R. Larson

Massachusetts Institute of Technology
Charles Stark Draper Laboratory
Cambridge, Massachusetts

Mission Simulation Memo # 13-70

H-A2

TO: Distribution
FROM: Hapet Berberian
DATE: June 12, 1970
SUBJECT: Effect of Down-Range Component of LR Range Beam On the A Priori Terrain Model for Littrow II.

SUMMARY

Simulation runs over science site Littrow II have been made using the a priori terrain model of Fig. 1. The terrain model is stored in the LGC as a function of down-range distance from the vehicle to the landing site. The purpose of this study is to determine whether the a priori terrain can be efficiently used without accounting for the fact that the range beam does not, in general, point along the vertical direction during the landing maneuver. The distance between the local terrain below the vehicle and the terrain beneath the LR range beam is called $RLR_{P,2}$. More specifically, $RLR_{P,2}$ is the down-range component of the LR range beam in platform coordinates. If no compensation were made for this distance, the LGC would extract a priori knowledge of the terrain which is a distance $RLR_{P,2}$ from the terrain that the range beam sees. If the a priori model were an exact fit to the real world terrain, it would always be best to extract a priori knowledge of the terrain that the range beam sees in order to measure accurately the vehicle altitude with respect to the site. Several runs were made with and without compensation for $RLR_{P,2}$. It was found that the compensation term was large only for high altitudes when altitude weighting functions are small. Table 1 presents typical values for $RLR_{P,2}$ during the landing maneuver. For the cases studied, time profiles of LPD pointing errors, LPD angles, and terminal phase trajectories show very little difference in system performance for the uncompensated case when compared to the compensated.

GENERAL INFORMATION

Simulation runs over science site Littrow II have been made using the a priori terrain model of Fig. 1. The orientation of the LR range beam plays an important role in this study; therefore, it should be kept in mind that, generally, the terrain seen by the LR will be different from the local terrain below the vehicle because the range beam usually points forward and not in a vertical direction. The purpose of this report is to determine how the LR "pointing" effects the use of the terrain model which is stored as a function of range-to-go to the landing site, and whether the a priori terrain will increase system performance efficiently without compensating for LR "pointing". Figure 2 shows the pointing angle of the range beam on a typical trajectory. The distance between local terrain and the terrain below the range beam (which will be referred to as the compensation term, $RLR_{P,2}$) is large when the altitude and pointing angle are large since

COMPENSATION = ALTITUDE TAN (POINTING ANGLE).

Typical values for this compensation at various time points during a powered descent maneuver along with altitudes with respect to the landing site and range beam pointing angles are given in Table 1. A time profile of $RLR_{P,2}$ for a nominal landing trajectory is shown in Fig. 3.

The a priori terrain model is stored in the LGC as a function of RZG, the down-range distance from the vehicle to the landing site.

$$RZG = R_{P,2} - RS_{P,2}$$

where $R_{P,2}$ is the down-range component of the LM position vector in platform coordinates, and $RS_{P,2}$ is the down-range component of the site position vector in platform coordinates. Since the range beam generally does not point along the local vertical, the relation:

$$RZG = R_{P,2} - RS_{P,2} + RLR_{P,2}$$

should be used to extract a priori terrain information. The quantity

$RLR_{P,2}$ is the down-range component of the LR range beam vector in platform coordinates. The question at hand is whether or not the compensation term, $RLR_{P,2}$, can be omitted in the computation of RZG without appreciable decrease in system performance.

SIMULATION RESULTS

To determine whether or not the LR "pointing" effect should be accounted for, powered descent simulations wer made with

1) $RZG = R_{P,2} - RS_{P,2}$

2) $RZG = R_{P,2} - RS_{P,2} + RLR_{P,2}$

In case 2 the a priori terrain should fit the real world better than in case 1 (provided that the modeling is accurate), since the range beam actually measures the terrain variation at a distance $R_{P,2} - RS_{P,2} + RLR_{P,2}$ from the landing site. Each case was first tested with no initial condition errors and no terrain datum uncertainty, and then with a -1^{o} slope in the terrain and an initial 10 ft/sec vertical velocity error.

Consider first the error free cases. Figure 4 shows the terrain model error which is the difference between the actual terrain variation below the range beam and the variation computed in the LGC from the a priori model. The compensated terrain model error is generally smaller than the uncompensated. The inaccuracies in the a priori model itself can under certain conditions cause the uncompensated error to be slightly smaller than the compensated. In the example of Fig. 4 the compensation is seen to be most effective from distances of about 3.75 to 6 n.m. from the landing site. It should be noted here that the approach phase begins about 4.1 miles from the site.

