N87-20682

AERO-ASSISTED ORBITAL TRANSFER VEHICLE (AOTV)

Oliver Hill, NASA/Johnson Space Center

The AOTV will make use of the atmosphere to provide braking on return from a planetary mission or geosynchronous orbit. The minimum altitude for aerobraking is typically 255,000 ft at the equator (only the equatorial region is being considered for AOTV braking). Time of the braking maneuver is typically 480 sec from 400,000 ft to 255,000 ft and back out - about 8 min. The problem is to design a control system that will be able to handle density irregularities ("bumps") such as those that have shown up in shuttle data near 280,000 ft. To obtain data, one has to use model-produced statistics or information obtained during the atmospheric transit time. The GRAM appears to bracket the shuttle data, but it is not clear that the statistics are correct. The model-data exhibits strong density shears over small step size that are probably an artifact.

[Gamble] The shuttle entry itself, particularly in the region where the trajectory is nearly horizontal, is a new data source for middle atmosphere density. There is a new National Weather Service (NWS) rocket program to study atmospheric density along shuttle entry paths (M. Gellman).

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AFE PROJECT
USE OF GRAM ATMOSPHERIC MODELS

O. HILL
NOVEMBER 19-21, 1985
MPAD-JSC

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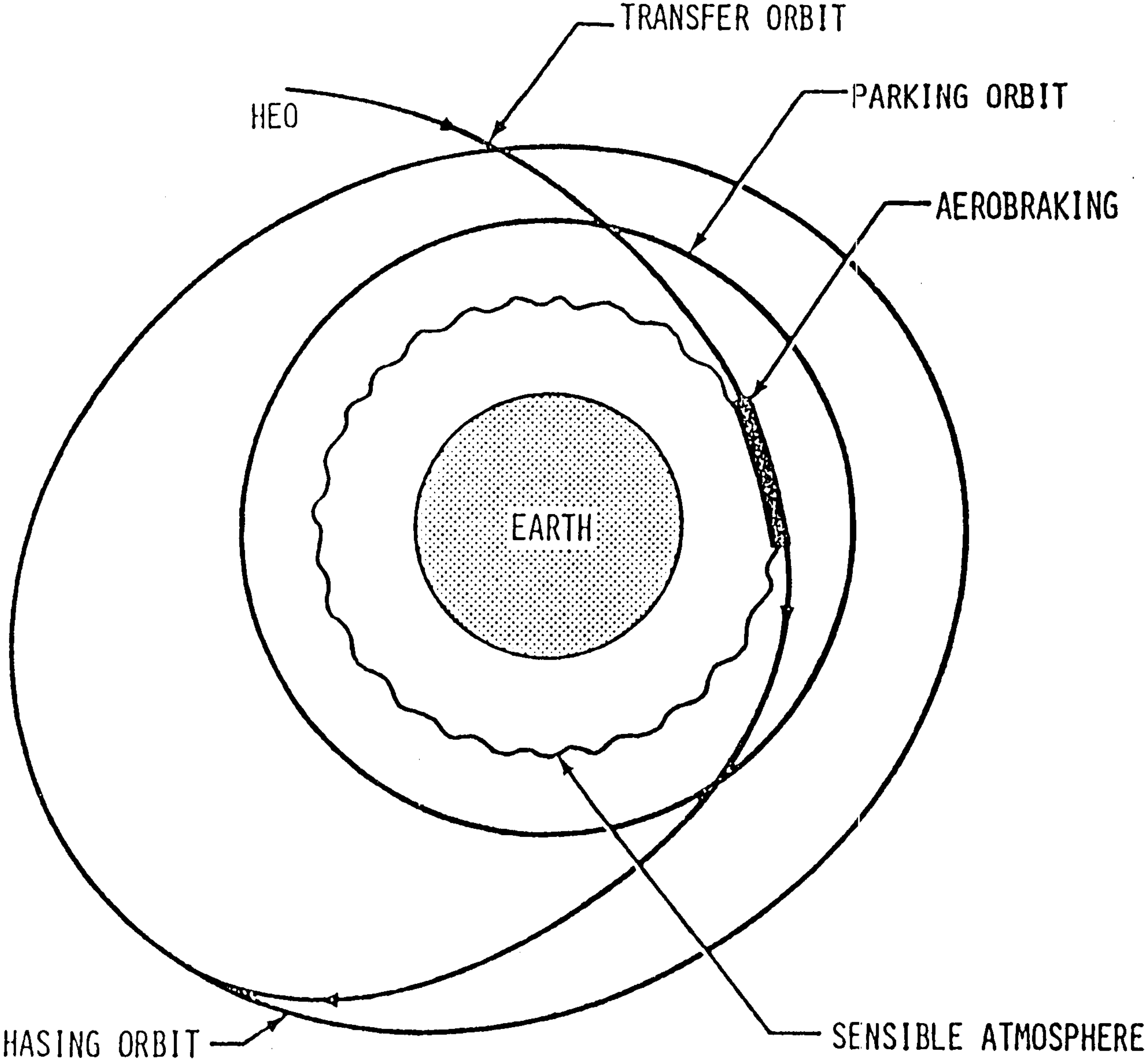
GUIDANCE OBJECTIVE

