U.S. Government

MEMORANDUM

Lyndon B. Johnson Space Center

NASA

REFER TO:	DATE	INITIATOR	ENCL
CB-76-042	4/14/76	CB/RLCrippen:cao:4/14/76:2221	3

TO: CB, TE, DF/All Astronauts

CC

FROM: CB/R. L. Crippen

SIGNATURE

Robert L. Crippen /Crip/

SUBJ: Orbiter Crew Reference Systems or Which Way is Up?

The software world is starting to firm up on-orbit requirements. This includes how the crew reads attitude and how we perform maneuvers. Which brings us around to our old friend the aft station and its orientation.

We are basically designing the system to work around a single reference system which is front-of-the-vehicle oriented.

Al Bean has raised the question, "Do we need to have an additional system that is top-of-the-vehicle oriented?"

The enclosed paper attempts to describe what we have now.

We intend to meet next week to try and decide whether we should go with one or two systems.

If you have any comments, please let us hear them.

ON-ORBIT ORIENTATION FOR SHUTTLE

The purpose of this paper is to describe the crew reference systems currently being baselined for the Space Shuttle Orbiter.

Certain basic facts should be acknowledged initially:

1. The Orbiter has three 4-gimbal IMU's which even when aligned together (which is not the case for end of mission and entry) still have slight misalignments, and thus each must be transformed to NAV BASE (body). Hence, it no longer is required; nor is it reasonable to constrain the crew's ADI's to represent the IMU's inertial orientation.

2. There are three ADI's in the crew station (left, right, and aft). Each is capable of being powered individually. All ADI's can display the Orbiter's attitude with respect to three reference frames independently. There are two inertial references and one LVLH (similar to ORDEAL) frame. They are described in Enclosure 2.

3. The ADI's are like those used in the Command Module. They are constructed as pitch, yaw, roll Euler sequence balls.

4. The aft ADI ball is physically numbered different from the front ADI's. Pitch and roll numbers are reversed to allow the front and aft balls to read the same attitude numbers when they are selected to common reference frames.

5. A "SENSE" switch at the aft panel changes the effective ball orientation from "-X" to "-Z" to facilitate pilot maneuver coordination from both the aft facing window and the top window. The rotation sense is noted in Enclosure 2, and examples are illustrated in Enclosure 3 courtesy of Bob Anderson. The aft station effective orientation of the RHC, THC, and rotation DAP panel are also changed by the "SENSE" switch.

The CRT SPEC functions are being designed to accept crew input and display attitude information in terms of:

1. Vehicle body axes (X, Y, and Z), and

2. The INRTL inertial frame.

This means that delta velocity of burns will be displayed as V_{GO} X, Y, and Z. Hence, when using the THC at the aft station to trim residuals or execute RCS burns, the operator must be aware of the SENSE switch selection and his orientation with respect to the body axes.

It also means that maneuvers and body attitude will be input and displayed on CRT's as roll, pitch, and yaw numbers that will agree with all ADI ball readings if the ADI ATTITUDE switch is set to INTRL and the aft ADI SENSE switch set to -X. The intent was to keep a single reference for handling maneuvers.

It should also be noted that for the aft ADI if the SENSE switch is at -X and the ball is reading 0, 0, 0 it will also be reading 0, 0, 0 when -Z is selected. If a pitch maneuver is performed the ball numbers are the same for both -X and -Z. For any roll or yaw maneuver the numbers cannot be easily correlated between -X and -Z. Hence, with the current mechanization the numbers on the ball are not very useful in the -Z position. The ADI itself is still useful with -Z selected for determing relative movement from a selected attitude (attitude error) and attitude rates.

ON-ORBIT ATTITUDE DIRECTOR INDICATOR PROCESSING

This principal function prepares data for display, independently, on the left, right, and aft ADI displays. This shall include body attitude, body attitude errors, and body rates. The software shall also provide data-valid flags to the indicator. See Figure 4-169 for ORB ADI PROC functional level interfaces.

Functional requirements - During on-orbit flight, the ADI software shall provide for display of the Orbiter attitude to each of the ADI's with respect to the required reference frame indicated by the position of the respective ADI ATTITUDE switch. The attitude shall be defined with respect to the reference frame in a pitch, yaw, roll Euler sequence. An attitude of zero, zero, zero will always be when the X, Y, Z body axes are aligned with the X, Y, Z axes of the reference frame. The selectable reference frames are as follows:

(1) "INRTL" - This is an inertial reference frame defined by a relative matrix (RELMAT) transformation from M50 to a desired inertial orientation. This RELMAT may be changed by ground uplink.

(2) "REF" - This is an inertial reference frame defined by a relative matrix (RELMAT) transformation from M50 to a desired inertial orientation. The RELMAT may be changed by ground uplink and in response to any of the three ATT REF push buttons. When an ATT REF push button is depressed, the current vehicle attitude becomes the new REF inertial reference frame. There is only one such frame which is available to all ADI's.

