MARS GLOBAL SURVEYOR

LAUNCH VEHICLE

TRAJECTORY CERTIFICATION REVIEW

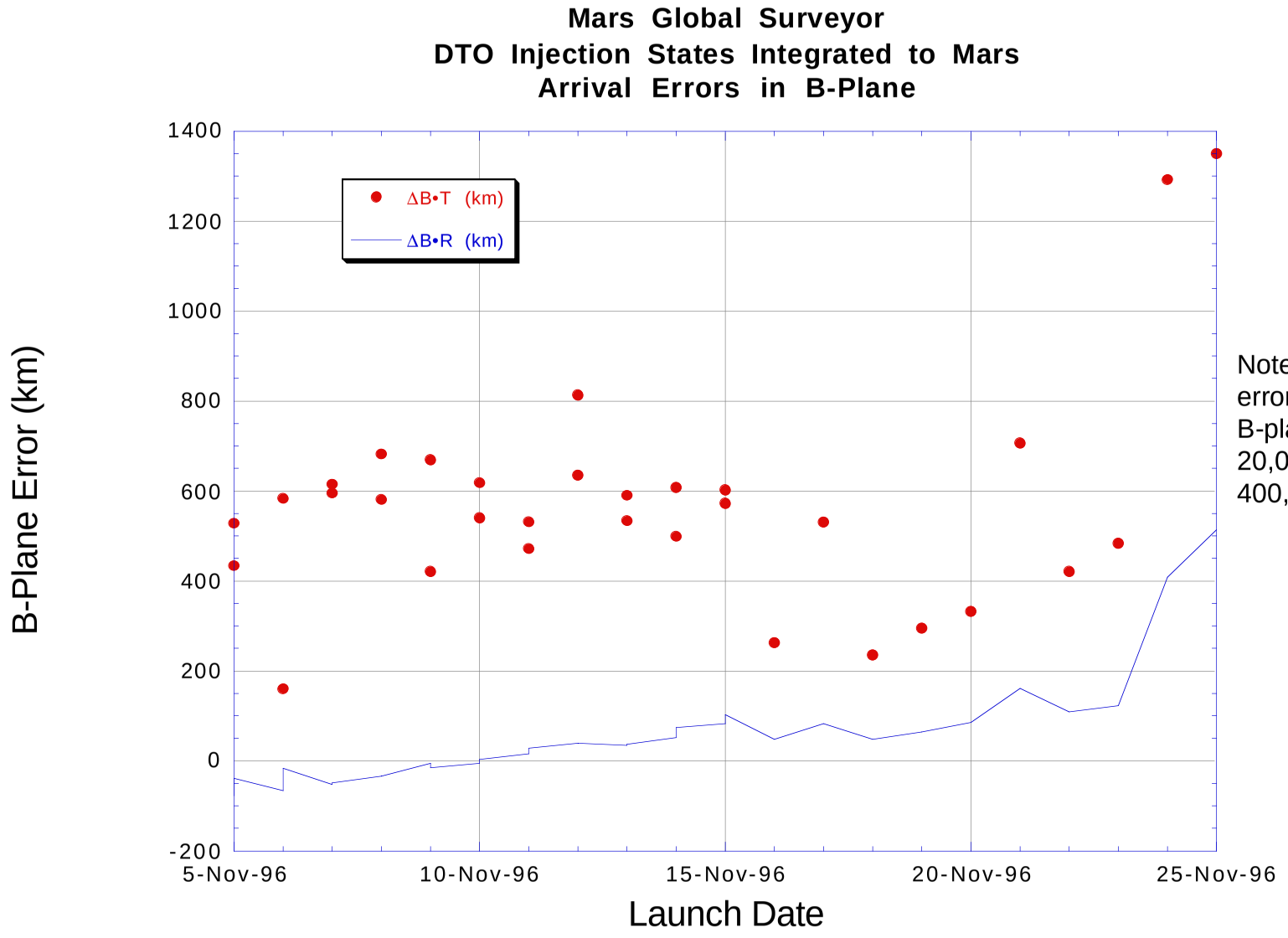
ACHIEVED TARGET CONDITIONS

- TARGET VERIFICATION APPROACH
  - CHECK COORDINATE FRAME CONVERSIONS
    - TARGET SPECIFICATION IS C3, DLA, RLA - MDAC OUTPUT USED IN DPTRAJ IS EME2000 CARTESIAN, DELTA FLIES EARTH-RELATIVE PROFILE
    - CARTESIAN VS. C3, DLA, RLA
      - DPTRAJ CONVERSION FROM EME2000 CARTESIAN TO ASYMPTOTIC ELEMENTS AGREES WITH MDAC DATA
    - CARTESIAN VS. LAT/LON
      - DPTRAJ CONVERSION FROM EME2000 CARTESIAN TO EARTH TRUE LAT/LON AGREES WITH MDAC DATA TO 10^{-6} DEGREES IN LATITUDE, 0.0003 DEGREES LONGITUDE
  - INTEGRATE TARGETING INTERFACE POINT STATE TO MARS
- NEAR EARTH TARGET SETS ACHIEVED
  - ALL MDAC ACHIEVED TARGETS MATCH SPECIFICATION EXACTLY
  - LAUNCH WILL NOT OCCUR AT TARGETED TIME GIVEN TO MILLISECOND, BUT AT NEAREST INTEGER SECOND DUE TO RANGE REQUIREMENTS
    - UP TO 0.5 SECOND DIFFERENCE RESULTS IN ~0.002° RLA ERROR SINCE VEHICLE FLIES AN EARTH-RELATIVE TRAJECTORY
      - NO IMPACT ON DSN INITIAL ACQUISITION GEOMETRY
    - 30 SECOND EARLY LAUNCH COSTS ~5 M/S AT TCM-1 —> 0.5 SEC DELAY SHOULD BE MUCH LESS THAN 1 M/S

