(NASA-CR-150971) ABORT-ONCE-AROUND ENTRY DISPERSION CORRIDOR ANALYSIS (McDonnell-Douglas Technical Services) 58 p HC $4.50 CSCL 22A

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MCDONNELL DOUGLAS TECHNICAL SERVICES CO.
HOUSTON ASTRONAUTICS DIVISION

SPACE SHUTTLE ENGINEERING AND OPERATIONS SUPPORT

DESIGN NOTE NO. 1.4-4-12

ABORT-ONCE-AROUND ENTRY DISPERSION CORRIDOR ANALYSIS

MISSION PLANNING, MISSION ANALYSIS AND SOFTWARE FORMULATION

31 JULY 1975

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1.0 SUMMARY

Abort-Once-Around (AOA) entry dispersion corridors have been determined for Shuttle Mission 3A. These corridors are presented in this report as plots of entry interface flight path angle versus range to target. The methods used to determine the corridors are discussed. Major dispersion sources are discussed and results presented.

While specific trajectory inputs and constraints are subject to change, the dispersion corridors show the trends under consideration. The corridors presented show the ΔV advantage of the two-burn over the one-burn AOA. The atmospheric dispersion study illustrates the need to target for the seasonal atmosphere. The 40°/30° angle of attack (α) (TPS design) profile did not provide adequate crossrange capability with worst case aerodynamic dispersions. This problem was alleviated with the change to a 38°/28° α profile. The back-face temperatures calculated were generally higher than the present limits.

2.0 INTRODUCTION

The abort-once-around concept is based on a one or two post-Main Engine Cutoff (MECO) burn maneuver which provides conditions at entry-interface (400,000 feet) as close as possible to those for nominal entry. For abort situations which occur early in the flight, use of maximum delta-V available for the AOA results in entry ranges of up to 6000 miles from entry interface to the landing site. These extended entry ranges produce conditions during the entry phase which approach the vehicle structural and trajectory design limits. Among the vehicle constraints which must be considered are thermal protection system (TPS) surface and backface temperatures. Trajectory considerations include maximum bank angle required to insure convergence to the reference drag-velocity profile, and minimum bank angle during the equilibrium glide phase to assure adequate crossrange capability. Based on these limiting parameters, an entry dispersion corridor can be defined depicting the allowable range-velocity-flight path angle (R-V-γ) conditions at entry interface (EI). A set of these corridors has been determined as discussed in this report. The results were obtained from a series of Space Vehicle Dynamic Simulation (SVDS) computer runs (Reference 1) using the current aerodynamic and atmosphere models and the presently imposed values of the constraints involved. As these are updated, the AOA entry corridors must be redefined. A computer program to automate this corridor definition is being designed and will be documented at a later date.

3.0 DISCUSSION

AOA entry dispersion corridors were defined for the following conditions:

(1) One-burn AOA, 40°/30° α profile

(2) Two-burn AOA, Minimum ΔV, 40°/30° α profile

(3) One-burn AOA with atmospheric dispersions, 40°/30° α profile

(4) One-burn AOA, 38°/28° α profile

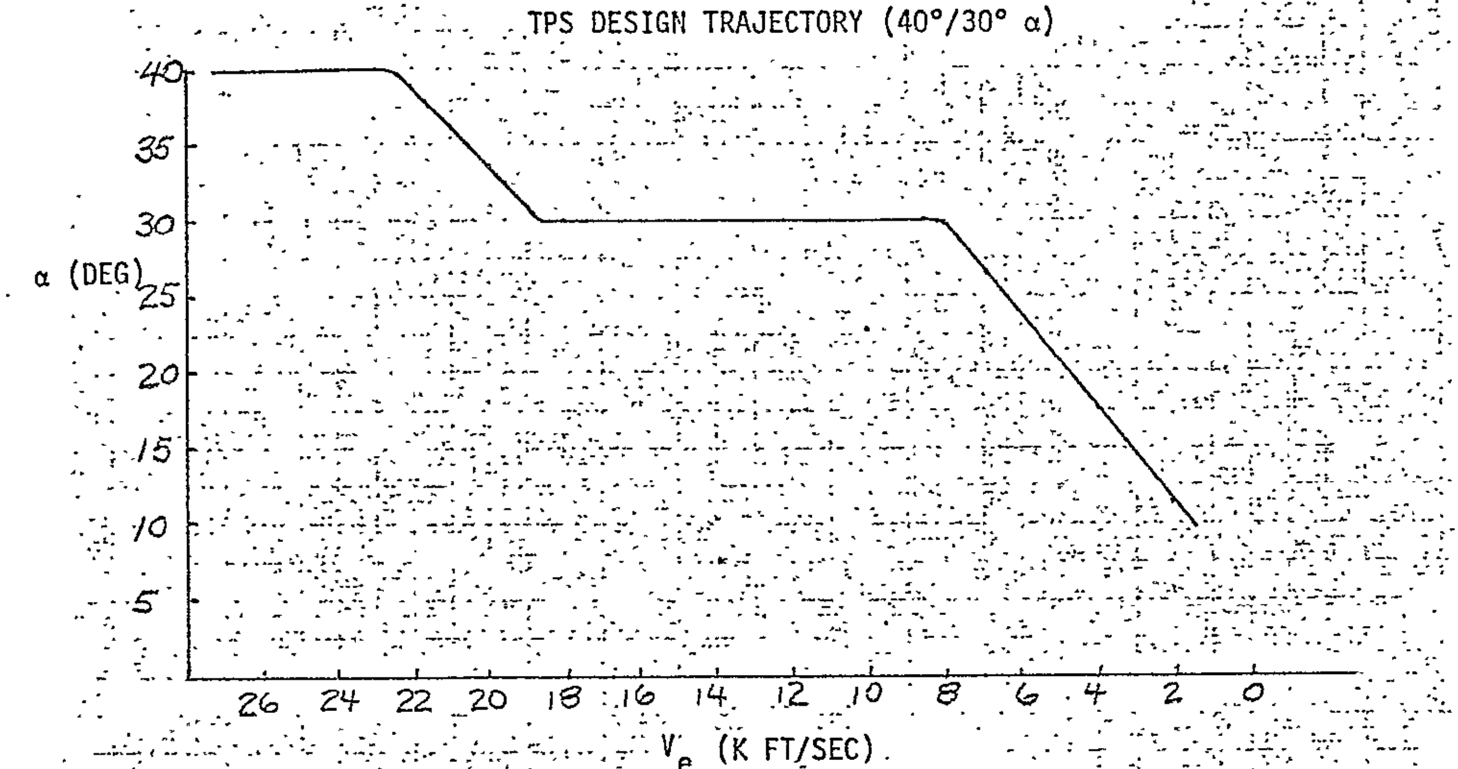
The 40°/30° and 38°/28° α profiles are presented in Figure 3.0-1. In addition, selected 38°/28° α EI points were used for a detailed dispersion analysis.

Guidance constants for the 40°/30° α profile were those which correspond to the TPS design trajectory. Guidance constants for the 38°/28° α profile were those corresponding to the Western Test Range (WTR) nominal Mission 3B.

3.1 Entry Interface State Vector Determination:

AOA MECO-to-entry trajectory solutions were computed for both one-burn and minimum-ΔV two-burn sequences. These trajectories were generated using MLTBRN (Reference 2), a computer program based on conic orbit and impulsive burn assumptions. AOA trajectories were generated to result in predefined entry interface range-gamma combinations. For each case, the corresponding entry interface latitude, longitude and velocity were computed. The MECO downrange (from launch site) used by MLTBRN corresponds to the earliest AOA for one engine out.

ANGLE OF ATTACK VS. RELATIVE VELOCITY FOR ENTRY TRAJECTORIES STUDIED



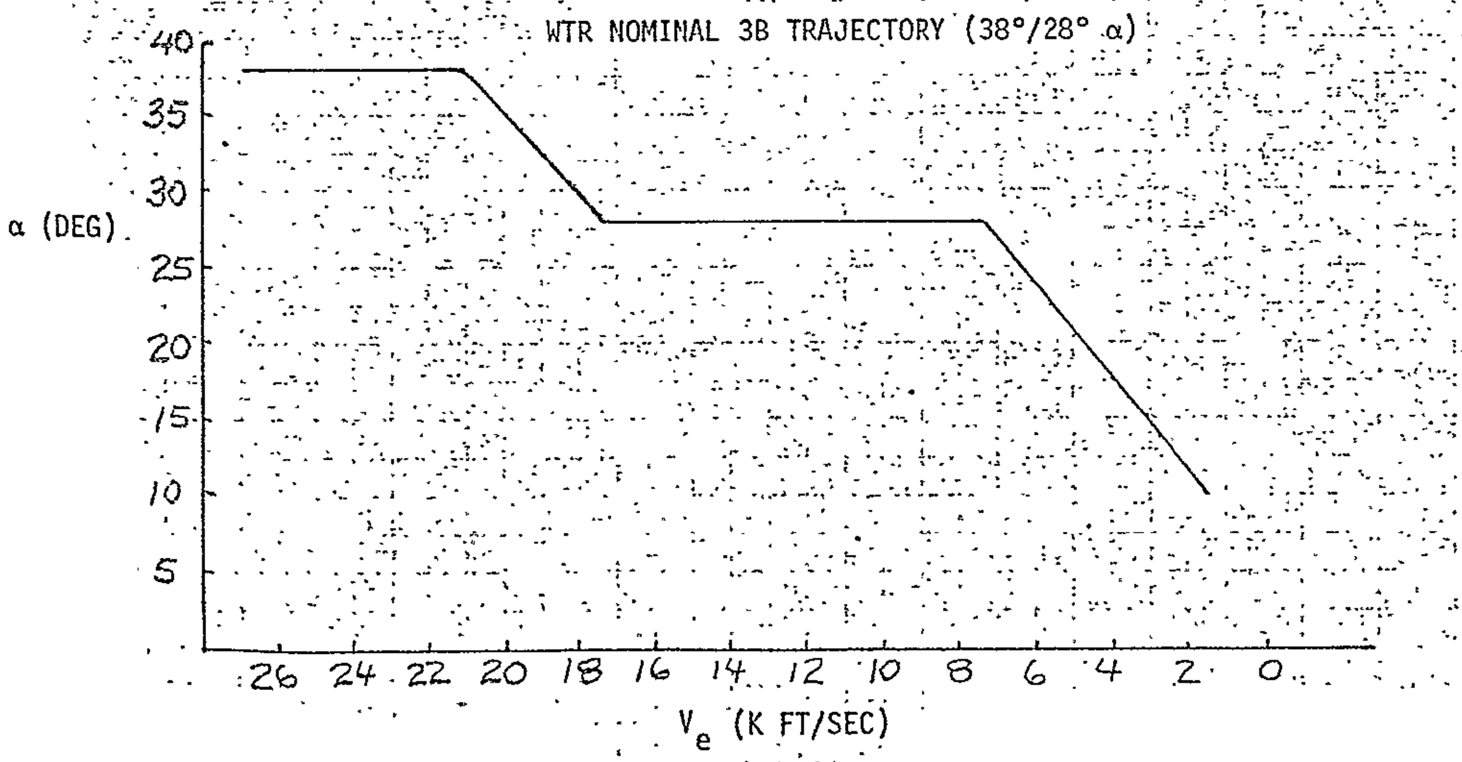


FIGURE 3.0-1

The position and velocity vectors obtained from MLTBRN were input to the SVDS program for a series of gamma scans (γ =-0.4° to -1.4°) at 200-mile range intervals from 5200 NM to 6200 NM (entry interface to target). Figures 3.1-1 and 3.1-2 show the resulting EI (R-V-γ) for one-burn and two-burn AOA's. These figures also show the ΔV required to obtain each EI state vector.

3.2 Program Setup:

For the SVDS simulations, the vehicle weight was input as 191,866 pounds (Mission 3A with 32,000 pound payload) and c.g. as 67.5% body length. To account for aerodynamic uncertainties, a bank angle of 90° is flown from entry interface to the point where the automatic guidance is initiated (load factor reaches .05 g's). Body flap schedules used were provided by the Flight Performance Branch (FPB) of NASA at the Johnson Space Center (JSC).

3.3 Corridor Constraints:

Using data from these SVDS simulations, the allowable entry dispersion corridors were determined based on the constraints shown in Table 3.3-I.

As a measure of TPS backface overtemperature, the highest individual panel overtemperature was used unless noted. The reusable carbon-carbon (RCC) panels (panels 1 and 7) and the aero-surfaces (panels 11, 12, 19) were excluded, as the current backface temperature model (Reference 3) in SVDS is not accurate for those panels. The backface overtemperature limit is not currently established, but should be in the range 35° to 50°F (over the 350°F reference). Overtemperature

ENTRY INTERFACE CONDITIONS
FOR ONE-BURN AOA (MISSION 3A)

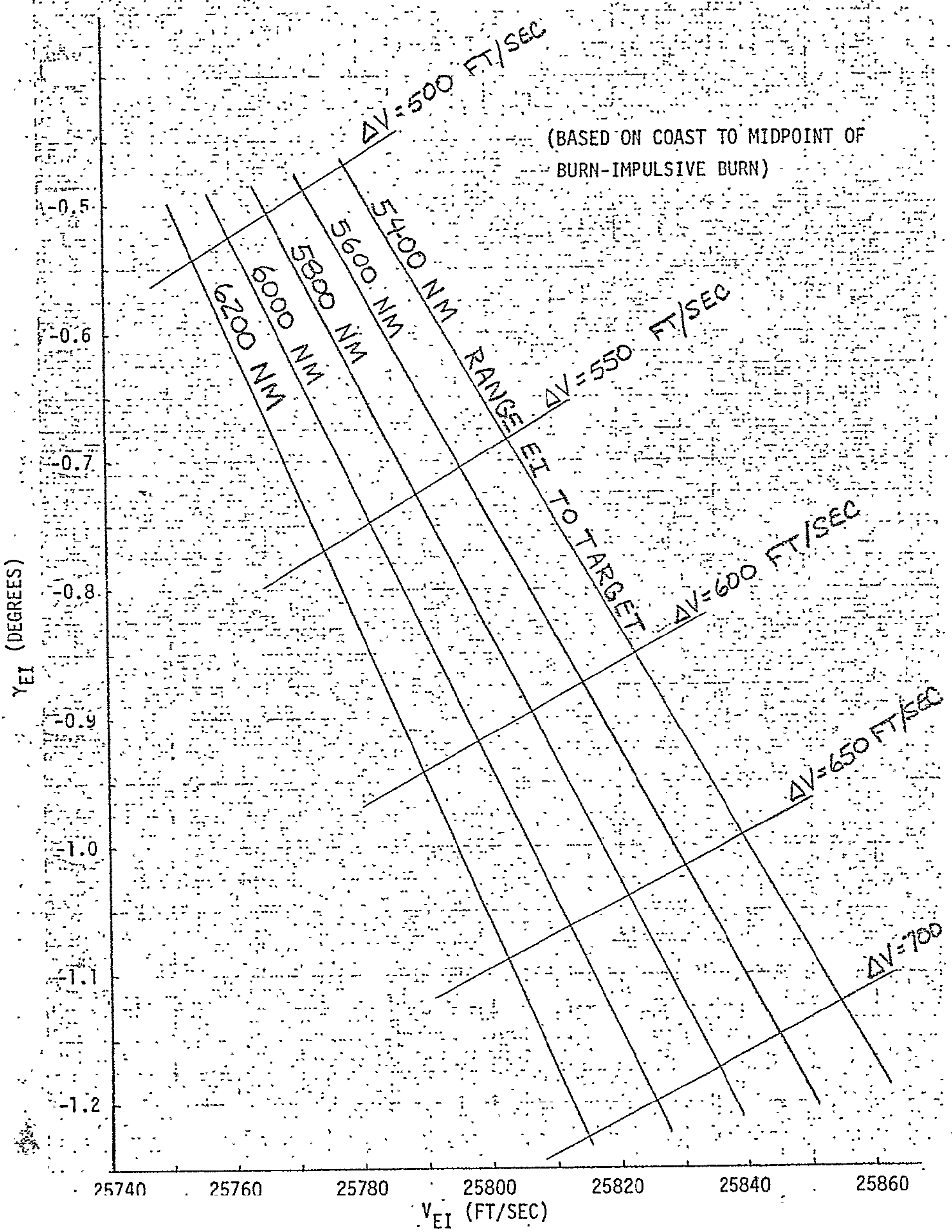


Figure 3.1-1

ENTRY INTERFACE CONDITIONS FOR
MINIMUM ΔV TWO-BURN AOA (MISSION 3A)

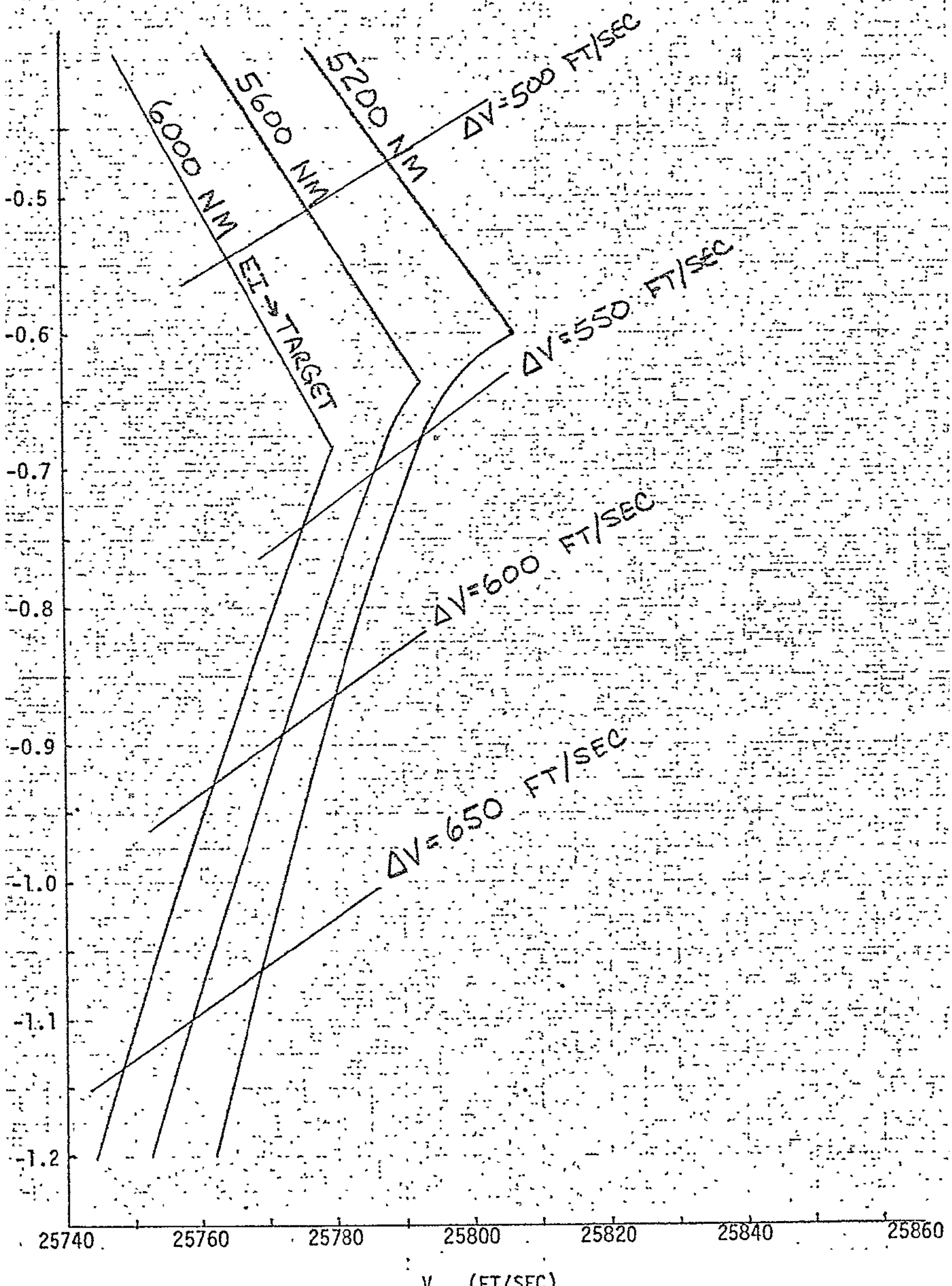


Figure 3.1-2

TABLE 3.3-I

AOA ENTRY CONSTRAINTS

Surface temperature, nose	2950°F
Surface temperature, body flap	2800°F
Surface temperature, wing leading edge	2950°F
Surface temperature, elevon	2500°F
Total heat load	74,000 BTU/FT^2
Altitude at Relative velocity of 20,000 ft/sec	211,500 FT
Maximum bank angle during pullup	90°
Minimum bank angle during equilibrium glide	42°
TPS backface overtemperature	To be determined