The effect of the compensation in system performance can be seen by comparing LPD angles, LPD pointing errors, and terminal phase trajectories. Figure 5 shows very small differences in LPD pointing errors and LPD angles. Terminal phase trajectories have negligable differences. The results are reasonable since the terrain model error is large through only the first .4 n.m. of the approach phase. It can be seen in Fig. 3 that the compensation term is small during and after the approach phase.

Figure 6 shows the terrain model error, compensated and uncompensated, for a -1^{o} slope in terrain (1^{o} uphill to the site) and an initial 10 ft/sec vertical velocity error. Again there is no appreciable degradation in system performance as seen in Fig. 7. Terminal phase trajectories for compensated and uncompensated RZG have negligable differences. Similar results were obtained using a 1^{o} slope downhill to the site.

Comparison runs similar to those described above have been made with initial altitude errors of 15,000 ft. Others were made with down-range errors of 3,000 ft. Again there was no appreciable decrease in system performance.

In view of the particular simulations made for this study, it appears that the compensation term, $RLR_{P,2}$, can be omitted in the computation of RZG without compromising system performance.

Time (Sec) W.R.T. FTP*	$RLR_{P,2}$ (FT)	Altitude W.R.T Site (FT)	Range Beam Pointing Angle with respect to local vertical	Range-to-go (n.m)
202	19321	40000	31.7°	83
468 (High Gate)	1256	6757	10.5°	3.6
610 (Low Gate)	-21	101	-13.9°	.08

