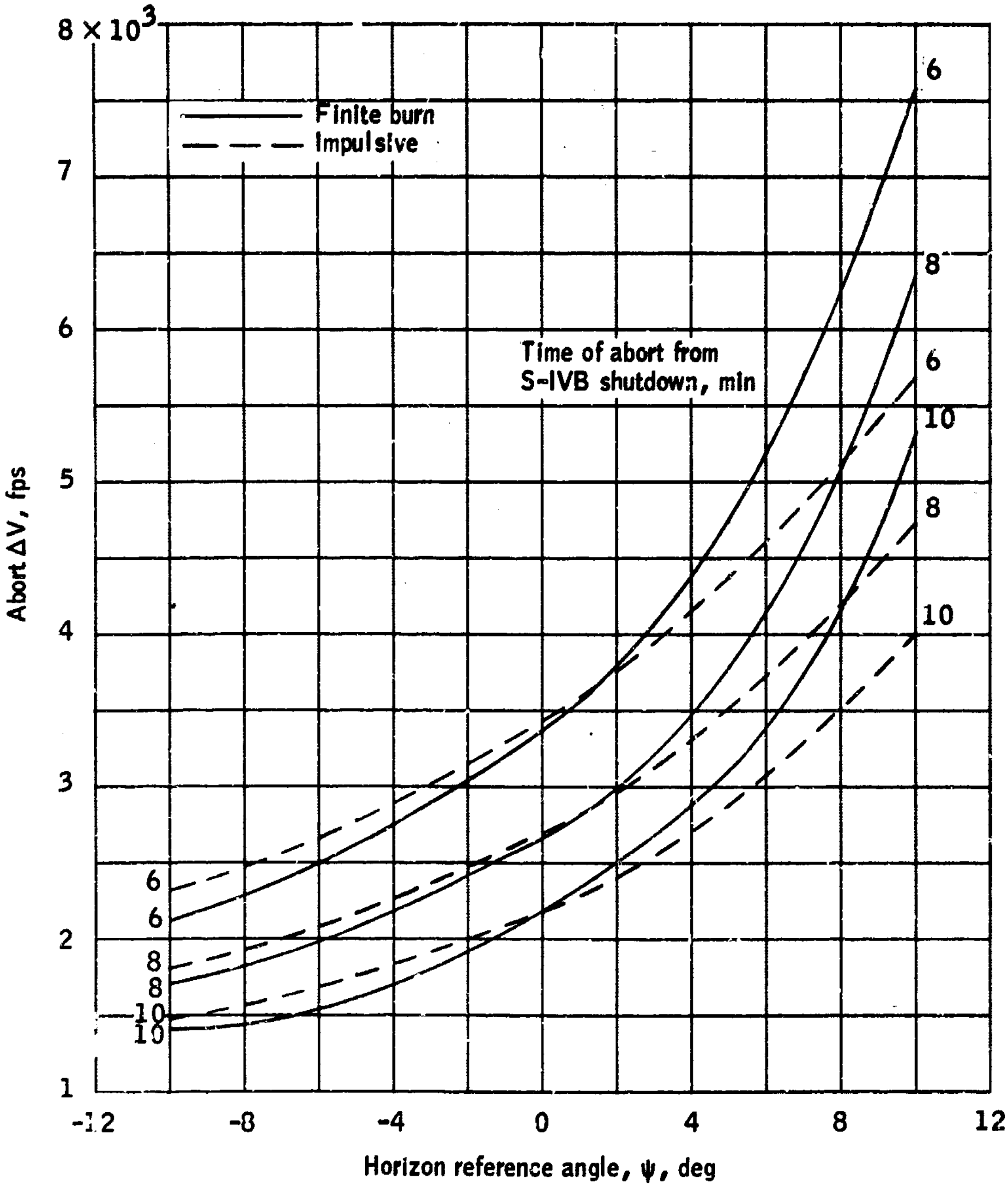
