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COLOSSUS MEMO #217

TO: Cmdr. Richard Gordon
FROM: J. F. Turnbull
DATE: September 24, 1969
SUBJECT: Performance of R64 Y axis option at a rate = .0507 with
CDUX = 180 deg.

The Y axis option of Routine 64 (V79) was designed to be used with the restrictions that CDUX be close to 7.25 deg. and CDUZ be zero. If these conditions are met, the positive Y stable member axis and the positive Y RCS control axis are parallel and point in the same direction. This is important because of the way the Y axis option is implemented in the computer. Basically the situation is that sufficient storage was not available when R64 was coded to make the command rate a function of CDUX.

The easiest way to explain the effect of this is to consider a specific example. Let us assume that register 1 of N79 is loaded with a rate of -0.05 deg/sec. Routine 64 will give two commands to the DAP. One will be a commanded increment for CDUY to be added every 0.1 sec. For the case we are considering, the increment will be a negative number, -0.005 deg. The second command will be the commanded rate about the Y RCS control axis. For our example, that will be -0.05 deg/sec. If CDUX = 7.25 and CDUZ = 0, then both commands will be negative about axes which point in the same direction so everything is coordinated. If, however, CDUX = 180 deg and CDUZ = 0 both commands will still be negative but about axes that point in roughly opposite directions so that the effect is that of having the commanded gimbal angle increment in one direction and the commanded rate in the opposite direction. This obviously is a contradictory situation.

The question is what penalty do you pay for flying in a "heads down" (CDUX = 180 deg.) configuration? To answer this question two simulations were run on the MIT all digital simulator. Both simulations used the Y axis option of R64 with a rate of -0.0507 deg/sec and a deadband of 0.5 deg loaded in N79. The sequence of astronaut actions executed in both simulations is the same and is listed in Table 1. The difference between the two runs is that one simulation, referred to as "heads up", starts from initial gimbal angles CDUX = 0, CDUY = 0, and CDUZ = 0, which nearly meet the restrictions of the R64 Y axis option. The other run, referred to as "heads down", starts from initial gimbal angles CDUX = 180, CDUY = 0, and CDUZ = 0 which violates the CDUX restriction by 172 degrees.

Figure 1 is a plot of CDUY for the HEADS UP run. As can be seen, CDUY is a smoothly decreasing function of time. Figure 2 is a plot of CDUY for the HEADS DOWN run. The plot in this case has a saw tooth nature. What is important is that, despite the fact that CDUY does not decrease smoothly, its average rate of decrease, over the long term, is correct.

Figure 3 is a plot of the Y component in body axes of S/C angular velocity for the HEADS UP run. It is not a constant, but it does remain in the vicinity of -.05 as is desired. Figure 4 is a plot of Y body rate for the HEADS DOWN run. Keep in mind that with CDUX = 180 a positive Y body rate implies a negative rotation about Y stable member. As can be seen, R64 starts by producing a negative body rate which is the wrong direction since a negative rotation about Y stable member is desired. After a brief time the DAP drives the rate positive. This type of behavior has been observed on the Command Module Simulator and is understandable from the way R64 is programmed. The positive rate achieved is too high and eventually the DAP slows the vehicle down, so much so that the rate is actually driven negative. After a brief time, the rate is again driven positive. This cycle can be seen to repeat as time passes and is the rate history that corresponds to the saw tooth CDUY history of Figure 2. All the changes in rate shown in Figure 4 are, of course, the result of jet firing.

One indicator of the efficiency of DAP operation is the phase plane. Figure 5 is the Y phase plane for the HEADS UP run showing a nice small limit cycle centered near the horizontal axis. Figure 6, on the other hand, is the Y phase plane for the HEADS DOWN run. Here the height of the limit cycle is much greater and is centered considerably above the horizontal axis indicating less efficient operations.