Range Beam Pointing Effect Compensation

Table 1

* Beginning of Fixed Throttle Position

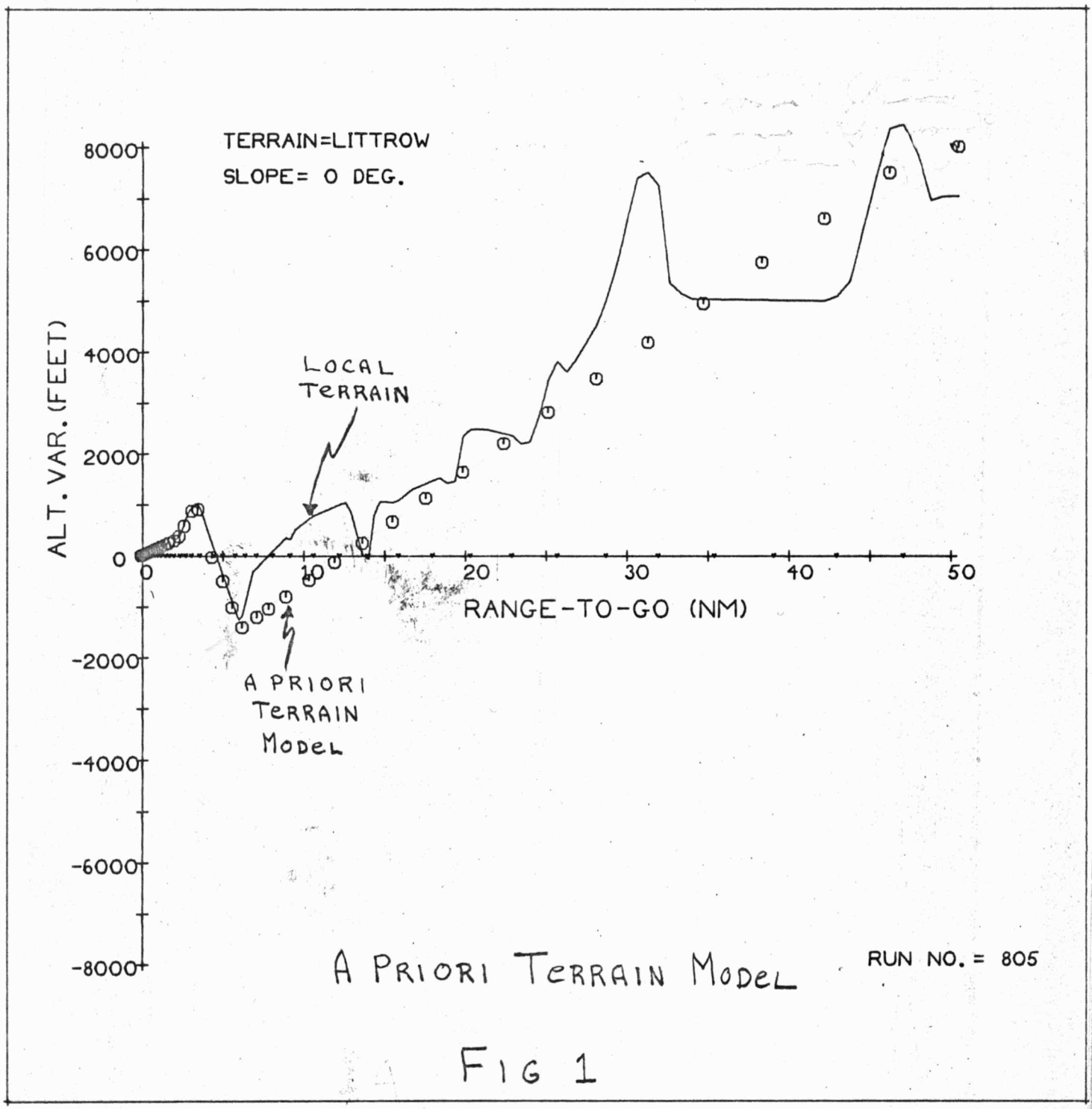

TERRAIN=LITTROW
SLOPE= 0 DEG.
8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
ALT. VAR. (FEET)
0
10
20
30
40
50
RANGE-TO-GO (NM)
LOCAL TERRAIN
A PRIORI TERRAIN MODEL
A PRIORI TERRAIN MODEL
RUN NO. = 805