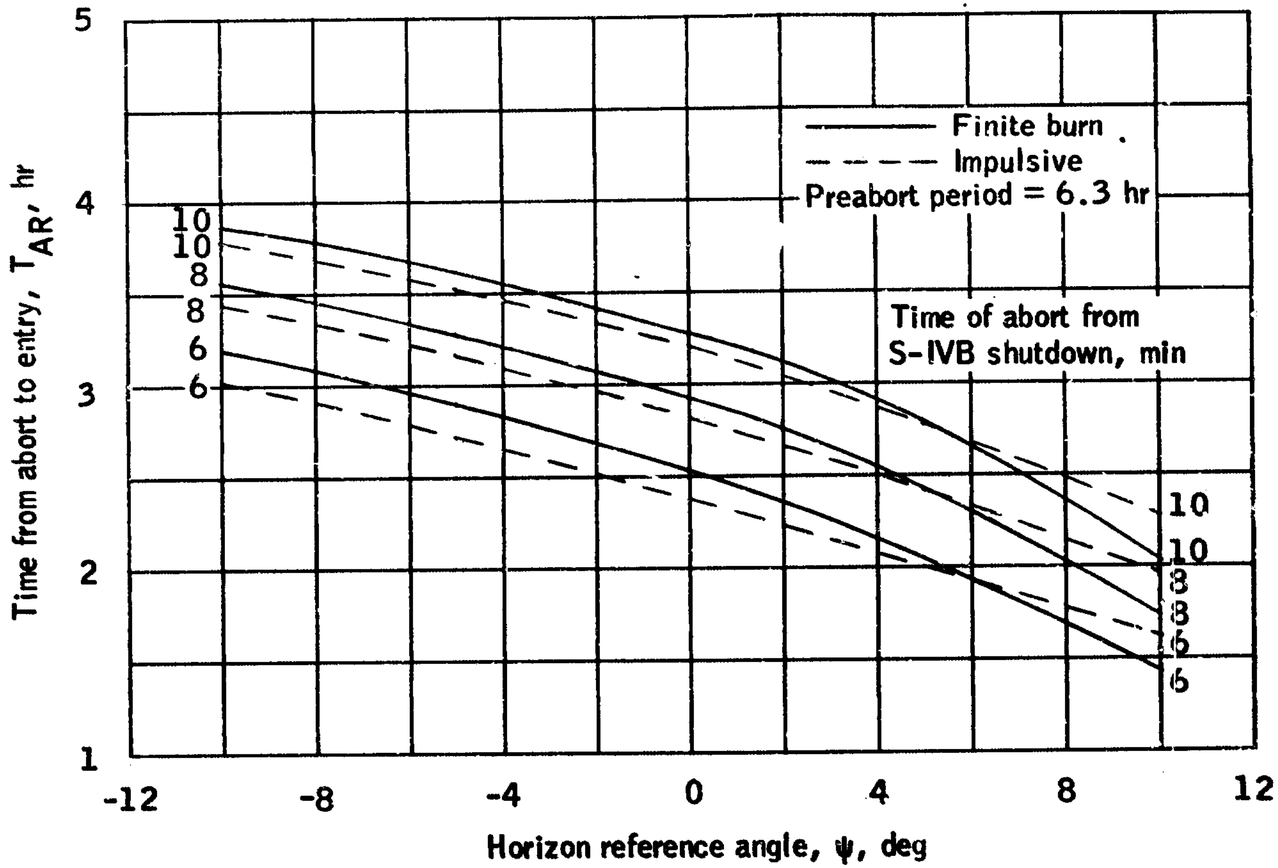