(3) "LVLH" - This is a local vertical, local horizontal reference frame that is defined as +Z pointed at the center of the earth, +Y pointed opposite to the momentum vector, and +X oriented to make an orthogonal set biased by a transformation matrix. The transformation matrix may be changed by ground uplink.

The ADI software shall drive the error needles to provide a display of the body attitude errors in pitch, roll, and yaw as defined by the Digital Auto Pilot. Scaling of these signals is determined by the setting of the ADI ERROR switch to "HIGH," "MED," or "LOW."

Vehicle pitch, yaw, and roll body rates shall be output by the ADI software to be displayed on the ADI rate needles. Scaling of these outputs is determined by the setting of the ADI RATE switch to "HIGH," "MED," or "LOW."

Pitch, yaw, and roll for the ADI's shall be defined as follows:

(1) Left and Right Forward ADI's

Rotation	Body Axis
Pitch	+Y
Yaw	+Z
Roll	+X

(2) Aft ADI, SENSE switch -X

Rotation	Body Axis
Pitch	-Y
Yaw	+Z
Roll	-X

(3) Aft ADI, SENSE switch -Z

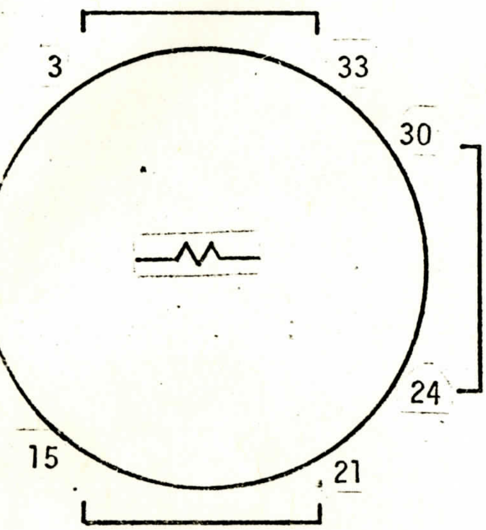
Rotation	Body Axis
Pitch	-Y
Yaw	-X
Roll	-Z

DESCRIPTION

_____ STATION

FRONT | AFT | TOP

WIDOW VIEW



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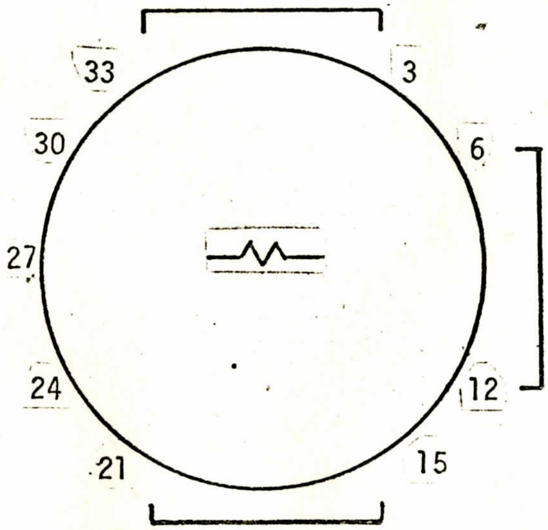

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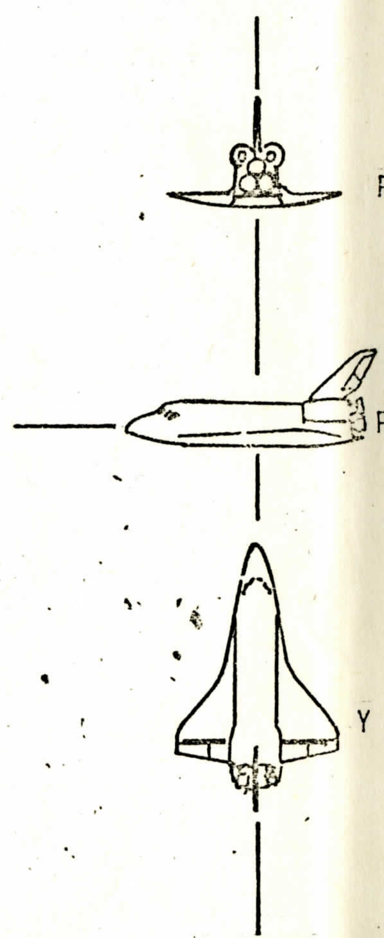
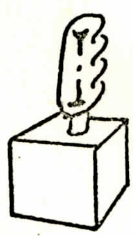
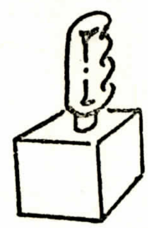