Of course the most important criterion for judging efficiency is fuel consumption. Table 2 is a summary of jet activity and fuel usage for the HEADS UP run. Total firings is 22 and total fuel is 0.17 lbs. The same summary for the HEADS DOWN run, Table 3, shows total firings to be 90 and total fuel to be 1.02 lbs. Both runs are of exactly the same length.

CONCLUSION

Analysis of the simulation runs indicates that flying heads down in R64 at -0.0507 deg/sec will work but at a penalty in smoothness and efficiency. The S/C motion will be considerably more jerky than flying heads up in R64. The S/C will fly in the correct direction for a while at too high a rate then briefly reverse its direction and effectively back up a bit then start forward again and so on. Fuel usage will be considerably higher for heads down operation. Comparison of the two simulations discussed in this memo shows fuel usage to be increased by a factor of six. Actual increase in flight may be greater or less depending on what disturbances the S/C experiences.

TABLE 1

Astronaut sequence for both simulation runs.

```
T = 5 V 48E
IF V 04 N 46 THEN PROCEED
IF V 06 N 47 THEN PROCEED
IF V 06 N 48 THEN PROCEED
T = 15 V 46 E
T = 17 V 79 E
IF V 06 THEN V 25 E
IF V 21 THEN -00507 E
IF V 22 THEN +00050 E
IF V 23 THEN +11111 E
WAIT 2 PROCEED
```

TABLE 2

Jet firing and fuel consumption table for HEADS UP simulation run

RCS JET #	TIME ON	# FIRINGS	FUEL USED
1	0.01	1	0.00
2	0.05	3	0.02
3	0.01	1	0.00
4	0.05	3	0.02
5	0.01	1	0.00
6	0.02	2	0.01
7	0.01	1	0.00
8	0.02	2	0.01
9	0.00	0	0.00
10	0.00	0	0.00
11	0.00	0	0.00
12	0.00	0	0.00
13	0.02	2	0.01
14	0.02	2	0.01
15	0.02	2	0.01
16	0.02	2	0.01
ALL JETS	0.28	22	0.17