B-PLANE TARGET SETS ACHIEVED

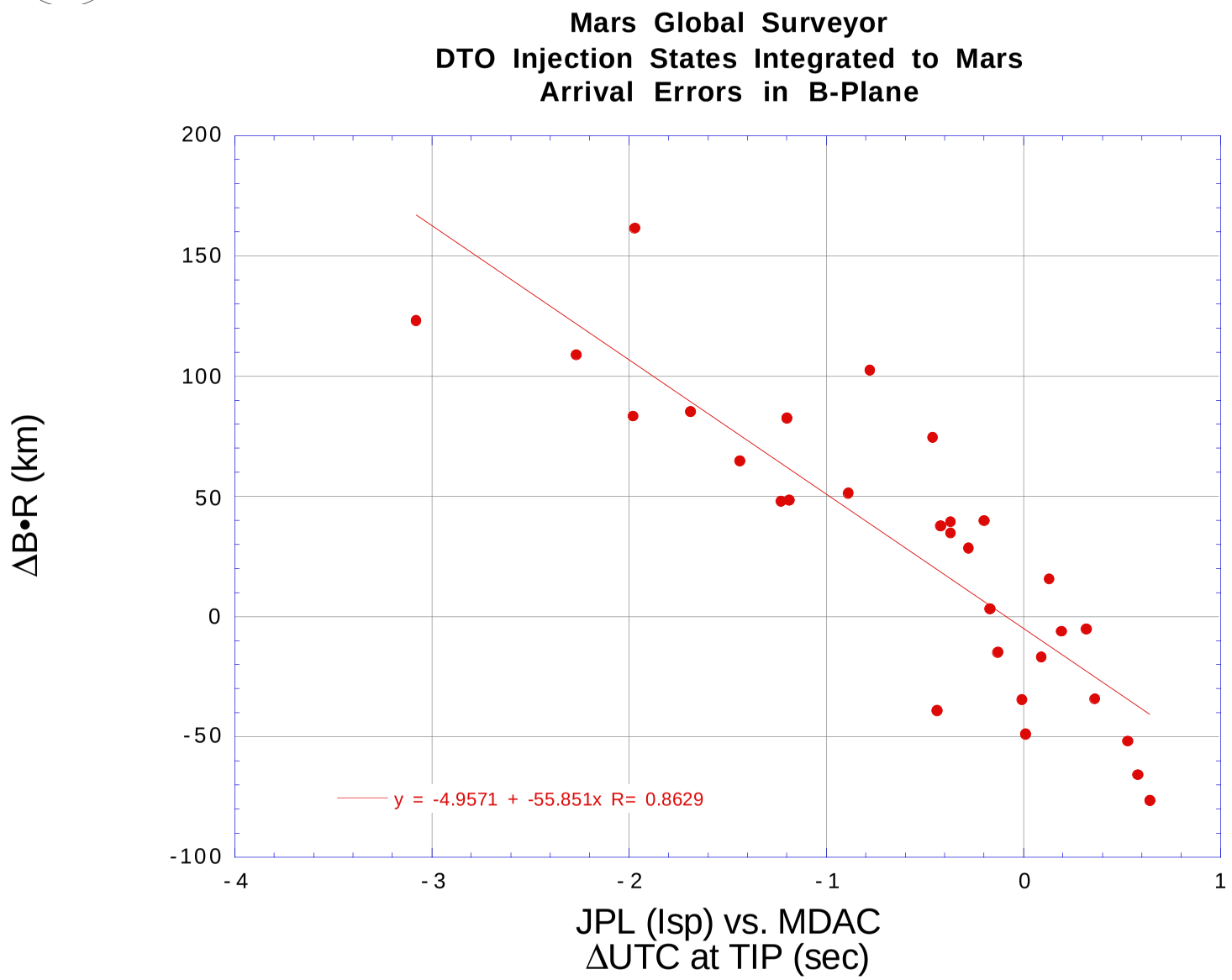
- TIP STATE INTEGRATED TO MARS USING DPTRAJ
  - MODELING SAME AS IN TARGET SPECIFICATION
  - SUN, MOON, ALL PLANETS, SOLAR RADIATION PRESSURE
  - MASS UPDATED FROM 1055 TO 1060 KG
- BIASED B-PLANE AIMPOINTS ACHIEVED TO WITHIN 1400 KM
  - 1σ INJECTION ERRORS MAPPED TO B-PLANE EXCEED 20,000 KM IN B•R ("OUT OF PLANE") AND 400,000 KM IN B•T ("IN PLANE")
- TIME-OF-FLIGHT AGREES TO WITHIN 18 MINUTES
  - 0.004% OF 10 MONTH FLIGHT
- B•T ERRORS NOT DUE TO MASS UPDATE
  - COMPARED 1055 VS. 1060 KG MASS RESULTS FOR 05-NOV LAUNCH
  - B•T CHANGED BY ONLY 33 KM
- B•R ERRORS CORRELATE TO DIFFERENCES IN UTC TIME AT TARGETING INTERFACE POINT BETWEEN *ISP* SIMULATION AND MDAC TRAJECTORIES