Figure 2.- Perigee altitude variation during SPS fixed-attitude abort maneuver following nominal translunar injection burn. Abort initiated 10 min following S-IVB shutdown.



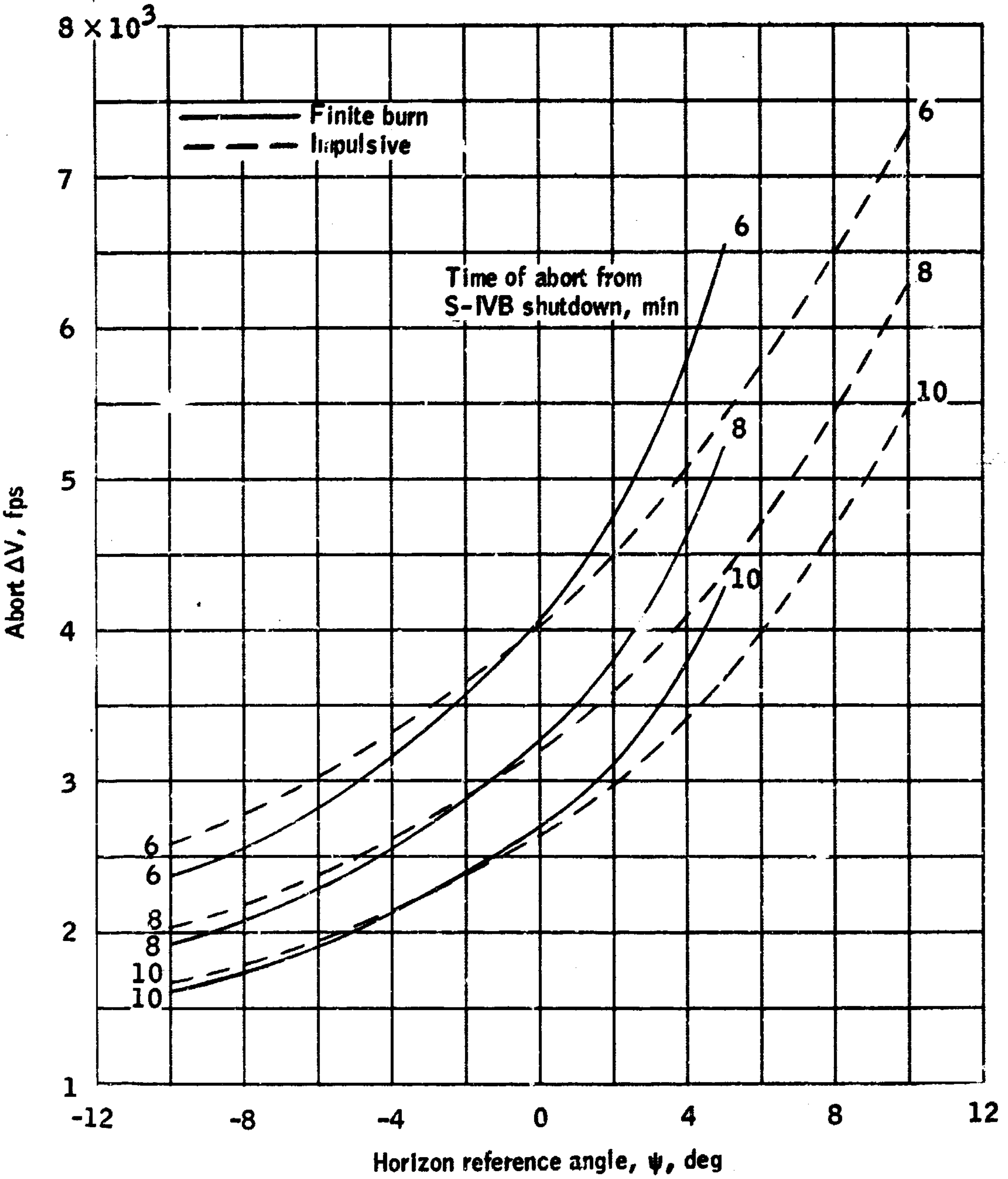
(a) Abort ΔV versus horizon reference angle.

Figure 3.- Fixed-attitude abort maneuver following 250-sec translunar injection burn.