FIG 1

RADAR BEAM ANGLES W.R.T. LOCAL VERTICAL

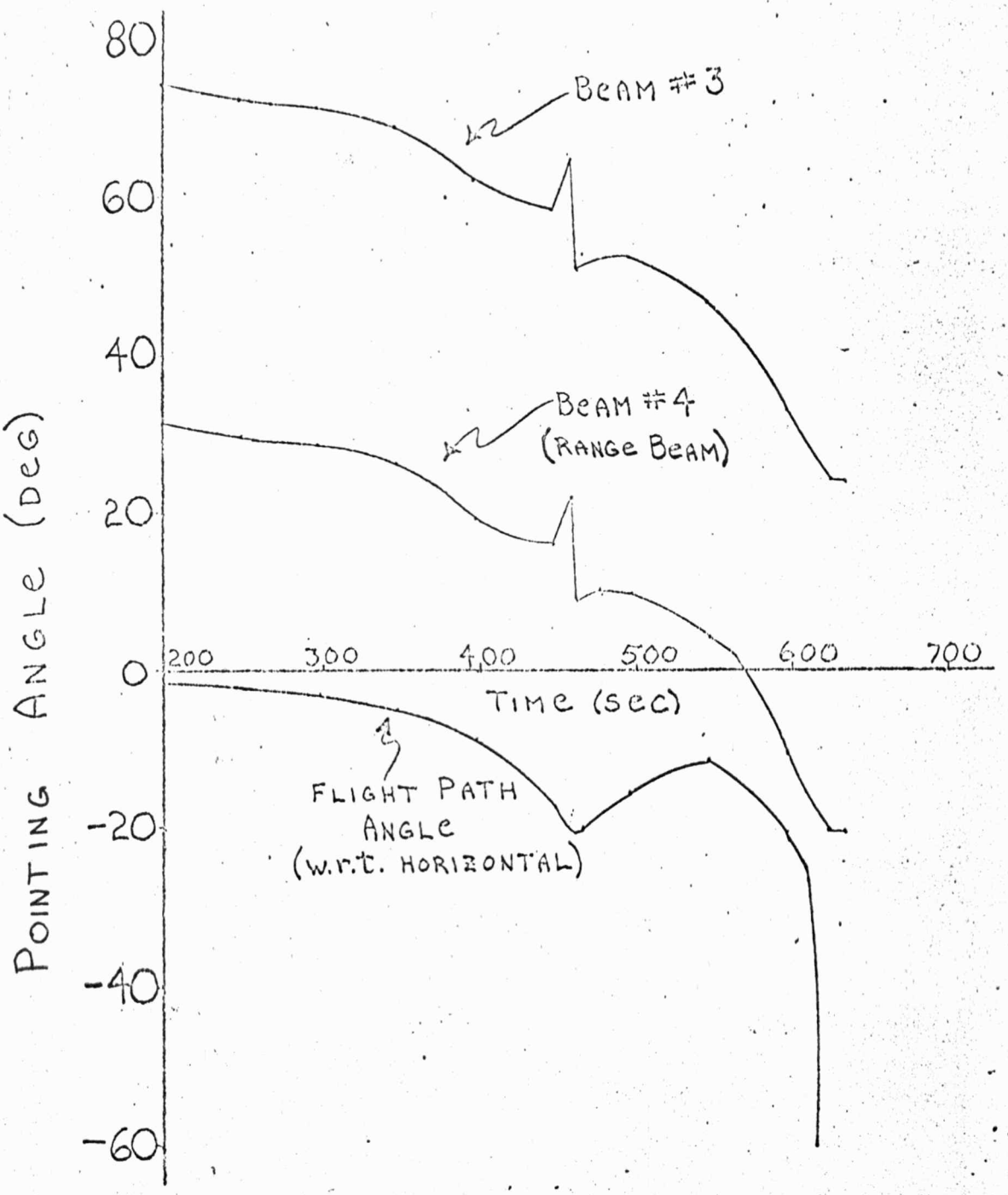


FIG 2