B-PLANE TARGET SETS ACHIEVED



Note: 1σ injection errors mapped to B-plane exceed 20,000 km in B•R, 400,000 km in B•T

B-PLANE TARGET SETS ACHIEVED



B-PLANE TARGET SETS ACHIEVED

DTO TIP State - Integration to Mars					PQ Biased Target				B-Plane Errors			
File	Date ET	Time ET	B*T (km)	B*R (km)	Arrival Date	Arrival Time	B•T (km)	B•R (km)	ΔArrival (hr)	ΔB•T (km)	ΔB•R (km)	ΔΘ (deg)
05az93.out	11-Sep-97	03:19:02.7	-55528.5	-49923.4	11-Sep-97	03:27:53.0	-55000.	-50000.	0.15	528.	-77.	-8.2
05az99.out	11-Sep-97	13:38:12.6	-55433.9	-49960.9	11-Sep-97	**13:45:25.9** *	-55000.	-50000.	**0.12** *	434.	-39.	-5.1
06az93.out	11-Sep-97	04:17:37.0	-44584.5	-51934.4	11-Sep-97	04:27:53.0	-44000.	-52000.	0.17	585.	-66.	-6.4
06az99.out	11-Sep-97	04:24:25.9	-44160.6	-51983.1	11-Sep-97	04:27:53.0	-44000.	-52000.	0.06	161.	-17.	-6.0
07az93.out	12-Sep-97	06:15:10.6	-34595.6	-53948.3	12-Sep-97	06:26:09.0	-34000.	-54000.	0.18	596.	-52.	-5.0
07az99.out	12-Sep-97	06:15:33.8	-34615.1	-53951.2	12-Sep-97	06:26:09.0	-34000.	-54000.	0.18	615.	-49.	-4.5
08az93.out	12-Sep-97	07:14:39.5	-23682.2	-54965.8	12-Sep-97	07:26:09.0	-23000.	-55000.	0.19	682.	-34.	-2.9
08az99.out	12-Sep-97	07:15:12.8	-23581.3	-54965.4	12-Sep-97	07:26:09.0	-23000.	-55000.	0.18	581.	-35.	-3.4
09az93.out	13-Sep-97	08:16:38.0	-13420.8	-54994.8	13-Sep-97	08:24:28.0	-13000.	-55000.	0.13	421.	-5.	-0.7
09az99.out	13-Sep-97	08:13:21.3	-13669.6	-54985.3	13-Sep-97	08:24:28.0	-13000.	-55000.	0.19	670.	-15.	-1.3
10az93.out	13-Sep-97	09:13:31.4	-2618.9	-54994.0	13-Sep-97	09:24:28.0	-2000.	-55000.	0.18	619.	-6.	-0.6
10az99.out	13-Sep-97	09:14:53.3	-2540.6	-55003.2	13-Sep-97	09:24:28.0	-2000.	-55000.	0.16	541.	3.	0.3
11az93.out	14-Sep-97	10:13:50.2	8467.8	-55015.7	14-Sep-97	10:22:47.0	9000.	-55000.	0.15	532.	16.	1.7
11az99.out	14-Sep-97	10:14:45.0	8527.9	-55028.6	14-Sep-97	10:22:47.0	9000.	-55000.	0.13	472.	29.	3.5
12az93.out	14-Sep-97	11:09:09.5	18186.5	-55040.0	14-Sep-97	11:22:47.0	19000.	-55000.	0.23	813.	40.	2.8
12az99.out	14-Sep-97	11:12:07.0	18363.8	-55039.4	14-Sep-97	11:22:47.0	19000.	-55000.	0.18	636.	39.	3.5
13az93.out	14-Sep-97	11:12:05.6	34409.4	-54034.8	14-Sep-97	11:22:47.0	35000.	-54000.	0.18	591.	35.	3.4
13az99.out	14-Sep-97	11:13:34.9	34465.6	-54037.7	14-Sep-97	11:22:47.0	35000.	-54000.	0.15	534.	38.	4.0
14az93.out	15-Sep-97	11:13:01.8	49500.3	-53051.5	15-Sep-97	11:21:07.0	50000.	-53000.	0.13	500.	51.	5.9
14az99.out	12-Sep-97	13:15:17.0	49391.7	-53074.6	**12-Sep-97** *	**13:27:37.4** *	50000.	-53000.	**0.21** *	608.	75.	7.0
15az93.out	15-Sep-97	13:10:43.8	65398.3	-50083.5	15-Sep-97	13:21:07.0	66000.	-50000.	0.17	602.	84.	7.9
15az99.out	11-Sep-97	12:36:26.9	65427.7	-50102.5	**11-Sep-97** *	**12:48:46.1** *	66000.	-50000.	**0.21** *	572.	103.	10.2
16az110.out	16-Sep-97	17:15:15.5	115737.3	-46048.4	16-Sep-97	17:19:29.0	116000.	-46000.	0.07	263.	48.	10.4
17az110.out	16-Sep-97	19:11:24.8	131469.0	-41082.7	16-Sep-97	19:19:29.0	132000.	-41000.	0.13	531.	83.	8.9
18az110.out	17-Sep-97	20:14:16.4	147764.3	-35048.0	17-Sep-97	20:17:52.0	148000.	-35000.	0.06	236.	48.	11.5
19az110.out	18-Sep-97	19:12:34.6	137704.8	-35064.7	18-Sep-97	19:16:14.0	138000.	-35000.	0.06	295.	65.	12.4
20az110.out	18-Sep-97	18:11:49.4	128667.4	-35085.2	18-Sep-97	18:16:14.0	129000.	-35000.	0.07	333.	85.	14.4
21az110.out	19-Sep-97	16:05:24.5	118293.9	-37161.6	19-Sep-97	16:14:40.0	119000.	-37000.	0.15	706.	162.	12.9
22az110.out	20-Sep-97	15:07:50.0	109579.3	-39108.9	20-Sep-97	15:13:05.0	110000.	-39000.	0.09	421.	109.	14.5
23az110.out	20-Sep-97	14:07:04.5	100515.6	-42123.3	20-Sep-97	14:13:05.0	101000.	-42000.	0.10	484.	123.	14.3
24az110.out	21-Sep-97	12:54:03.8	89708.2	-45407.8	21-Sep-97	13:11:32.0	91000.	-45000.	0.29	1292.	408.	17.5
25az110.out	22-Sep-97	10:54:27.9	80650.3	-49513.9	22-Sep-97	11:10:01.0	82000.	-49000.	0.26	1350.	514.	20.8