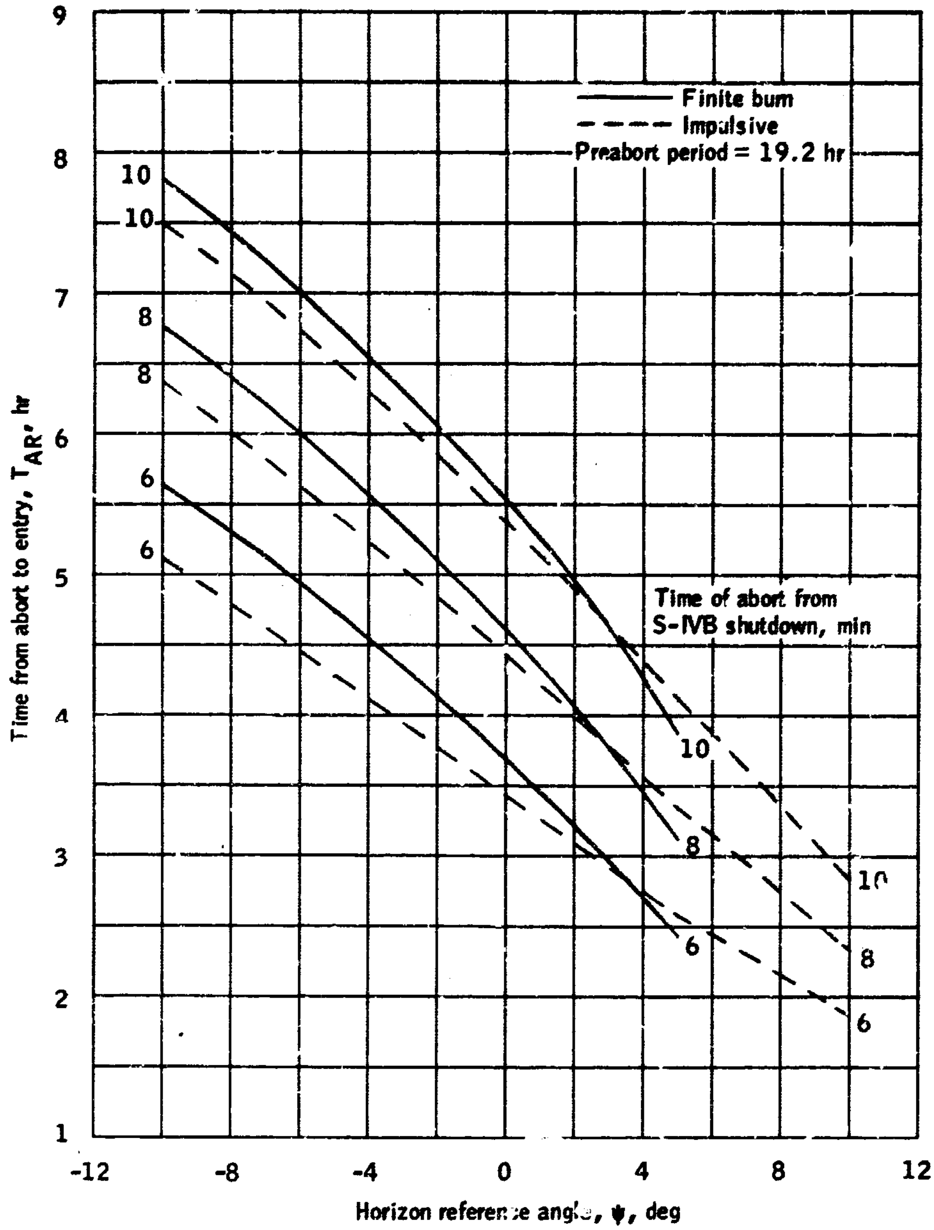
(b) Time from abort to entry versus horizon reference angle.

Figure 3.- Concluded.