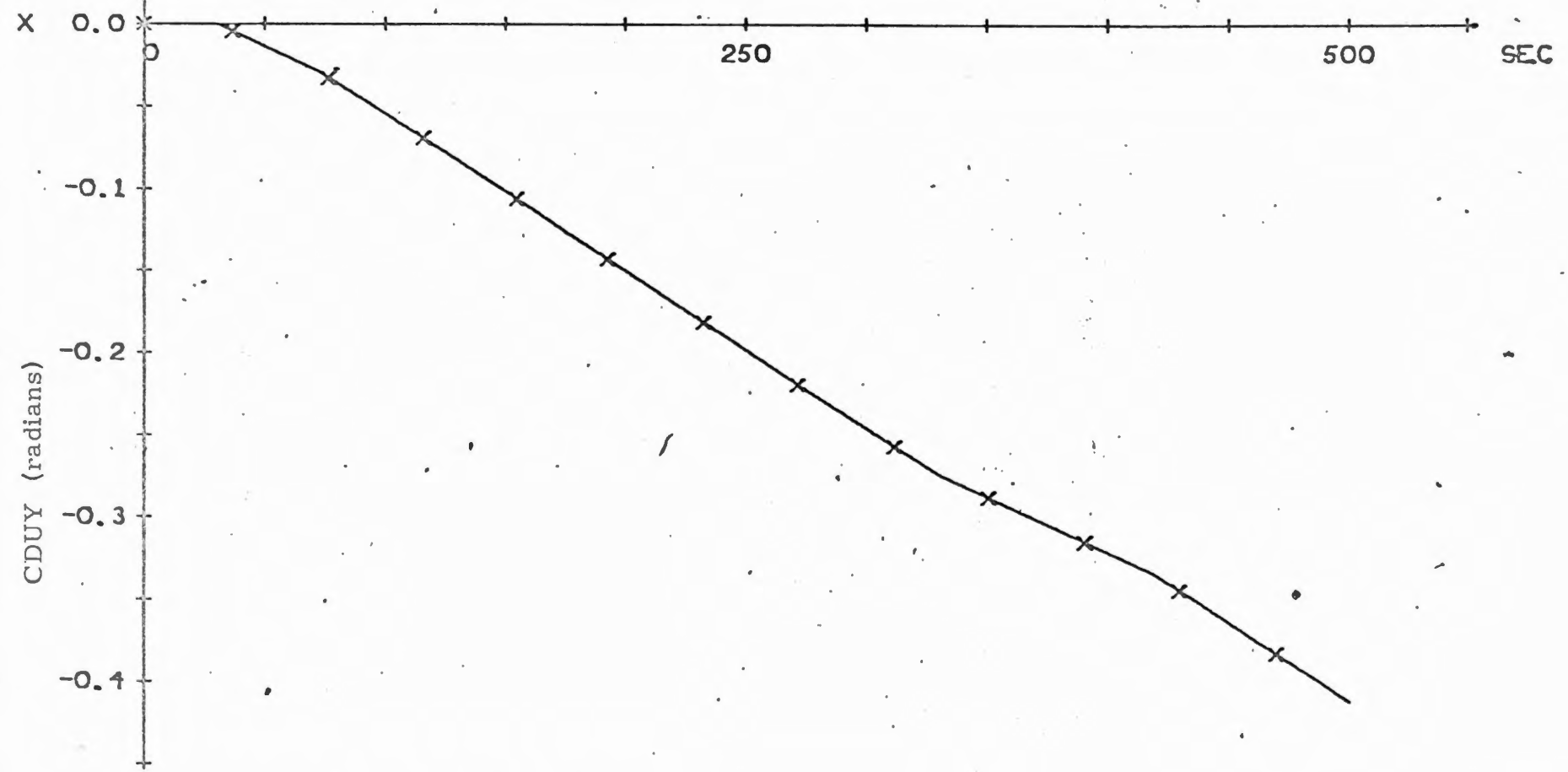
Jet firing and fuel consumption table for HEADS DOWN simulation run

RCS JET #	TIME ON	# FIRINGS	FUEL USED
1	0.45	31	0.26
2	0.47	7	0.19
3	0.45	31	0.26
4	0.47	7	0.19
5	0.02	2	0.01
6	0.01	1	0.00
7	0.02	2	0.01
8	0.01	1	0.00
9	0.00	0	0.00
10	0.00	0	0.00
11	0.00	0	0.00
12	0.00	0	0.00
13	0.02	2	0.01
14	0.02	2	0.01
15	0.02	2	0.01
16	0.02	2	0.01
ALL JETS	2.00	90	1.02