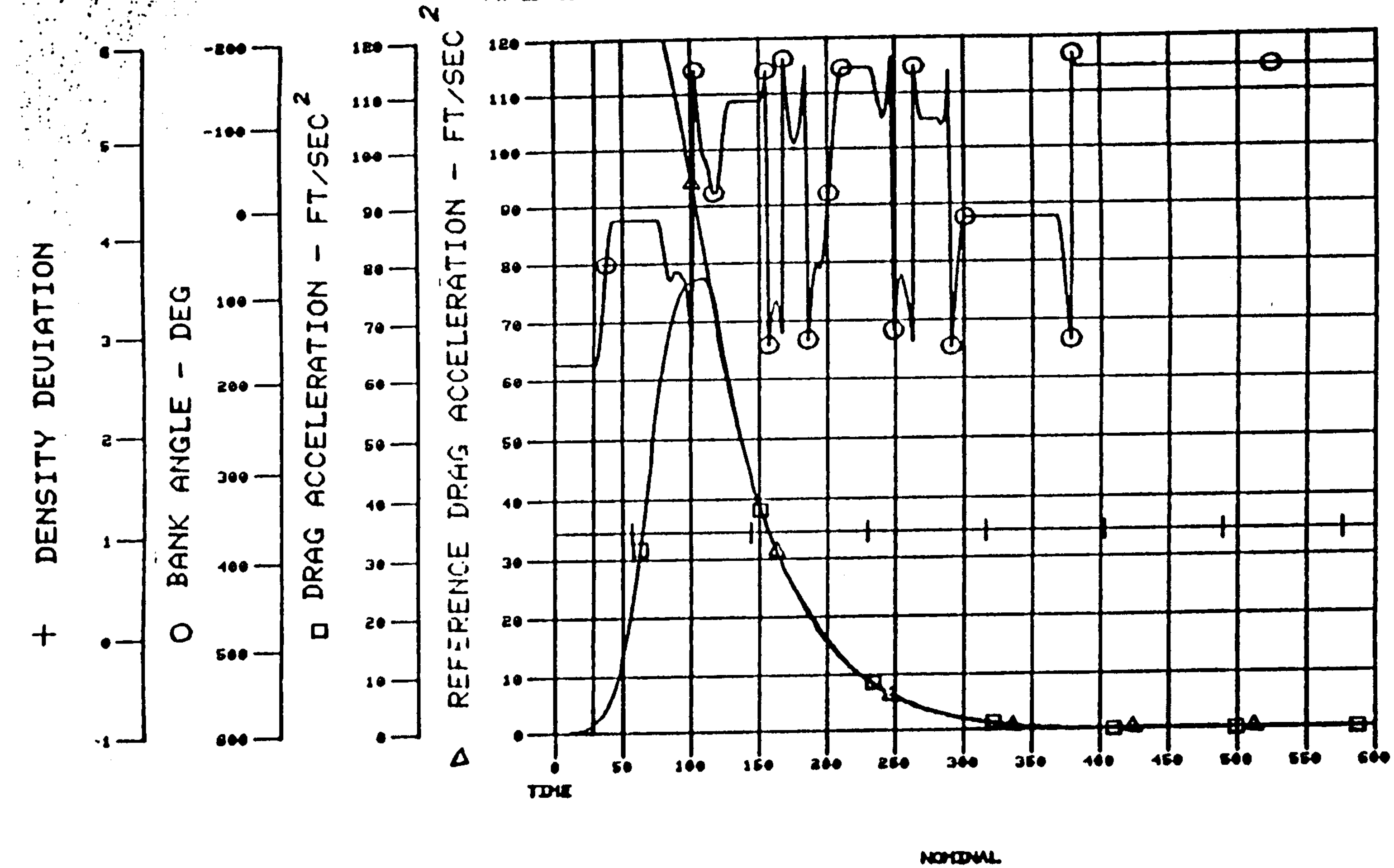
CENTRAL ANGLE
OF 37 DEG

TOTAL FLIGHT TIME
OF 480 SEC

MINIMUM ALTITUDE
OF 255000 FT