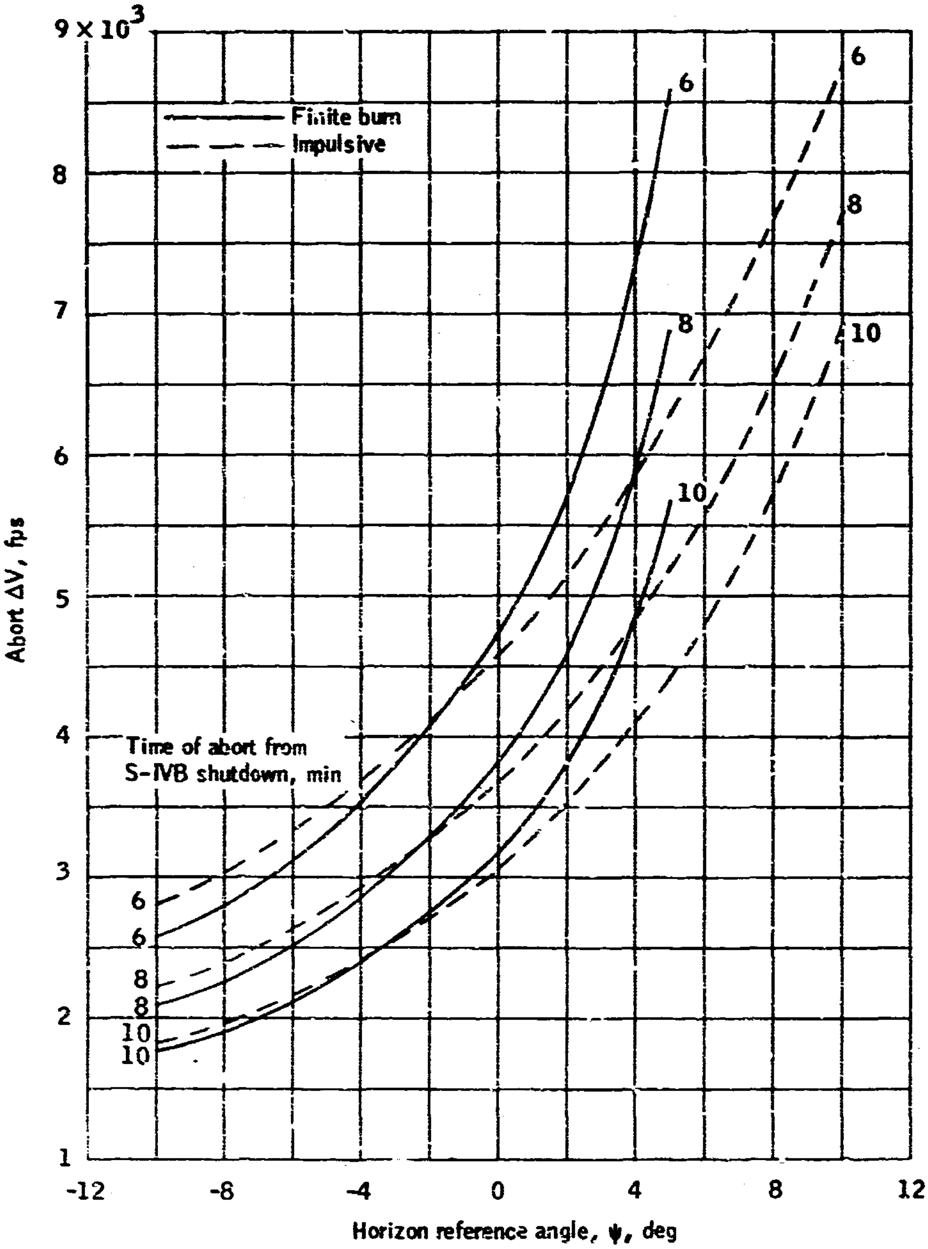
(a) Abort ΔV versus horizon reference angle.

Figure 4.- Fixed-attitude abort maneuver following 300-sec translunar injection burn.



