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LUMINARY Memo # 211 Rev. 1

TO: Distribution
FROM: David Moore
DATE: 28 April 1971
SUBJECT: "Erasable Memory Program" for a guided RCS burn (for Luminary 1E)

Summary

The Erasable Memory Program -P99- of Apollo 14 (see Luminary Memos # 168 and 180) has been re-written for the Apollo 15 LM Deorbit. This memo includes a "breakdown" of the erasable program into appropriate sections (for further understanding by the reader), a complete listing of the program (with ECADR, octal contents, and symbolic instructions), a revised sequence for P99 performance (using astronaut/ground transmission procedures), and a test report for procedural verification of the " new" Apollo 15 LM Deorbit Erasable Burn Program: P99.

This memo also states the differences between the Apollo 14 version and the present version of P99.

This memo includes corrections made, due to comments received concerning previously unnoticed typographical errors, to Luminary Memo #211, dated 18 March 1971. In addition, an updated procedure for P99 usage is included, replacing the P99 procedure contained in Luminary Memo #211, dated 18 March 1971.

The "New" LM Deorbit Program for Apollo 15

The Erasable Memory Program for a Guided RCS Burn has been used in Apollo 14 as the LM Deorbit Burn for the seismometer experiments package left by astronauts of Apollo 12 and Apollo 14. The history of germination of this program has been described in Luminary Memo #168. It also gave the program listing and a rudimentary procedure for P99. A refined procedure was worked out for the Apollo 14 Deorbit,and a Luminary 1D, Level 6 Special Test was performed and subsequently reported upon in Luminary Memo #180.

The Erasable Memory Program used in Apollo 14 differs in two ways from the program as presently written. The Powered Flight Downlist (Orbital Maneuvers) will be used in the Apollo 15 version, whereas the Coasting Flight (Coast Align) Downlist was used in Apollo 14. Also, the DAP offset acceleration estimator will be enabled in the Apollo 15 version, whereas the Apollo 14 version of P99 did not do so. It is possible to separate portions of the program into sequences of programming for set purposes. This breakdown of sequences is described in detail in the following section.

P99 - In Sections

The following is a list of programming sections of the erasable RCS burn program for Luminary 1E.

1) Initialization of parameters:

DVTHRUSH = 0 to prevent DVMON failure
WHICH = address of "WHICH" table
F = 200 or 400 lb (for 2 or 4 RCS jets)
MDOT = APS MDOT (not used but, uplink easier)
TDECAY = 0 (RCS jets have no decay time)
VEX = RCS exhaust velocity
DVCNTR = 4

2) "WHICH" table:

P99	WHICH	+0	VN	0640
		+1	TCF	WANTAPS
		+5	TCF	P40SPOT
		+6	DEC	2990
		+7	ADRES	STEERING
		$+10_8$	BBCON	STEERING
		$+11_8$	TCF	COMMON
		$+12_8$	TCF	IGNITION
		$+13_8$	TC	P99IGN

3) The P99IGN Routine is as follows:

P99IGN	TC	DOWNFLAG
	ADRES	IDLEFLAG
	TC	SETDAPFL

and the SETDAPFL routine is merely a continuation of the P99IGN routine:

SETDAPFL	TC	DOWNFLAG
	ADRES	DRIFTDFL
	TC	TASKOVER

4) The P99 lead-in is as follows:

```
P99     TC      NEWMODEX
        DEC     99
        CAF     THREE
        TS      DNLSTCOD
        TC      INTPRET
        RTB
                E/CALL
        CADR    S40.1
        GOTO
                P40IN +3
```

5) To call P99 via DSKY, the keystrokes V30E are performed; where V30 is an extended verb which follows the following instructions from N26:

```
N26/PRI     OCT     13001
N26/2CAD    ADRES   P99
            BBCON   P99
```

P99 - Erasable RCS Guided Burn Program

NAME	ECADR	OCTAL	SYMBOLIC
SETDAPFL	3400	05520	TC DOWNFLAG
	3401	00312	ADRES DRIFTDFL
	3402	05263	TC TASKOVER
P99WHICH	3404	01450	VN 0640
	3405	12324	TCF WANTAPS
P99IGN	3406	05520	TC DOWNFLAG
	3407	00161	ADRES IDLEFLAG
	3410	01400	TC SETDAPFL
	3411	12150	TCF P40SPOT
	3412	05656	DEC 2990
	3413	03667	ADRES STEERING
	3414	74066	BBCON STEERING
	3415	12404	TCF COMMON
	3416	12433	TCF IGNITION
	3417	01406	TC P99IGN
P99	3420	05313	TC NEWMODEX
	3421	00143	DEC 99
	3422	36266	CAF THREE
	3423	54333	TS DNLSTCOD
	3424	06060	TC INTPRET
	3425	77634	R TB
	3426	10636	E/CALL
	3427	56246	CADR S40.1
	3430	77650	GOTO
	3431	75202	P40IN + 3

NAME	ECADR	OCTAL	SYMBOLIC
F	3734	00026	2 DEC 0.17792 B-7
	3735	30605	(400 lb - 4 JETS)
MDOT	3736	00151	2DEC 0.05135B-3
	3737	05214	(APS MDOT)
TDECAY	3740	00000	2DEC 0
	3741	00000	
VEX	3742	15400	2DEC 273-6
	3743	00000	(27.00 M/CS)
WHICH	3455	01404	ADRES P99 WHICH
DVTHRUSH	1250	00000	OCT 0
DVCNTR	3515	00004	DEC 4
N26/PRI	2371	13001	OCT 13001
N26/2CAD	2372	01420	ADRES P99
	2373	12067	BBCON P99

Assumptions for P99 - Erasable RCS Burn Program

1. The LM may be either DPS/APS or APS.
2. The program may be performed in either Earth or Lunar Orbit.
3. There will be no more IMU alignments after P99 unless the AOTAZ and AOTEL padloads are re-uplinked.
4. There will not be an attempt on the lunar landing after P99 unless the landing radar padloads are re-uplinked.
5. There will not be an attempt to perform P35 after P99 unless the ATIGINC and PTIGINC padloads are re-uplinked.
6. P30 must be done before P99 as the targetting program.
7. PGNCS control; Auto "mode selected".
8. APS Engine Arm off.
9. P99 coding uplinked as follows in the next section.

Uplink for P99 - Erasable RCS Burn Program

Load 1	Load 2	Load 3	Load 4	Load 5
V71E	V71E	V71E	V71E	V72E
24E	12E	5E	6E	15E
3404E	3734E	3400E	3426E	3455E
1450E	26E	5520E	10636E	1404E
12324E	30605E	312E	56246E	1250E
5520E	151E	5263E	77650E	0E
161E	5214E	V33E	75202E	3515E
1400E	0E		V33E	4E
12150E	0E			2371E
5656E	15400E			13001E
3667E	0E			2372E
74066E	V33E			1420E
12404E				2373E
12433E				12067E
1406E				V33E
5313E				
143E				
36266E				
54333E				
6060E				
77634E				
V33E				

Procedure for P99 LM Deorbit in Apollo 15

Action	Meaning
V37E00E	Call POO
V82E	Call Orbital Parameter Routine (R30)
V4N12 R1 = 00002 R2 = 00001	Option code display for "This" (LM) vehicle
Proceed	Accept this vehicle for parameter computation
V16N44 R1 R2	Orbital Parameter Display Apolune Altitude Perilune Altitude
Proceed	Complete orbital parameter routine (R30)
V48E	Call DAP Data Load Routine (R03)
V04N46	DAP Configuration
Load N46 via V21	Load Desired DAP Configuration
Proceed	Accept DAP Configuration
V06N47	LM Weight
Load N47 via V21	Load Desired LM Weight
Proceed	Complete DAP Data Load Routine (R03)
V37E30E	Call P30 - External ΔV Targetting Program
V06N33	TIG for ERCS Burn
Load N33 via V25	Load Desired TIG
Proceed	Accept TIG
V06N81	ΔV to be accomplished by ERCS Burn
Load N81 via V25	Load Desired ΔV
Proceed	Accept ΔV