AFE BASELINE TRAJECTORY



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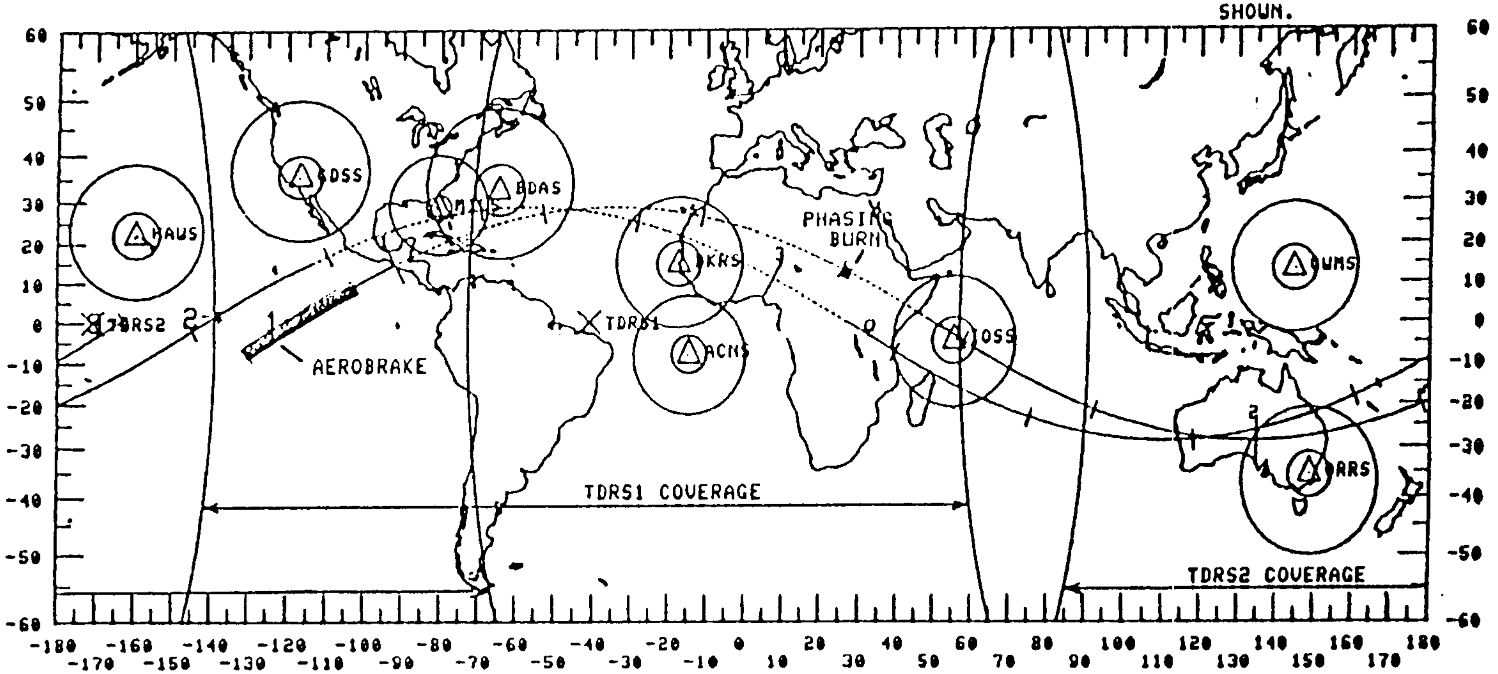
MSD