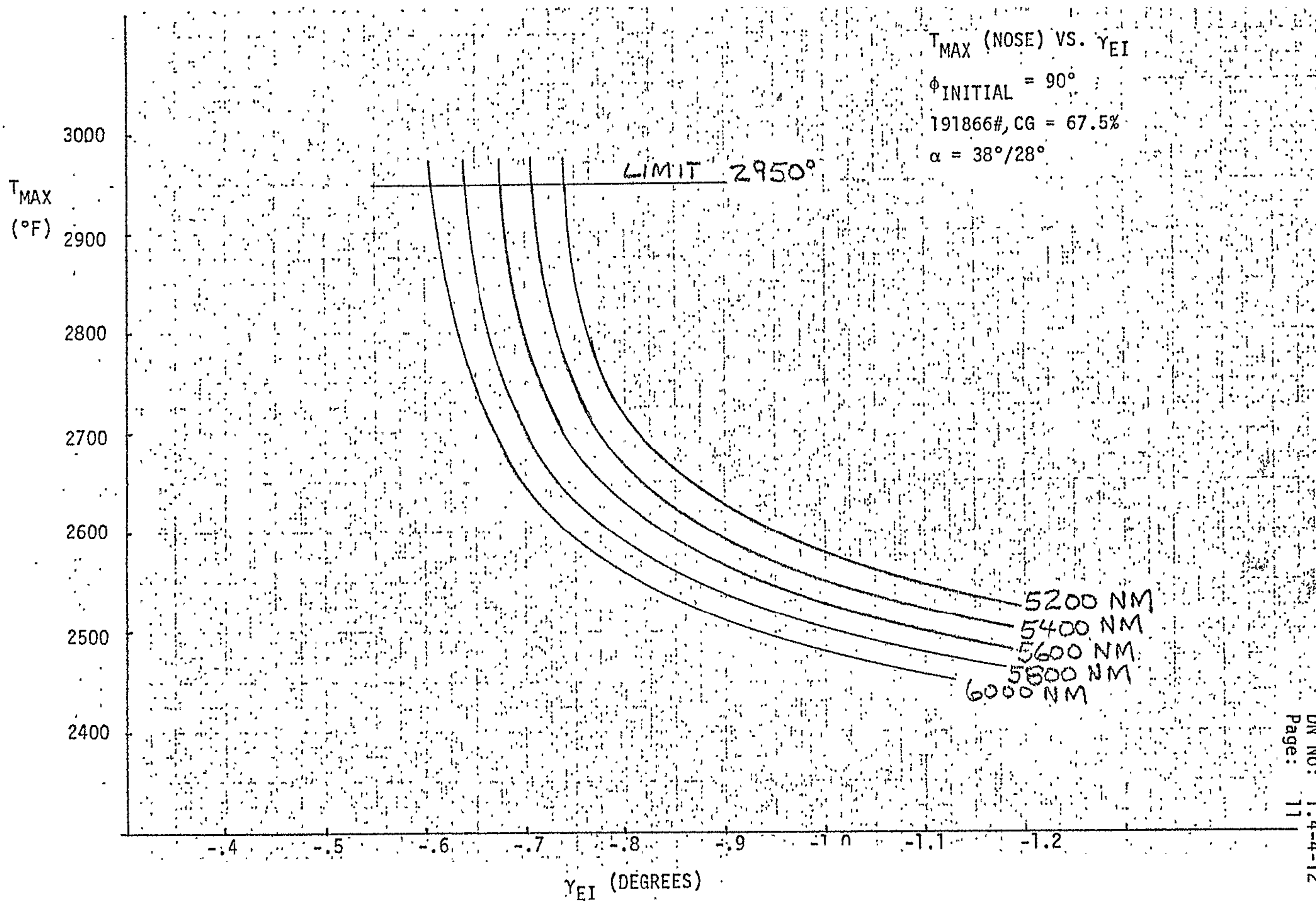
limits in this range were considered. During the early part of the study the backface overtemperature model was not yet incorporated into SVDS. During this time, the total heat load constraint (Table 3.3-I) was used as a measure of backface temperature. Backface overtemperature contours shown on later graphs for the 40°/30° α profile are high temperature reusable surface insulation (HRSI) panels only.

The maximum bank angle limit was set at 90° to preclude the necessity of using "lift-vector down" to insure convergence to the reference drag profile. This eliminates the necessity of relying upon aerodynamics to insure capture. The minimum equilibrium glide bank angle is set at 42° to provide adequate margin from the equilibrium glide boundary and insure crossrange capability with allowance for dispersions.

3.4 General Study Method:

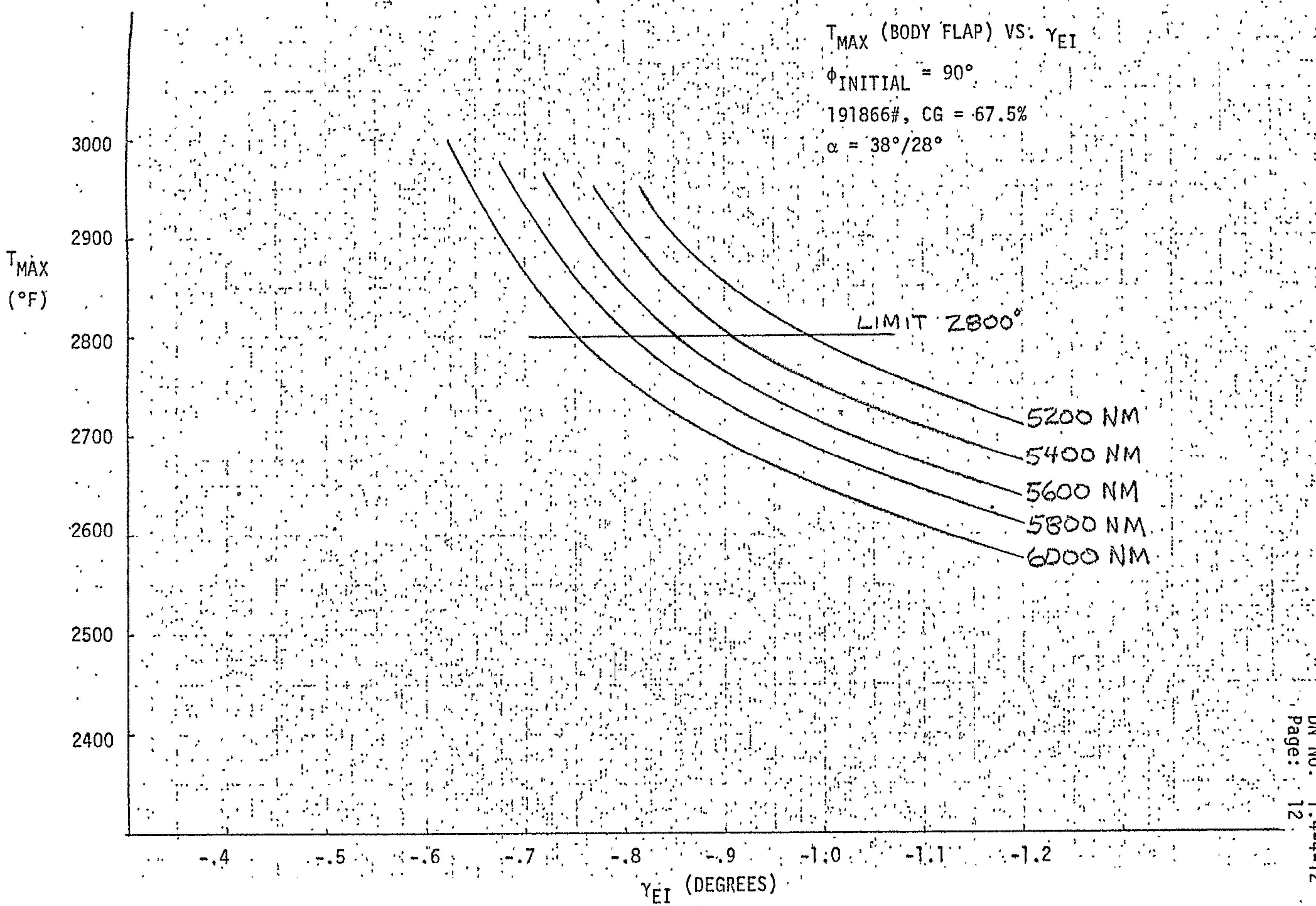
Pertinent data from each of the SVDS trajectories were plotted versus EI flight path angle for each constant range. The data from the 38°/28° α case studied are shown in Figures 3.4-1 through 3.4-8. The limits for the individual parameters (Table 3.3-I) are superimposed on these figures.

Each parameter thus establishes an upper or lower limit on the entry flight path angle for a given entry range and corresponding velocity. These individual constraint boundaries are plotted in the Range-γ plane as shown in Figures 3.4-9 through 3.4-11. The most restricting



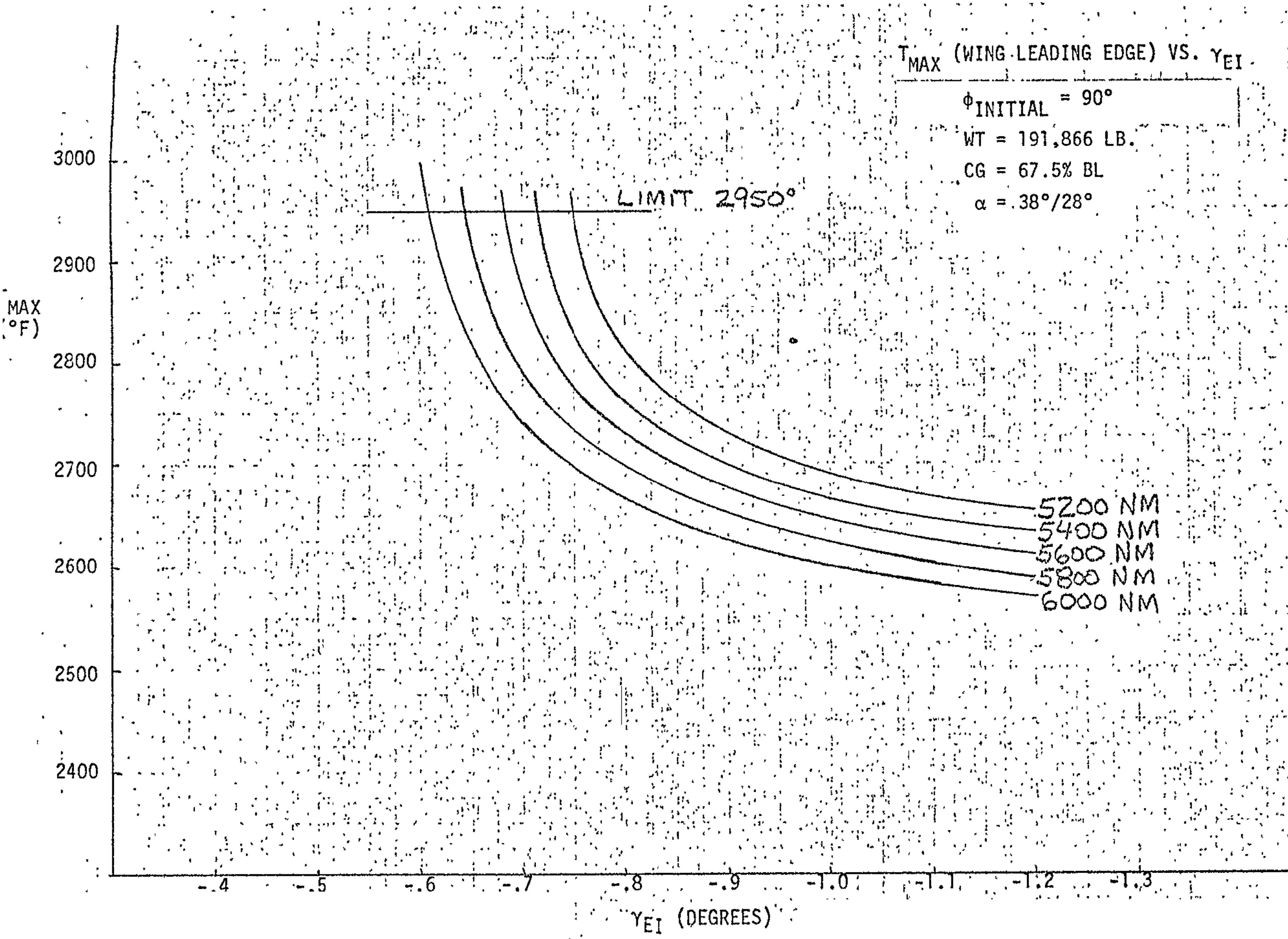
T_{MAX} (NOSE) VS. γ_{EI}
$\phi_{INITIAL}$ = 90°
191866#, CG = 67.5%
α = 38°/28°
LIMIT 2950°
5200 NM
5400 NM
5600 NM
5800 NM
6000 NM
T_{MAX} (°F)
3000
2900
2800
2700
2600
2500
2400
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
-1.1
-1.2
γ_{EI} (DEGREES)

Figure 3.4-1



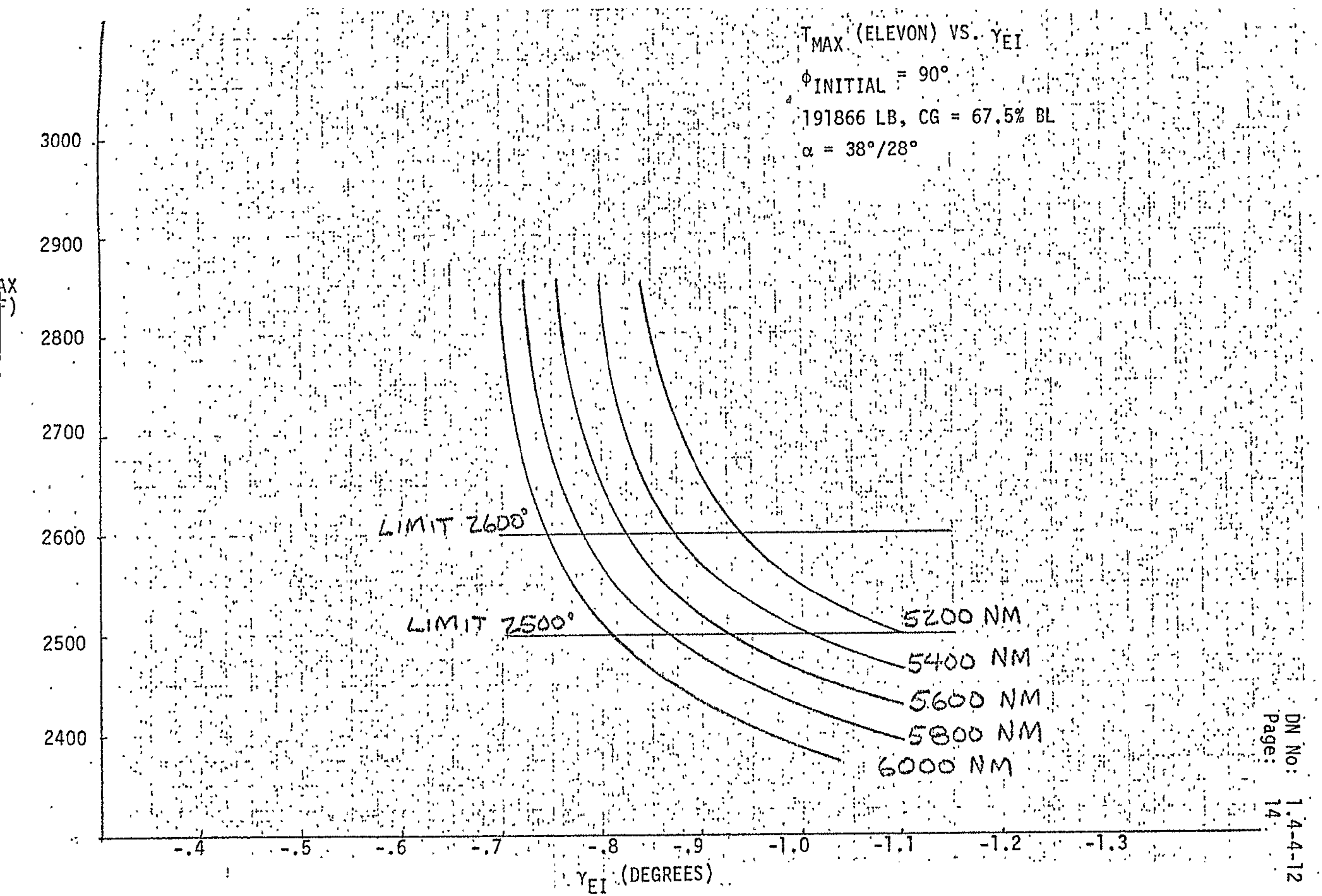
T_{MAX} (BODY FLAP) VS. γ_{EI}
$\phi_{INITIAL}$ = 90°
191866#, CG = 67.5%
α = 38°/28°
LIMIT 2800°
5200 NM
5400 NM
5600 NM
5800 NM
6000 NM
T_{MAX} (°F)
3000
2900
2800
2700
2600
2500
2400
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
-1.1
-1.2
γ_{EI} (DEGREES)

Figure 3.4-2



T_{MAX} (WING LEADING EDGE) VS. γ_{EI}
$\phi_{INITIAL}$ = 90°
WT = 191,866 LB.
CG = 67.5% BL
α = 38°/28°
LIMIT 2950°
5200 NM
5400 NM
5600 NM
5800 NM
6000 NM
MAX (°F)
3000
2900
2800
2700
2600
2500
2400
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
-1.1
-1.2
-1.3
γ_{EI} (DEGREES)

Figure 3.4-3



T_{MAX} (ELEVON) VS. γ_{EI}
$\phi_{INITIAL}$ = 90°
191866 LB, CG = 67.5% BL
α = 38°/28°
LIMIT 2600°
LIMIT 2500°
5200 NM
5400 NM
5600 NM
5800 NM
6000 NM
3000
2900
2800
2700
2600
2500
2400
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
-1.1
-1.2
-1.3
γ_{EI} (DEGREES)