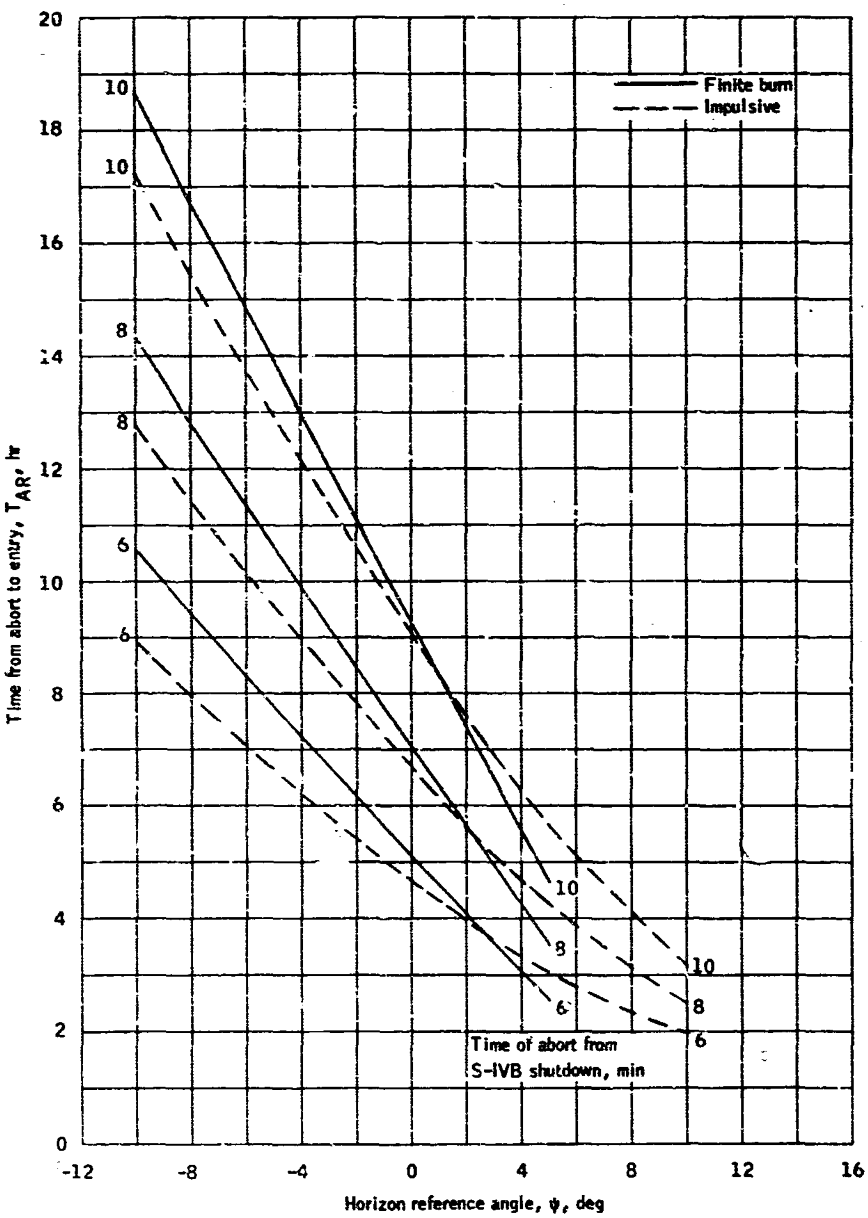
(b) Time from abort to entry versus horizon reference angle.

Figure 4.- Concluded.



(a) Abort ΔV versus horizon reference angle.

Figure 5. - Fixed-attitude abort maneuver following nominal 333.3-sec translunar injection burn.



(b) Time from abort to entry versus horizon reference angle.

Figure 5.- Concluded.