ORBITER MOVEMENT

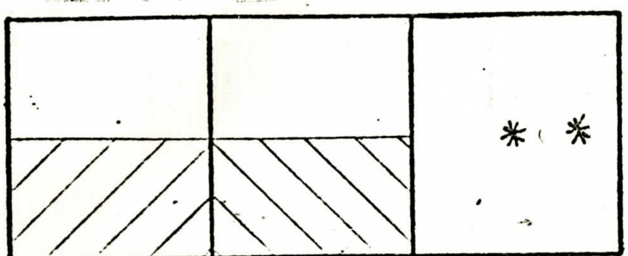


FRONT RHC



AFT RHC

AFT STATION



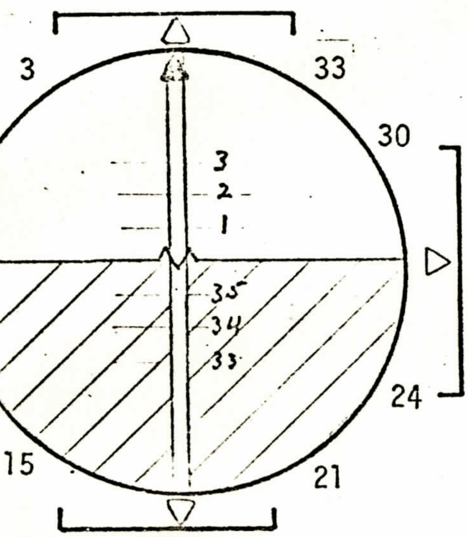
FRONT AFT TOP

WIDOW VIEW

DESCRIPTION

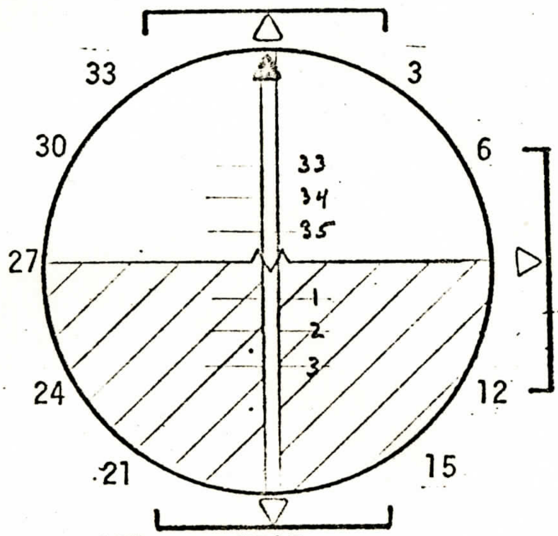
- Pilot at aft station with sense switch at -X.

- Inertial orientation of +X control axis = (0°, 0°, 0°).



FRONT FDAI MOVEMENT

(0,0,0)



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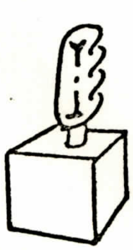
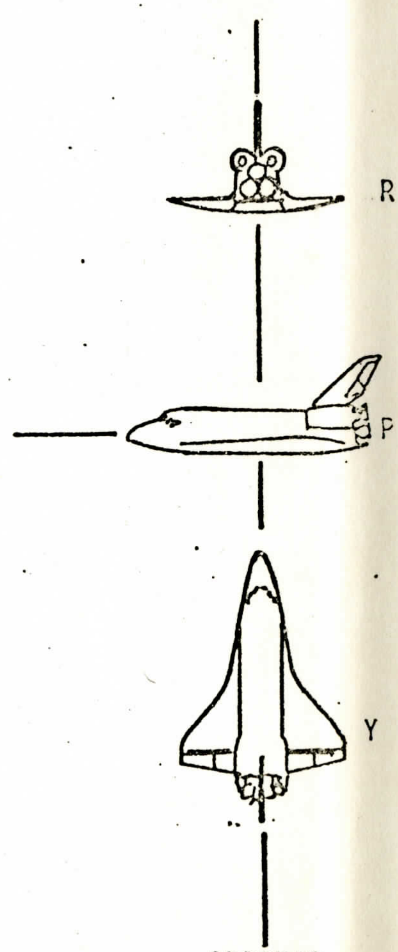
(0,0,0)