GTRACE / NASA-A

'POST' AFE GROUNDTRACK W/ EXIT AEROBRAKE STATE VECTOR
DATE 10/17/85 TIME 17/48/45

PAGE 1

AFE NOMINAL MANEUVER EVENT SUMMARY



MNVR	DELTA-V(fps)	PET(H:M:S)	WEIGHT(lbs)	BURN TIME(sec)	PHASE(deg)	MEAN ORBIT(nm)
BEGIN	-	00:00:00	6292	-	-	160x160
DIRECT ENTRY	9243	00:45:04	2311	77.05	.2	18180x 41
TRIM BURN	111	00:46:41	2276	19.74	1.7	19232x 41
ATM ENTRY	-	00:48:10	2276	-	3.4	19232x 41
ATM EXIT	-	00:57:23	2261	-	8.5	196x 36
PHASING BURN	249	01:30:30	2184	43.02	8.8	196x169

RENDEZVOUS COMPLETE 10:57:42 SHUTTLE DELTA-V• 120fps W/ 9fps SEP

NEXTPAGE 1

MISSION PLANNING AND ANALYSIS DIVISION

AFE AEROBRAKING ANALYSIS

MONTE CARLO ANALYSIS

- 100 GRAM ATMOSPHERIC MODELS ARE GENERATED FOR A SPECIFIED MONTH AND ARE STORED AND CALLED SEQUENTIALLY FOR A 100 TRAJECTORY SIMULATION
- SHUTTLE DERIVED ATMOSPHERES ARE TO BE INCLUDED IN THE MONTE CARLO DATA BASE

AFE AEROBRAKING ANALYSIS

PARAMETRIC DATA

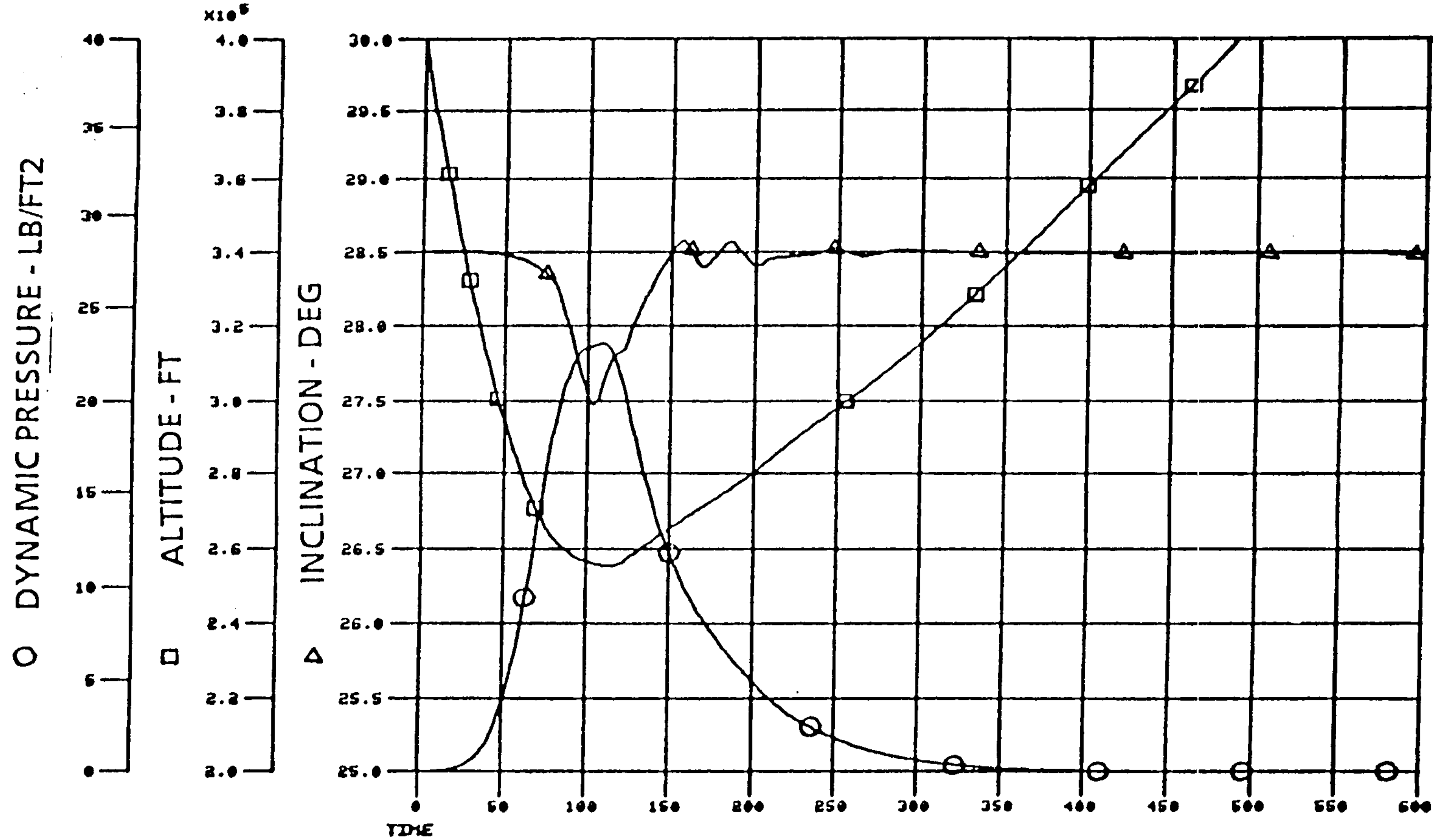
- GRAM MONTHLY MEAN IS USED FOR NOMINAL AEROBRAKING TRAJECTORIES
- SHUTTLE DERIVED ATMOSPHERES (STS 1-14) ARE USED TO SIMULATE DENSITY BIASES AND DENSITY SHEARS ABOUT THE GRAM MONTHLY MEAN ATMOSPHERES
- GRAM DENSITY SHEAR AND DENSITY BIAS
- TRAPAZOIDAL DENSITY SHEARS
  - MAGNITUDE
  - RISE TIME