Action	Meaning
V06N42 R1 R2 R3	Expected Orbital parameters Apolune Altitude of new orbit Perilune Altitude (negative → impact) ΔV for ERCS burn.
Proceed	Accept new orbital data
V16N45 R2	Time to go until ERCS TIG
Proceed	Complete External ΔV Targetting Program (P30)
V37 Flashing	Please select another program
V96E POO appears in mode lights	Exit, go to P00 (Reset POOHFLAG to terminate POO integration routine for P99)
Guidemode - Primary (PGNCS) PGNCS Select - AUTO ASC Eng. arm - off	Configure Spacecraft prior to egress
Update Uplink - Erasable	Prepare uplink for ground action
Uplink erasable program	Ground takes over from this point
V5N26E R1 = 13001 R2 = 01420 R3 = 12067	Verify Address for erasable memory burn program - P99
V30E	Call P99 via Extended Verb
V50N18	Burn Attitude
V33E	Do burn attitude maneuver
V50N18	Maneuver completed

Action	Meaning
E	Accept burn attitude
V06N40 R2	Monitor countdown to TIG (Time to go in R2)
V06N40 R2 = 00X29	Average G-Routine on at TIG-30
V06N40 R2 = 00X00	TIG: Powered Flight Downlist selected; P42 guidance equations enabled; DAP offset acceleration estimator enabled.
V06N40 R2	Monitor Countdown to Cutoff (Time to go in R2)
V16N40	RCS cutoff; DAP offset acceleration estimator disabled.
V33E	Accept Cutoff conditions
V16N85	Burn residuals.
V82E	Call orbital parameter Routine (R30)
V16N44 R1 R2 R3	Orbital Parameters Display Apolune Altitude Perilune Altitude Time-free-fall to 35K ft
V33E	Accept Orbital Parameters
V16N85	Burn residuals
V33E	Accept
V37 Flashing	Select another program
00E	Select POO
POO appears in Mode lights	Average G Routine off; Coast/Align Downlist selected.

End of P99 - Apollo 15 - Procedure

Test Report for P99 - Erasable Memory Program

Introduction

The "new" Apollo 15 LM Deorbit Program, P99, was tested at MIT/CSDL on the Hybrid LM Facility and the All-Digital Simulator. The test was to verify the procedure used and to verify that the erasable locations were not used by any other computer operations active at the time of P99 usage. The data in the following table involves:

1) The initialization of the digital simulation and
2) The displays noted as results of the digital simulation.

The hybrid simulation was run as an attempt to ascertain the performance of the coding with respect to flag-setting and the change in the downlist identification code. The developed sequence was followed on the Hybrid facility, and it was seen that the proper operations were carried out by the erasable program. The Hybrid simulation was also done with the LM in the DPS/APS configuration while in Earth orbit in order to ascertain that the program could be used in this configuration as well as in the Ascent configuration in Lunar orbit.

The All-Digital simulation involved clocks and traces of the coding in the erasable program and the related guidance equations, as well as the timing and RCS jet firing data obtained from the environment. Following the tabulated displays is an RCS Data Summary and DAP performance results including an attitude error time-history and plots of the vehicle attitudes and vehicle attitude rates during the burn.

The test effort, of which this is a report, was a Level 4-type effort using the Apollo 14 vehicle characteristics (on both simulation facilities). The initialization data was provided by the Apollo 14 Data Pack and post-Apollo 14 flight data.

Results

As can be seen from the tabulated displays, the RCS burn was successful and that the rewritten P99 is comparable to the Apollo 14 version (see Luminary Memo #180 - discussion, tabulated displays, and RCS data summary). It is seen that the total run time was approximately 77 seconds, the total RCS fuel used was 109.47 lb., and the burn residuals (N85) were small. It is also noticed that the orbit attained after the burn does not equal the expected orbit computed by the targetting program. This is because of an ignition time-slip of approximately 4.25 minutes. The time slip was the only off-nominal occurrence in the test, and the only off-nominal result was the mismatched orbits between the expected and the attained after the burn.

Further tests, of the Level 6 variety, will be run for performance and stress testing.

Conclusion

The Erasable Memory Program for an RCS guided burn: P99, as rewritten for Luminary 1E, was designed to enable the performance of LM Deorbit in Apollo 15. Since tests were run in the DPS/APS - Earth orbit and APS - Lunar orbit configurations, and the results appeared favorable (as compared to Apollo 14 data), then it is concluded that the design criteria has been met.

All-Digital Simulator Initialization for P99

R = (1803425.4, 76203.9, -369488.9) meters

V = (-98.1, -1436.88, -770.74) meters/sec.

Time = 147:49:23 G.E.T.

$$\text{REFSMMAT} = \begin{bmatrix} -.267 & -.867 & -.418 \\ +.193 & -.474 & +.859 \\ -.944 & +.148 & +.294 \end{bmatrix}$$

PIPA Compensation errors = nil

Lunar sphere of influence

RCS fuel = 344.8 lb.

APS fuel = 244.9 lb.

Total LM Weight = 5269 lb.