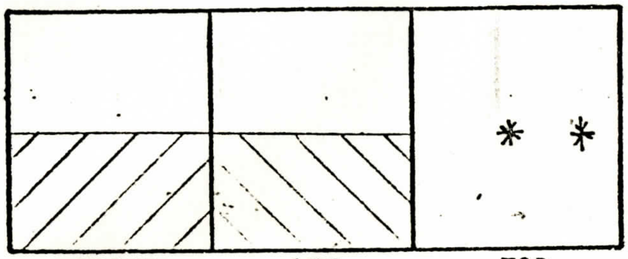
FRONT RHC

AFT RHC



ORBITER MOVEMENT

AFT STATION

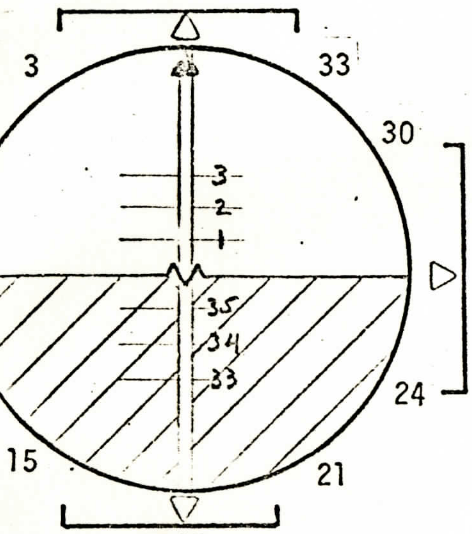


WIDOW VIEW

DESCRIPTION

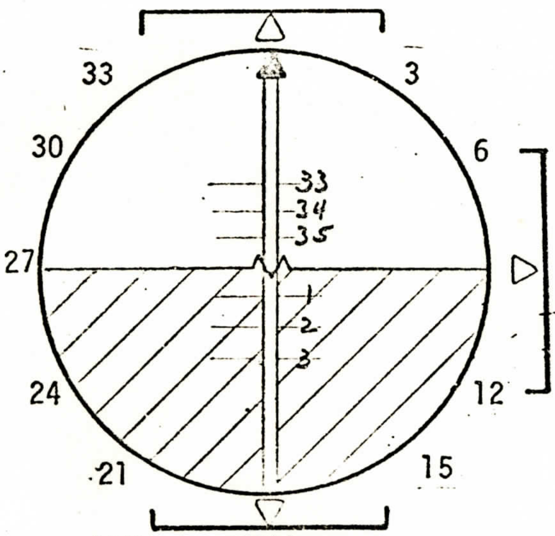
- Pilot switches sense switch to -Z to establish IC.

- Inertial orientation of +X control axis = (0°, 0°, 0°).



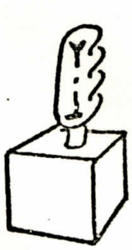
FRONT FDAI MOVEMENT

(0, 0, 0)



AFT FDAI MOVEMENT

(0, 0, 0)



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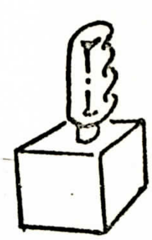
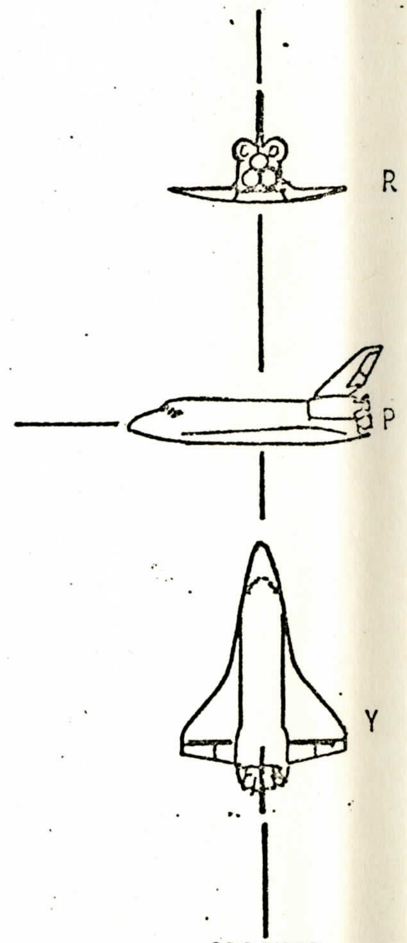
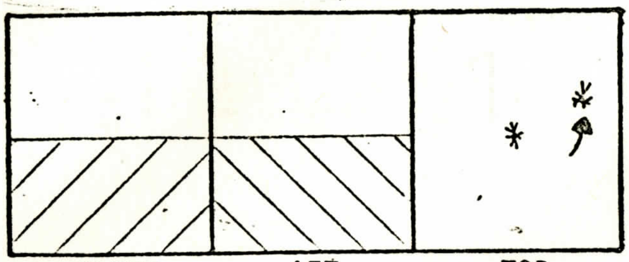