Figure 3.4-4

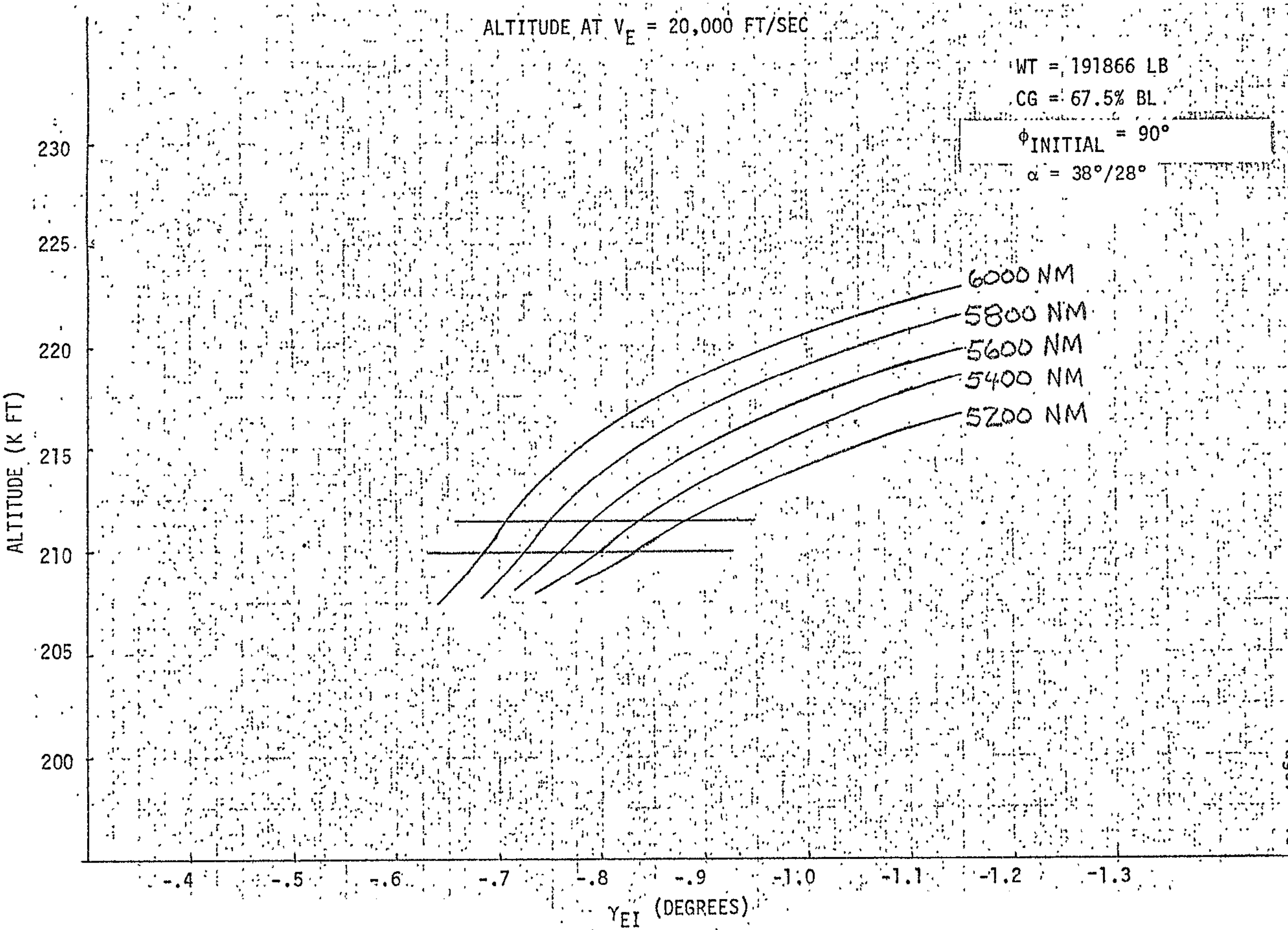

ALTITUDE AT V_E = 20,000 FT/SEC
WT = 191866 LB
CG = 67.5% BL
$\phi_{INITIAL}$ = 90°
α = 38°/28°
6000 NM
5800 NM
5600 NM
5400 NM
5200 NM
ALTITUDE (K FT)
230
225
220
215
210
205
200
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
-1.1
-1.2
-1.3
γ_{EI} (DEGREES)

Figure 3.4-5

TOTAL HEAT LOAD EI TO TAEM

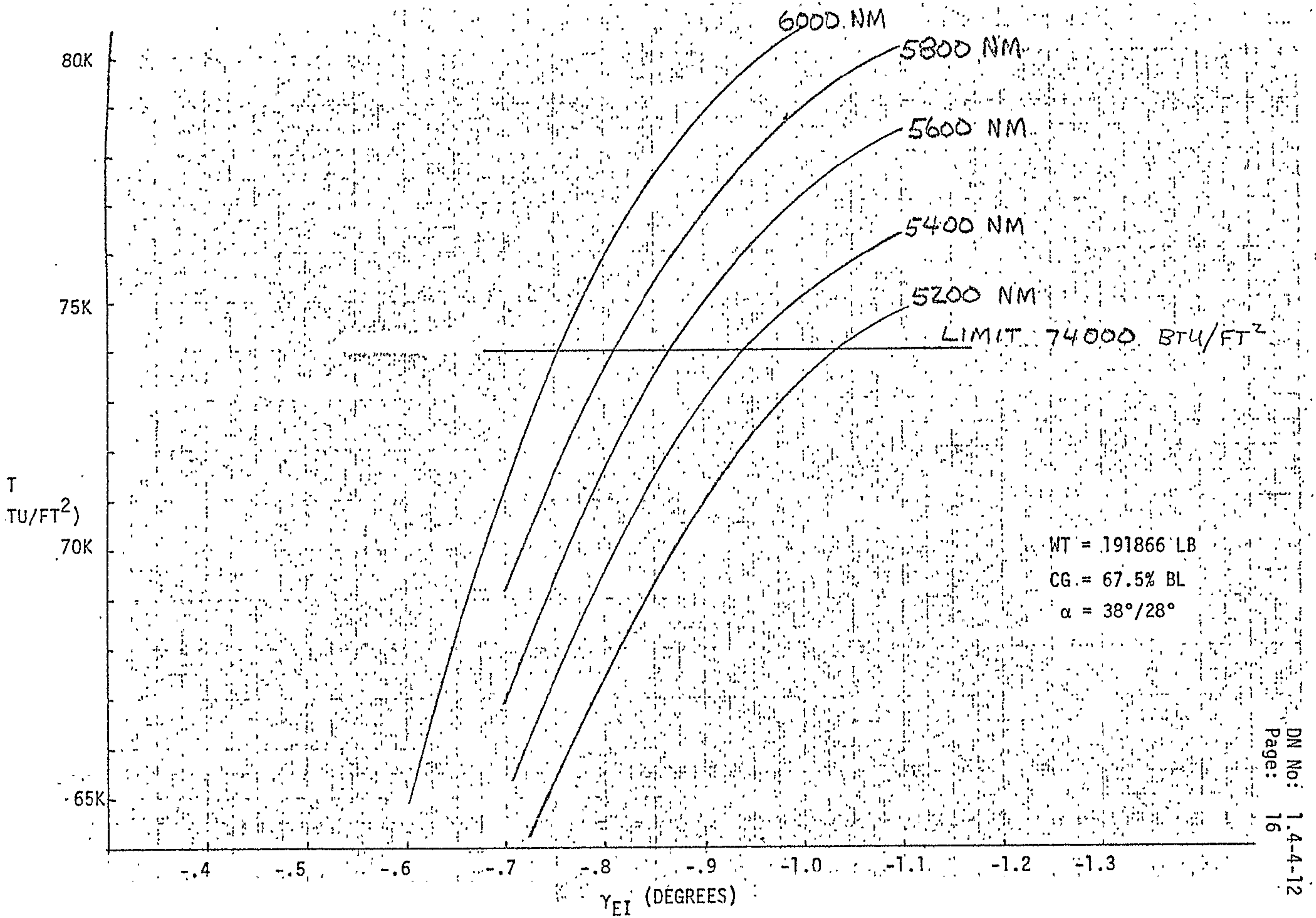


Figure 3.4-6

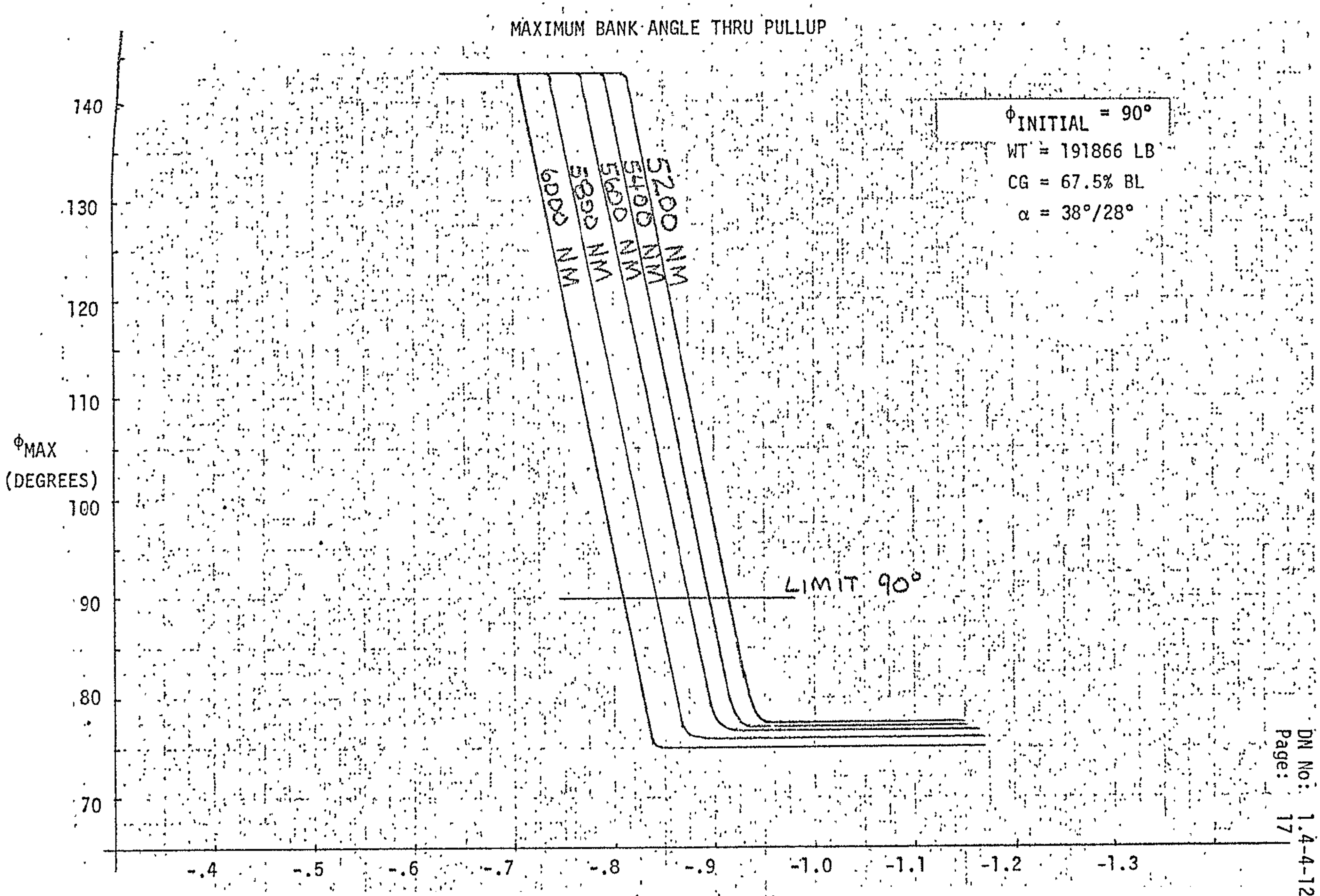

MAXIMUM BANK ANGLE THRU PULLUP
$\phi_{INITIAL}$ = 90°
WT = 191866 LB
CG = 67.5% BL
α = 38°/28°
5200 NM
5400 NM
5600 NM
5800 NM
6000 NM
LIMIT 90°
140
130
120
110
100
90
80
70
ϕ_{MAX} (DEGREES)
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
-1.1
-1.2
-1.3
γ_{EI} (DEGREES)

Figure 3.4-7

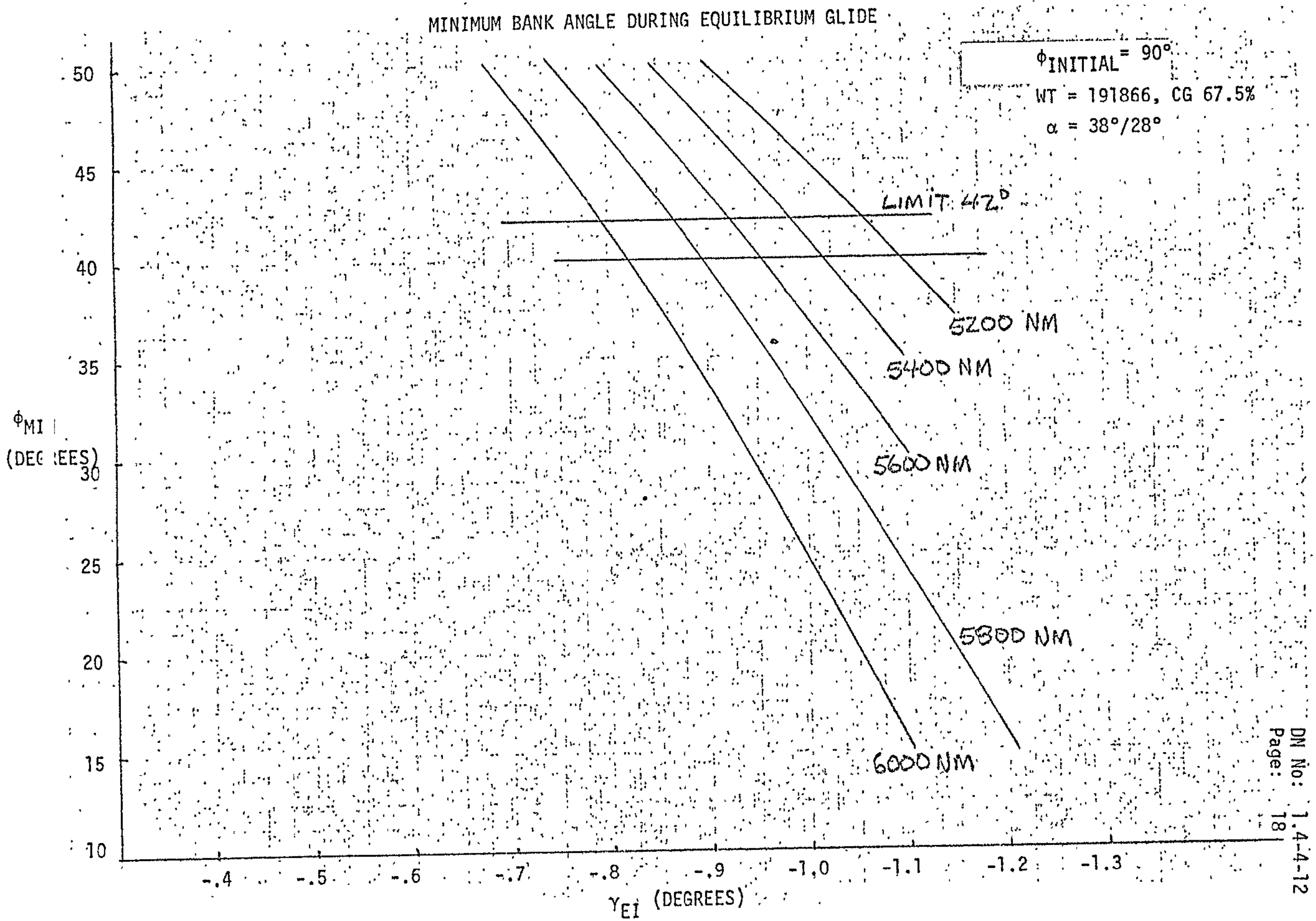
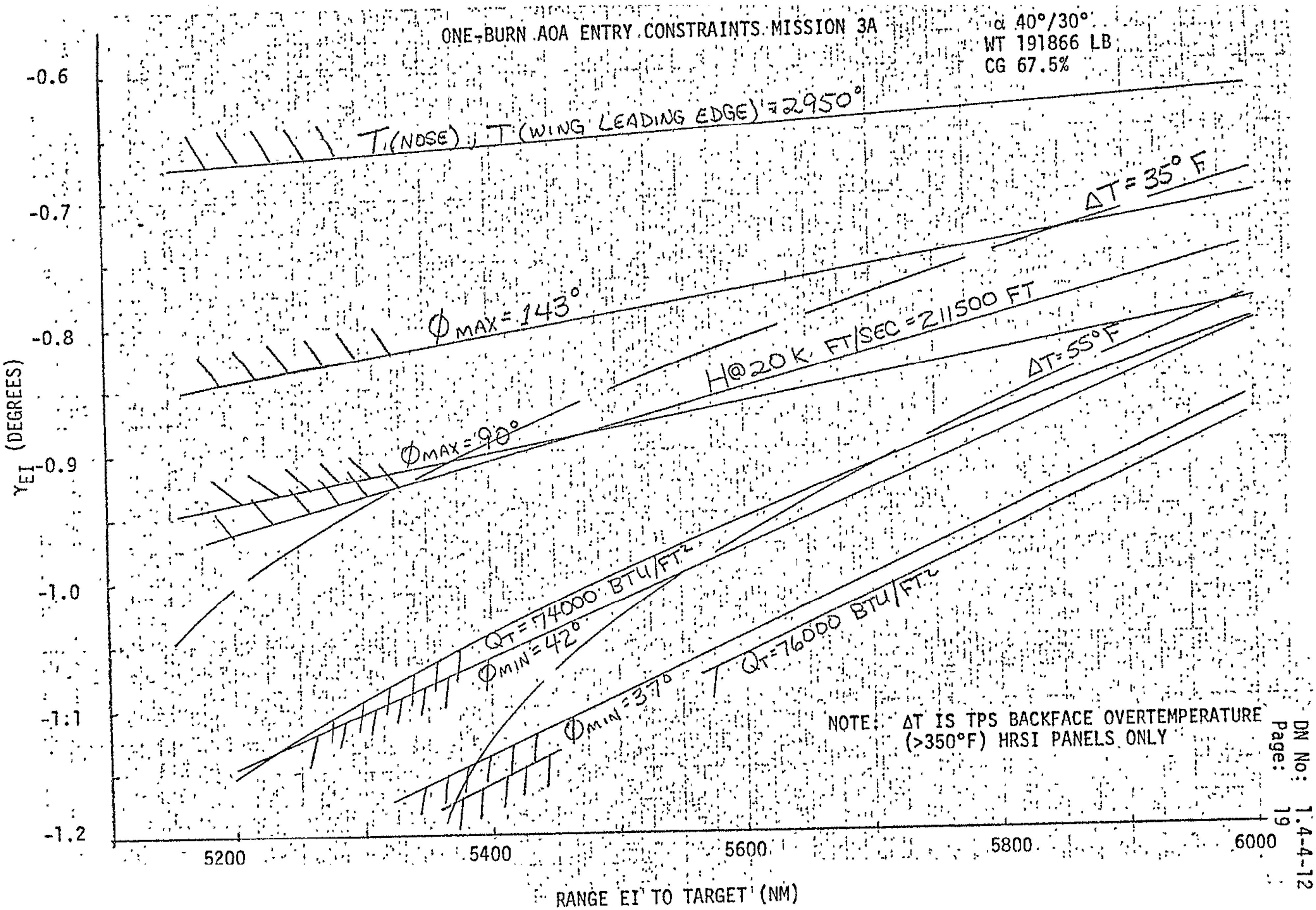

MINIMUM BANK ANGLE DURING EQUILIBRIUM GLIDE
$\phi_{INITIAL}$ = 90°
WT = 191866, CG 67.5%
α = 38°/28°
LIMIT 42°
5200 NM
5400 NM
5600 NM
5800 NM
6000 NM
ϕ_{MIN} (DEGREES)
50
45
40
35
30
25
20
15
10
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
-1.1
-1.2
-1.3
γ_{EI} (DEGREES)

Figure 3.4-8



ONE-BURN AOA ENTRY CONSTRAINTS MISSION 3A
α 40°/30°
WT 191866 LB
CG 67.5%
T (NOSE) ; T (WING LEADING EDGE) = 2950°
ΔT = 35° F
ϕ MAX = 143°
H @ 20 K FT/SEC = 211500 FT
ΔT = 55° F
ϕ MAX = 90°
QT = 74000 BTU/FT²
ϕ MIN = 42°
QT = 76000 BTU/FT²
ϕ MIN = 37°
NOTE: ΔT IS TPS BACKFACE OVERTEMPERATURE (>350°F) HRSI PANELS ONLY
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
γEI (DEGREES)
5200
5400
5600
5800
6000
RANGE EI TO TARGET (NM)