DOWN-RANGE COMPONENT OF LR

RANGE BEAM

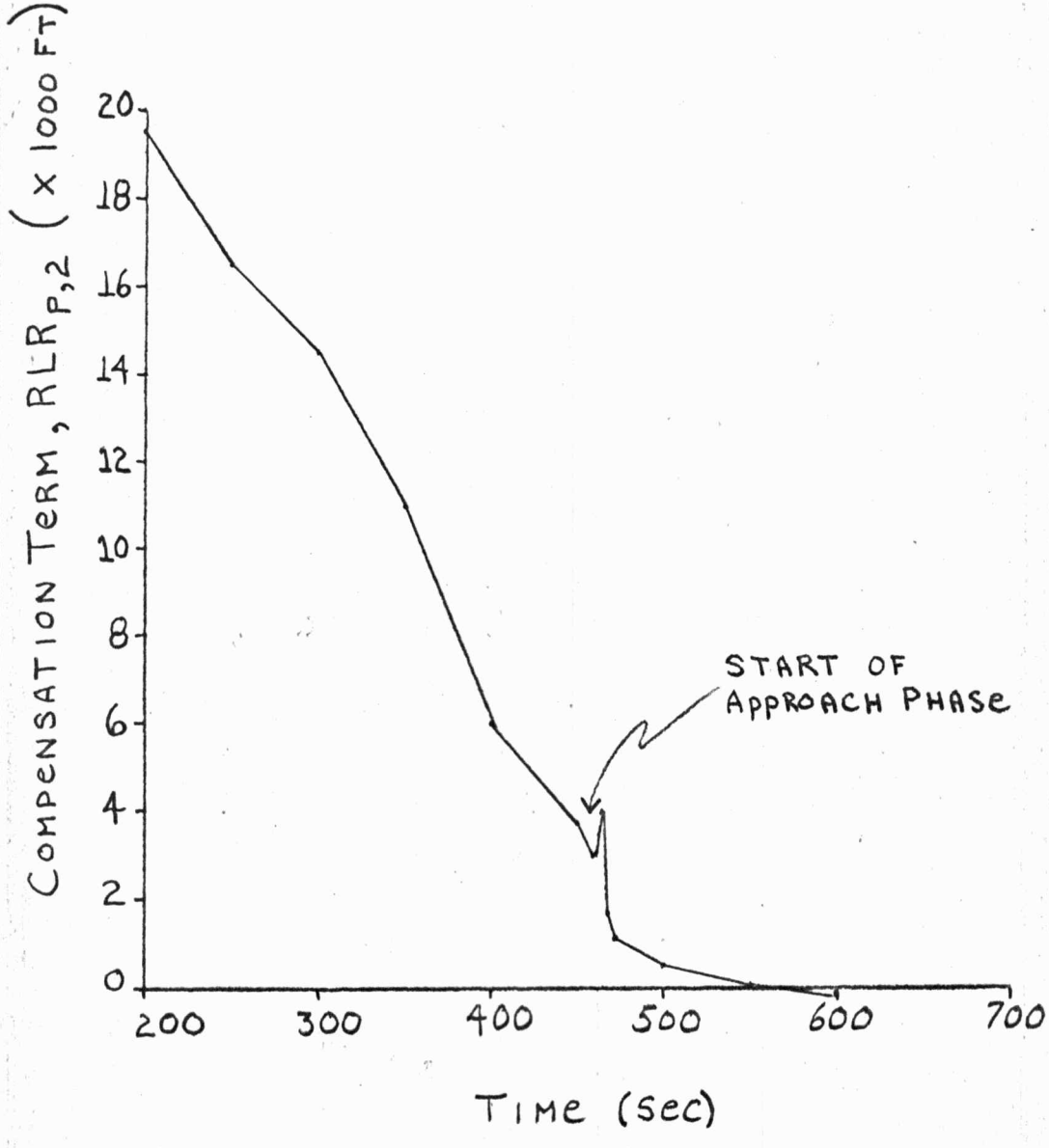
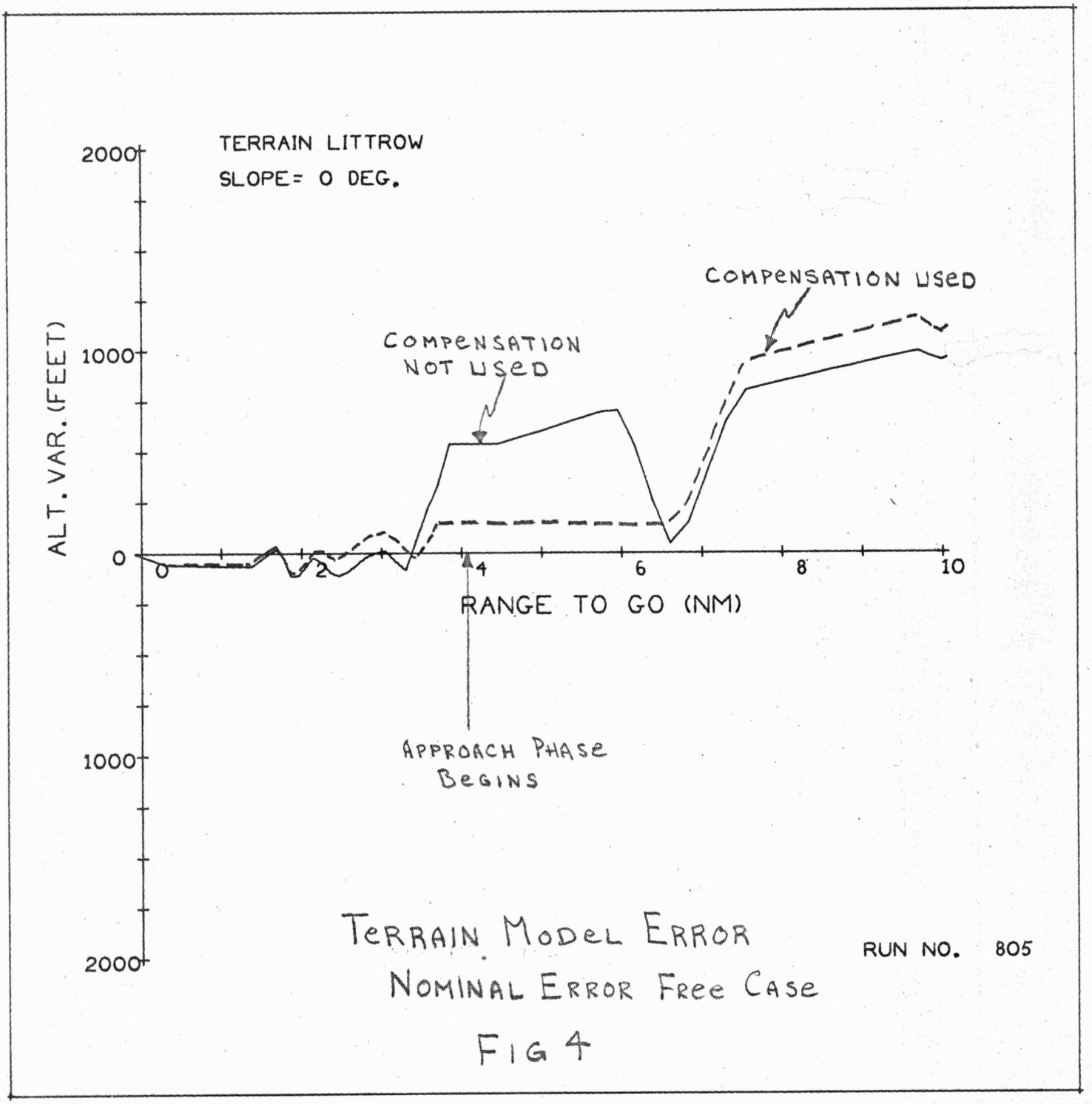