CG = (257.66, 1.055, 2.242) inches

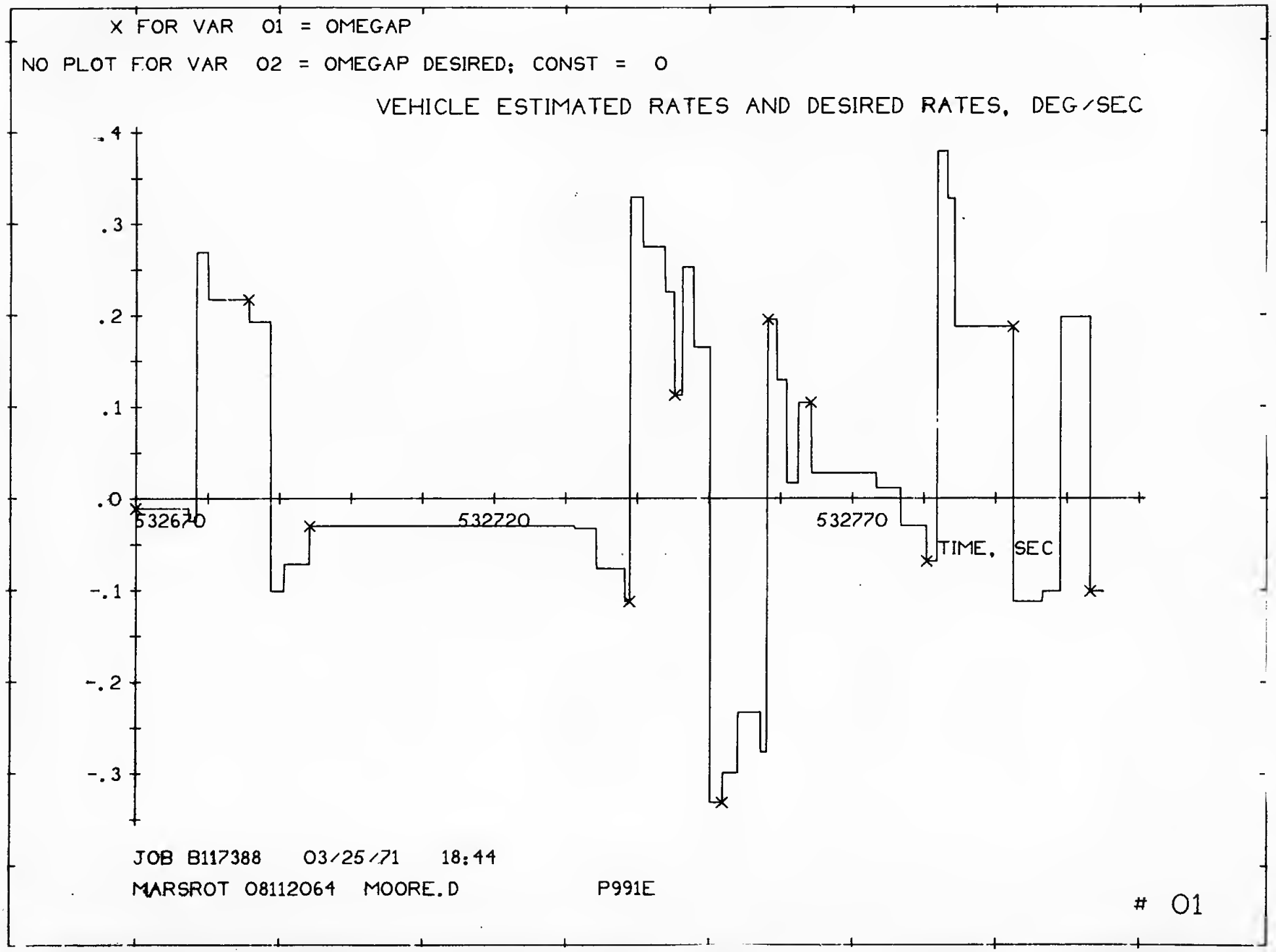
Tabulated Displays for Level 4 - P99

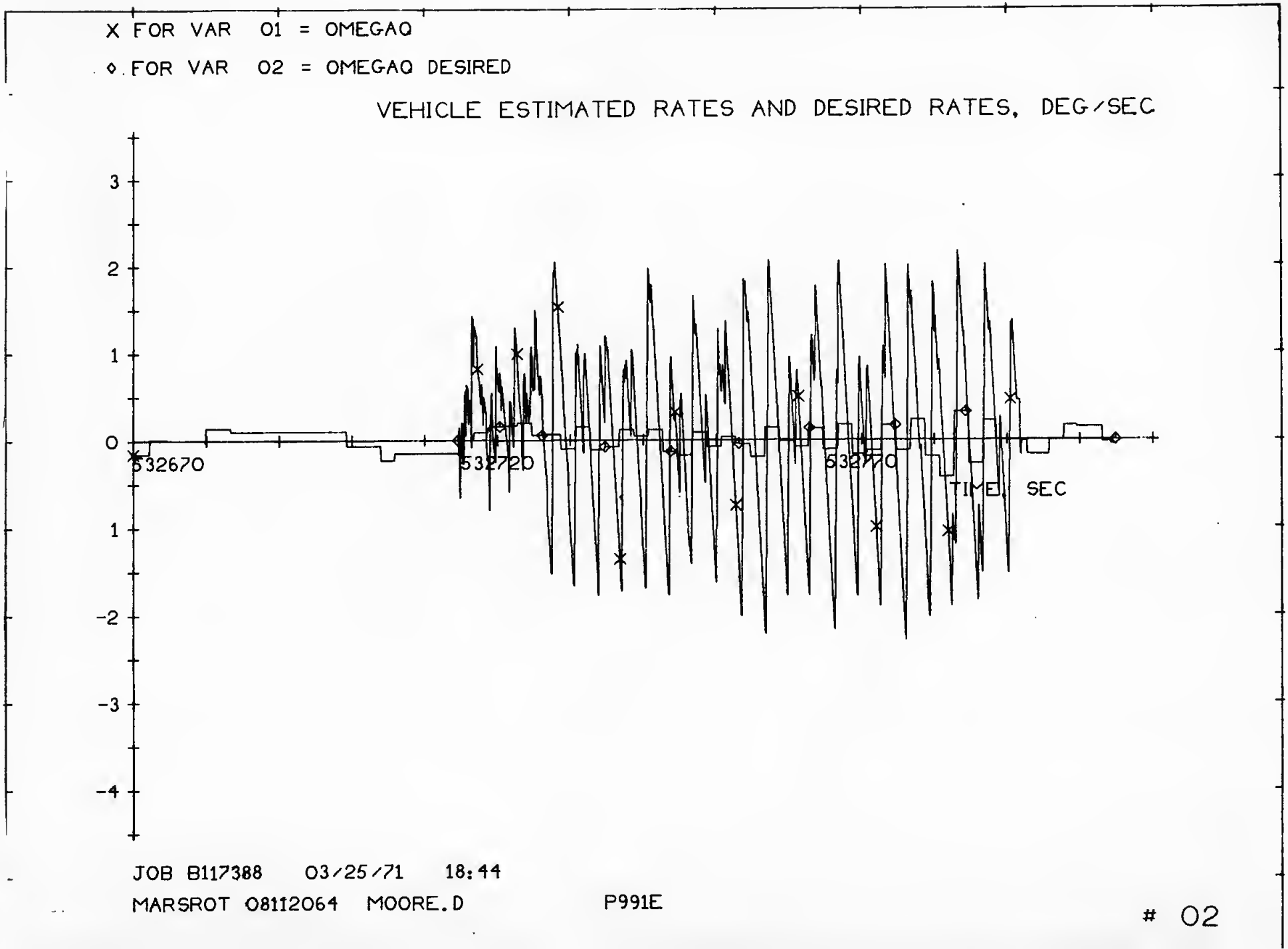
DSKY (VN)	R1	R2	R3	Mode
V82E				00
V16N44	+62.7	+57.1		
V48E				
V21N46E	12021			
V21N47E	+5268			
V37E30E				30
V6N33	+147	+54	+18	
V6N81	-182.0	+30.0	+0	
V6N42	+57.1	-62.9	+184.5	
V16N45	0	-4X00	+9.31	
V96E				0
V71E				27
V71E				
V71E				
V71E				
V72E				
V5N26	13001	1420	12067	0
V30E				99
V50N18	+164.89	+7.33	+51.58	
V06N40	-00X40	+184.5	0	
V06N40	+00X00	+184.5	+.3	
V16N40	-00X00	+.3	+184.7	
V16N85	+.3	+.1	+0	
V82E				
V16N44	+57.6	-60.1	-23X12	
V16N85	+.3	+.1	+0	
V37E00E				00