Figure 3.4-9

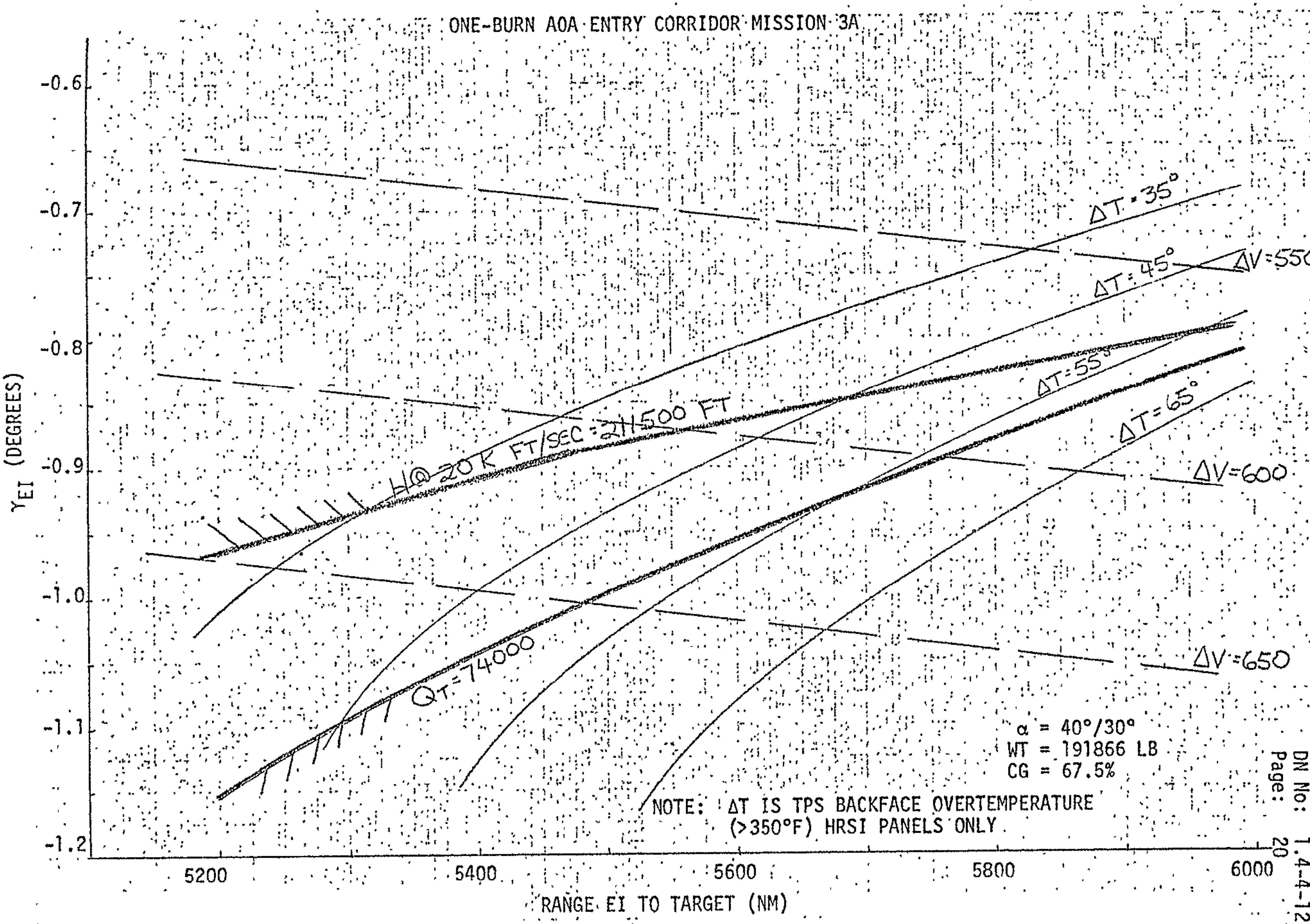

ONE-BURN AOA ENTRY CORRIDOR MISSION 3A
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
γ_{EI} (DEGREES)
5200
5400
5600
5800
6000
RANGE EI TO TARGET (NM)
ΔT = 35°
ΔT = 45°
ΔT = 55°
ΔT = 65°
ΔV = 550
ΔV = 600
ΔV = 650
H @ 20 K FT/SEC = 211500 FT
QT = 74000
α = 40°/30°
WT = 191866 LB
CG = 67.5%
NOTE: ΔT IS TPS BACKFACE OVERTEMPERATURE (>350°F) HRSI PANELS ONLY

Figure 3.4-9a

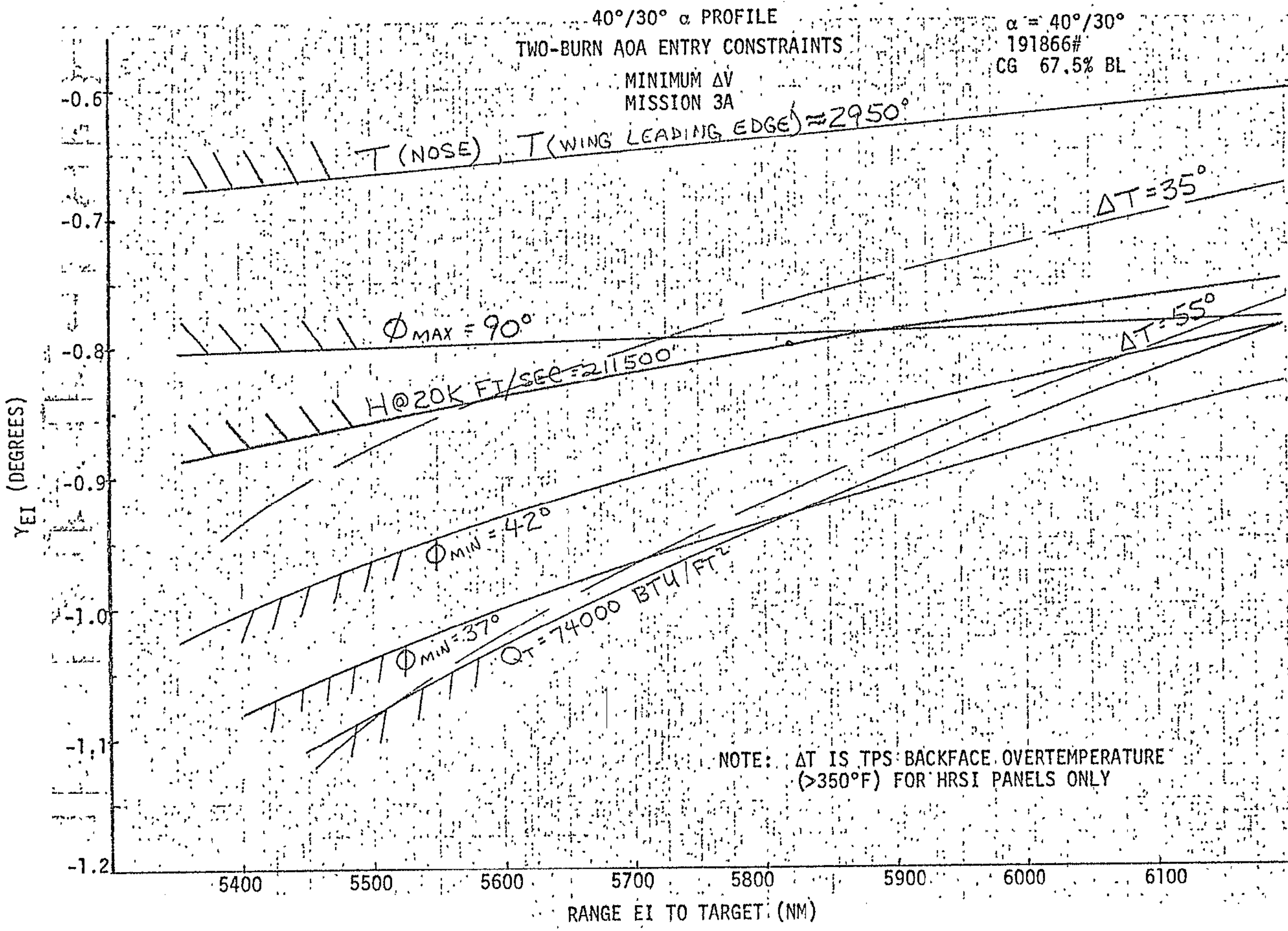

40°/30° α PROFILE
TWO-BURN AOA ENTRY CONSTRAINTS
MINIMUM ΔV
MISSION 3A
α = 40°/30°
191866#
CG 67.5% BL
T (NOSE), T (WING LEADING EDGE) ≈ 2950°
ΔT = 35°
Φ MAX = 90°
H @ 20K FT/SEC = 211500'
ΔT = 55°
Φ MIN = 42°
Φ MIN = 37°
QT = 74000 BTU/FT²
NOTE: ΔT IS TPS BACKFACE OVERTEMPERATURE (>350°F) FOR HRSI PANELS ONLY
YEI (DEGREES)
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
5400
5500
5600
5700
5800
5900
6000
6100
RANGE EI TO TARGET (NM)

Figure 3.4-10

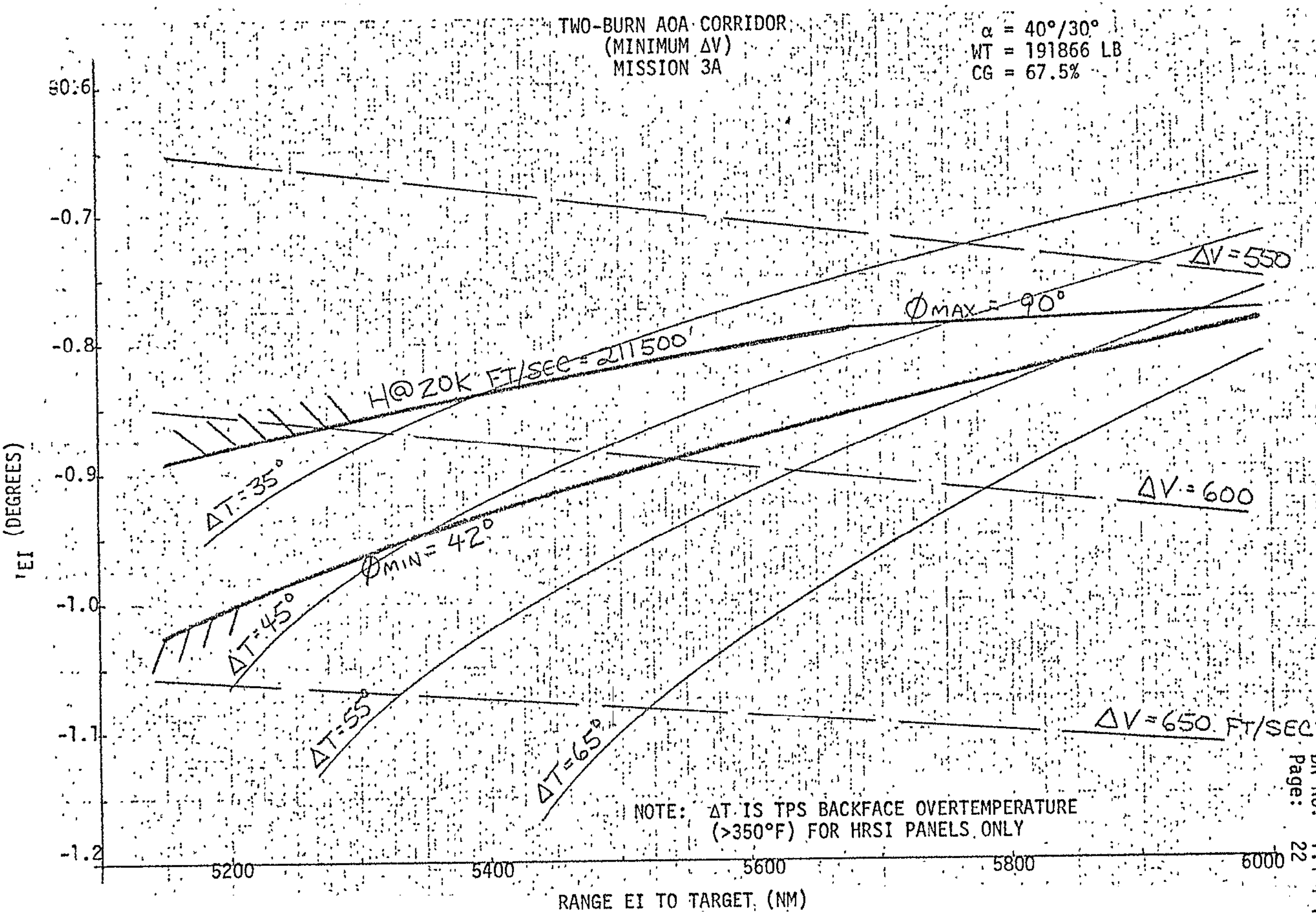
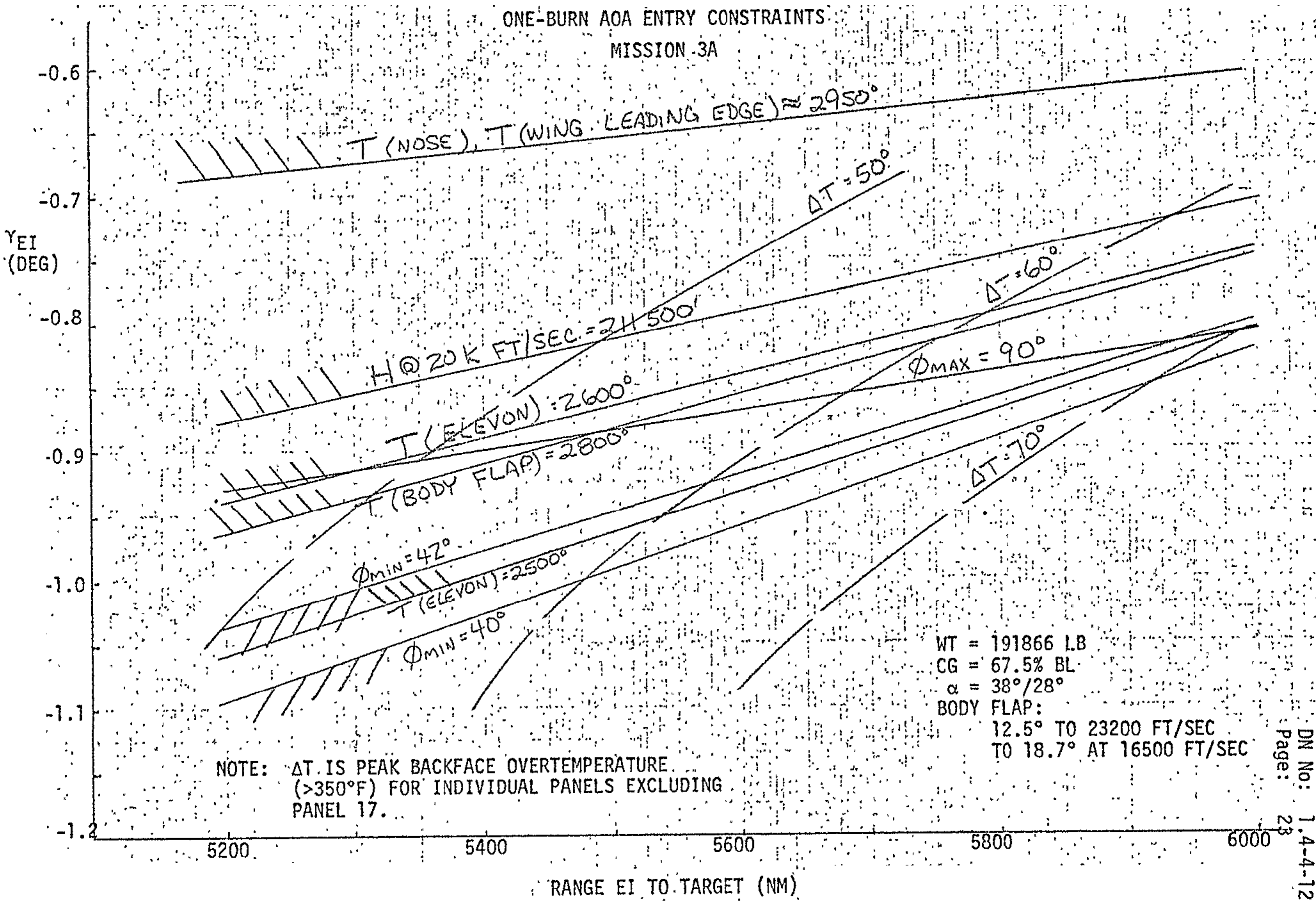


Figure 3.4-10a



ONE-BURN AOA ENTRY CONSTRAINTS
MISSION 3A
T (NOSE), T (WING LEADING EDGE) ≈ 2950°
ΔT = 50°
ΔT = 60°
H @ 20 K FT/SEC = 211500'
ϕMAX = 90°
T (ELEVON) = 2600°
T (BODY FLAP) = 2800°
ΔT = 70°
ϕMIN = 42°
T (ELEVON) = 2500°
ϕMIN = 40°
WT = 191866 LB
CG = 67.5% BL
α = 38°/28°
BODY FLAP:
12.5° TO 23200 FT/SEC
TO 18.7° AT 16500 FT/SEC
NOTE: ΔT IS PEAK BACKFACE OVERTEMPERATURE (>350°F) FOR INDIVIDUAL PANELS EXCLUDING PANEL 17.
γEI (DEG)
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
5200
5400
5600
5800
6000
RANGE EI TO TARGET (NM)

Figure 3.4-11

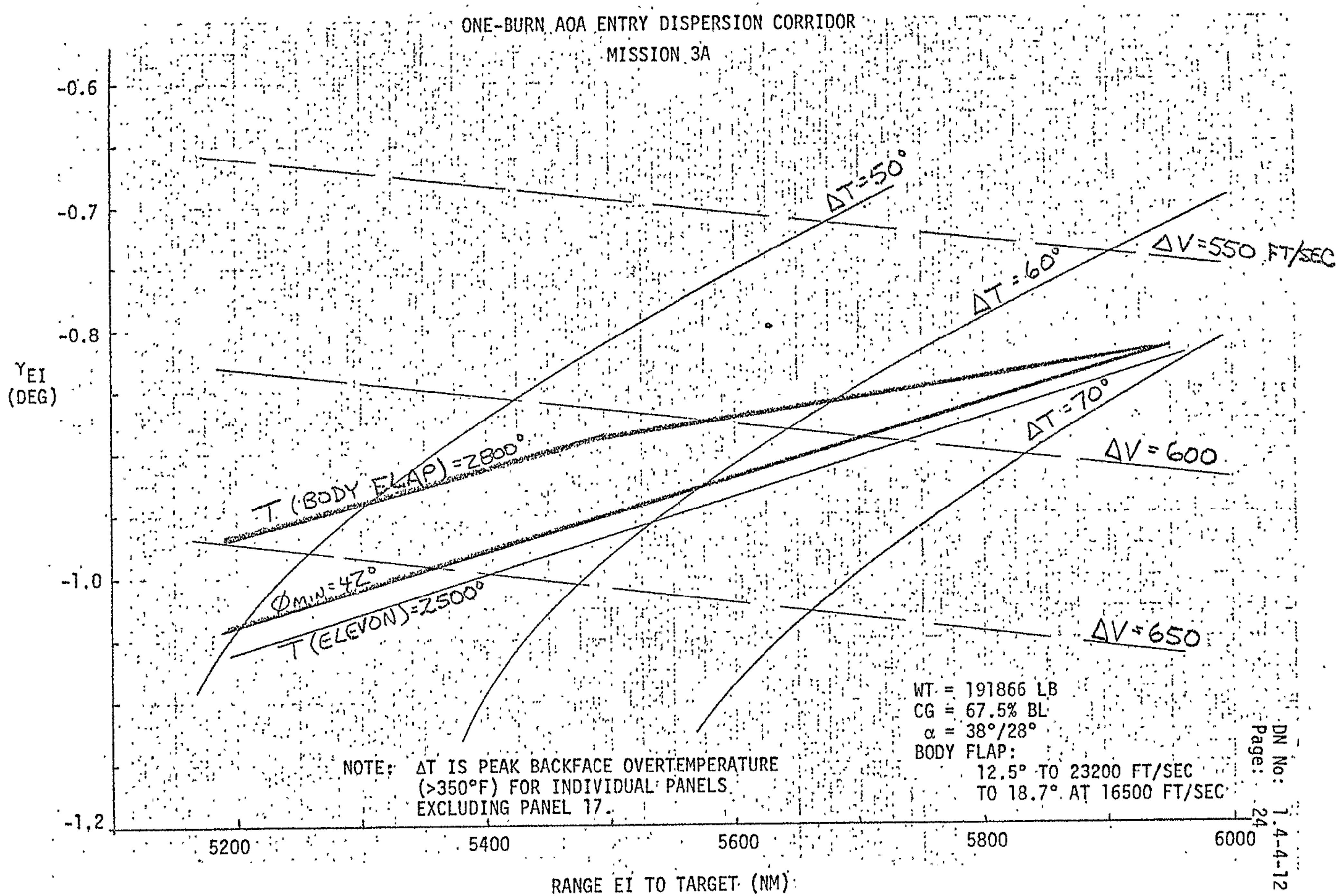


Figure 3.4-11a

constraints at any range determine the allowable gamma regions, as are shown in Figures 3.4-9a through 3.4-11a.