FIG 3

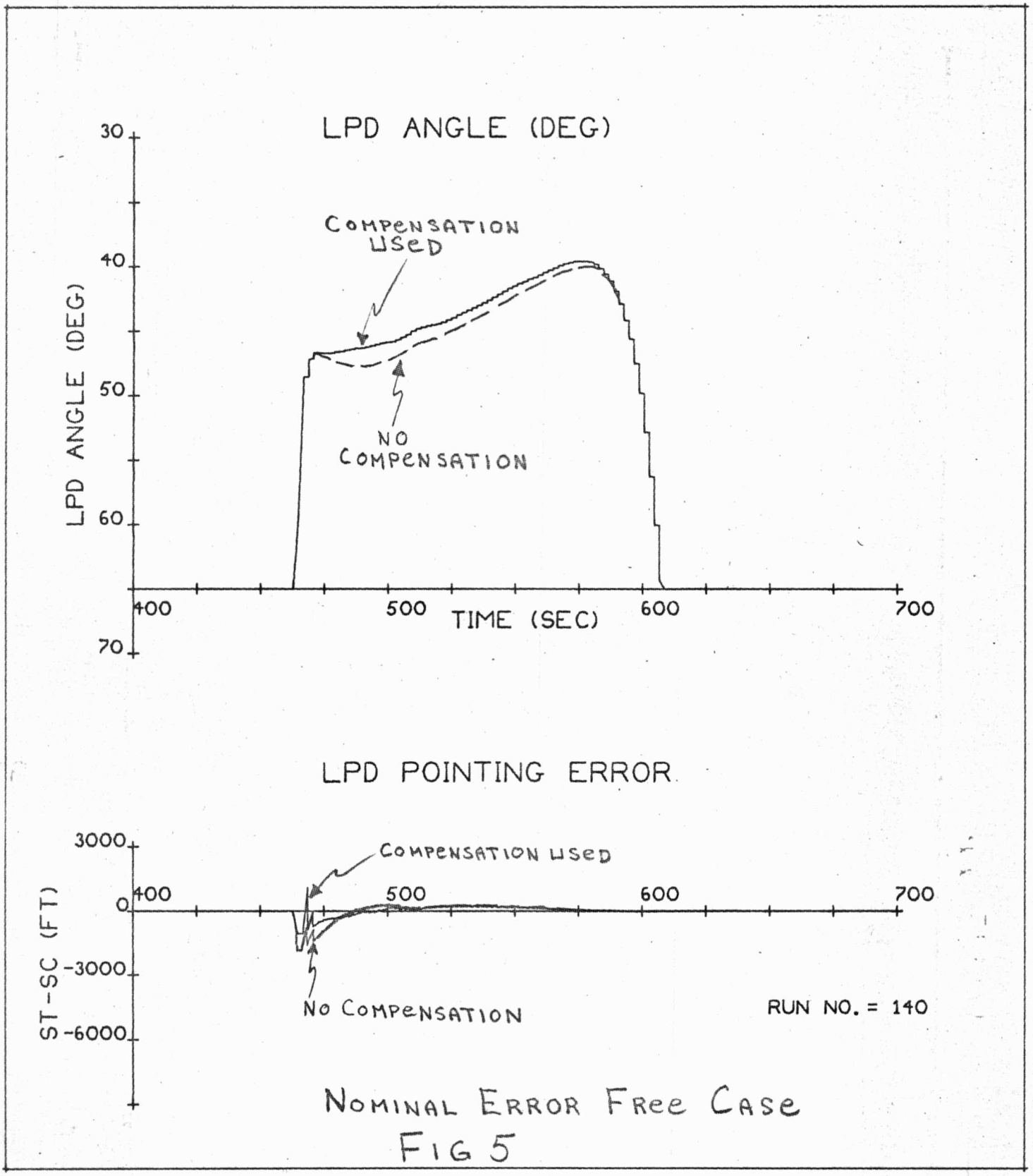


TERRAIN MODEL ERROR

NOMINAL ERROR FREE CASE

RUN NO. 805

FIG 4



Nominal Error Free Case

Fig 5

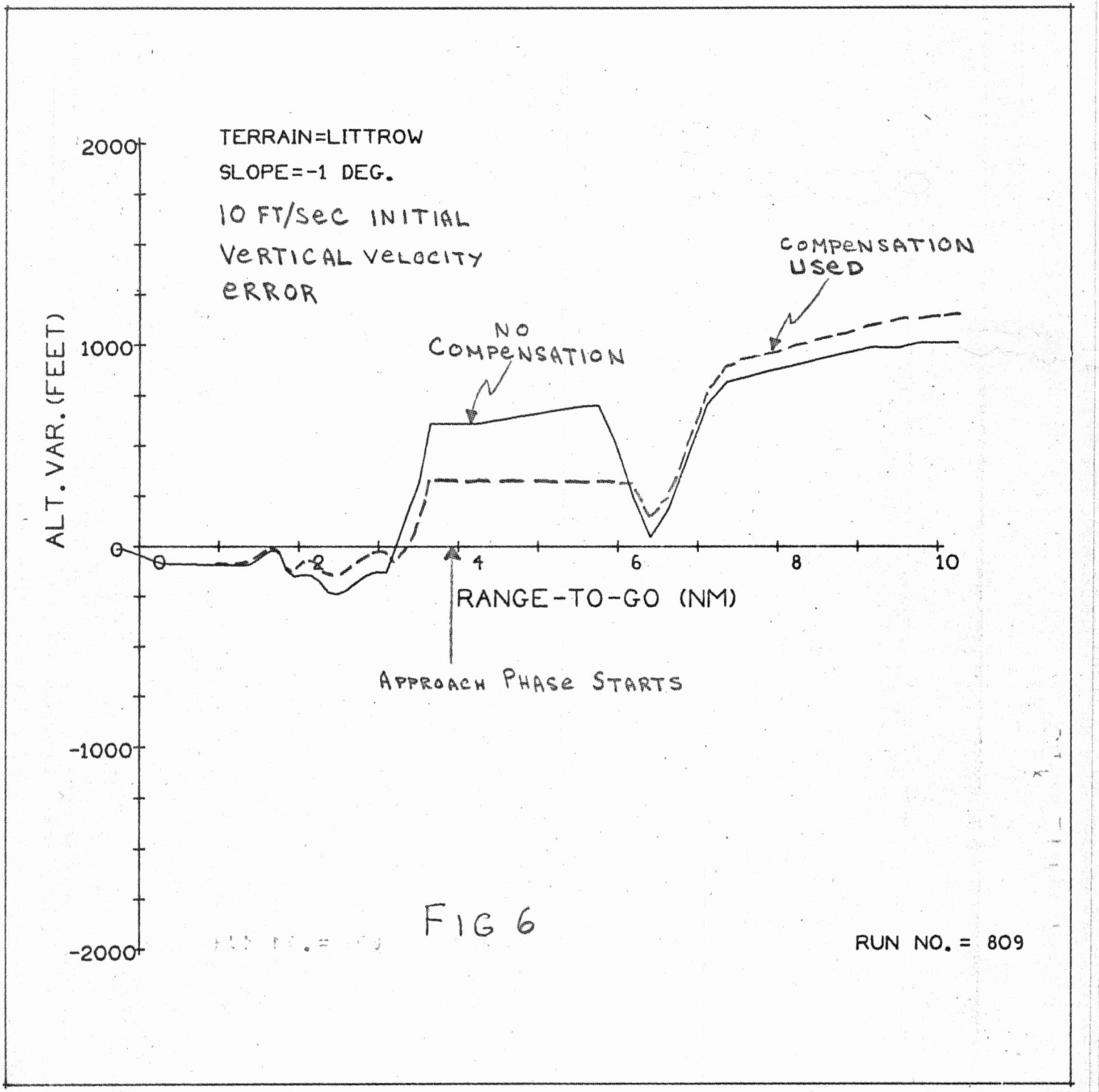

TERRAIN=LITTROW
SLOPE=-1 DEG.
10 FT/SEC INITIAL
VERTICAL VELOCITY
ERROR
COMPENSATION USED
NO COMPENSATION
2000
1000
0
-1000
-2000
ALT. VAR. (FEET)
2
4
6
8
10
RANGE-TO-GO (NM)
APPROACH PHASE STARTS
RUN NO. = 809