X IS VAR 05

Figure 1 CDUY vs. TIME for HEADS UP simulation run

TIME



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MARSROT 25923025 TURNBULL

HEADS UP

HEADS UP

05

X IS VAR 05

Figure 2 CDUY vs. TIME for HEADS DOWN simulation run

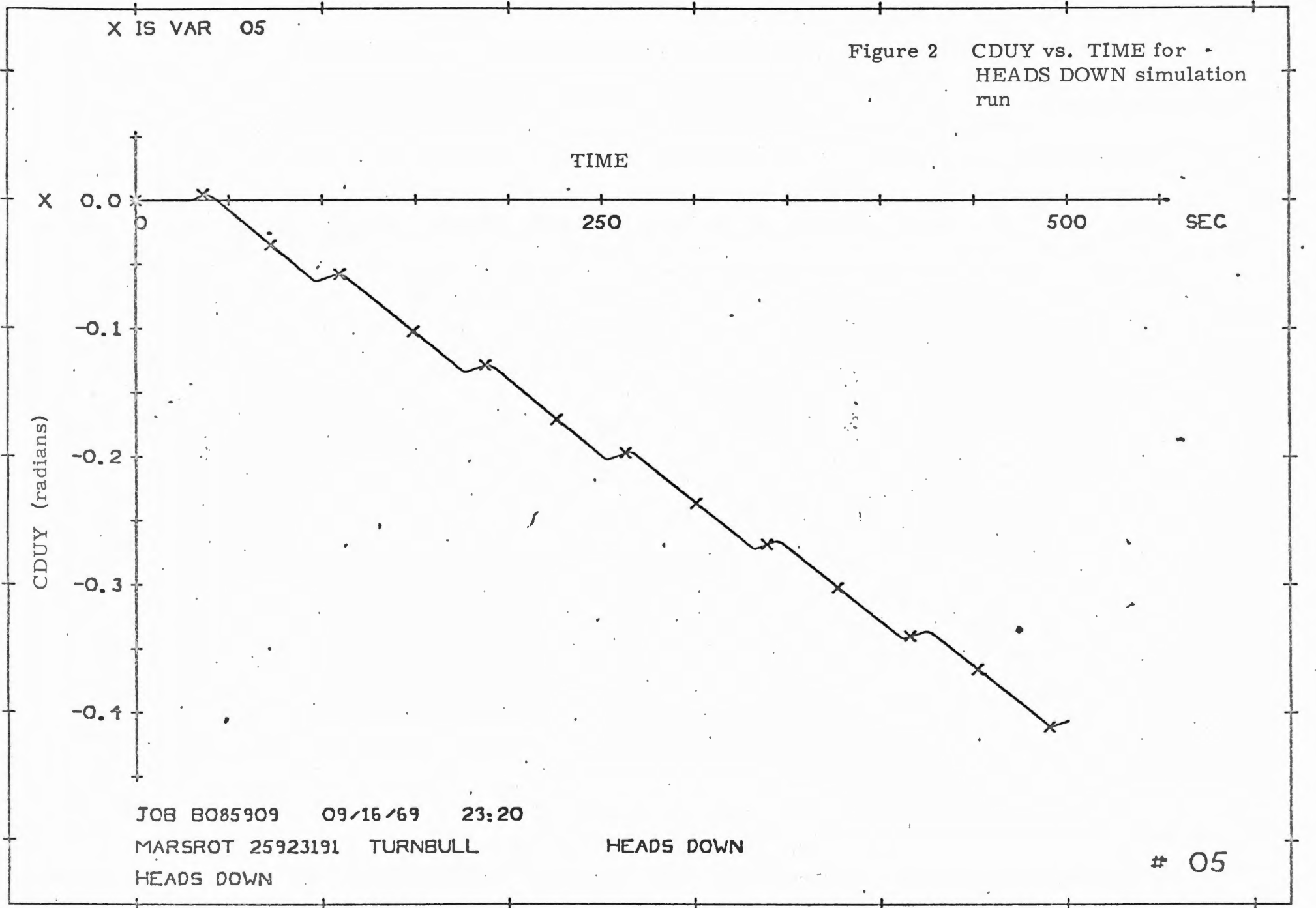
TIME

X 0.0 250 500 SEC

CDUY (radians)

