

Massachusetts Institute of Technology
Instrumentation Laboratory
Cambridge, Massachusetts

COLOSSUS Memo # 148

TO: Distribution
FROM: Joe Turnbull
DATE: 30 January 1969
SUBJECT: Orbital Rate (and Passive Thermal Control) Operational
Information for COLOSSUS 1A* (Rev. 249)

I. Erasable Load Procedure for Rotation about Y Stable Member
(Orbital Rate)

Colossus Memo #143 outlined a procedure which effectively will produce orbital rate S/C rotation. The procedure outlined in this memo is longer but because it supplies more information to the DAP, will save RCS fuel. The exact saving will be dependent on the rotation rate commanded, the weight and configuration of the vehicle involved, and the presence of disturbance torques. It is expected that the longer procedure can cut fuel consumption by a factor of 4 in some cases.

The following assumptions have been made. In earth or moon orbit Y stable member is assumed to be aligned with $V \times R$. Desired middle gimble angle (CDUZ) is assumed to be zero. The desired rate about Y stable member will be called ORBRATE and is assumed to be 0.1 deg/sec or less in magnitude. If the above assumptions restrict mission profile, contact Joe Turnbull, MIT Ext. 1593, for tradeoffs involved in changing the assumptions.

The procedure is:

V49 E

Load gimbal angles that are to be the gimbal angles at the initiation of orbital rate rotation.
(Middle gimbal angle should be zero.)

* Memo will be revised shortly for COLOSSUS 2.

PROCEED on V06 N22

CMC MODE switch in AUTO

PROCEED on V50 N18

ENTER on V50 N18

It is not necessary that the above sequence result in physical motion of the S/C. In other words, it may be a trivial maneuver to present attitude. Nevertheless, the sequence of key strokes should be executed so that erasable memory is properly setup.

After the V49 maneuver, execute the following:

V24 N01 ENTER

3127 ENTER (address of high order part of WBODY1)

VVVVV ENTER

WWWWW ENTER

V24 ENTER

3131 ENTER (address of high order part WBODY2)

XXXXX ENTER

YYYYY ENTER

V21 ENTER

3200 ENTER (address of low order part of DELCDUY)

ZZZZZ ENTER

The maneuver will now be in progress.

The maneuver can be terminated by switching the CMC MODE switch to HOLD, keying V46E, or by RHC activity.

The numbers VVVVV through ZZZZZ are octal numbers and have the following significance.

VVVVV and WWWW are the high and low order parts of the double precision representation of WBODY1, the Y control axis component of rotation rate.

XXXXX and YYYYY are the high and low order parts of the double precision representation of WBODY2, the Z control axis component of rotation rate.

ZZZZZ is the low order part of the double precision representation of DELCDUY, the incremental angle for CDUY. For rates less than 0.1 deg/sec the high order part is zero and need not be loaded.

Table 1 presents values to be loaded for XXXXX through ZZZZZ for a number of ORBRATEs and for four values of CDUXD. In order that no more non-zero digits be loaded than is necessary, values of WWWW and YYYYY have been rounded to three significant digits. This yields representations of WBODY1 and WBODY2 accurate to within 10^{-4} deg/sec.