AFT RHC



ORBITER MOVEMENT

__AFT__ STATION

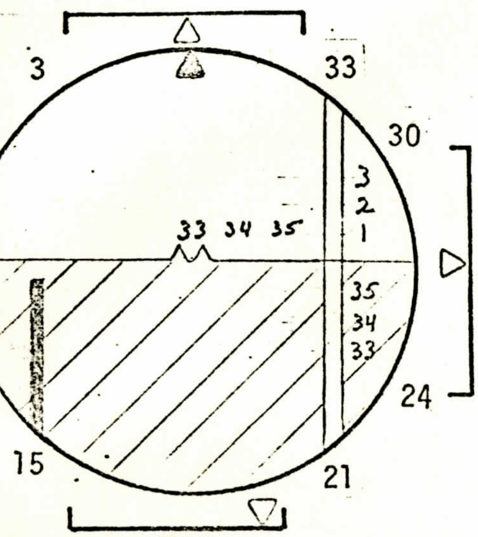


FRONT AFT TOP

WIDOW VIEW

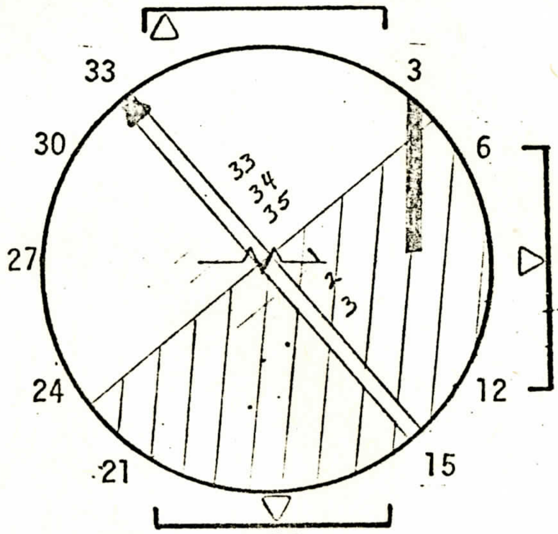
DESCRIPTION

- Pilot rolls right 30° from IC.
- Inertial orientation of +X control axis = (0°, 0°, 330°)



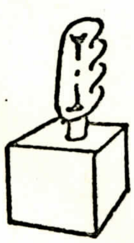
FRONT FDAI MOVEMENT

(0, 0, 330)

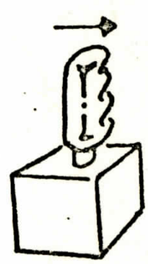


AFT FDAI MOVEMENT

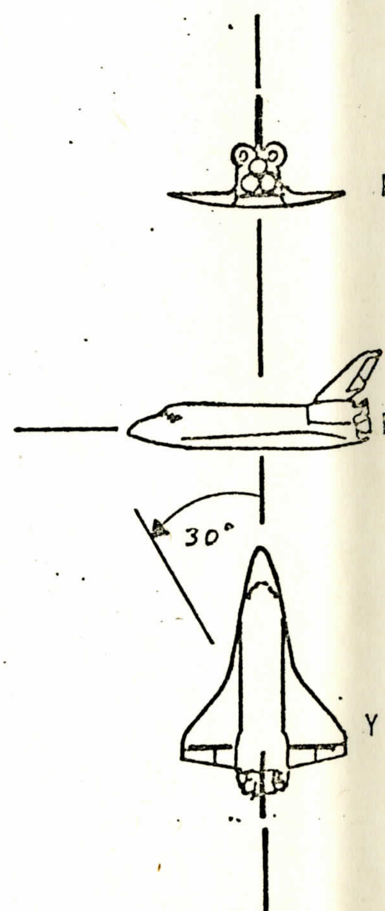
(330, 0, 0)