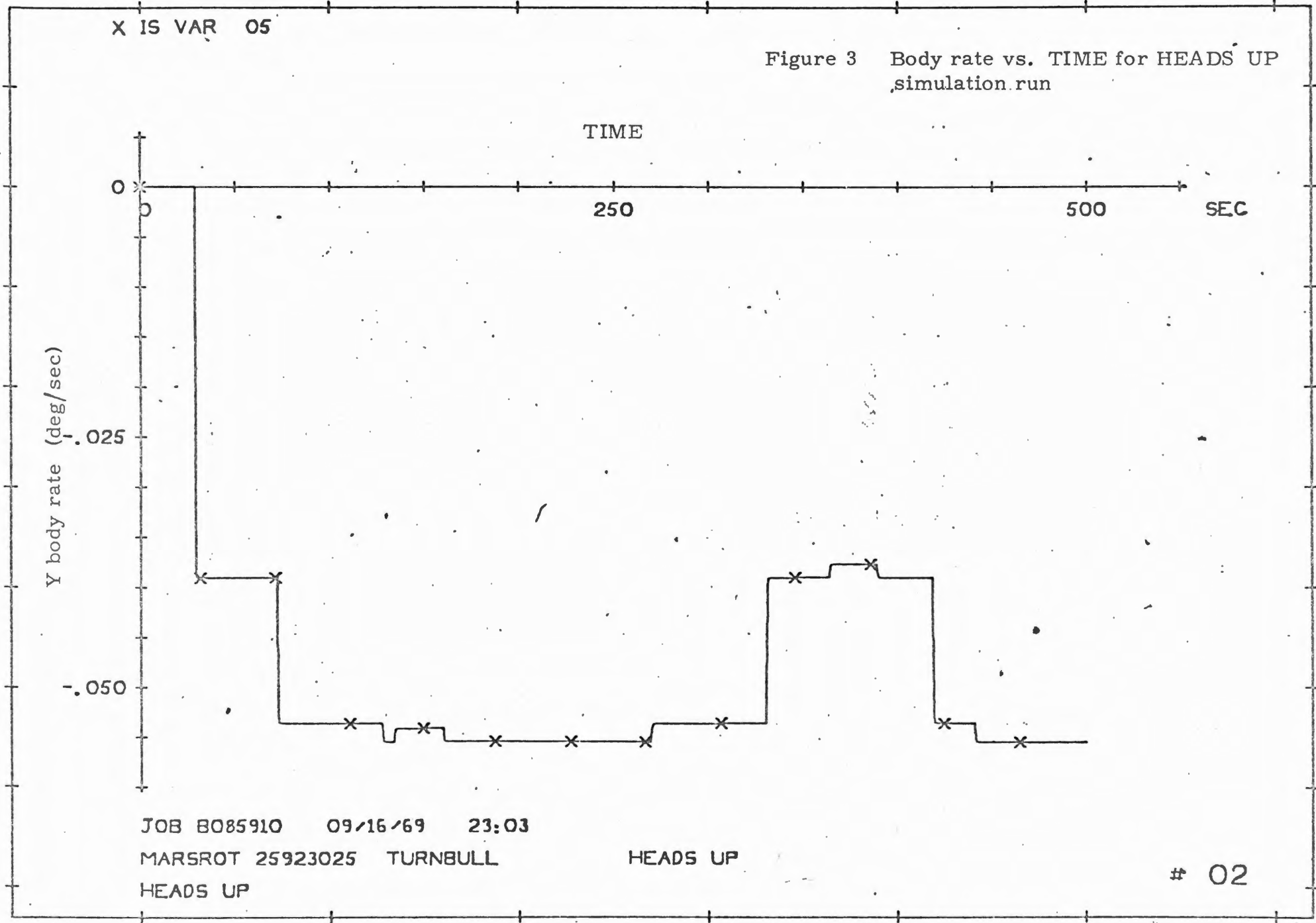
-0.1
-0.2
-0.3
-0.4

JOB B085909 09/16/69 23:20
MARSROT 25923191 TURNBULL HEADS DOWN # 05
HEADS DOWN



X IS VAR 05

Figure 3 Body rate vs. TIME for HEADS UP simulation run