The two-burn AOA corridor is based on the minimum ΔV solution. It should be noted that a small increase (1 ft/sec) in ΔV results in a wide range of velocities possible at entry interface and corresponding changes to the corridor. Also, at shallow entry gammas, the MLTBRN two-burn solution degenerates to the one-burn solution. Since ΔV is the major determinant of how close to the ideal "nominal" entry is possible, ΔV contours are superimposed on these figures. Note the ΔV required to obtain a given dispersion corridor width is less for the two-burn than the one-burn AOA case.

3.5 <u>Dispersion Analysis</u>:

After determining the entry dispersion corridors, a detailed dispersion analysis was made at selected entry interface points, within these corridors. The 6000 NM, $\gamma = -.81°$ point was considered for both α-profiles. Two additional points were taken from the center of the 38°/28° α corridor at ranges of 5200 NM and 5600 NM. Initial conditions for these points are given in Table 3.5-I. Dispersion sources considered were atmospheric, aerodynamic, and range-gamma error at entry interface. A summary of the dispersion analysis results is presented in Tables 3.5-II through 3.5-V. Methods used are discussed below.

TABLE 3.5-I

ENTRY INTERFACE INITIAL CONDITIONS
FOR SELECTED STUDY POINTS

RANGE EI TO TARGET	=	6000 NM
ALTITUDE	=	400,000 FT
VELOCITY (Inertial)	=	25787.1 FPS
GAMMA (I)	=	-.81°
AZIMUTH (I)	=	-17.73760°
LONGITUDE	=	21.40157°E
GEODETIC LATITUDE	=	37.61777°N
INCLINATION	=	104°
RANGE EI TO TARGET	=	5600 NM
ALTITUDE	=	400,000 FT
VELOCITY (I)	=	25817.9 FPS
GAMMA (I)	=	-.90°
AZIMUTH (I)	=	-19.56002°
LONGITUDE	=	18.13689°E
GEODETIC LATITUDE	=	43.92277°N
INCLINATION	=	104°
RANGE EI TO TARGET	=	5200 NM
ALTITUDE	=	400,000 FT
VELOCITY (I)	=	25851.2 FPS
GAMMA (I)	=	-1.0°
AZIMUTH (I)	=	-22.10038°
LONGITUDE	=	14.26136°E
GEODETIC LATITUDE	=	50.17259°N
INCLINATION	=	104°

TABLE 3.5-II

RESULTS OF AOA ENTRY TARGETING ANALYSIS FOR RT_{EI} = 6000 N.MI., γ_{EI} = -.81°, VI_{EI} = 25787 FPS* α = 40°/30°

CASE	MAXIMUM TEMPERATURES NOSE, °F	MAXIMUM TEMPERATURES WING LEADING EDGE, °F	ALTITUDE AT VELOCITY = 20K FPS, FT.	MAXIMUM BANK ANGLE DURING PULLUP	MINIMUM BANK ANGLE DURING EQUILIBRIUM GLIDE	TOTAL HEAT LOAD, BTU/FT^2	RANGE TO TARGET AT ALTITUDE = 67K FT., N.MI.
NO DISPERSIONS							
NOMINAL	2520	2662	214,100	80.0°	41.4°	74,300	28.3
AERODYNAMIC UNCERTAINTIES							
Study Point 1	2497	2635	215,700	86.0°	45.0°	72,000	27.6
Study Point 2	2530	2670	213,200	88.0°	46.0°	74,750	28.6
Study Point 3	2567	2715	209,700	89.0°	47.0°	77,700	29.8
Study Point 4	2555	2695	209,500	83.0°	37.0°	77,150	39.3
Study Point 5	2515	2655	214,300	81.7°	37.0°	74,000	28.3
Study Point 6	2486	2615	216,500	79.5°	37.0°	71,000	47.0
Study Point 4'	2554	2696	211,200	83.5°	37.0°	76,900	29.3
Study Point 6'	2481	2619	217,000	75.2°	37.0°	71,600	27.6
ATOMSPHERIC DISPERSIONS							
January Atm	2548	2687	203,700	83.2°	45.0°	73,500	28.3
July Atm	2502	2646	223,400	77.8°	38.7°	74,695	27.6
RANGE - GAMMA DISPERSIONS							
Range=5820,γ=-.759	2572	2714	210,300	124.5°	48.5°	70,818	28.3
Range=5880,γ=-.776	2553	2695	211,600	107.3°	47.5°	72,031	28.2
Range=5940,γ=-.793	2536	2678	213,100	93.0°	44.2°	73,181	28.2
Range=6060,γ=-.827	2507	2649	215,100	75.3°	38.9°	75,260	28.3
Range=6120,γ=-.844	2493	2635	216,000	73.6°	36.0°	76,278	28.3
Range=6180,γ=-.861	2482	2624	217,000	72.4°	33.1°	77,195	28.7

* Weight = 191,866 lbs., AFT cg (67.5%), ϕ_{EI} = 90°

NOTE: Body flap and elevon temperature model not accurate in SVDS, temperature not shown.

TABLE 3.5-III

RESULTS OF AOA ENTRY TARGETING ANALYSIS FOR RT_{EI} = 6000 NM, γ_{EI} = -81°, V_{EI} = 25787 FT/SEC α = 38°/28°

CASE	MAX TEMPERATURE (°F) NOSE	BODY FL	WING L.E.	ELEV.	ALTITUDE AT VEL = 20K FPS, FT	MAX BANK ANGLE DURING PULLUP (DEG)	MINIMUM BANK ANGLE DURING EQUILIBRIUM GLIDE (DEG)	BACKFACE OVER-TEMPERATURE (F°) TWO HIGHEST PANELS	TOTAL HEAT LOAD (BTU/FT²)
NO DISPERSIONS									
NOMINAL	2547	2747	2667	2498	216,400	90.0	41.0	87.89 (17) 69.34 (9)	76389
AERODYNAMIC UNCERTAINTIES									
Study Point 1	2527	2707	2645	2459	217,700	89.5	45.0	79.4 (17) 59.7 (24)	74423
Study Point 2	2556	2762	2682	2513	215,700	91.2	45.4	88.6 (17) 73.2 (21)	76879
Study Point 3	2591	2832	2724	2608	212,700	92.5	46.2	97.7 (17) 92.0 (21)	79769
Study Point 4	2573	2784	2695	2544	213,900	88.5	37.0	99.5 (17) 84.0 (21)	78989
Study Point 5	2541	2720	2656	2471	216,850	86.1	34.2	88.5 (17) 67.5 (24)	76022
Study Point 6	2508	2706	2648	2457	219,400	84.2	32.0	79.9 (17) 60.1 (24)	73455
ATMOSPHERIC DISPERSIONS									
January	2585	2780	2691	2533	205,600	44.7	93.8	84.9 (17) 68.9 (9)	75514
July	2529	2709	2647	2463	225,700	38.8	86.6	90.9 (17) 69.1 (20)	76836
RANGE - GAMMA DISPERSIONS									
R_{EI}=6060, γ=-.827	2535	2714	2651	2467	217,350	80.2	38.0	94.5 (17) 73.6 (20)	77390
R_{EI}=6120, γ=-.844	2519	2700	2635	2453	218,400	76.0	35.1	109.2 (17) 79.5 (20)	78491
R_{EI}=6180, γ=-.860	2504	2672	2621	2425	219,100	75.5	31.2	109.1 (17) 85.5 (24)	79434
R_{EI}=5940, γ=-.793	2569	2770	2686	2526	215,200	101.7	43.6	80.5 (17) 66.2 (21)	75198
R_{EI}=5880, γ=-.776	2586	2804	2704	2560	213,950	117.3	45.6	72.9 (17) 63.1 (21)	73969
R_{EI}=5820, γ=-.760	2611	2838	2724	2634	212,300	138.0	49.1	65.8 (17) 60.6 (21)	72667

TABLE 3.5-IV

RESULTS OF AOA ENTRY TARGETING ANALYSIS FOR RT_{EI} = 5600 NM, γ_{EI} = -.9°, V = 25817.9 FT/SEC α = 38°/28°

CASE	MAX TEMPERATURE (°F)				ALTITUDE AT VEL = 20K FPS, FT	MAX BANK ANGLE DURING PULLUP (DEG)	MINIMUM BANK ANGLE DURING EQUILIBRIUM GLIDE (DEG)	BACKFACE OVER-TEMPERATURE (F°) TWO HIGHEST PANELS	TOTAL HEAT LOAD (BTU/FT²)
	NOSE	BODY FL	WING L.E.	ELEV.					
NO DISPERSIONS									
NOMINAL	2569	2762	2681	2514	214,500	79.7	42.7	74.14 (17) 58.98 (21)	74879
AERODYNAMIC UNCERTAINTIES									
Study Point 1	2543	2726	2658	2477	216,900	81.4	47.5	65.9 (17) 48.4 (21)	72911
Study Point 2	2569	2794	2682	2556	214,600	81.0	46.7	74.2 (17) 63.7 (21)	75358
Study Point 3	2605	2854	2741	2731	212,100	82.8	47.8	83.6 (17) 80.7 (21)	78211
Study Point 4	2589	2800	2709	2563	213,400	76.6	36.9	85.7 (17) 72.9 (21)	77502
Study Point 5	2554	2737	2671	2493	216,100	76.3	37.0	75.6 (17) 55.4 (21)	74584
Study Point 6	2522	2689	2632	2441	218,200	76.6	36.3	67.8 (17) 47.6 (24)	72120
ATMOSPHERIC DISPERSIONS									
January	2600	2803	2702	2555	205,200	82.9	45.3	71.9 (17) 60.5 (21)	74040
July	2542	2731	2660	2483	224,900	76.7	40.3	76.8 (17) 61.0 (21)	75319
RANGE - GAMMA DISPERSIONS									
R_{EI}=5660,γ=-.917	2552	2739	2667	2490	216,500	77.8	40.4	80.5 (17) 61.8 (21)	75822
R_{EI}=5720,γ=-.934	2534	2725	2653	2476	217,700	76.5	36.7	86.9 (17) 65.8 (20)	76747
R_{EI}=5780,γ=-.950	2519	2699	2640	2451	218,000	75.5	35.2	92.9 (17) 70.5 (20)	77614
R_{EI}=5540,γ=-.883	2578	2782	2694	2541	214,400	85.4	44.7	68.7 (17) 56.1 (21)	73923
R_{EI}=5480,γ=-.866	2596	2809	2707	2545	213,300	97.4	46.4	62.9 (17) 53.1 (21)	72891
R_{EI}=5420,γ=-.850	2617	2836	2722	2635	212,300	111.6	48.2	57.4 (17) 50.5 (21)	71861

TABLE 3.5-V

RESULTS OF AOA ENTRY TARGETING ANALYSIS FOR RT_{EI} = 5200 NM, γ_{EI} = -1.0, V_{EI} = 25851 FT/SEC, α = 38°/28°

CASE	MAX TEMPERATURE (°F)				ALTITUDE AT VEL = 20K FPS, FT	MAX BANK ANGLE DURING PULLUP (DEG)	MINIMUM BANK ANGLE DURING EQUILIBRIUM GLIDE (DEG)	BACKFACE OVER-TEMPERATURE (F°) TWO HIGHEST PANELS	TOTAL HEAT LOAD (BTU/FT²)
	NOSE	BODY FL	WING	ELEV.					
NO DISPERSIONS									
NOMINAL	2578	2790	2696	2541	214,450	77.7	43.4	60.65 (17) 48.36 (21)	73231
AERODYNAMIC UNCERTAINTIES									
Study Point 1	2559	2750	2673	2505	216,100	78.9	48.9	53.3 (17) 38.5 (21)	71262
Study Point 2	2594	2810	2708	2577	213,800	79.2	49.0	60.8 (17) 52.3 (21)	73667
Study Point 3	2622	2887	2749	2800	211,100	79.0	48.7	70.5 (21) 69.8 (17)	76508
Study Point 4	2602	2824	2719	2644	212,600	75.7	38.3	71.5 (17) 53.9 (9)	75865
Study Point 5	2571	2755	2677	2510	214,800	76.3	38.0	61.9 (17) 45.0 (21)	72952
Study Point 6	2535	2710	2648	2461	217,400	75.6	37.5	54.3 (17) 34.5 (24)	70529
ATMOSPHERIC DISPERSIONS									
January	2615	2820	2712	2623	204,200	81.6	47.7	58.6 (17) 50.1 (21)	72467
July	2560	2762	2682	2515	223,450	77.6	42.0	62.9 (17) 48.8 (21)	73664
RANGE - GAMMA DISPERSIONS									
R_{EI}=5260, γ=-1.017	2564	2767	2682	2682	215,400	77.2	42.9	65.6 (17) 50.9 (21)	74086
R_{EI}=5320, γ=-1.034	2549	2749	2673	2673	216,100	77.1	42.5	71.3 (17) 53.8 (21)	74921
R_{EI}=5380, γ=-1.050	2540	2727	2658	2485	216,600	77.3	39.9	76.9 (17) 56.4 (21)	75723
R_{EI}=5140, γ=-.983	2592	2808	2708	2708	213,500	79.5	47.3	55.6 (17) 46.6 (21)	72380
R_{EI}=5080, γ=-.966	2605	2836	2721	2721	212,600	81.2	47.9	50.5 (17) 43.8 (21)	71486
R_{EI}=5020, γ=-.950	2620	2852	2732	2732	211,600	85.6	50.0	46.0 (17) 42.2 (21)	70590

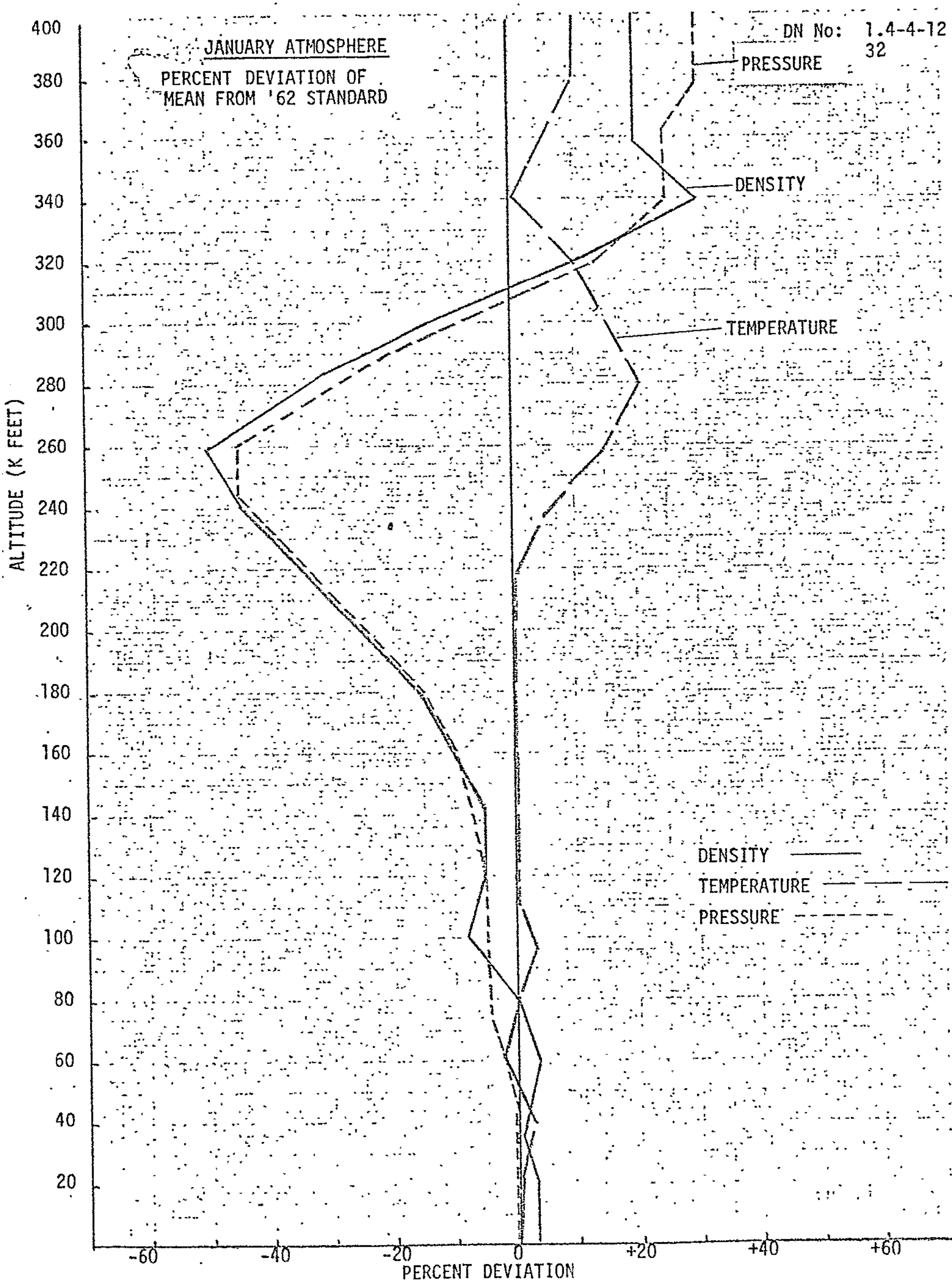
3.5.1 Atmospheric Dispersions

Two extreme dispersed atmosphere models were studied in addition to the 1962 Standard Atmosphere used in SVDS. These dispersed atmospheres are based on the January and July deviations to the 1962 Standard. The models use the means of the results of a Monte Carlo analysis made by the Flight Performance Branch of JSC. This analysis included the altitude range from sea level to 400,000 feet. Mean deviations in density, pressure and temperature are shown in Figures 3.5.1-1 and 3.5.1-2. These seasonal variations were incorporated into the SVDS 1962 Standard Atmosphere in subroutine ATMOS. This allowed corresponding corrections to all atmosphere-based parameters, i.e., viscosity, Reynold's number, Mach number, etc. Entry dispersion corridors were then determined in the same manner as previously described.