FRONT RHC

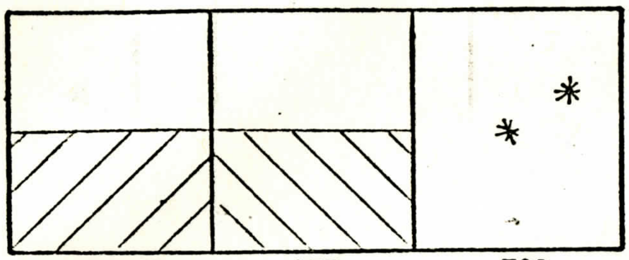


AFT RHC

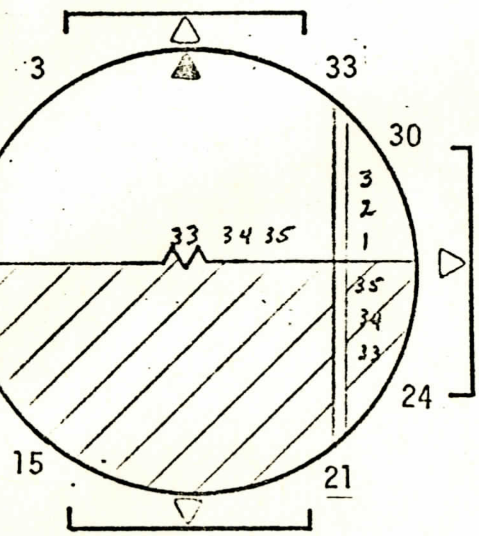


ORBITER MOVEMENT

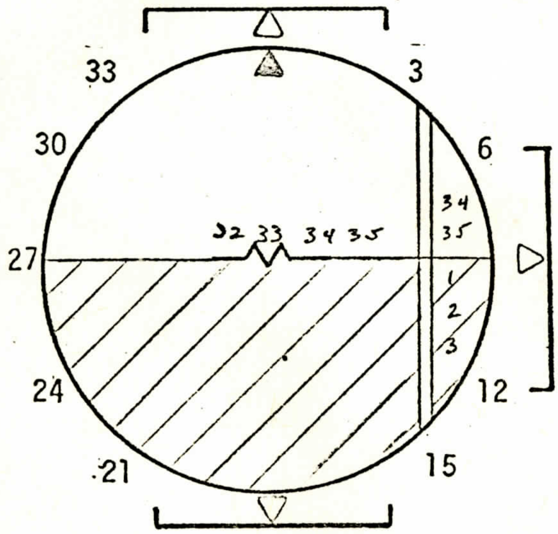
AFT STATION



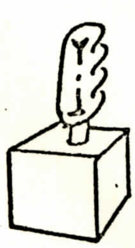
FRONT AFT TOP
WIDOW VIEW



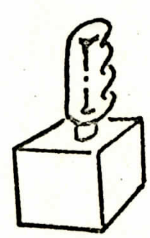
FRONT FDAI MOVEMENT
(0,0,330)



AFT FDAI MOVEMENT
(0,0,330)



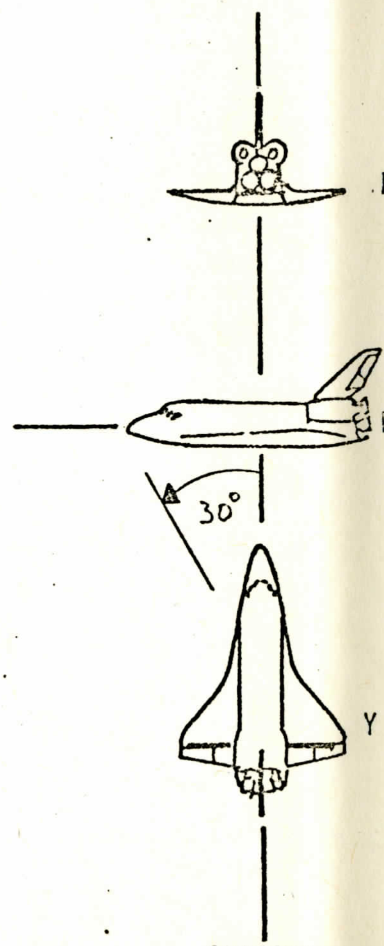
FRONT RHC



AFT RHC

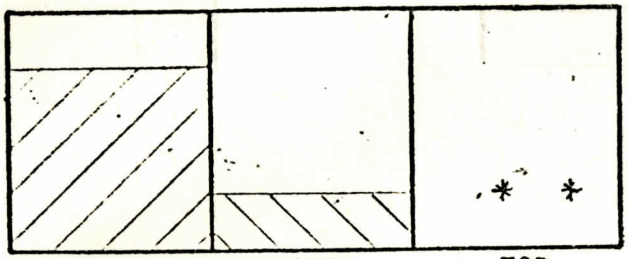
DESCRIPTION

- Pilot places sense switch back to −X, leaving the orbiter in previous attitude
- Inertial orientation of +X control axis = (0°, 0°, 330°)



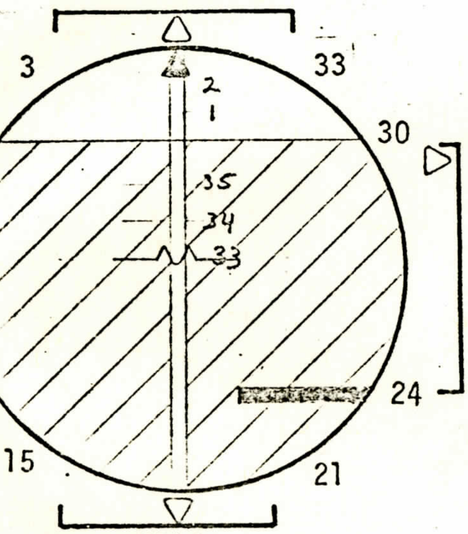
ORBITER MOVEMENT

AFT STATION



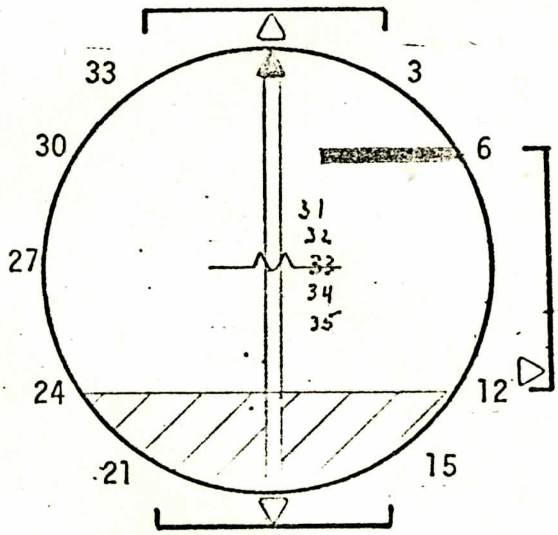
FRONT AFT TOP

WIDOW VIEW



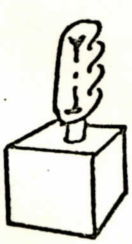
FRONT FDAI MOVEMENT

(0, 330, 0)