FIG 6

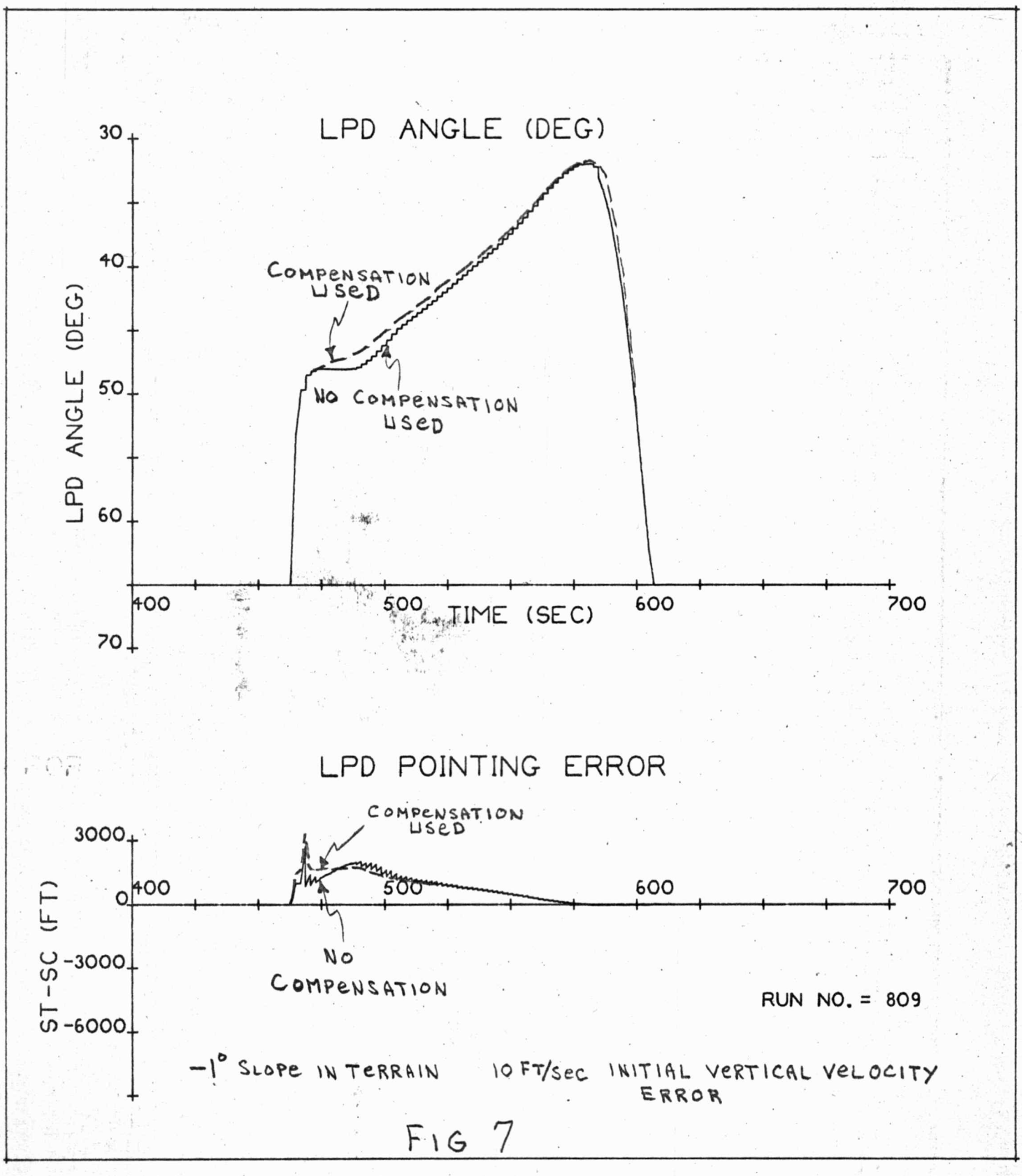

LPD ANGLE (DEG)
30
40
50
60
70
LPD ANGLE (DEG)
COMPENSATION USED
NO COMPENSATION USED
400
500
600
700
TIME (SEC)
LPD POINTING ERROR
COMPENSATION USED
3000
0
-3000
-6000
ST-SC (FT)
400
500
600
700
NO COMPENSATION
RUN NO. = 809
-1° SLOPE IN TERRAIN
10 FT/SEC INITIAL VERTICAL VELOCITY ERROR

FIG 7