**Arrival Date/time was not targeted*

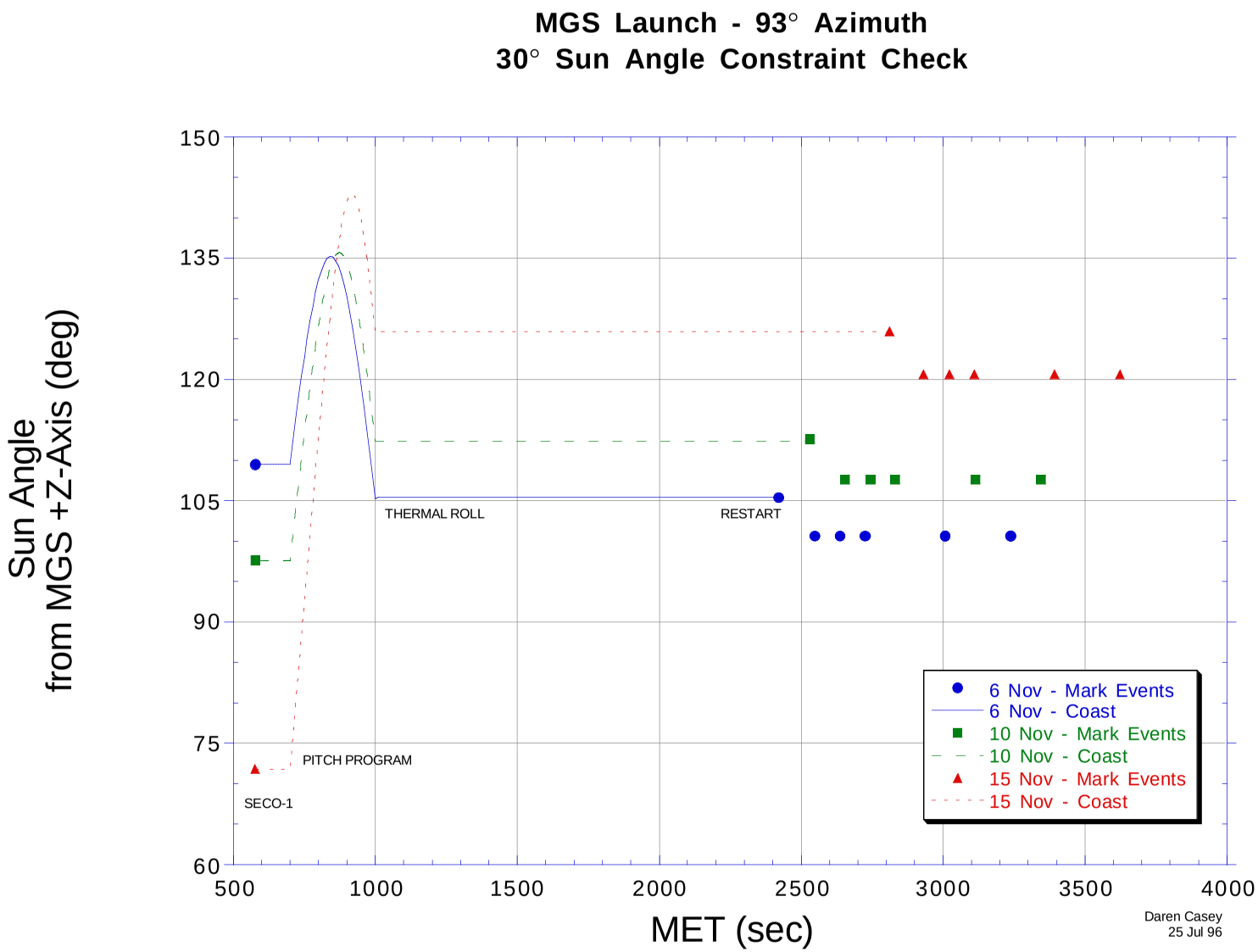
**Difference based on untargeted arrival time*
Using nominal biased arrival time:

Launch	Arrival (hr)
5-Nov-96	-10.17
14-Nov-96	70.1
15-Nov-96	96.74

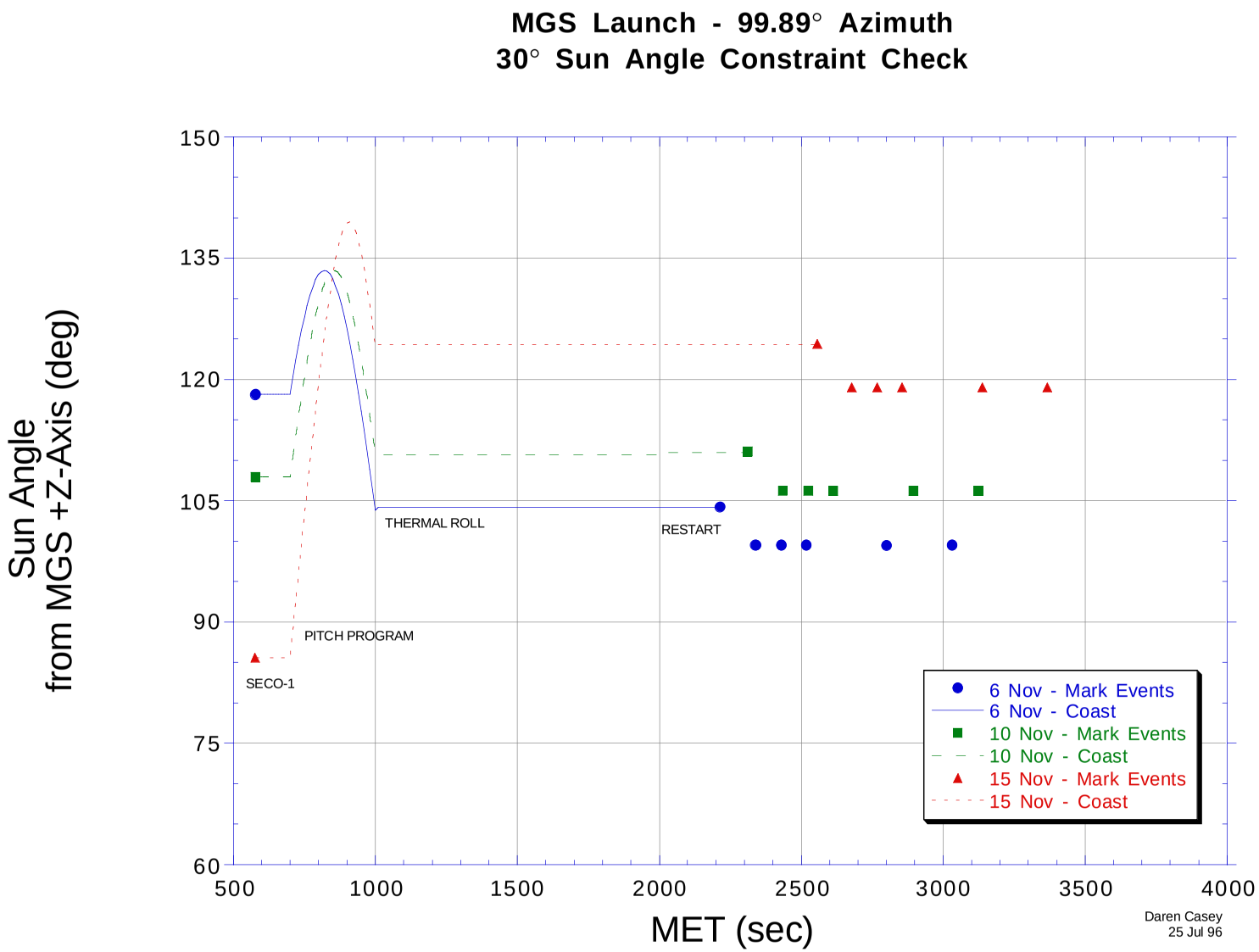
"NON-BURN" ATTITUDE REQUIREMENTS

- ATTITUDE VERIFICATION APPROACH
  - DTO REPORT PROVIDES TWO SOURCES OF ATTITUDE INFORMATION
    - VEHICLE CENTERLINE (MGS +Z-AXIS) AZIMUTH AND ELEVATION FOR EACH MARK EVENT (SECO-1, RESTART, SECO-2, STAGE III IGNITION, TECO, SEP, TIP)
    - ATTITUDE RATE TIMELINE
      - PITCH, YAW, ROLL RATES VS. MISSION ELAPSED TIME
  - SIMULATED TRAJECTORY AND ATTITUDE BETWEEN SECO-1 AND TIP
    - CONVERT CENTERLINE ANGLES INTO INERTIAL ATTITUDE AT MARK EVENTS
      - CUSTOM ROUTINE FROM (AZ/EL,LAT/LON) TO EARTH-FIXED VECTOR, *CTRANS* TO INERTIAL VECTOR (TRUE VS. MEAN EQUATOR IGNORED - 0.0015° SUN ANGLE ERROR)
    - PROPAGATE POSITION AND VELOCITY BETWEEN SECO-1 AND RESTART
      - LOAD STATE WITH MASL *CPLANN, ORBIN, ORBSPK*; *BODPOS* FINDS VECTOR TO SUN
    - PROPAGATE COAST ATTITUDES USING RATE TIMELINE
      - POSITION & VELOCITY FROM *ORBPOS, ORBVEL*; PITCH & YAW AXES FROM *VCROSS, VNEG*; NEW CENTERLINE FROM *VROTAT*, SUN ANGLE FROM *ANGV*
- SUN ANGLE CONSTRAINTS *TARGET SPEC SECTION 3.16*
  - *SPACECRAFT +Z-AXIS SHALL BE MAINTAINED AT AN ANGLE GREATER THAN 30 DEG RELATIVE TO THE SUN-SPACECRAFT LINE, OR AT A SLEW RATE OF GREATER THAN 0.4 DEG/S THROUGH THIS ZONE*
  - REQUIREMENT SATISFIED - ANGLES ARE BETWEEN 65-145 DEG DURING LAUNCH WINDOW