TABLE 1

CDUX ORBRATE				
	0 deg	+90 deg	+180 deg	+270 deg
-0.100 deg/sec	VVVVV = 77774	00000	00003	00000
	WWWWW = 54300	61300	23500	16500
	XXXXX = 00000	00003	00000	77774
	YYYYY = 61300	23500	16500	54300
	ZZZZZ = 42676	42676	42676	42676
-0.095	VVVVV = 77774	00000	00003	00000
	WWWWW = 62200	62000	15600	16000
	XXXXX = 00000	00003	00000	77774
	YYYYY = 62000	15600	16000	62200
	ZZZZZ = 44250	44250	44250	44250
-0.090	VVVVV = 77774	00000	00003	00000
	WWWWW = 70000	62600	10000	15200
	XXXXX = 00000	00003	00000	77774
	YYYYY = 62600	10000	15200	70000
	ZZZZZ = 45622	45622	45622	45622
-0.085	VVVVV = 77774	00000	00003	00000
	WWWWW = 75600	63400	02200	14400
	XXXXX = 00000	00003	00000	77774
	YYYYY = 63400	02200	14400	75600
	ZZZZZ = 47173	47173	47173	47173
-0.080	VVVVV = 77775	00000	00002	00000
	WWWWW = 43400	64100	34400	13700
	XXXXX = 00000	00002	00000	77775
	YYYYY = 64100	34400	13700	43400
	ZZZZZ = 50545	50545	50545	50545
-0.075	VVVVV = 77775	00000	00002	00000
	WWWWW = 51300	64700	26500	13100
	XXXXX = 00000	00002	00000	77775
	YYYYY = 64700	26500	13100	51300
	ZZZZZ = 52117	52117	52117	52117

TABLE 1 (Cont.)

CDUX ORBRATE				
	0 deg	+90 deg	+180 deg	+270 deg
-0.070 deg/sec	VVVVV = 77775	00000	00002	00000
	WWWWW = 57100	65500	20700	12300
	XXXXX = 00000	00002	00000	77775
	YYYYY = 65500	20700	12300	57100
	ZZZZZ = 53467	53467	53467	53467
-0.065	VVVVV = 77775	00000	00002	00000
	WWWWW = 64700	66300	13100	11500
	XXXXX = 00000	00002	00000	77775
	YYYYY = 66300	13100	11500	64700
	ZZZZZ = 55041	55041	55041	55041
-0.060	VVVVV = 77775	00000	00002	00000
	WWWWW = 72500	67100	05300	10700
	XXXXX = 00000	00002	00000	77775
	YYYYY = 67100	05300	10700	72500
	ZZZZZ = 56413	56413	56413	56413
-0.055	VVVVV = 77776	00000	00001	00000
	WWWWW = 40300	67600	37400	10200
	XXXXX = 00000	00001	00000	77776
	YYYYY = 67600	37400	10200	40300
	ZZZZZ = 57765	57765	57765	57765
-0.050	VVVVV = 77776	00000	00001	00000
	WWWWW = 46200	70400	31600	07400
	XXXXX = 00000	00001	00000	77776
	YYYYY = 70400	31600	07400	46200
	ZZZZZ = 61337	61337	61337	61337

The octal numbers can be generated as follows. Let ORBRATE be the desired rate in deg/sec about the Y stable member axis. This angular rate can be transformed into an angular velocity coordinatized in RCS control axes by a matrix transformation. For zero desired middle gimbal angle and constant desired outer gimbal angle, CDUX , the transformation is

$$\begin{pmatrix} \text{WBODY} \\ \text{WBODY1} \\ \text{WBODY2} \end{pmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\text{CDUX} - 7.25^\circ) & \sin(\text{CDUX} - 7.25^\circ) \\ 0 & -\sin(\text{CDUX} - 7.25^\circ) & \cos(\text{CDUX} - 7.25^\circ) \end{bmatrix} \begin{bmatrix} 0 \\ \text{ORBRATE} \\ 0 \end{bmatrix}$$

This implies that

$$\begin{aligned} \text{WBODY} &= 0 \\ \text{WBODY1} &= \text{ORBRATE} \cos(\text{CDUX} - 7.25^\circ) \\ \text{WBODY2} &= -\text{ORBRATE} \sin(\text{CDUX} - 7.25^\circ) \end{aligned}$$

At this point WBODY1 and WBODY2 are signed decimal numbers. The next step is to convert WBODY1 and WBODY2 to their octal machine representation. The procedure for both is the same so from this point everything that is said for WBODY1 applies equally to WBODY2.