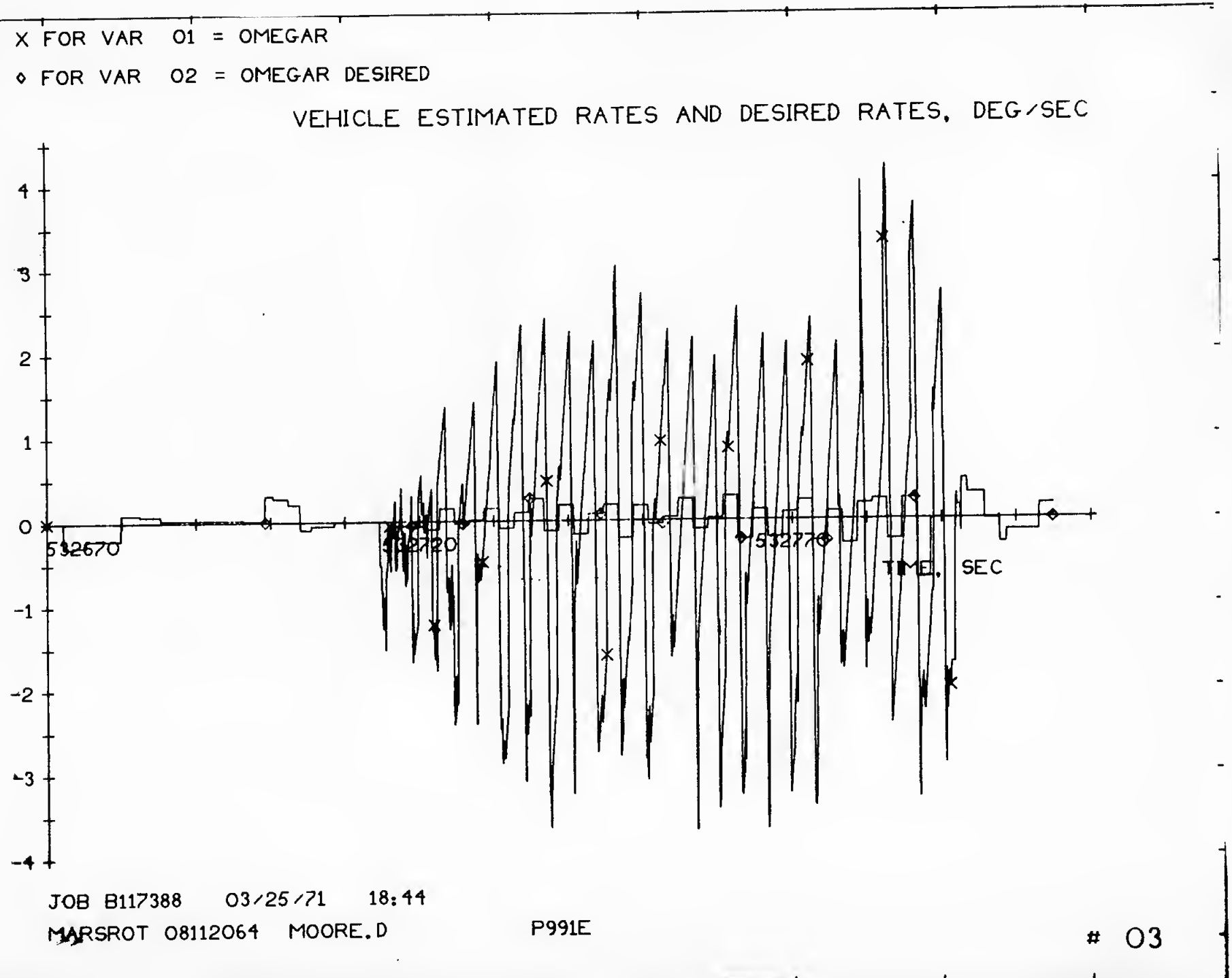
RCS Data Summary

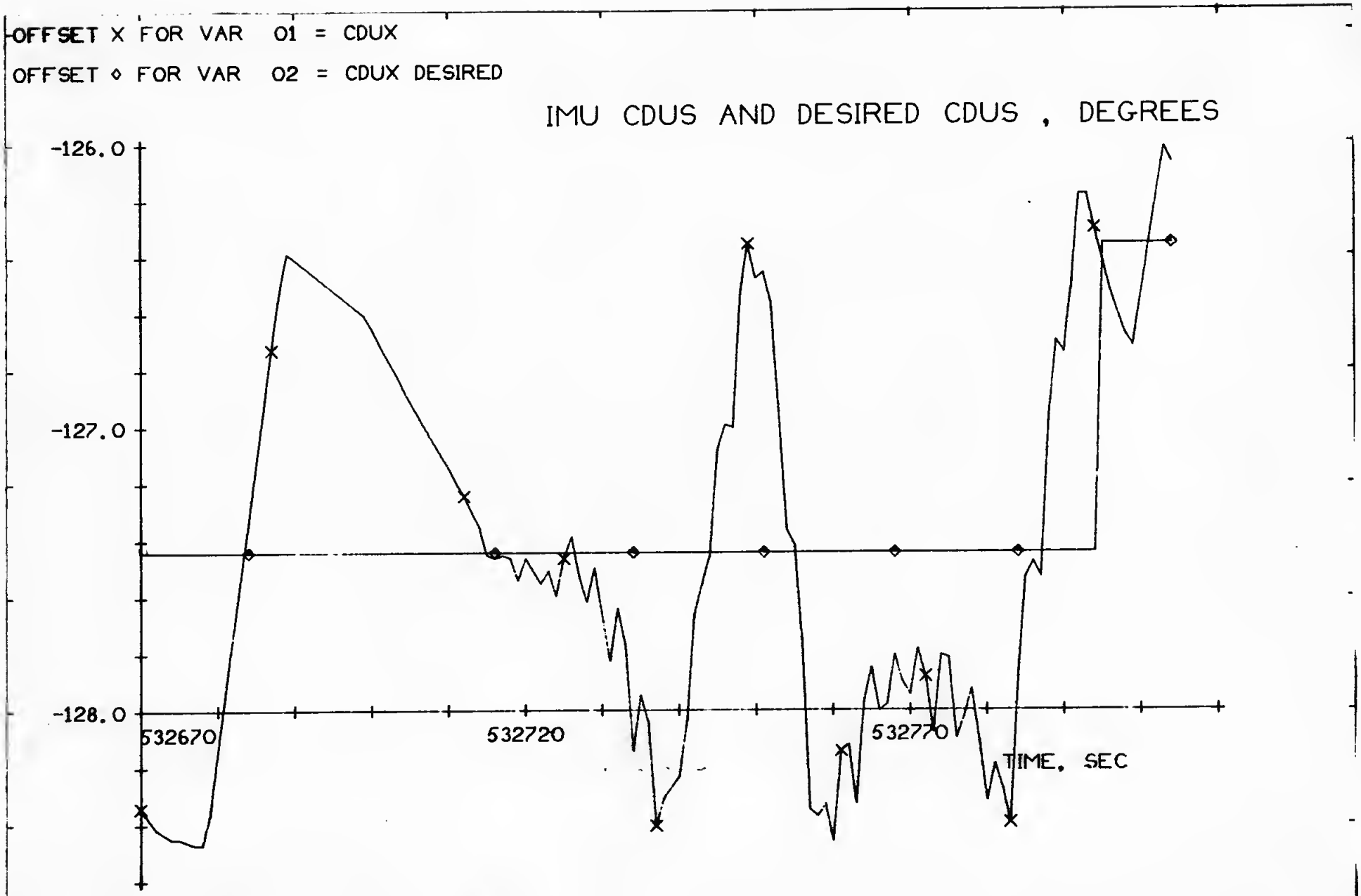
Jet #	Time on (sec)	#Firings	Fuel Used (lb.)
1	.12	9	.05
2	77.39	9	28.02
3	.11	9	.05
4	.26	22	.13
5	.10	9	.05
6	74.65	38	27.08
7	.12	9	.05
8	.24	21	.12
9	.16	14	.08
10	69.64	81	25.33
11	.11	9	.05
12	.26	22	.13
13	.12	11	.06
14	77.43	13	28.05
15	.12	9	.05
16	.24	21	.12

Total RCS Fuel Used = 109.47 lb.