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MARSROT 25923025 TURNBULL

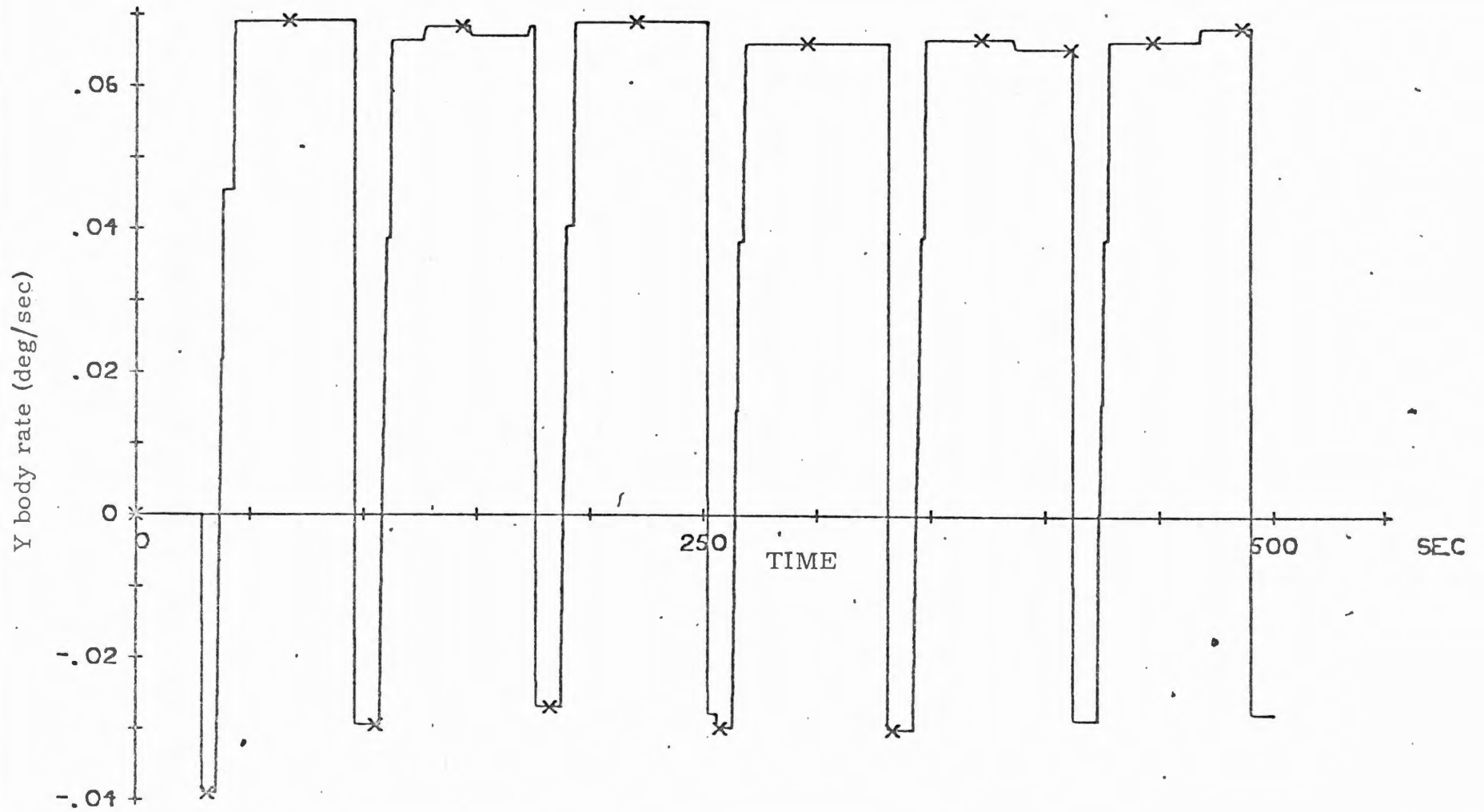
HEADS UP

HEADS UP

02

X IS VAR 05

Figure 4 Y body rate vs. TIME for HEADS DOWN simulation run