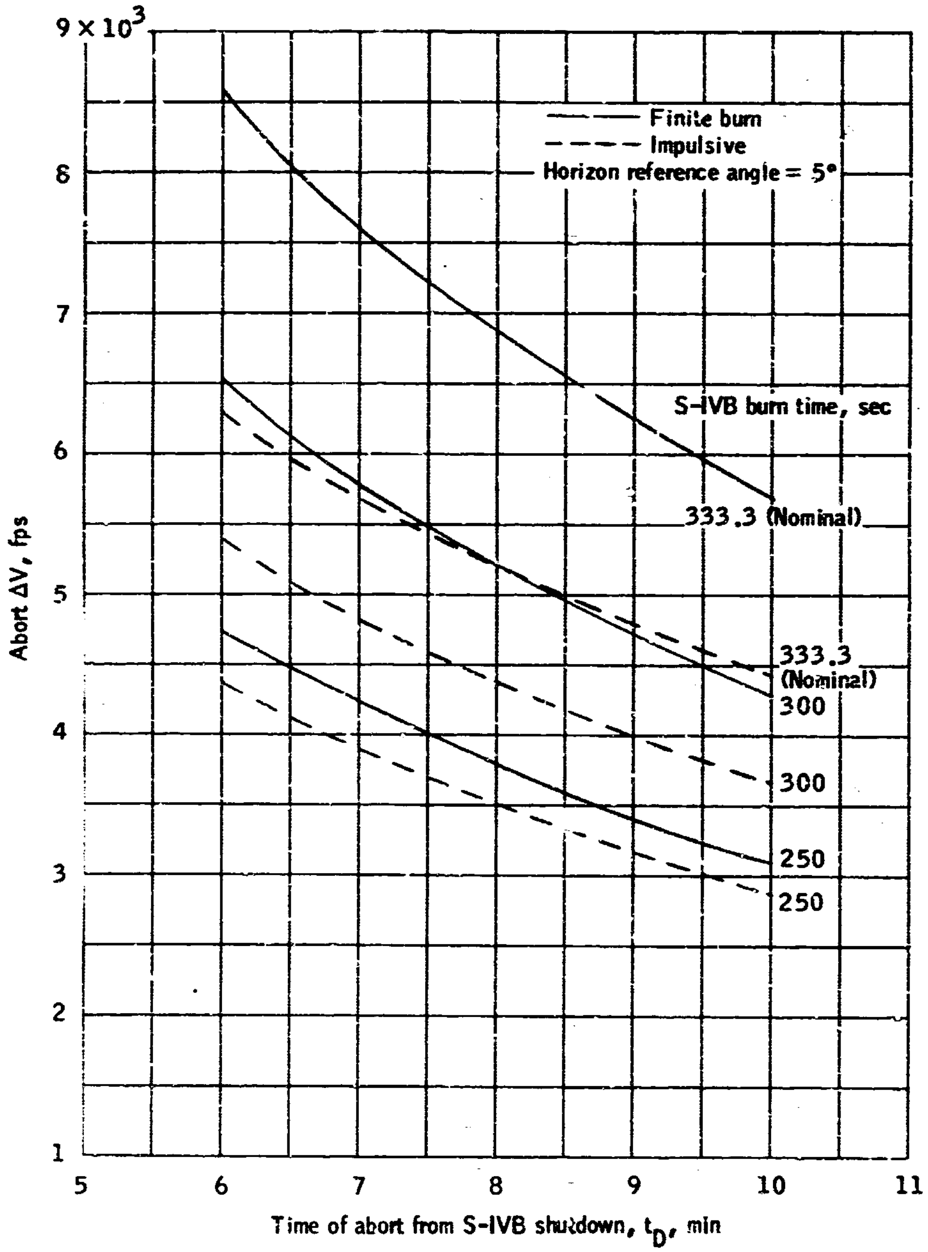


Figure 6.- Summary of abort ΔV for various S-IVB burn times.