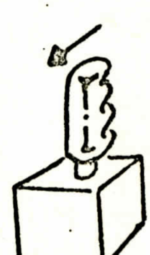


AFT FDAI MOVEMENT

(0,330,0)



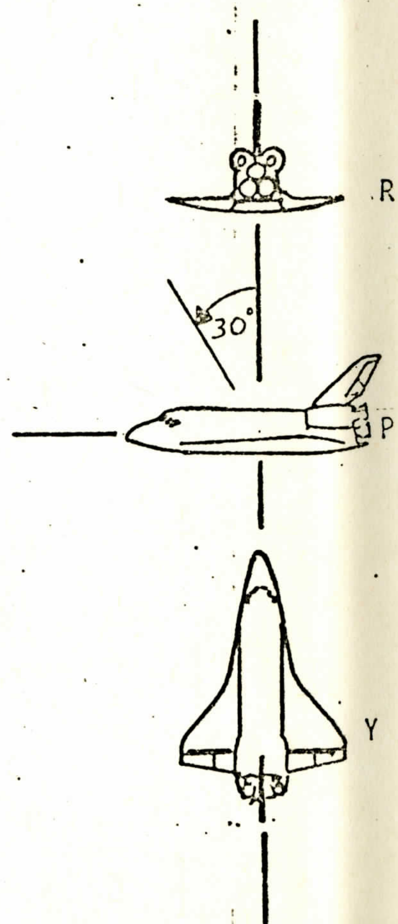
FRONT RHC



AFT RHC

DESCRIPTION

- Pilot pitches up 30° from IC.
- Inertial orientation of +X control axis = (0°, 330°, 0°)



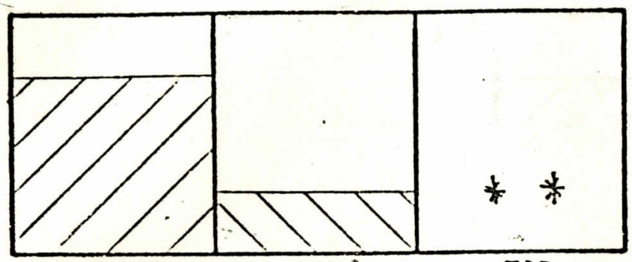
ORBITER MOVEMENT

DESCRIPTION

- *Pilot places sense switch back to -X, leaving the orbiter in previous attitude*

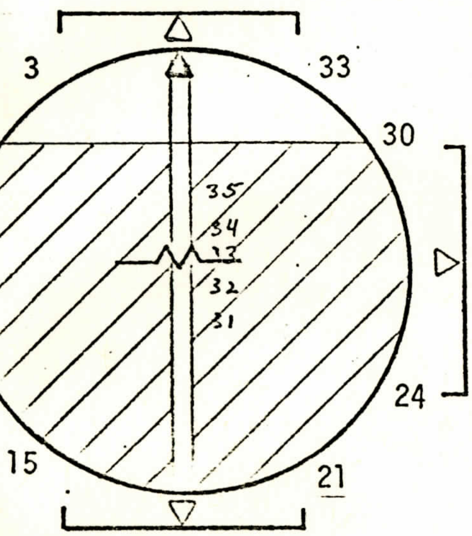
- *Inertial orientation of +X control axis = (0°, 330°, 0°)*