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MARSROT 25923191 TURNBULL

HEADS DOWN

HEADS DOWN

02

Figure 5 Y phase plane for HEADS UP simulation run

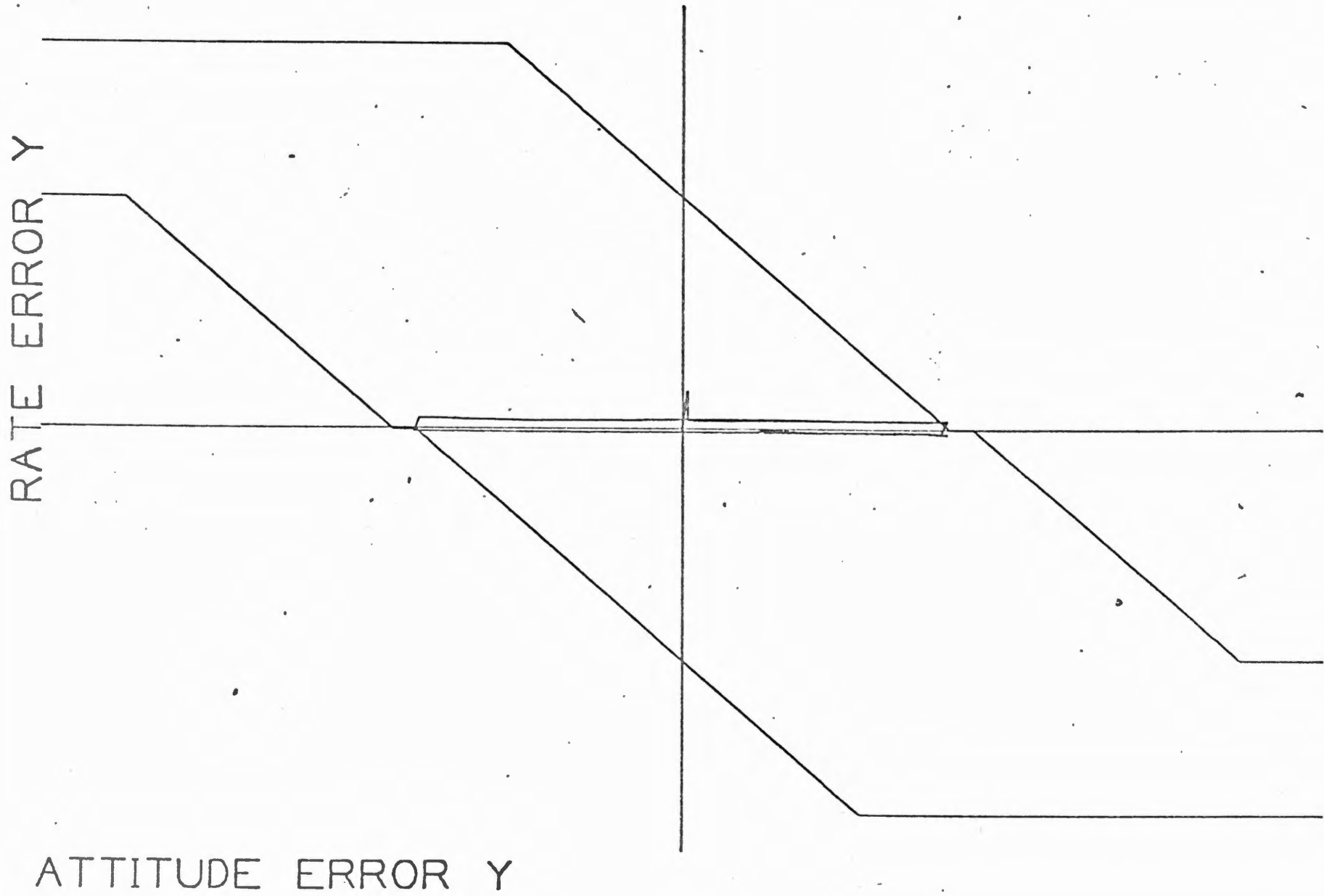


Figure 6 Y phase plane for HEADS DOWN simulation run