X FOR VAR 01 = OMEGAP
NO PLOT FOR VAR 02 = OMEGAP DESIRED; CONST = 0
VEHICLE ESTIMATED RATES AND DESIRED RATES, DEG/SEC
.4
.3
.2
.1
.0
-.1
-.2
-.3
532670
532720
532770
TIME, SEC
JOB B117388 03/25/71 18:44
MARSROT 08112064 MOORE.D P991E
01


X FOR VAR 01 = OMEGAQ
◇ FOR VAR 02 = OMEGAQ DESIRED
VEHICLE ESTIMATED RATES AND DESIRED RATES, DEG/SEC
3
2
1
0
1
-2
-3
-4
532670
532720
532770
TIME, SEC
JOB B117388 03/25/71 18:44
MARSROT 08112064 MOORE.D
P991E
02


X FOR VAR 01 = OMEGAR
◇ FOR VAR 02 = OMEGAR DESIRED
VEHICLE ESTIMATED RATES AND DESIRED RATES, DEG/SEC
4
3
2
1
0
-1
-2
-3
-4
532670
532720
532770
TIME, SEC
JOB B117388 03/25/71 18:44
MARSROT 08112064 MOORE.D
P991E
03



JOB B117388 03/25/71 18:44

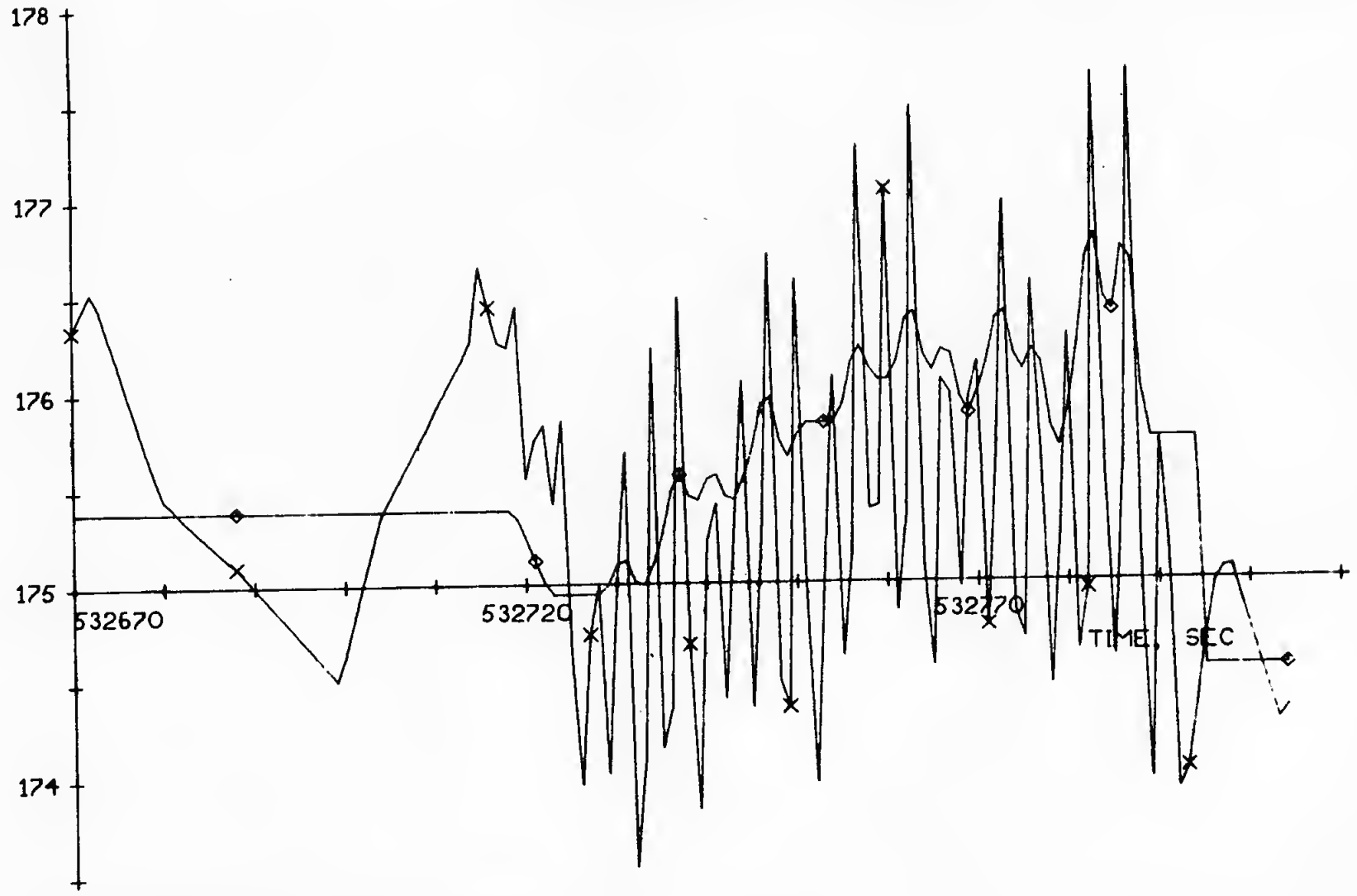
MARSROT 08112064 MOORE.D P991E

04

OFFSET X FOR VAR 01 = CDUY

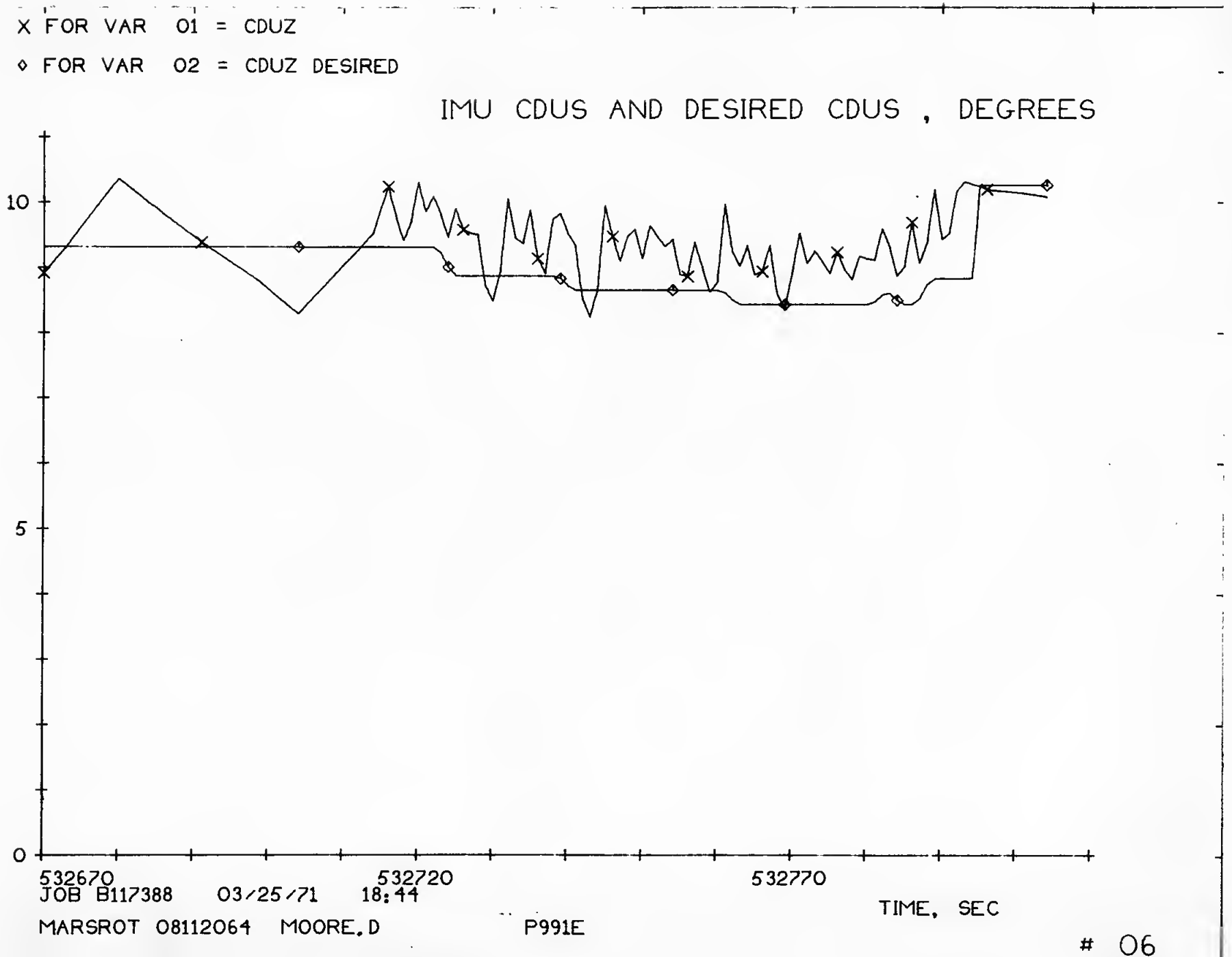
OFFSET ◇ FOR VAR 02 = CDUY DESIRED

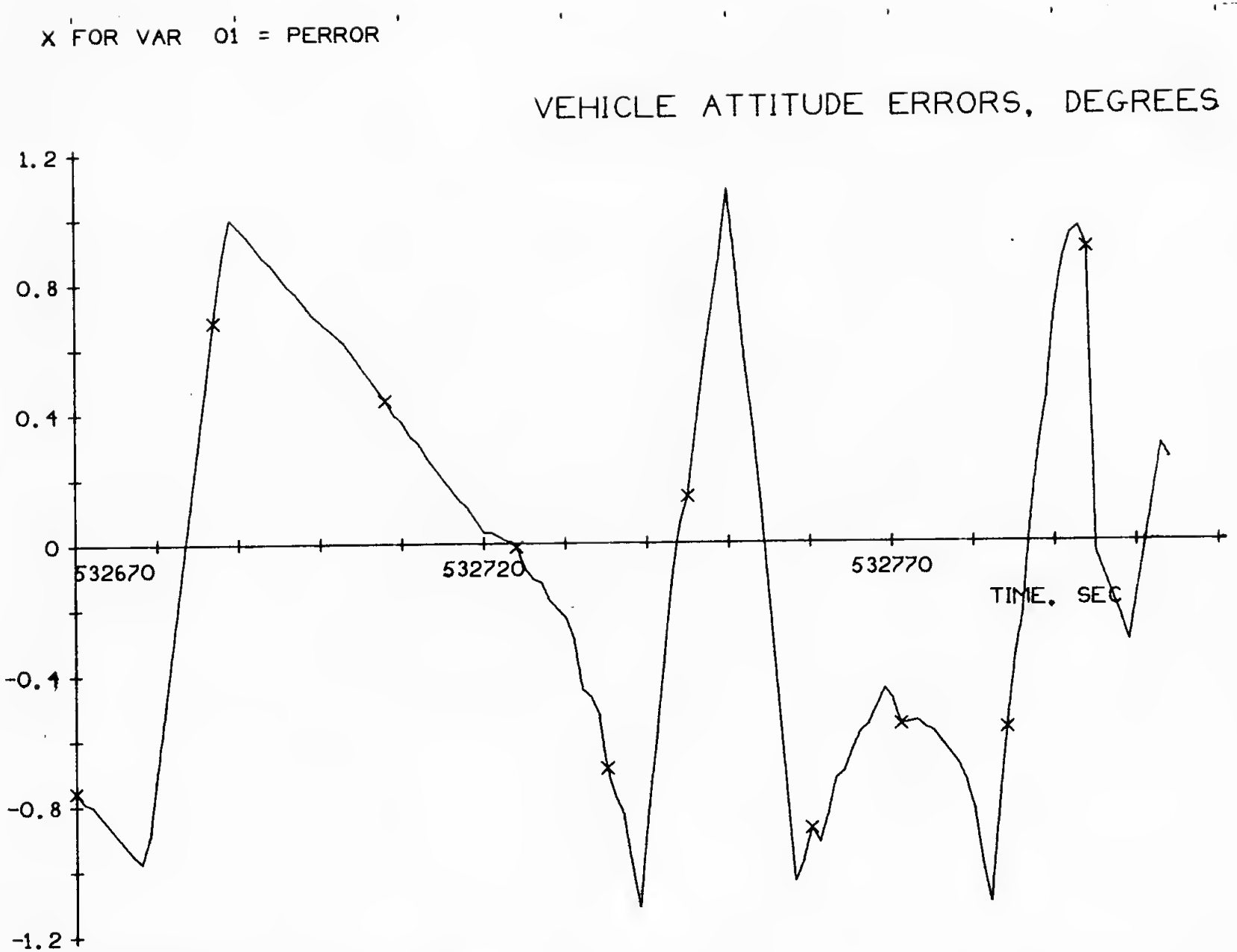
IMU CDUS AND DESIRED CDUS , DEGREES



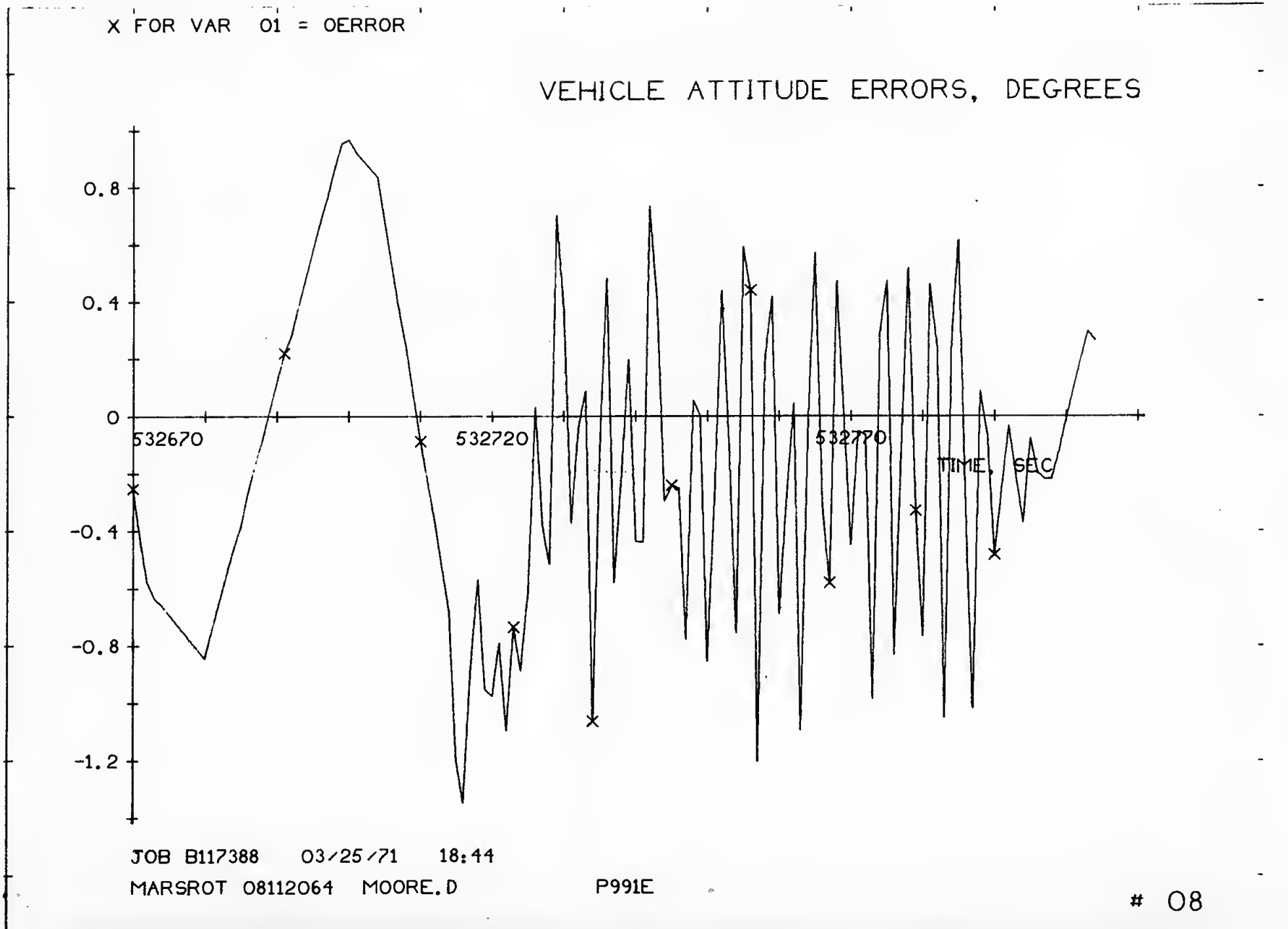
JOB B117388 03/25/71 18:44

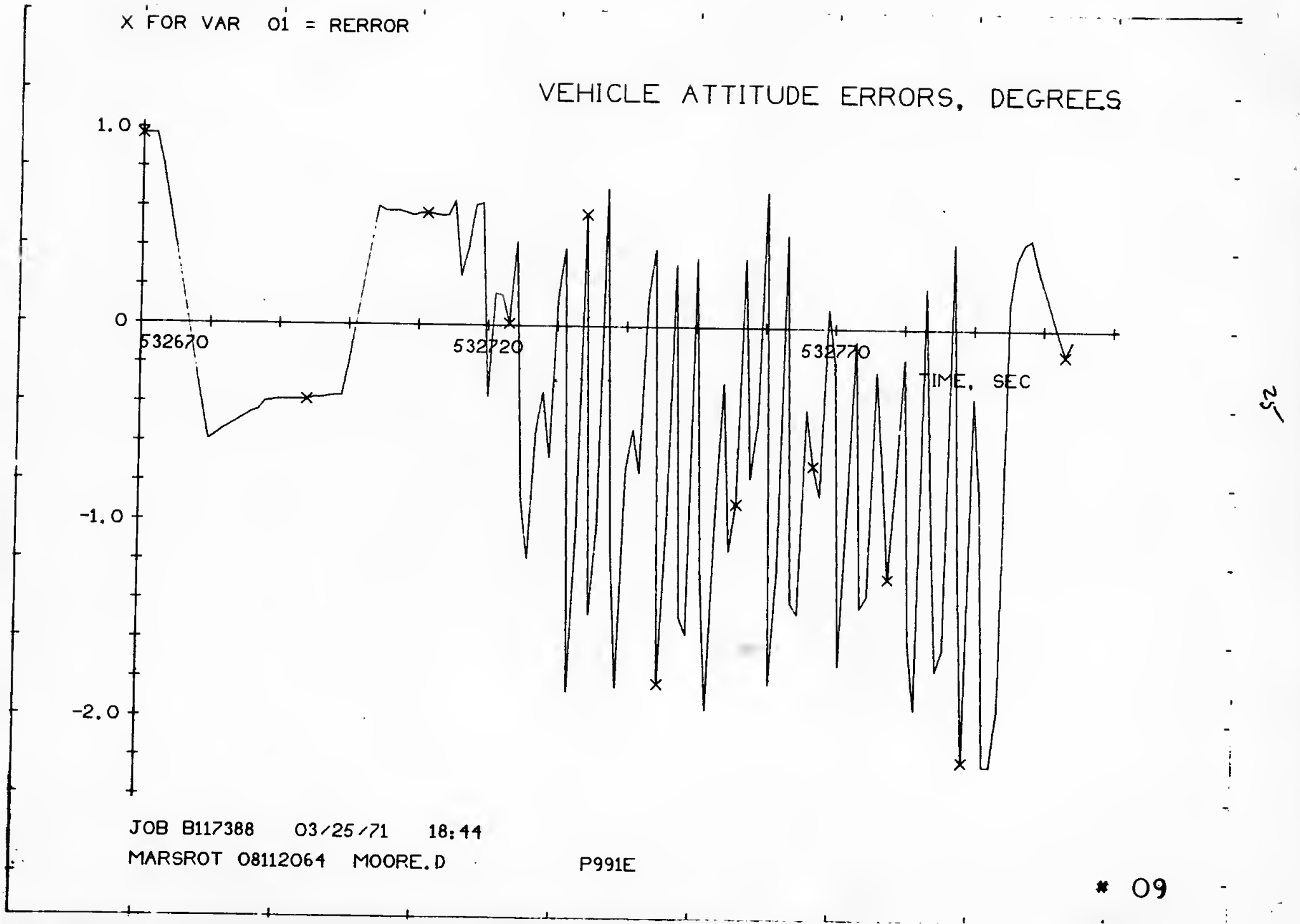
MARSROT 08112064 MOORE.D P991E

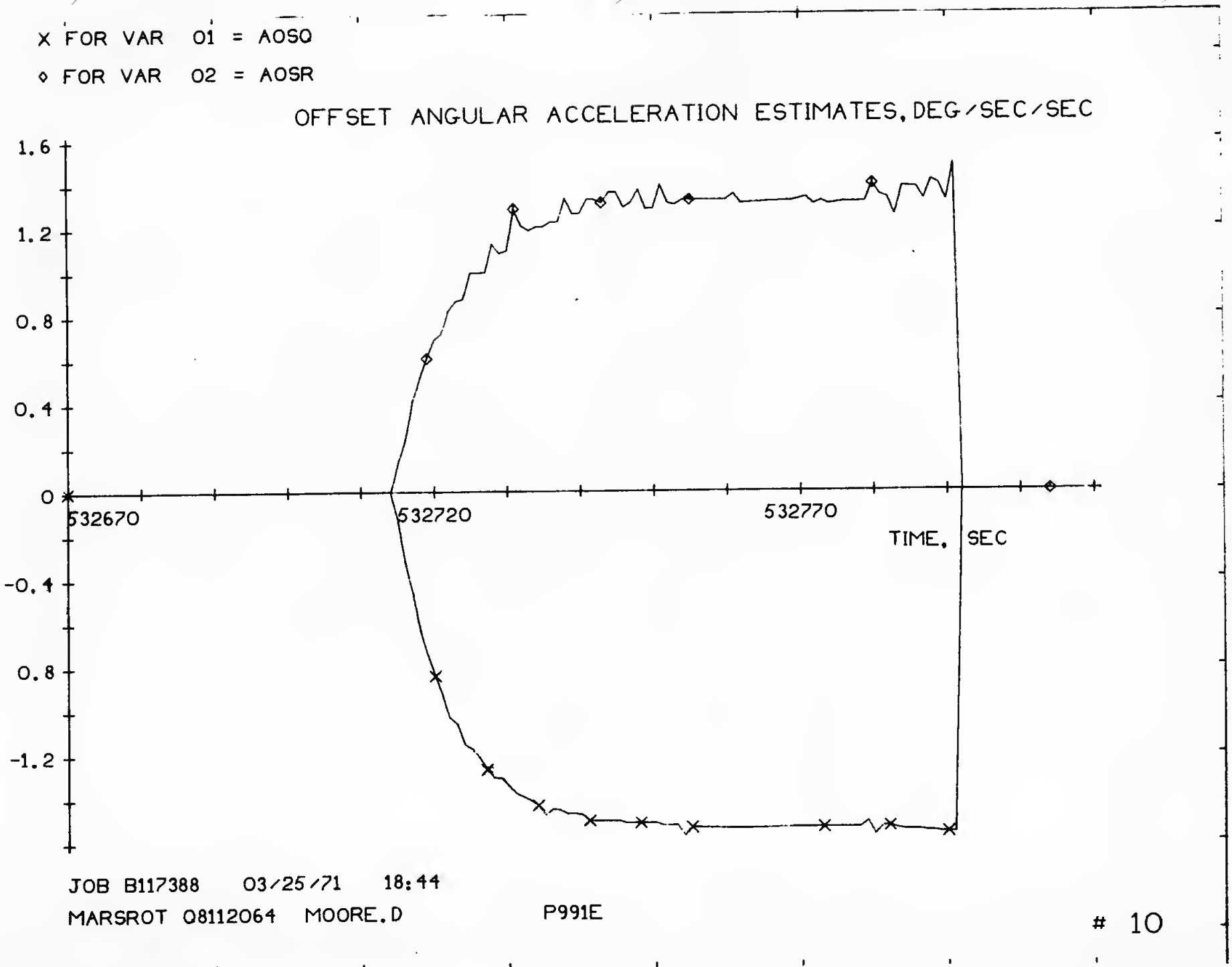

X FOR VAR 01 = CDUZ
◇ FOR VAR 02 = CDUZ DESIRED