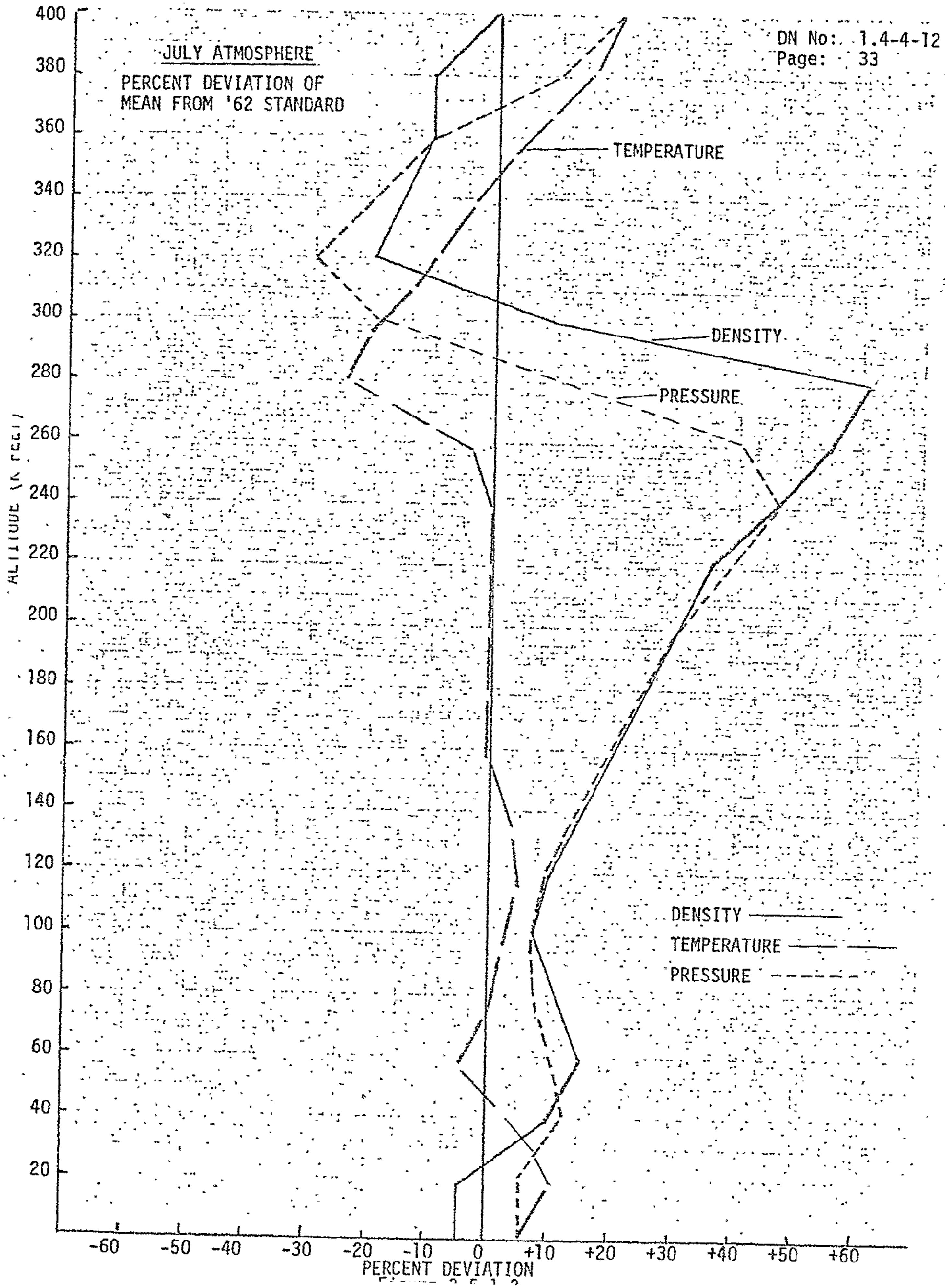
The entire 40°/30° α one-burn corridor was run with atmospheric dispersions included. The dispersions did not significantly affect the size or shape of the corridor. The corridor shifted to steeper gammas than nominal for the January atmosphere and shallower than nominal for the July model (Figures 3.5.1-3 and 3.5.1-4). This indicates the need to target for a specific seasonal atmosphere for AOA entry.

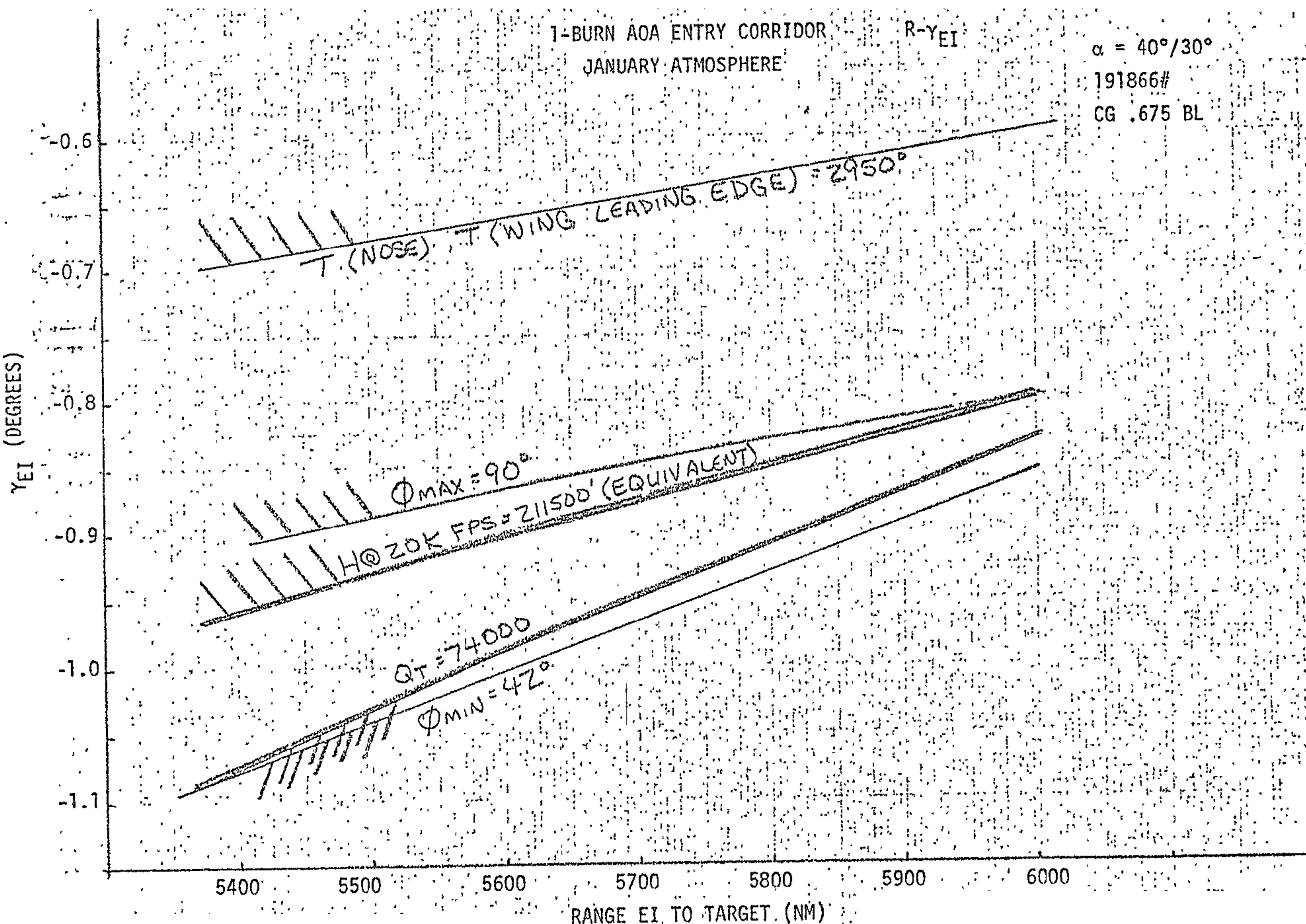
3.5.2 Aerodynamic Dispersions

The aerodynamic uncertainty study conducted was based on pre-established uncertainties for viscous C_L, C_D and $L/_D$. These



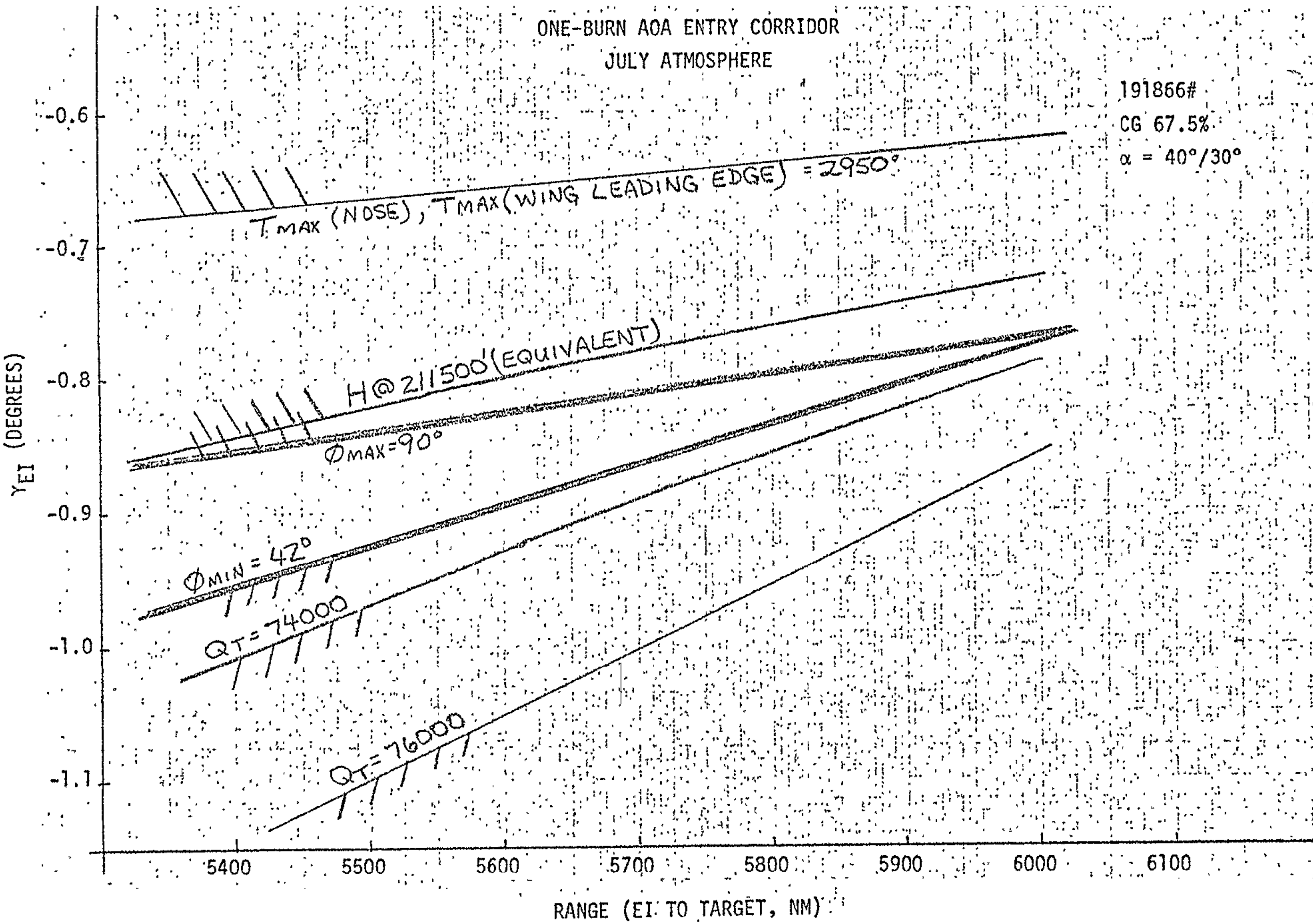
DN No: 1.4-4-12
32
JANUARY ATMOSPHERE
PERCENT DEVIATION OF
MEAN FROM '62 STANDARD
PRESSURE
DENSITY
TEMPERATURE
DENSITY
TEMPERATURE
PRESSURE
ALTITUDE (K FEET)
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
-60
-40
-20
0
+20
+40
+60
PERCENT DEVIATION


JULY ATMOSPHERE
PERCENT DEVIATION OF
MEAN FROM '62 STANDARD
TEMPERATURE
DENSITY
PRESSURE
DENSITY
TEMPERATURE
PRESSURE
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
-60
-50
-40
-30
-20
-10
0
+10
+20
+30
+40
+50
+60
PERCENT DEVIATION



1-BURN AOA ENTRY CORRIDOR
R-γ_{EI}
JANUARY ATMOSPHERE
α = 40°/30°
191866#
CG .675 BL
T (NOSE)
T (WING LEADING EDGE) = 2950°
ϕMAX = 90°
H@20K FPS = 211500' (EQUIVALENT)
Q_T = 74000
ϕMIN = 42°
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
γ_{EI} (DEGREES)
5400
5500
5600
5700
5800
5900
6000
RANGE EI TO TARGET (NM)

Figure 3.5.1-3



ONE-BURN AOA ENTRY CORRIDOR
JULY ATMOSPHERE
191866#
CG 67.5%
α = 40°/30°
TMAX (NOSE), TMAX(WING LEADING EDGE) = 2950°
H@211500'(EQUIVALENT)
ØMAX=90°
ØMIN = 42°
QT=74000
QT=76000
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
YEI (DEGREES)
5400
5500
5600
5700
5800
5900
6000
6100
RANGE (EI TO TARGET, NM)

Figure 3.5.1-4

uncertainties were generated by Rockwell/Space Division and are discussed in Reference 4. The C_L, C_D, and $L/_D$ percentage uncertainties are functions of $\overline{V}$, a viscous interaction parameter which is a function of Mach number, Reynolds number, and Chapman-Rubesen viscosity coefficient. $\overline{V}$ is computed in subroutine AR140C of SVDS. Percentage uncertainties for the aerodynamic coefficients are given in Table 3.5.2-I.

An aerodynamic dispersion survey similar to that described in Reference 4 was made with the AOA trajectories. The corresponding uncertainty "ellipses" are shown in Figure 3.5.2-1 for three values of $\overline{V}$. The relative locations of the six study points with respect to these ellipses, are shown in Figure 3.5.2-2. These aerodynamic dispersions were incorporated into the aerodynamic subroutine (AR140C) of SVDS for each of the six study points for selected entry conditions. Percentage uncertainties are shown in Table 3.5.2-II.

It was seen that with the aerodynamic dispersions defined by points 4 and 6 the vehicle using the 40°/30° α profile was incapable of flying the required crossrange at the entry ranges under consideration. The percentage uncertainties in C_L or C_D for these cases was reduced by 10%, which enabled the vehicle to reach the target. These modified uncertainties percentages in C_L and C_D are shown in Table 3.5.2-IIa. The 38°/28° α profile provided the required crossrange for all study points on the basic dispersion ellipse for all entry ranges considered.

TABLE 3.5.2-I

AERODYNAMIC DISPERSION MODEL

PERCENTAGE UNCERTAINTY VS $\overline{V}$

$\overline{V}$	C_L%	C_D%	L/D%
.005	± 13.0%	± 10.0%	± 6.0%
.007	± 13.0	± 10.0	± 6.0
.01	± 13.2	± 10.0	± 6.3
.02	± 14.8	± 9.6	± 8.8
.03	± 16.0	± 9.3	± 12.0
.04	± 17.0	± 9.0	± 15.0
.05	± 17.6	± 8.8	± 16.5
.06	± 18.0	± 8.7	± 17.8
.08	± 18.5	± 8.6	± 18.9

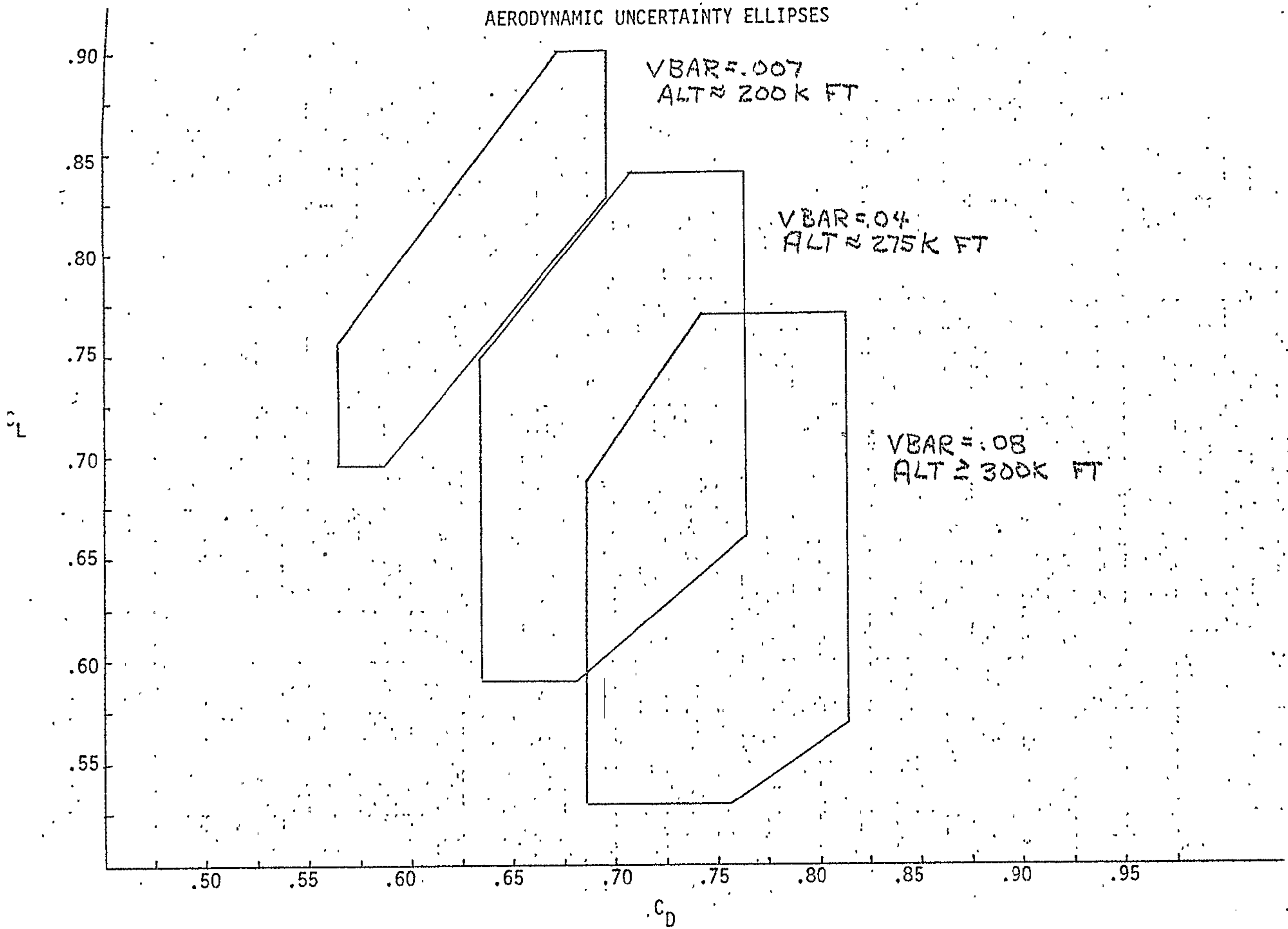

AERODYNAMIC UNCERTAINTY ELLIPSES
VBAR≈.007
ALT≈200K FT
VBAR≈.04
ALT≈275K FT
VBAR≈.08
ALT≥300K FT
.90
.85
.80
.75
.70
.65
.60
.55
C_L
.50
.55
.60
.65
.70
.75
.80
.85
.90
.95
C_D