In the computer, WBODY1 is a double precision quantity scaled at 450 deg/sec. To get its octal value multiply the magnitude of the decimal quantity WBODY1 by 596, 523 and round of the result to the nearest integer.

$$A = \text{ROUND} \left\{ 596, 523 \text{ WBODY1} \right\}$$

Divide A by 16, 384

$$B = \frac{A}{16,384}$$

B will have the form C.DDD where

C will be 0, 1, 2, or 3 if $|\text{RATE}| \leq 0.1 \text{ deg/sec}$

If $C = 0$ set $VVVVV = 00000$

If $C \neq 0$ and $WBODY1$ is positive set $VVVVV = 0000C$

If $C \neq 0$ and $WBODY1$ is negative set $VVVVV = 77777 - 0000C$

Compute the number E as

$$E = A - C \cdot 16,384$$

E should be an integer between 0 and 16,384

Convert the decimal integer E to its octal equivalent, $EOCT$.
This will be an octal number between 0 and 37777.

If $WBODY1$ is positive set $WWWWW = EOCT$

If $WBODY1$ is negative set $WWWWW = 77777 - EOCT$.

The low order part of $DELCDUY$ is computed as follows.

Multiply the magnitude of rate by 149,131 and round the product to the nearest integer

$$F = \text{round} \left\{ 149,131 \text{ RATE} \right\}$$

Convert F to its octal equivalent, $FOCT$.

Since for orbital rate $ORBRATE$ will be negative
set $ZZZZZ = 77777 - FOCT$.

II. Erasable Load Procedure for Rotation about Vehicle X Axis (PTC)

A procedure similar to that for ORBRATE can be used to produce an X axis rotation for Passive Thermal Control.

The procedure is as follows

V49 E

Load gimbal angles that are to be the gimbal angles at the initiation of PTC.

PROCEED on V06 N22

CMC MODE switch in AUTO

PROCEED on V50 N18

ENTER on V50 N18

It is not necessary that the above sequence result in physical motion of the S/C. In other words, it may be a trivial maneuver to present attitude, but nevertheless, the sequence of key strokes should be expected so that erasable memory is properly setup.

After V49 execute the following:

V24 N01 ENTER

3125 ENTER (address of WBODY)

SSSSS ENTER

TTTTT ENTER

V21 ENTER

3176 ENTER (address of low order part of DELCDUX)

UUUUU ENTER

The maneuver will now be in progress.

The maneuver can be terminated by switching the CMC MODE switch to HOLD, by keying V46E, or by RHC activity.

The numbers SSSSS through UUUUU are octal numbers and have the following significance:

SSSSS and TTTTT are the high and low order parts of the double precision representation of WBODY, the X axis rotation rate.

UUUUU is the low order part of the double precision representation of DELCDUX.

For a PTC rate of +0.1 deg/sec:

SSSSS = 00003

TTTTT = 24400

UUUUU = 35101

For a PTC rate of -0.1 deg/sec:

SSSSS = 77774

TTTTT = 53400

UUUUU = 42676

Rates other than ± 0.1 deg/sec can just as easily be obtained by loading WBODY and DELCDUX with appropriate numbers. Rates greater than .11 deg/sec require loading the upper as well as lower part of DELCDUX which would be a simple modification of the above procedure.

III. Some Comments on Fuel Consumption

The RCS DAP is designed so that in the absence of disturbance torques, it will approach minimum impulse limit cycle operation during attitude hold and low rate maneuvers. During minimum impulse limit cycle operation, disabling two adjacent quads will cut RCS fuel consumption by as much as a factor of four. The quads can be disabled by using R03 or by use of the 16 jet switches in the cockpit.

If there are no disturbance torques or there are to be no changes in maneuver rate, then R03 need not be used. However, if disturbance torques are present or if manual or V49 maneuvering is to be done, then DAP performance will be more satisfactory if R03 is used either by itself or in addition to the 16 jet switches so that the DAP is informed of disabled jets.

In the presence of disturbance torques large enough so that limit cycling is against one side of the deadband only, RCS fuel consumption will be determined by the amount of jet firing needed to cancel the average disturbance torque.

For maximum fuel economy during ORBRATE and PTC control, it is our recommendation to use R03 to disable two adjacent quads. This is not the only alternative as evidenced by the discussion in the three preceeding paragraphs, but it is a simple and effective alternative for all conditions.