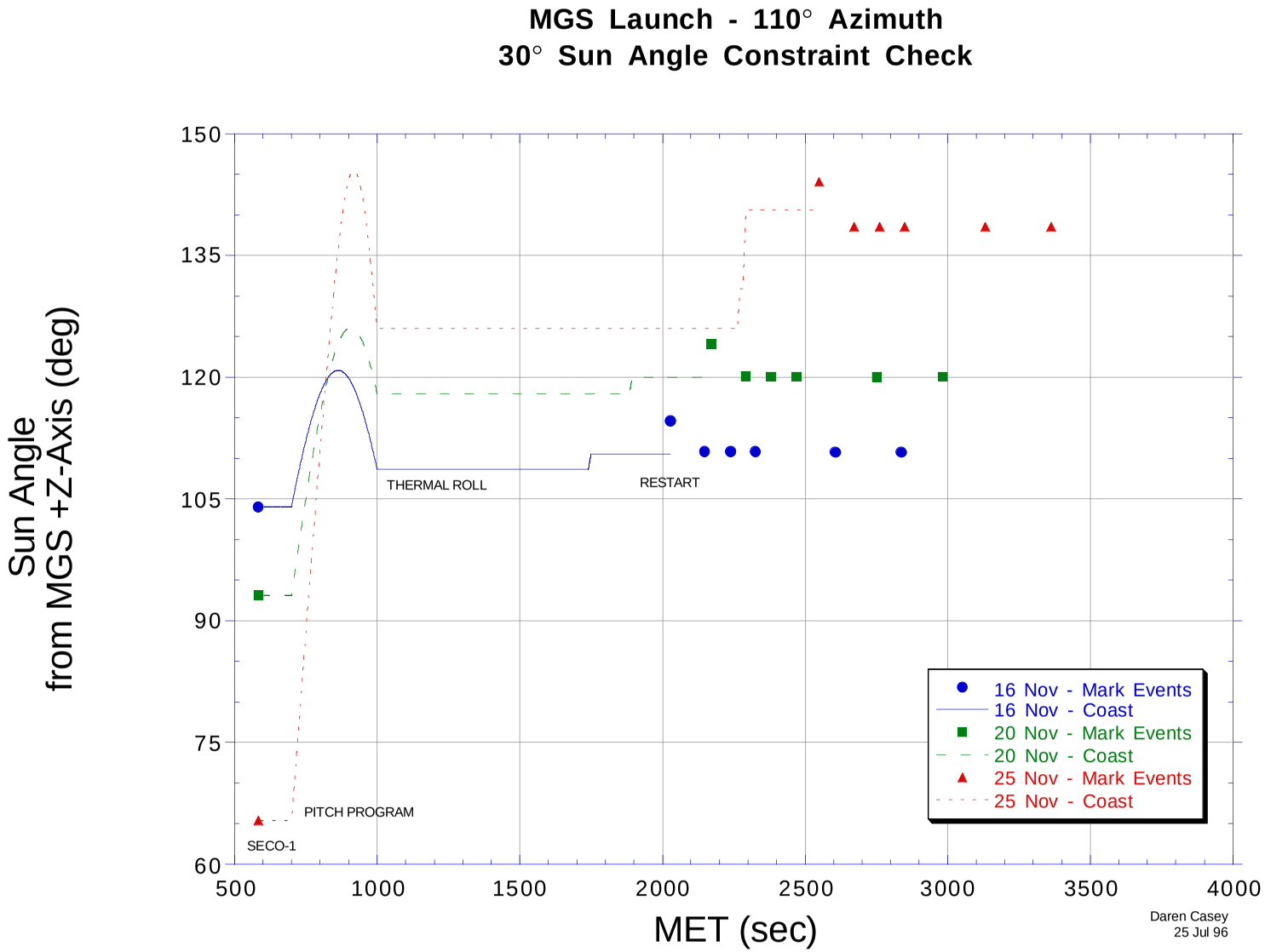
SUN ANGLE - 93° LAUNCH AZIMUTH



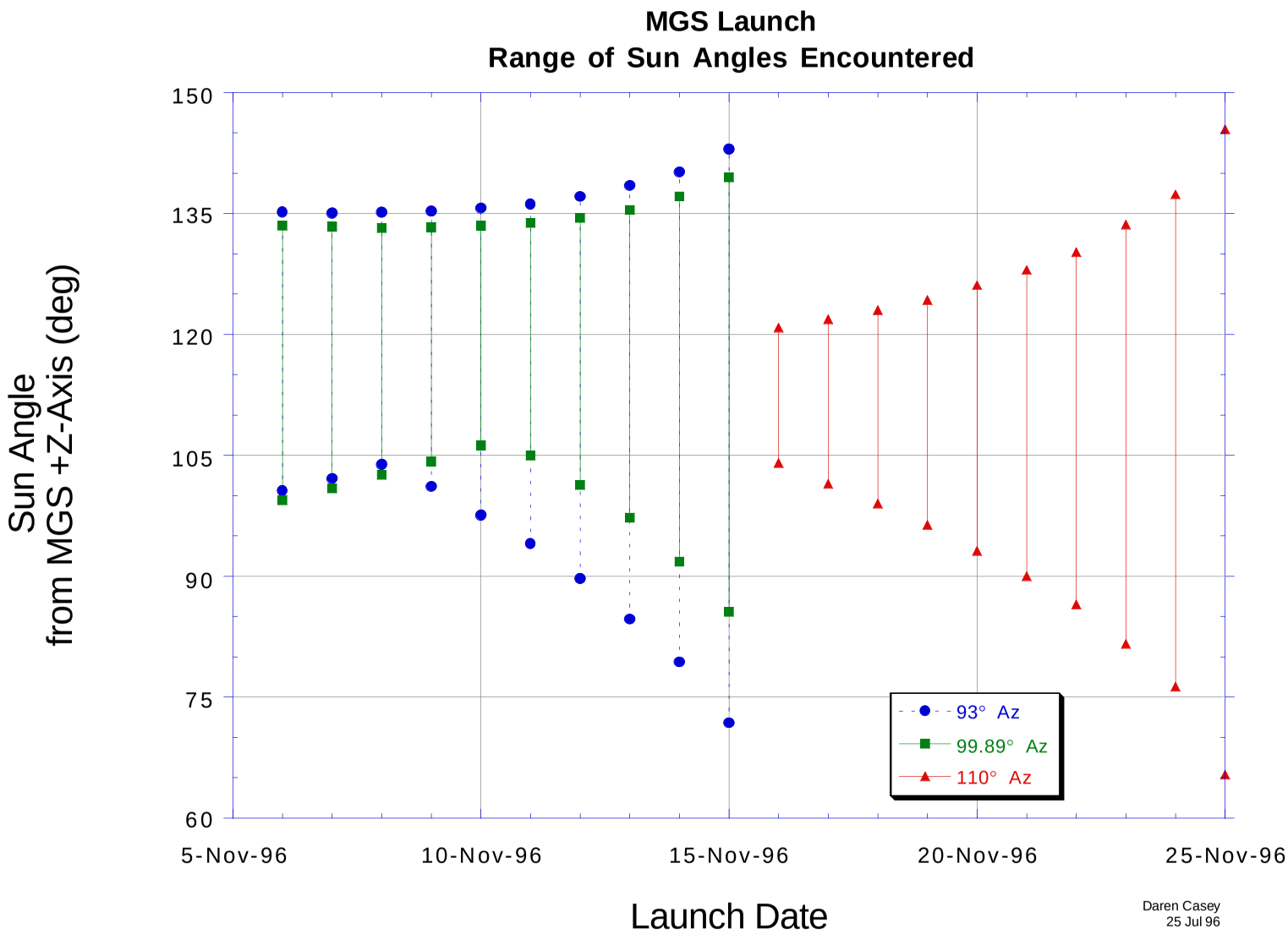
SUN ANGLE - 99.89° LAUNCH AZIMUTH



SUN ANGLE - 110° LAUNCH AZIMUTH



SUN ANGLE - EXTREMES

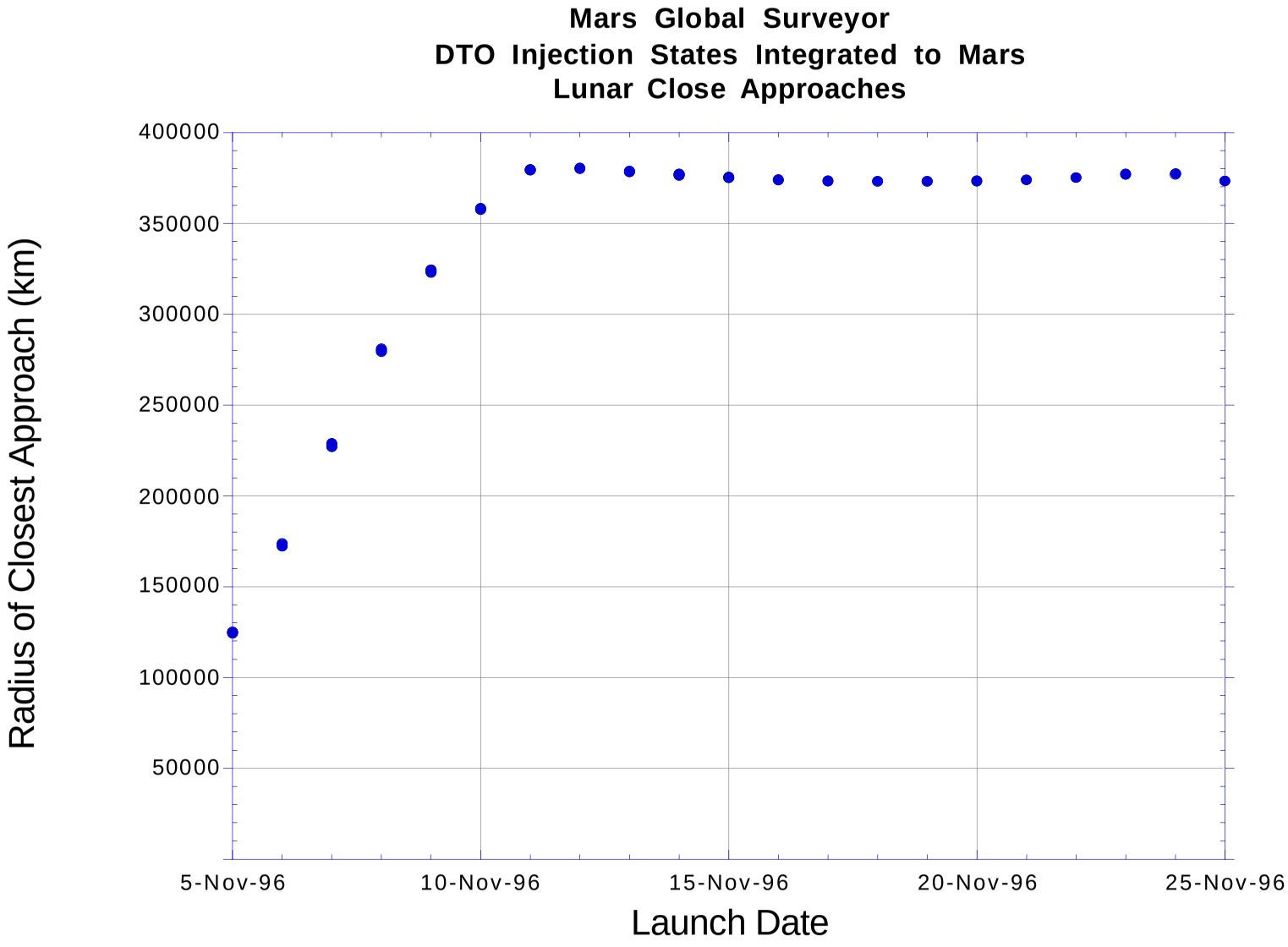


Daren Casey
25 Jul 96

"NON-BURN" ATTITUDE REQUIREMENTS cont.

- THERMAL ROLL *SECTION 3.17*
  - *WHEN NOT CONSTRAINED BY LAUNCH VEHICLE REQUIREMENTS A THERMAL ROLL OF ≥3 DEG/S IS REQUIRED, PREFERABLY WITH THE SPACECRAFT +Z-AXIS PERPENDICULAR TO THE SUN-SPACECRAFT LINE*
  - REQUIREMENT SATISFIED - DTO REPORT TIMELINES SHOW ROLL OF 3-3.5 DEG/S FOR ALL OPPORTUNITIES, +Z-AXIS 100-130 DEG OFF SUN LINE. MDAC REQUIREMENT IS 85-140 DEG