Figure 3.5.2-1

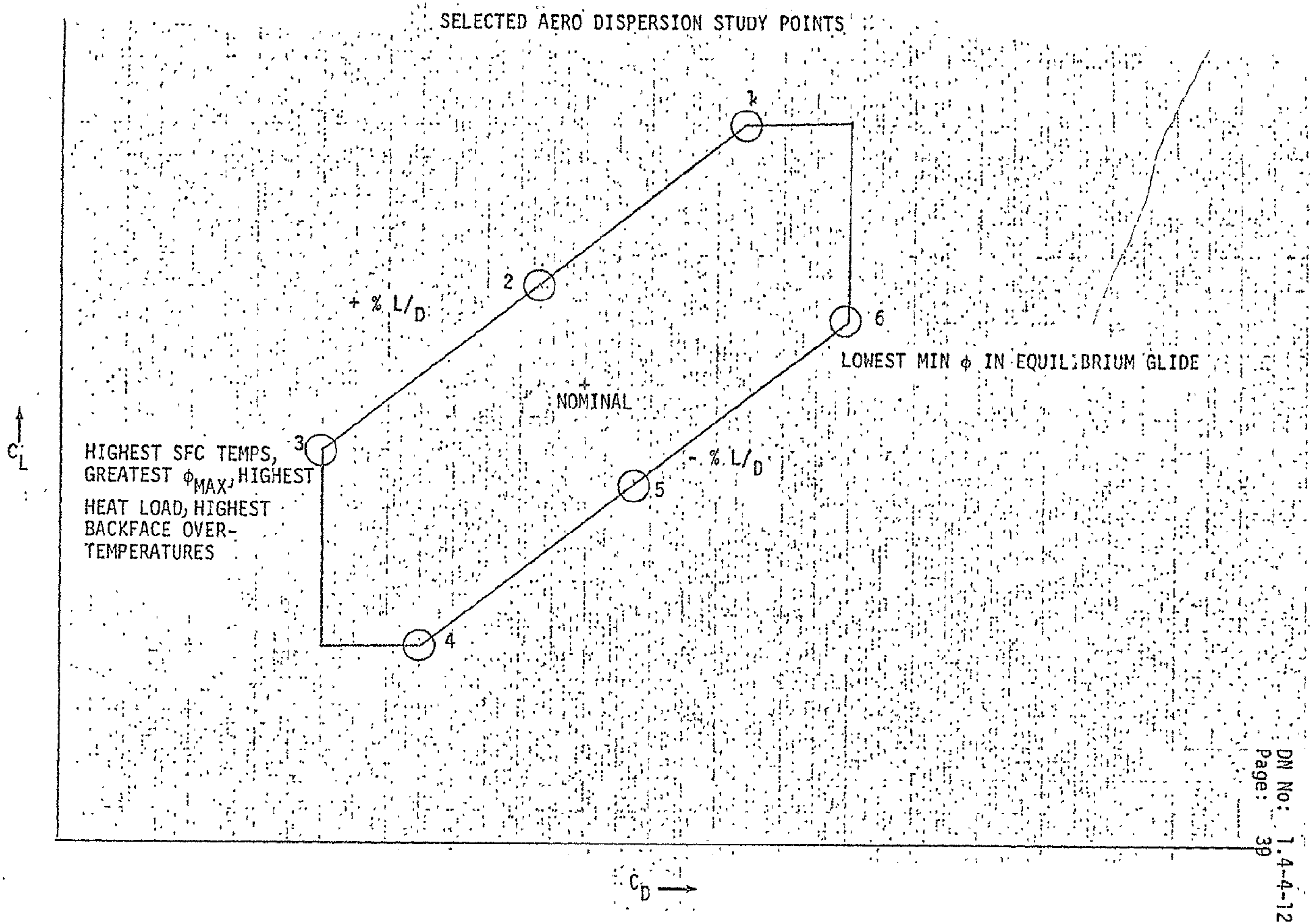

SELECTED AERO DISPERSION STUDY POINTS
1
2
+ % L/D
6
LOWEST MIN φ IN EQUILIBRIUM GLIDE
NOMINAL
3
HIGHEST SFC TEMPS, GREATEST φMAX, HIGHEST HEAT LOAD, HIGHEST BACKFACE OVER-TEMPERATURES
- % L/D
5
4
CL
CD

Figure 3.5.2-2

TABLE 3.5.2-II

Percentage Uncertainties in C_L

VBAR	STUDY POINT #1	STUDY POINT #2	STUDY POINT #3	STUDY POINT #4	STUDY POINT #5	STUDY POINT #6
.007	+ 13.0	+ 4.2	- 5.1	- 13.0	- 4.7	+ 3.1
.010	+ 13.2	+ 4.3	- 2.8	- 13.2	- 3.5	+ 4.9
.020	+ 14.8	+ 6.4	- 1.6	- 14.8	- 7.5	- .7
.030	+ 16.0	+ 8.8	+ 2.3	- 16.0	- 9.4	- 3.6
.040	+ 17.0	+ 10.7	+ 4.5	- 17.0	- 11.7	- 7.2
.050	+ 17.6	+ 11.9	+ 6.0	- 17.6	- 12.9	- 9.0
.060	+ 18.0	+ 13.3	+ 8.0	- 18.0	- 14.8	- 11.5
.100	+ 19.0	+ 14.5	+ 9.4	- 19.0	- 16.1	- 13.4

Percentage Uncertainties in C_D

.007	+ 6.7	- 1.6	- 10.0	- 6.8	+ 2.1	+ 10.0
.010	+ 5.3	- 1.7	- 10.0	- 7.2	+ 1.4	+ 10.0
.020	+ 5.5	- 1.2	- 9.6	- 5.8	+ 1.8	+ 9.6
.030	+ 3.8	- 3.1	- 9.3	- 4.9	+ 2.1	+ 9.3
.040	+ 1.6	- 3.9	- 9.0	- 3.0	+ 3.0	+ 9.0
.050	+ 0.8	- 3.9	- 8.8	- 1.5	+ 3.6	+ 8.8
.060	- 0.3	- 4.0	- 8.7	- .5	+ 4.3	+ 8.7
.100	- 0.4	- 5.1	- 8.5	+ 1.5	+ 4.9	+ 8.5

TABLE 3.5.2-IIa

MODIFIED PERCENTAGE UNCERTAINTIES IN C_L AND C_D

FOR 40°/30° α PROFILE

VBAR	STUDY POINT 4'		STUDY POINT 6'	
	C_L	C_D	C_L	C_D
.007	-11.7 %	-6.8%	+ 3.1%	+9.0%
.010	-11.8	-7.2	+ 4.9	+9.0
.020	-13.3	-5.8	- 0.7	+8.6
.030	-14.4	-4.9	- 3.6	+8.4
.040	-15.3	-3.0	- 7.2	+8.1
.050	-15.8	-1.5	- 9.0	+7.9
.060	-16.2	-0.5	-11.5	+7.8
.100	-17.1	+1.5	-13.4	+7.6

The high lift, low drag (aero study point 3) was the worst case with respect to surface temperature and maximum bank angle during entry pullup. This point also generally gave highest backface over-temperatures. Panel # 17 was, in many cases, 10° - 20° higher than the second highest overtemperature and was, in some cases, higher for study point 4. Low lift, high drag (study point 6) produced worst case minimum equilibrium glide bank angles.

3.5.3 Entry Interface Position Uncertainty

Range-gamma dispersions at entry interface were also considered. The three-sigma deviations of these parameters were given (Reference 5) as:

Downrange position	180 NM
Flight path angle	.05°.

The correlation coefficient for these is approximately -1.0. Dispersed cases were run for 1, 2, and 3-sigma R-γ dispersions for the selected entry conditions. The corresponding entry velocity was input for each case.

3.5.4 Combined Dispersions

The dispersions were combined using the Root Sum Square/Sum method as described in Reference 6. The results for combined dispersion cases are summarized in Tables 3.5.4-I through 3.5.4-III. With combined dispersions the vehicle was able to reach the target, although it exceeded vehicle and trajectory constraints.

TABLE 3.5.4-I

COMBINED DISPERSIONS 6000 NM, γ = .81°, VI = 25787 FT/SEC, α = 38°/28°

NOMINAL		T(NOSE)=2547°	T(BODY FLAP)=2747°	T(WING)=2667°	T(ELEV)=2498°	BACKFACE 87.89°(17) OVERTEMP 69.34°(9)	HEAT LOAD 76389	ϕ_{MAX}=90.0°	ϕ_{MIN}=41.0°
DISPERSION SOURCE	VALUE	ΔT(NOSE)	ΔT(BODY FLAP)	ΔT(WING)	ΔT(ELEV)	Δ BACKFACE OVERTEMPERATURE	ΔQ	$\Delta\phi_{MAX}$	$\Delta\phi_{MIN}$
R-γ	+.05°-180 NM	+64	+91	+57	+136	-8.74	-3722	+48.0	+8.1
ATMOS	JANUARY	+38	+33	+24	+35	-.44	-875	+3.8	+3.7
AERO	SP3	+44	+85	+57	+110	+22.66	+3380	+2.5	+5.2
RSS		86.5	128.8	84.1	178.4			48.2	
SUM		146	209	138	281			54.3	
RATIO RSS/SUM		.5922	.6164	.6095	.6348			.8879	
NOMINAL + RSS		2633	2876	2751	2676			138.2	
SVDS COMBINED		2645	2892	2753	2837			136.1	
R-γ	-.05°,+180 NM	-43	-75	-46	-73	+16.16	+3045	-14.5	-9.7
ATMOS	JULY	-18	-38	-20	-35	-.24	+447	-3.4	-2.2
AERO	SP3	+44	+85	+57	+110	+22.66	+3380	+2.5	+5.2
RSS						27.83	4571.2		
SUM						38.82	6872		
RATIO RSS/SUM						.71695	.6652		
NOMINAL + RSS						97.17	80960		
SVDS COMBINED						93.39 (20)	81949		
R-γ	-.05°,+180 NM	-43	-75	-46	-73	+16.16	+3045	-14.5	-9.7
ATMOS	JULY	-18	-38	-20	-35	-.24	+447	-3.4	-2.2
AERO	SP 6	-39	-41	-19	-41	-9.24	-2934	-5.8	-9.0
RSS									13.413
SUM									20.9
RATIO RSS/SUM									.6418
NOMINAL + RSS									27.6
SVDS COMBINED									25.8

NOTE: Backface overtemperature dispersion values based on highest valid panel temperature excluding panel 17.

TABLE 3.5.4-II

COMBINED DISPERSIONS 5600 NM, γ = -.9°, VI = 25818 FT/SEC, α = 38°/28°

NOMINAL		T(NOSE)=2569°	T(BODY FLAP)=2762°	T(WING)=2681°	T(ELEV)=2514°	BACKFACE OVERTEMP 74.14°(17) 58.98°(21)	HEAT LOAD 74879	ϕ_{MAX}=79.7°	ϕ_{MIN}=42.7°
DISPERSION SOURCE	VALUE	ΔT(NOSE)	ΔT(BODY FLAP)	ΔT(WING)	ΔT(ELEV)	Δ BACKFACE OVERTEMPERATURE	ΔQ	$\Delta\phi_{MAX}$	$\Delta\phi_{MIN}$
R-γ	+.05°,-180 NM	+48	+74	+41	+121	- 8.48	-3018	+31.9	+5.5
ATMOS	JANUARY	+31	+41	+21	+ 41	+ 1.52	- 839	+ 3.2	+2.6
AERO	SP3	+36	+92	+60	+217	+21.72	+3332	3.1	+5.1
RSS		67.54	124.98	75.64	251.81			32.21	
SUM		115	207	122	379			38.2	
RSS/SUM		.5873	.6037	.6200	.6644			.8432	
NOMINAL + RSS		2637	2887	2757	2766			111.9	
SVDS COMBINED		2651	2899	2758	2848			115.0	
R-γ	-.05°,+180 NM	-50	-63	-41	-37	+11.52	+2735	-4.2	-7.5
ATMOS	JULY	-27	-31	-21	-31	+ 2.02	+ 440	-3.0	-2.4
AERO	SP3	+36	+92	+60	+217	+21.72	+3332	+3.1	+5.1
RSS						24.66	4333.13		
SUM						35.26	6507		
RSS/SUM						.6996	.6659		
NOMINAL + RSS						83.64	79212		
SVDS COMBINED						80.00 (21)	80082		
R-γ	-.05°,+180 NM	-50	-63	-41	-37	+11.52	+2735	-4.2	-7.5
ATMOS	JULY	-27	-31	-21	-31	+ 2.02	+ 440	-3.0	-2.4
AERO	SP6	-47	-73	-49	-73	-11.32	-2759	-3.1	-6.4
RSS									10.15
SUM									16.3
RSS/SUM									.6226
NOMINAL + RSS									32.55
SVDS COMBINED									29.9

NOTE: Backface overtemperature dispersion values based on highest valid panel temperature excluding panel 17.

TABLE 3.5.4-III

COMBINED DISPERSIONS 5200 NM, γ = -1.0°, VI = 25851 FT/SEC, α = 38°/28°

NOMINAL		T(NOSE)=2578°	T(BODY FLAP)=2790°	T(WING)=2696°	T(ELEV)=2547°	BACKFACE OVERTEMP 60.65(17) 48.36(21)	HEAT LOAD 73231	ϕ_{MAX}=77.7°	ϕ_{MIN}=43.4°
DISPERSION SOURCE	VALUE	ΔT(NOSE)	ΔT(BODY FLAP)	ΔT(WING)	ΔT(ELEV)	Δ BACKFACE OVERTEMPERATURE	ΔQ_T	$\Delta\phi_{MAX}$	$\Delta\phi_{MIN}$
R-γ	+.05°,-180NM	+42	+62	+36	+185	- 6.16	-2641	+7.9	+6.6
ATMOS	JANUARY	+37	+30	+16	+ 82	+ 1.74	- 764	+3.9	+4.3
AERO	SP3	+44	+97	+53	+259	+21.44	+3277	+2.3	+5.3
RSS		+71.19	118.96	66.04	328.6			9.105	
SUM		123	189	105	526			14.1	
RATIO RSS/SUM		.5788	.6295	.6289	.6248			.64578	
NOMINAL + RSS		2649	2909	2762	2870			86.8	
SVDS COMBINED CASE		2663	2919	2765	2906			88.2	
R-γ	-.05°,+180NM	-38	-63	-38	-62	+ 8.04	+2492	-0.4	-3.5
ATMOS	JULY	-18	-28	-14	-26	+ .42	+ 433	-0.1	-1.4
AERO	SP3	+44	+97	+53	+259	+21.44	+3277	+2.3	+5.3
RSS						22.90	4139		
SUM						29.90	6202		
RATIO RSS/SUM						.7659	.6675		
NOMINAL + RSS						71.26	77370		
SVDS COMBINED CASE						68.80 (21)	76999		
R-γ	-.05°,+180NM	-38	-63	-38	- 62	+ 8.04	+2492	-0.4	-3.5
ATMOS	JULY	-18	-28	-14	- 26	+ .42	+ 433	-0.1	-1.4
AERO	SP6	-43	-80	-48	- 80	-13.86	-2702	-2.1	-5.9
RSS									7.001
SUM									10.8
RATIO RSS/SUM									.6483
NOMINAL + RSS									36.4
SVDS COMBINED CASE									37.0

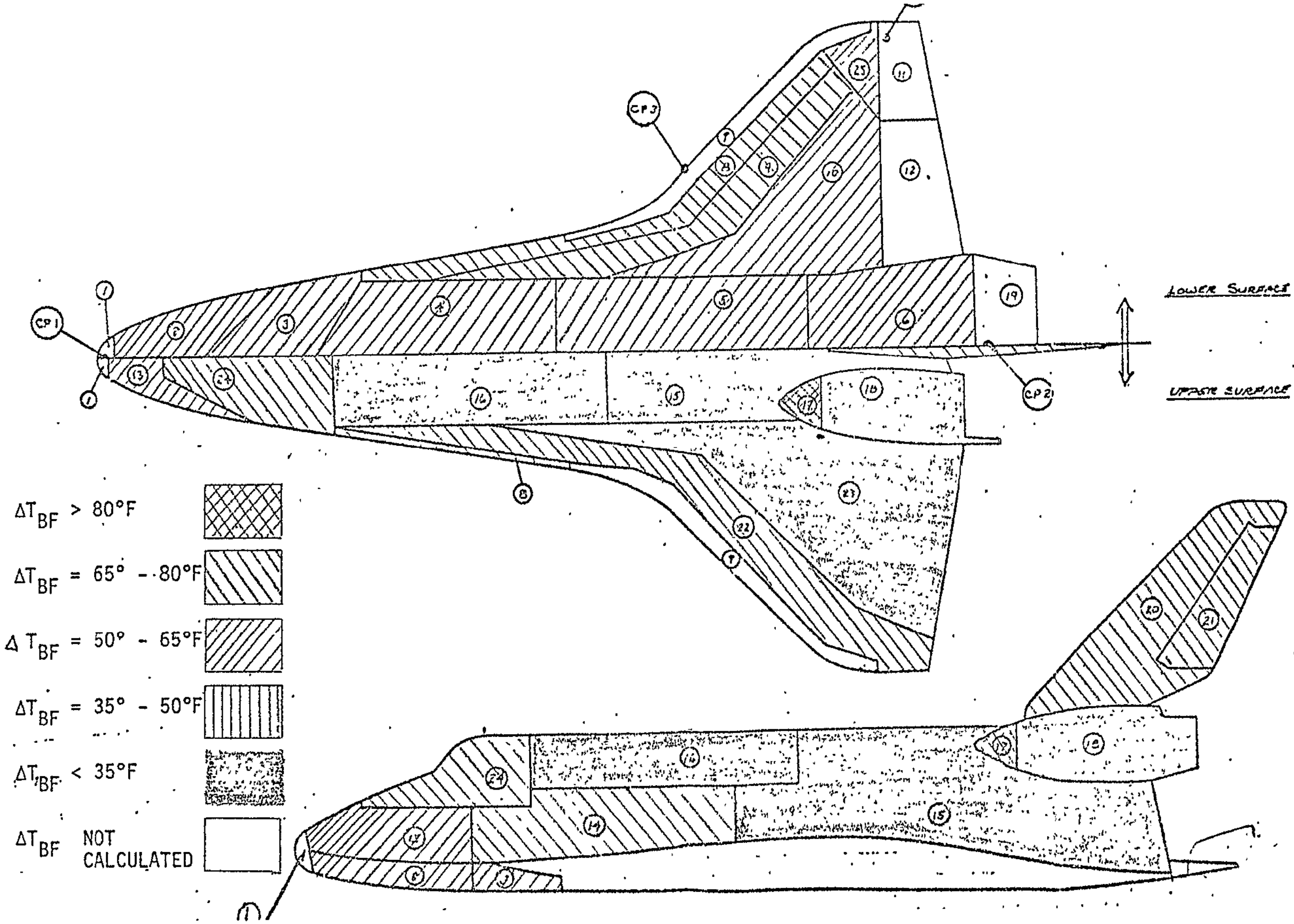
NOTE: Backface overtemperature dispersion values based on highest valid panel temperature excluding panel 17.

3.6 Panel Backface Overtemperatures

Figures 3.6-1 through 3.6-3 show individual panel backface over-temperatures for the three EI range-gammas considered. Panels 1, 7, 11, 12, and 19 are not accurately modelled in SVDS, and are so indicated on the figures. These range-gamma study points use the 38°/28° α profile with WTR nominal Mission 3B guidance parameters. These guidance constants are listed in Appendix A. It was seen that the resulting backface overtemperatures represent a significant problem area for the AOA entry.