IMU CDUS AND DESIRED CDUS , DEGREES
10
5
0
532670
532720
532770
JOB B117388 03/25/71 18:44
TIME, SEC
MARSROT 08112064 MOORE, D
P991E
06


X FOR VAR 01 = PERROR
VEHICLE ATTITUDE ERRORS, DEGREES
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
532670
532720
532770
TIME, SEC
JOB B117388 03/25/71 18:44
MARSROT 08112064 MOORE.D
P991E

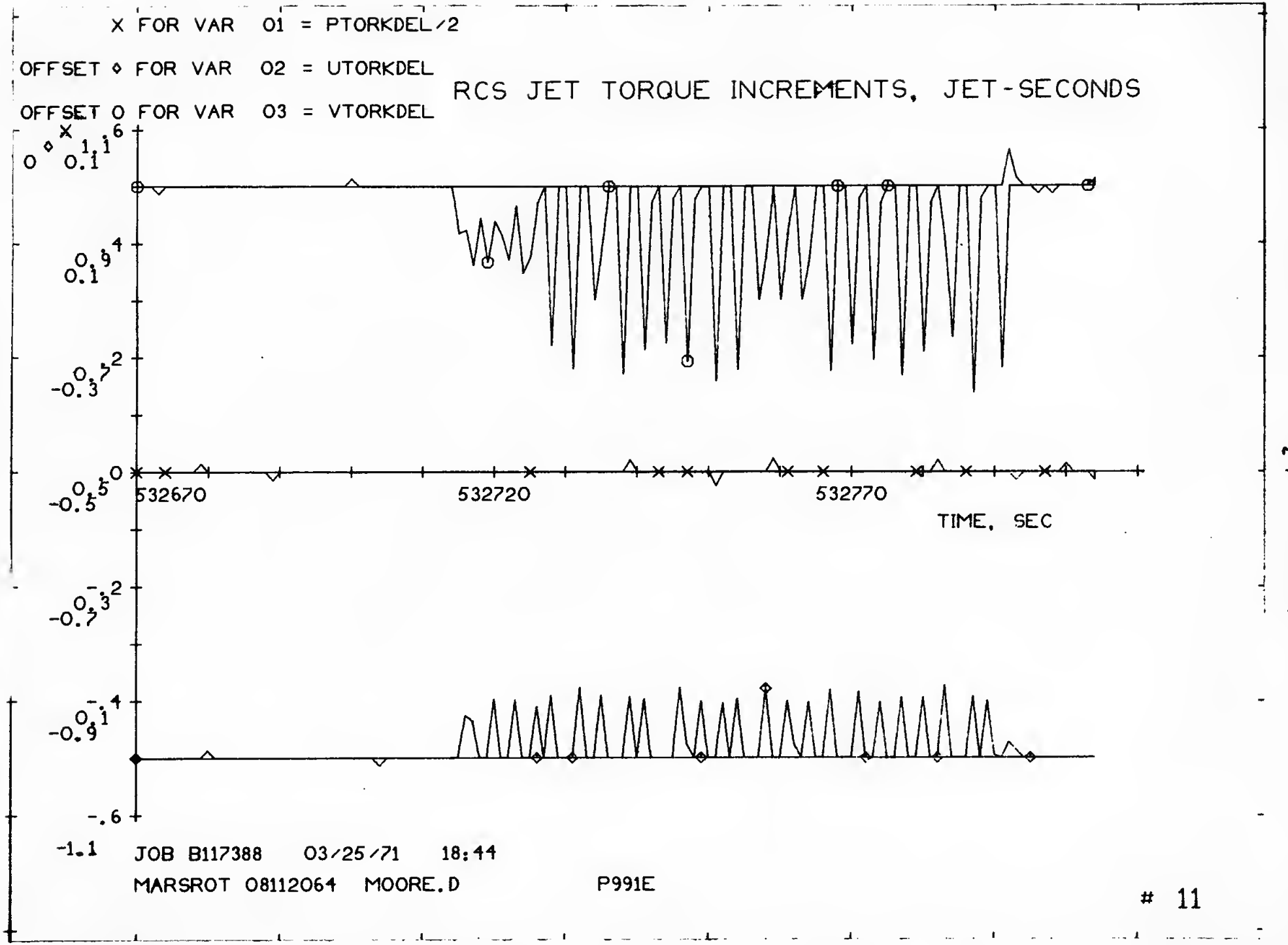
07


X FOR VAR 01 = OERROR
VEHICLE ATTITUDE ERRORS, DEGREES
0.8
0.4
0
-0.4
-0.8
-1.2
532670
532720
532770
TIME, SEC
JOB B117388 03/25/71 18:44
MARSROT 08112064 MOORE.D
P991E
08


X FOR VAR 01 = RERROR
VEHICLE ATTITUDE ERRORS, DEGREES
1.0
0
-1.0
-2.0
532670
532720
532770
TIME, SEC
JOB B117388 03/25/71 18:44
MARSROT 08112064 MOORE.D
P991E


X FOR VAR 01 = AOSQ
◇ FOR VAR 02 = AOSR
OFFSET ANGULAR ACCELERATION ESTIMATES, DEG/SEC/SEC
1.6
1.2
0.8
0.4
0
-0.4
0.8
-1.2
532670
532720
532770
TIME, SEC
JOB B117388 03/25/71 18:44
MARSROT 08112064 MOORE.D
P991E

10


X FOR VAR 01 = PTORKDEL/2
OFFSET ◇ FOR VAR 02 = UTORKDEL
OFFSET O FOR VAR 03 = VTORKDEL
RCS JET TORQUE INCREMENTS, JET-SECONDS
0
0.1
-0.3
-0.5
-0.7
-0.9
-1.1
532670
532720
532770
TIME, SEC
JOB B117388 03/25/71 18:44
MARSROT 08112064 MOORE.D P991E