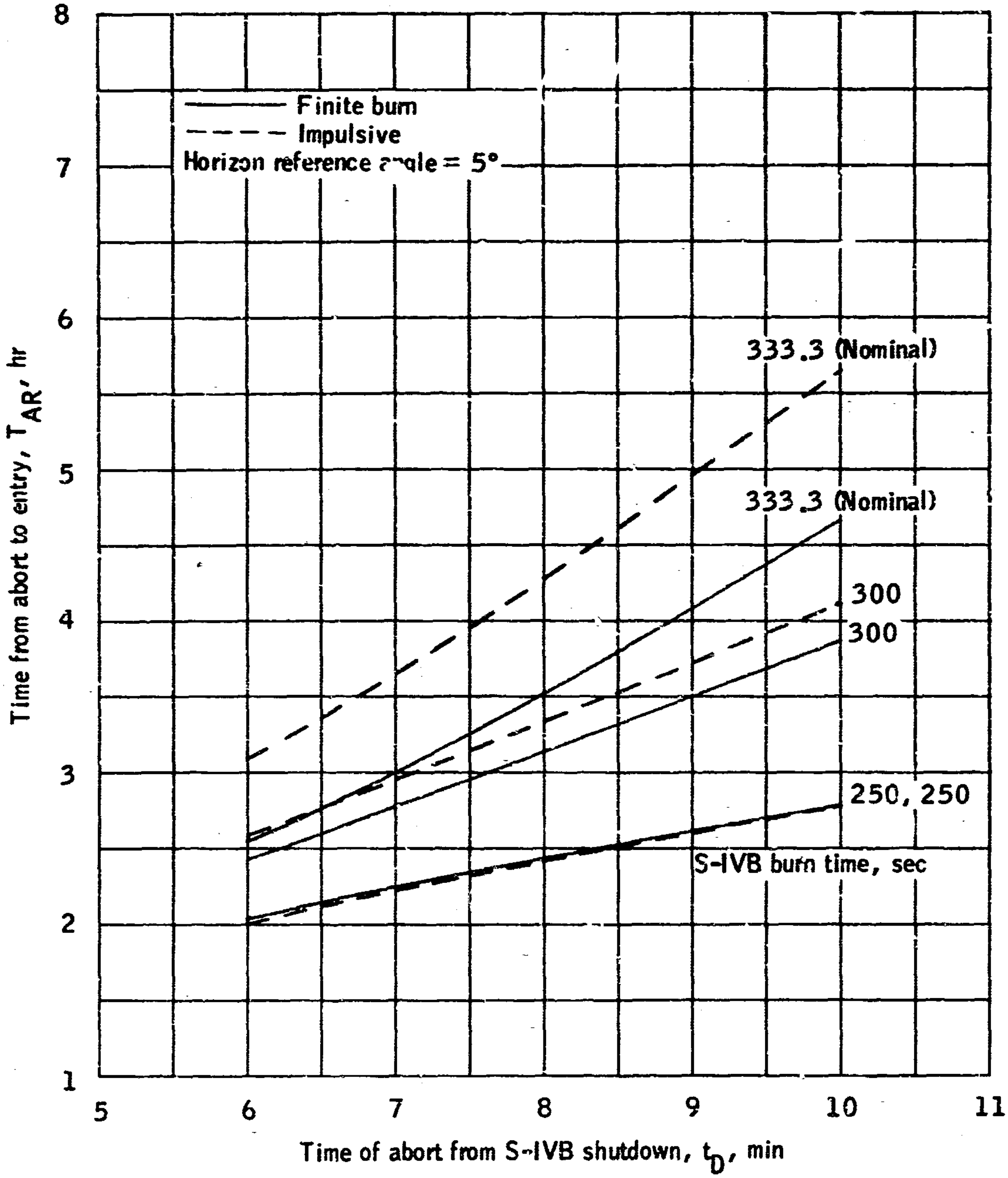


Figure 7.- Summary of time from abort to entry for various S-IVB burn times.

REFERENCES

1. Weber, Bobbie D.: Preliminary Backup Abort Procedures for Aborts Occurring During Translunar Injection. MSC Internal Note 67-FM-143, October 2, 1967.

2. TRW Systems: Program Guide for the Terra Earth Abort Program. TRW No. 05952-6080-R0-01, May 15, 1967.