3.7 Varying Guidance Parameters

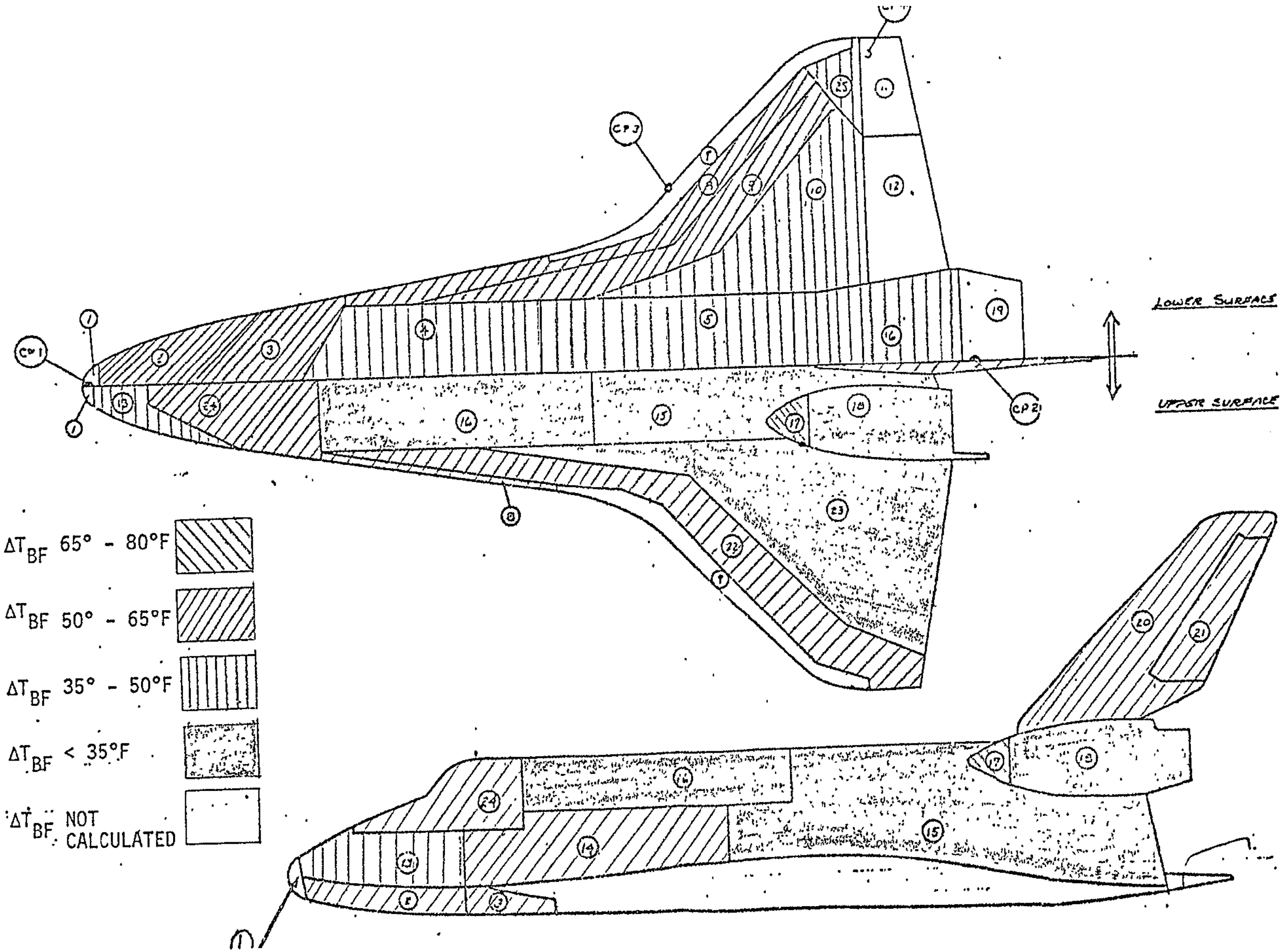
An additional set of entry guidance parameters was provided by the FPB of JSC for the 38°/28° α profile. This set is listed in Appendix A. The resulting AOA entry dispersion corridor is shown in Figure 3.7-1. This corridor requires steeper EI flight path angles, resulting in lower surface temperatures with slightly higher backface temperatures and additional ΔV required.



BACKFACE OVERTEMPERATURES FOR INDIVIDUAL PANELS (REFERENCE 350°F)

R_{EI} = 6000 NM, γ = .81°, V_{EI} = 25787 FT/SEC

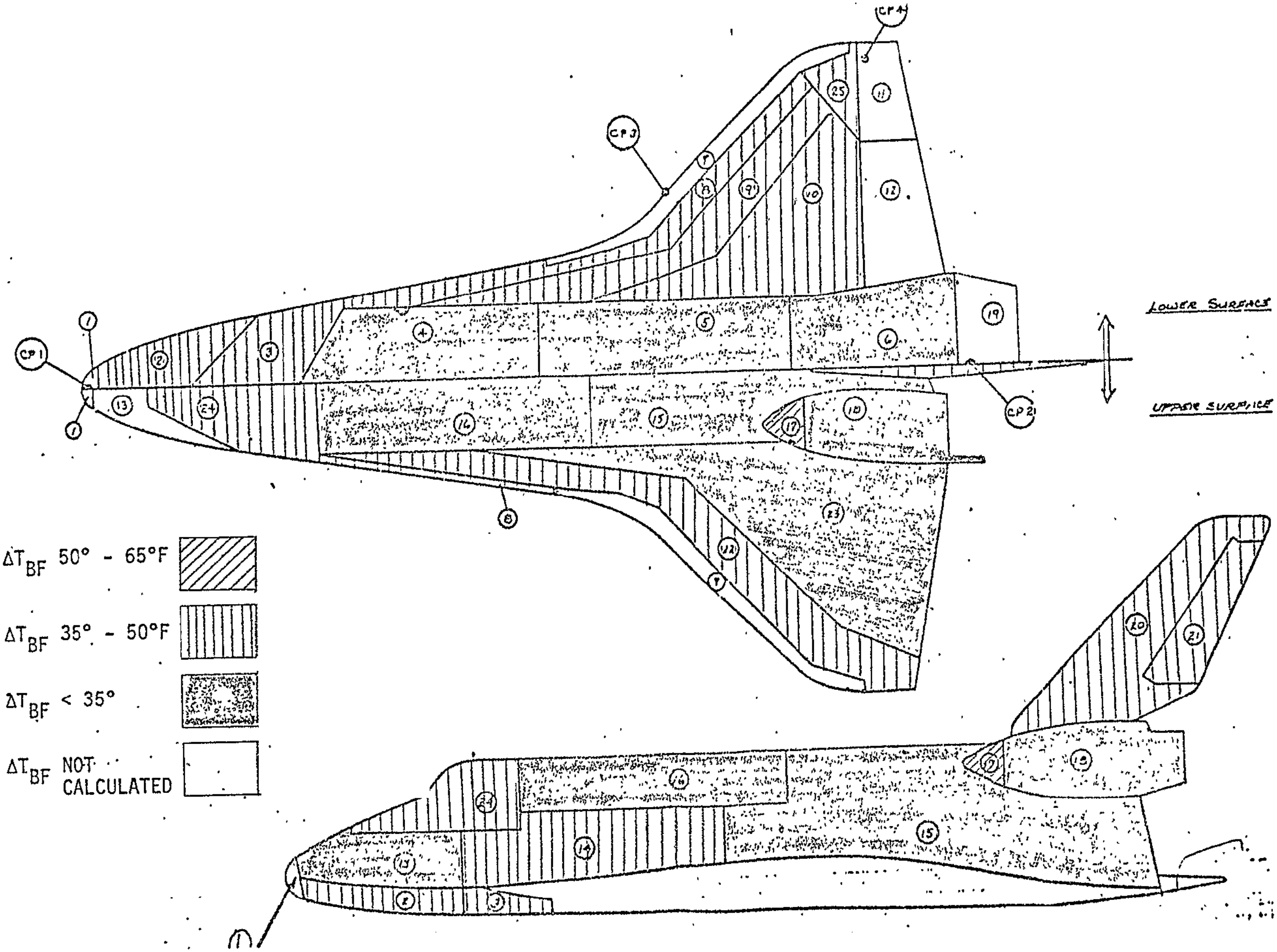
Figure 3.6-1



BACKFACE OVERTEMPERATURES FOR INDIVIDUAL PANELS (REFERENCE 350°F)

R_{EI} = 5600 NM, γ = -.9°, V_{EI} = 25818 FT/SEC

Figure 3.6-2



REFERENCE BACKFACE TEMPERATURE = 350°F

R_{EI} = 5200 NM, γ_{EI} = -1.0, V_{EI} = 25850 FT/SEC

Figure 3.6-3

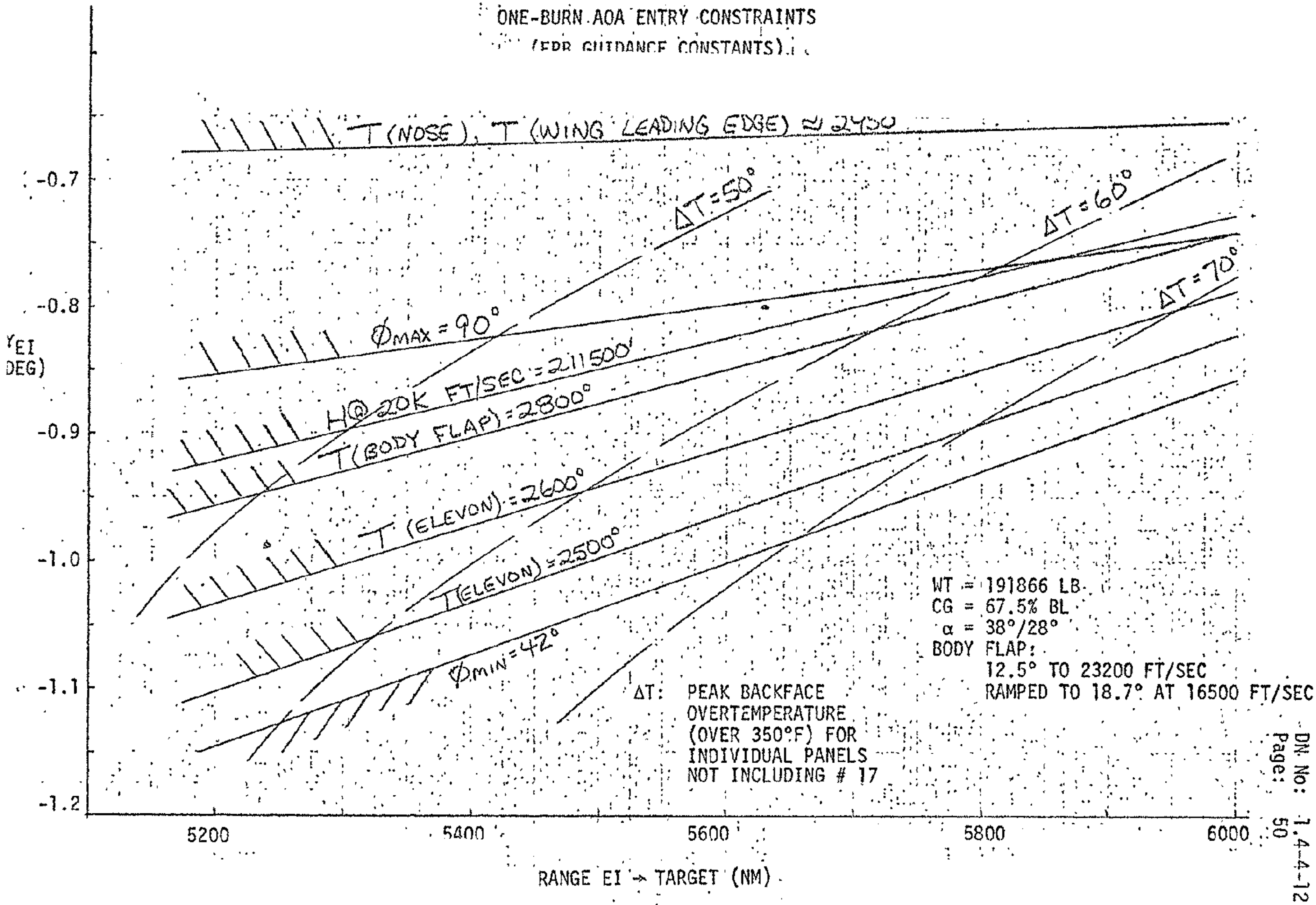

ONE-BURN AOA ENTRY CONSTRAINTS
(FDR GUIDANCE CONSTANTS)
T (NOSE), T (WING LEADING EDGE) ≈ 2450
ΔT = 50°
ΔT = 60°
ΔT = 70°
ØMAX = 90°
HQ 20K FT/SEC = 211500'
T(BODY FLAP) = 2800°
T (ELEVON) = 2600°
T(ELEVON) = 2500°
ØMIN = 42°
γEI (DEG)
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
5200
5400
5600
5800
6000
RANGE EI → TARGET (NM)
WT = 191866 LB
CG = 67.5% BL
α = 38°/28°
BODY FLAP:
12.5° TO 23200 FT/SEC
RAMPED TO 18.7° AT 16500 FT/SEC
ΔT: PEAK BACKFACE OVERTEMPERATURE (OVER 350°F) FOR INDIVIDUAL PANELS NOT INCLUDING # 17

Figure 3.7-1

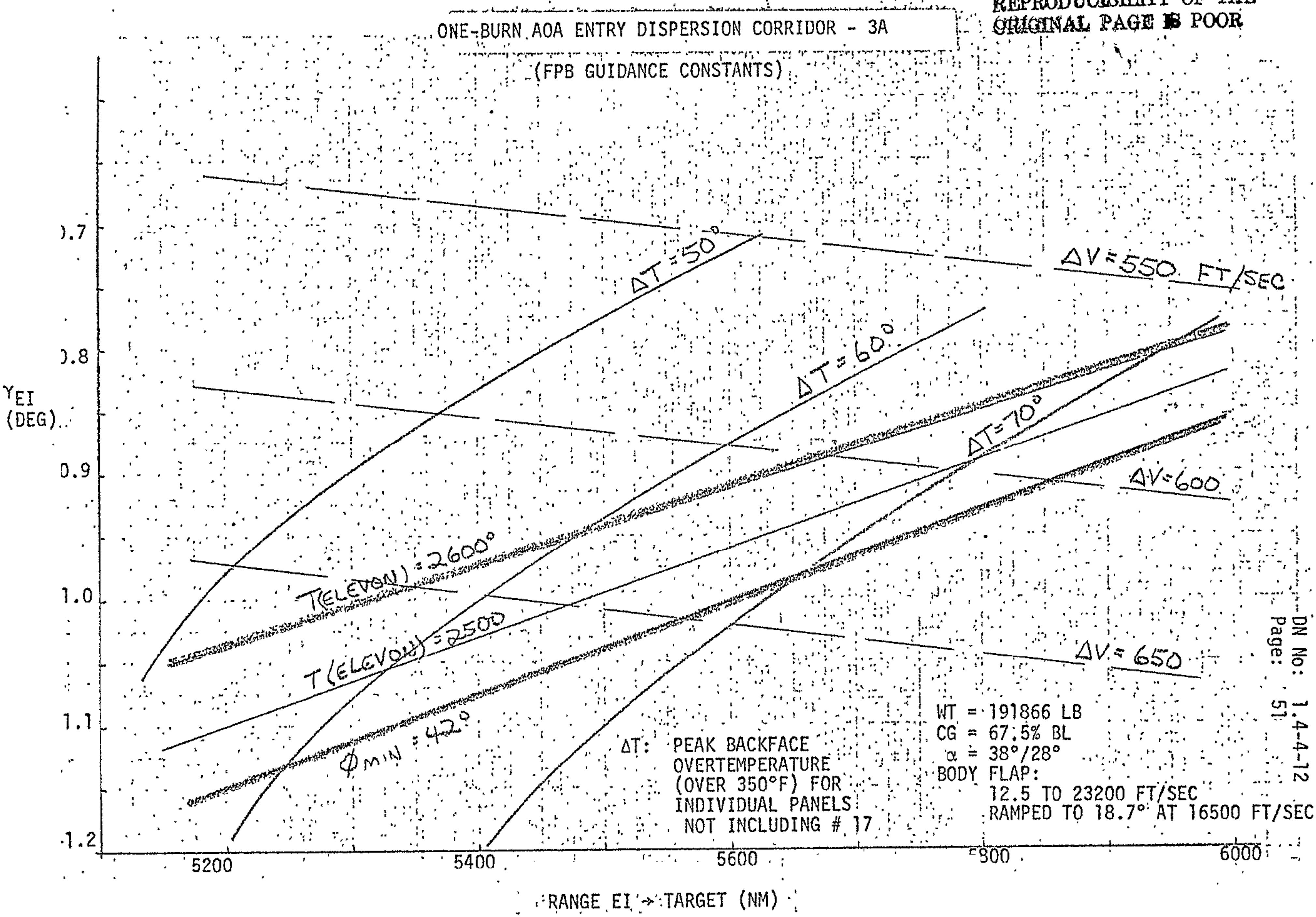


Figure 3.7-1a

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4.0 CONCLUSIONS

(1) The AOA entry dispersion corridors are presented based on current models and constraints.

(2) The maximum AOA entry range can be determined based on these constraints, acceptable backface overtemperatures, and ΔV available.

(3) The total ΔV required to obtain a given corridor width is less for the two-burn than the one-burn AOA.

(4) The corridor shift in the dispersed atmosphere cases shows the need to target for a specific seasonal atmosphere for the AOA.

(5) Incorporating the 38°/28° α profile gave the vehicle adequate crossrange capability to reach the target for worst case combined dispersions considered.

(6) Some dispersed cases caused vehicle and trajectory constraints to be exceeded.

(7) Backface overtemperatures were generally greater than the limits currently set (50°F) for AOA entry.

(8) Changing guidance parameters results in varying the dispersion corridor. In this manner certain constraint parameters may be optimized and/or traded at the expense of others.

5.0 REFERENCES

1. Space Vehicle Dynamics Simulation (SVDS) Program Description. JSC Internal Note No. 73-FM-85, 23 May 1973.

2. Hoch, H. R. and Hull, D. J.: Documentation of MLTBRN (Multiple Burn) Program for AOA Targeting. McDonnell Douglas Technical Services Company, Inc. Space Shuttle Engineering and Operations Support Design Note No. 1.4-4-2, 30 August 1974.

3. Maraia, R. J.: Structural Over-Temperature Correlation for the Simplified 25-Panel Orbiter TPS Program. JSC Memorandum, 7 February 1975.

4. Hanson, J'Ann: Effect of New Viscous Aerodynamic Uncertainties on the Entry Trajectory. JSC Memorandum FM43 (75-1) 7 January 1975.

5. Orbiter Vehicle End Item Specification for the Space Shuttle System, Part 1, Performance and Design Requirements IRD No TM-258 T, WBS 1.2.1.4.1 20 December 1973.

6. Space Shuttle Flight Performance Data Book, Volume II, Orbiter Entry, SD 73-SH-0173-2, January 1974.

APPENDIX A

GUIDANCE CONSTANTS USED FOR 38°/28° α ENTRY

SVDS ERASABLE MEMORY LOAD (ANALYTIC DRAG CONTROL INPUTS) FOR 38°/28° α ENTRY SIMULATIONS

	WTR NOMINAL	FPB MODIFIED
AK	2.51198	1.5
AK1	-4.22677	-4.3
ALFM	25.45	26.50
VA	19680.5	19000
VA1	22800	26000
VA2	28431.8	29500
VB1	17200	16500
VS1	25766	20500
VSAT	25766	25766
DF	19.09	19.09
EEF4	2000000	2000000
ETRAN	.453E8	.453E8
RPT1	18.64	18.64
VQ	5000	5000
VTRAN	9000	9000
VALP1	7349	7000
VALP2	17200	8000
VALP3	21000	16400
VALP4	.1E7	17400
VALP5	.1E7	20800
VALP6	.1E7	21800
CALP1	5.385	5.385
CALP2	.003077	.003007
CALP3	0	0
CALP4	28	-26.4
CALP5	0	.0132
CALP6	0	-.8E-6
CALP7	-17.263	28
CALP8	.00263158	0
CALP9	0	0

SVDS ERASABLE MEMORY LOAD (ANALYTIC DRAG CONTROL INPUTS) (CONT'D)
FOR 38°/28° α ENTRY SIMULATIONS

	WRT NOMINAL	FPB MODIFIED
CALP10	38	161.66
CALP11	0	-.01635
CALP12	0	.5E-6
CALP13	0	-17.263
CALP14	0	-.00263158
CALP15	0	0
CALP16	0	-200.7
CALP17	0	-.02185
CALP18	0	-.5E-6
CALP19	0	38
CALP20	0	0
CALP21	0	0
CD1	116.36	310
CD2	-.0509	-.1
CD3	-172.8	100
CD4	-.01714	-.037
CD5	-603.6	-224
CD6	.0727	.02
CD7	0	-571.4
CD8	0	.07
CD9	2133.4	0
CD10	-.12639	0
CD11	-167.52	0
CD12	.004633	.063157
CD13	-1670.9	.503448
CD14	-.07725	-.689655
CD15	0	-1152
CD16	0	.05333
CD17	-.3E7	0
CD18	.999E-3	0
DBAR	35261	35261
RTURN	20000	20000

SVDS ERASABLE MEMORY LOAD (ANALYTIC DRAG CONTROL INPUTS) (CONT'D)
FOR 38°/28° α ENTRY SIMULATIONS

	WRT NOMINAL	FPB MODIFIED
RAZ	-.76794	-.76794
TLATC	.6028	.6028
RTE	20903100	20909774
TLONG	-2.10425	-2.10425
GS1	0	.02
GS2	.005	.017
GS3	.025	.025
GS4	.035	.035