<u>DRIVERS</u>

DENSITY GRADIENTS

- MAGNITUDE
- ONSET TIME

AFE BASELINE TRAJECTORY



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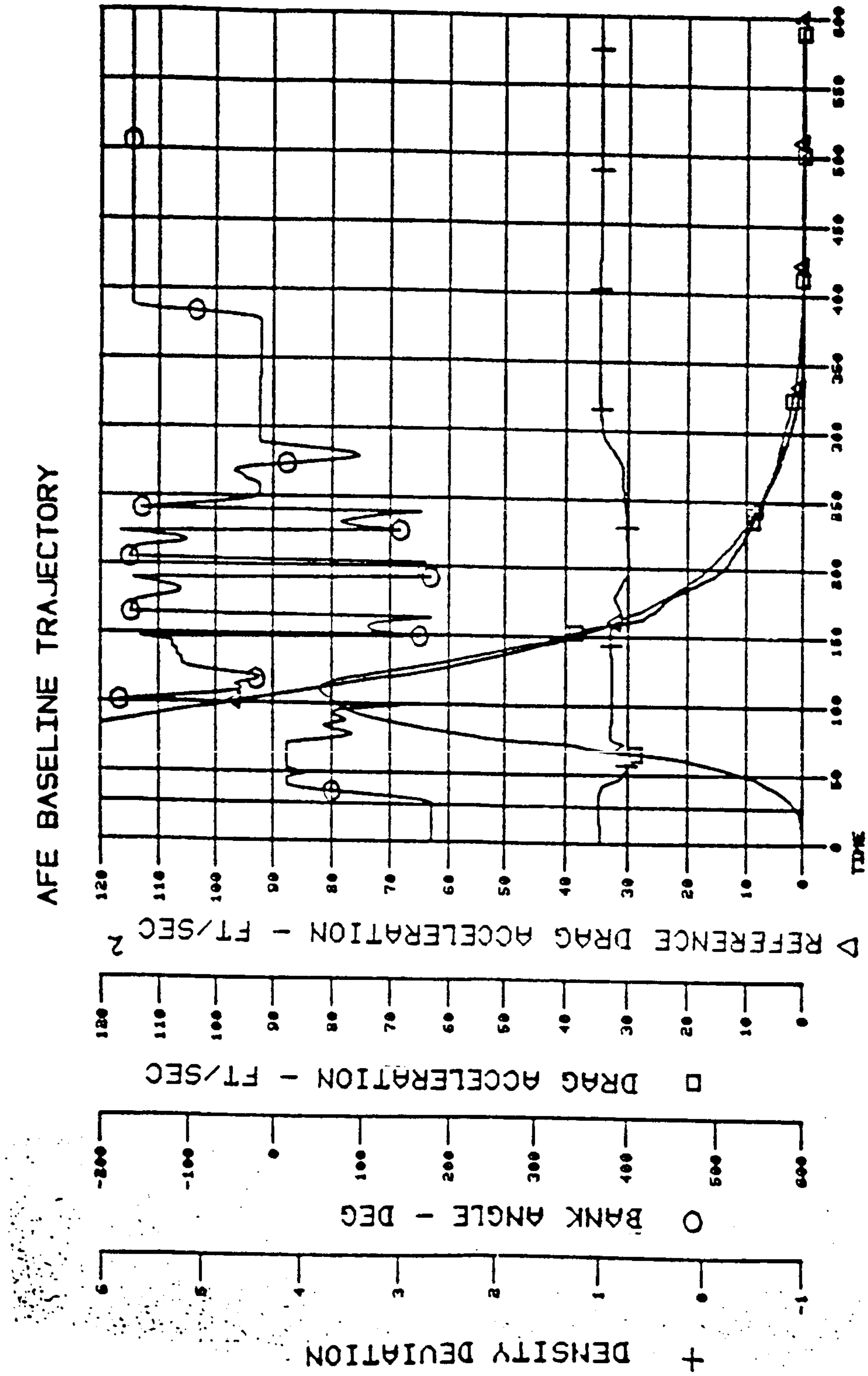
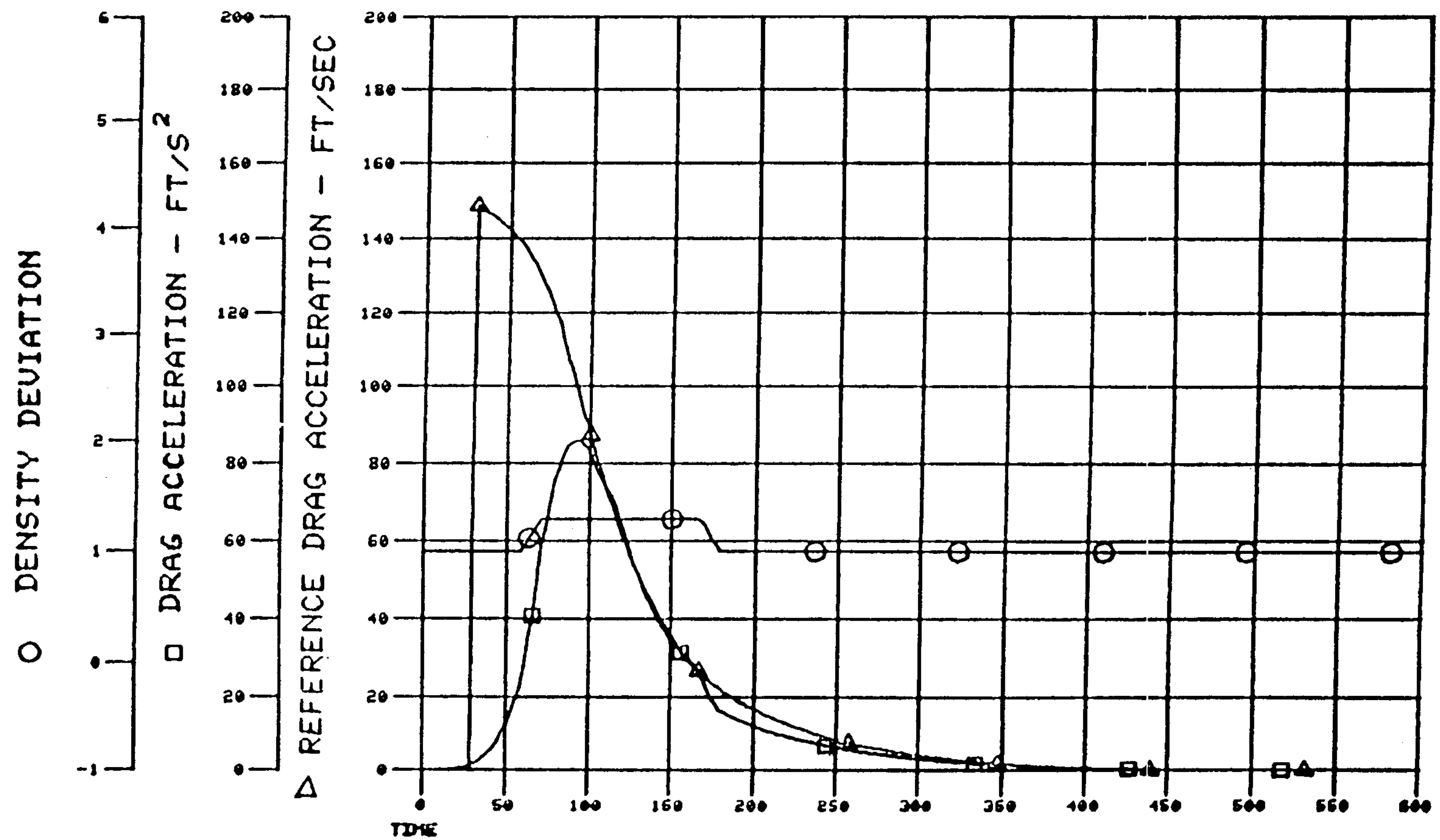
AFE BASELINE TRAJECTORY