- SPACECRAFT SEPARATION ATTITUDE *SECTION 3.18*
  - SAME AS THIRD STAGE BURN VECTOR
- COLLISION AVOIDANCE *SECTION 3.19*
  - *DELTA THIRD STAGE/SPACECRAFT COLLISION AVOIDANCE WILL BE ACHIEVED BY DELAYING THE SEPARATION OF THE SPACECRAFT FROM THE THIRD STAGE UNTIL CHUFFING OF THE THIRD STAGE MOTOR HAS BEEN COMPLETED AND BY THE ESTABLISHMENT OF A POSITIVE SEPARATION RATE IMPARTED BY THE FOUR SEPARATION SPRING ACTUATORS ASSOCIATED WITH THE SPACECRAFT SEPARATION MECHANISM*

LUNAR CLOSE APPROACHES



INDEPENDENT / EXTERNAL CHECKS

- GLEN HORVAT OF NASA LEWIS (LERC) ADVANCED SPACE ANALYSIS OFFICE (ASAO) PERFORMED INDEPENDENT CHECKS OF LAUNCH AND INTERPLANETARY TRAJECTORIES
  - USED *DUKSUP* SOFTWARE SIMULATING LIFTOFF TO TIP TO VALIDATE *ISP* AND MDAC RESULTS (NOV 5,10,15 LAUNCH)
    - LAUNCH TIME $\Delta T < 20$ SEC
    - PARK ORBIT $\Delta MET = 0$ SEC
    - INJECTION $\Delta MET < 4$ SEC
  - LERC SOFTWARE ENGINEERING OFFICE USED *NBODY* SOFTWARE TO INTEGRATE INJECTION STATES TO MARS TO VALIDATE DPTRAJ RESULTS (NOV 5 & 25 LAUNCH)
    - $\Delta B \bullet T < 30$ KM
    - $\Delta B \bullet R < 10$ KM
    - ΔTIME OF FLIGHT ~20 SEC
- EXTERNAL CHECK RESULTS IN GOOD AGREEMENT WITH JPL TARGET SPECIFICATION PRODUCTS