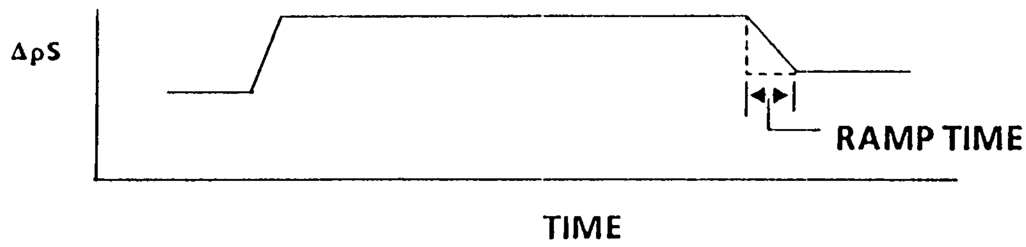


MISSION PLANNING AND ANALYSIS DIVISION

DENSITY SHEAR AT 282 000 FT ALTITUDE

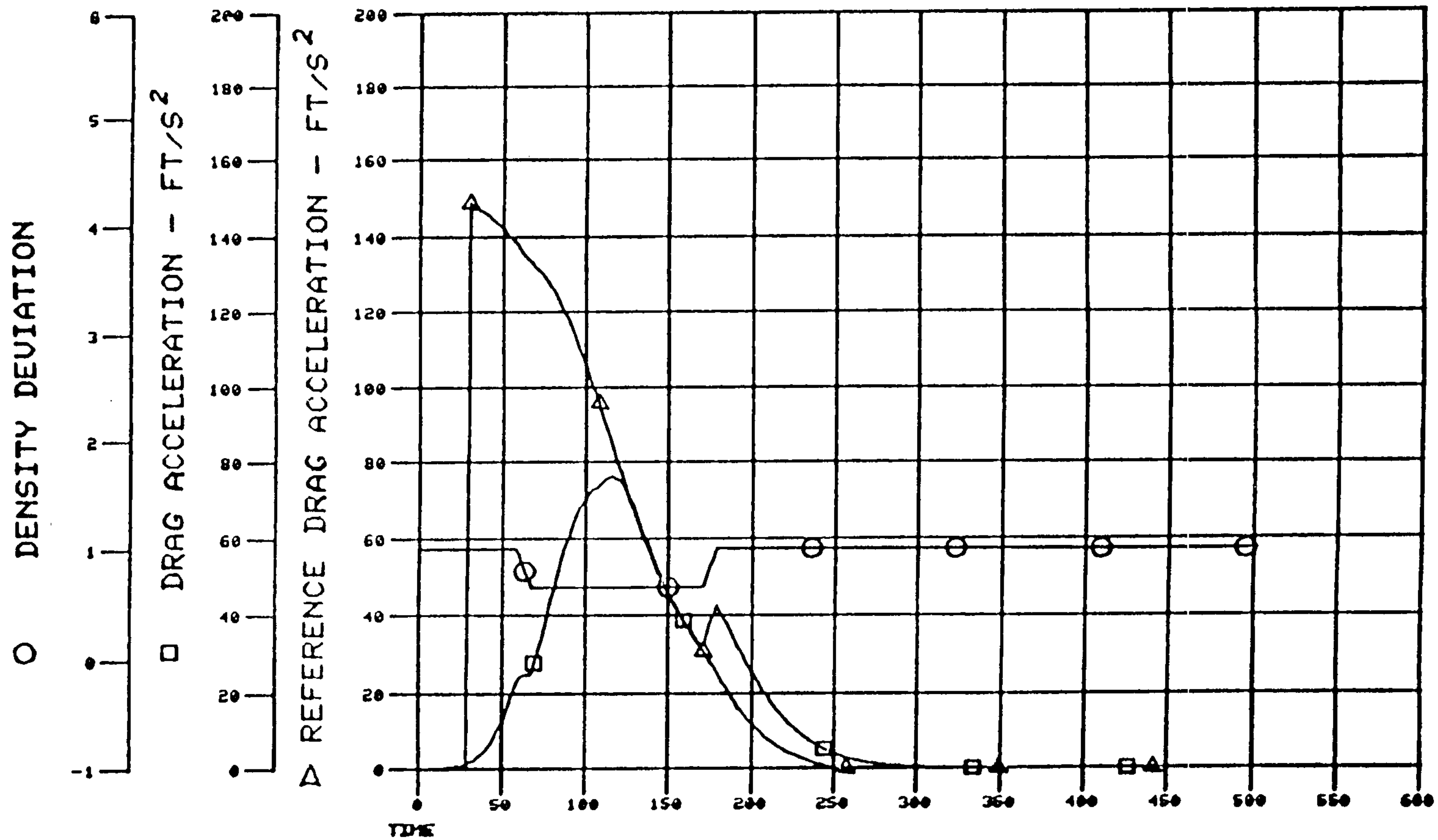


POSITIVE TRAPEZOIDAL DENSITY SHEAR AT 282000 FT.

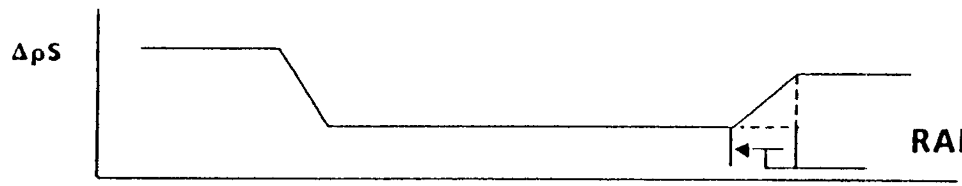


ΔρS	RAMP TIME	Δ RANGE	Δ ALTITUDE	APOGEE ALTITUDE ERROR
	SEC	N.MI.	FT	N.MI.
20%	2	9	500	-8
30%	4	17	1000	67
30%	8	34	2000	33
30%	12	51	3000	-10
35%	4	17	1000	72
35%	8	34	2000	53
35%	12	51	3000	59
35%	16	68	4000	-5

DENSITY SHEAR AT 282 000 FT ALTITUDE



POSITIVE TRAPEZOIDAL DENSITY SHEAR AT 282000 FT.



ΔρS	RAMP TIME	Δ RANGE	Δ ALTITUDE	APOGEE ALTITUDE ERROR	
	SEC	N.MI.	FT	N.MI.	
20%	2	9	500	-1	
30%	2	9	500	-39	
30%	4	17	1000	-18	
30%	8	34	2000	10	
30%	12	51	3000	11	
35%	4	17	1000	-43	ERATTIC RESULTS
35%	8	34	2000	-2	
35%	12	51	3000	-75	
35%	16	68	4000	9	

GUIDANCE SENSITIVITY TO ATMOSPHERIC DENSITY BIAS

AFE BASE LINE TRAJECTORY

- $\Delta\gamma$ = + 0.20 DEG, $\Delta\alpha$ = -2.0 DEG:

	APOGEE ALTITUDE ERROR - N.MI.
$\Delta\rho$ = -60%	778.5
$\Delta\rho$ = -50%	-13.8
$\Delta\rho$ = -40%	-4.0
↓	
$\Delta\rho$ = + 60%	NO EXTREMES

- OTHER $\Delta\gamma$, $\Delta\alpha$ COMBINATIONS HAVE NO EXTREME ERRORS IN APOGEE ALTITUDE FOR $-60\% \leq \Delta\rho \leq +60\%$

CONCLUSION

PROPER DEFINITION OF THE ATMOSPHERE AT THE LOCATION OF THE AEROBRAKING MANEUVER IS <u>CRITICAL</u> TO THE SUCCESS OF THE MISSION

- LOW INCLINATION ORBITS (EQUATORIAL)
- HIGH INCLINATION ORBITS (POLAR)