AFT STATION



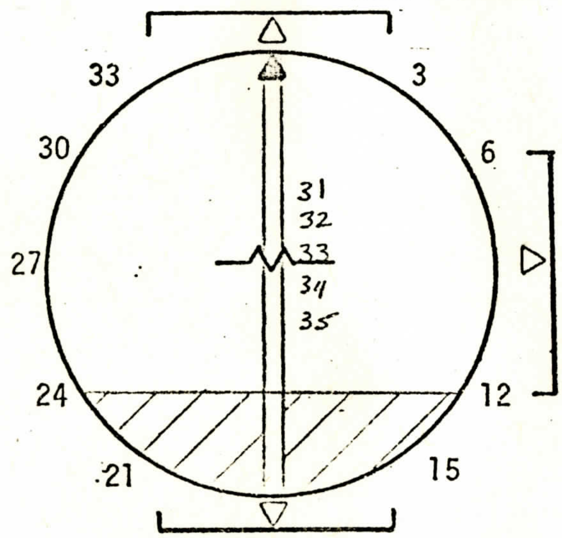
FRONT AFT TOP

WIDOW VIEW



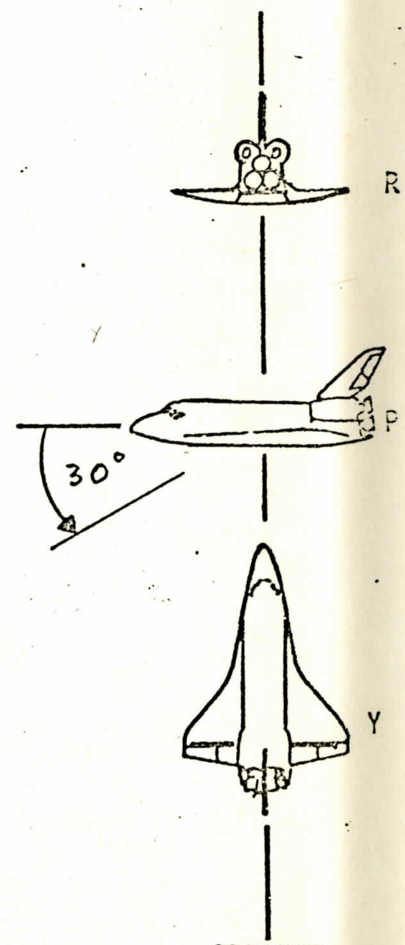
FRONT FDAI MOVEMENT

(0, 330, 0)

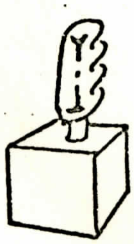


AFT FDAI MOVEMENT

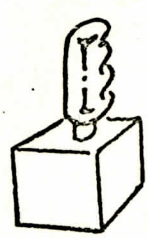
(0, 330°, 0°)



ORBITER MOVEMENT



FRONT RHC



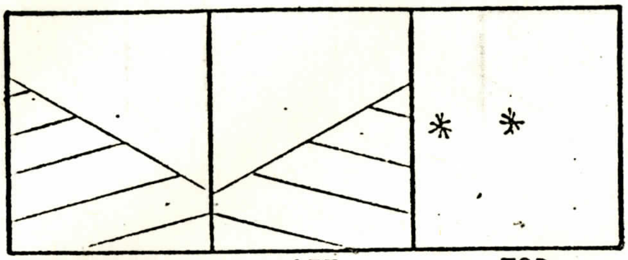
AFT RHC

DESCRIPTION

- Pilot yaws right from IC.

- Inertial orientation of +X control axis = (330°, 0°, 0°)

AFT STATION



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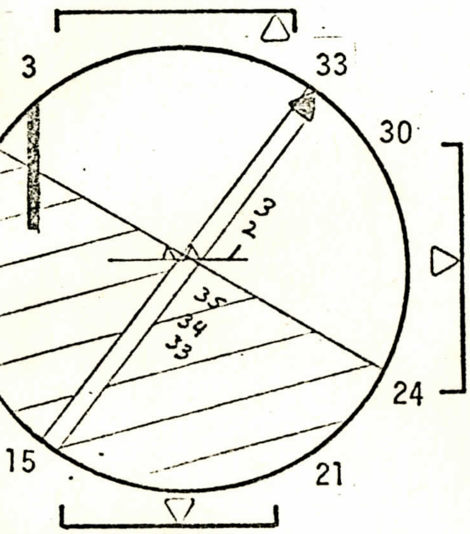
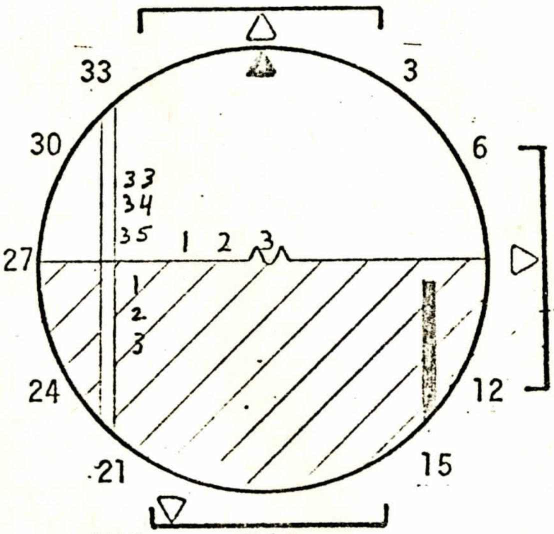
WIDOW VIEW



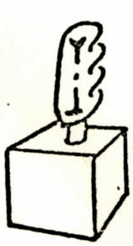
FRONT FDAI MOVEMENT

(330, 0, 0)



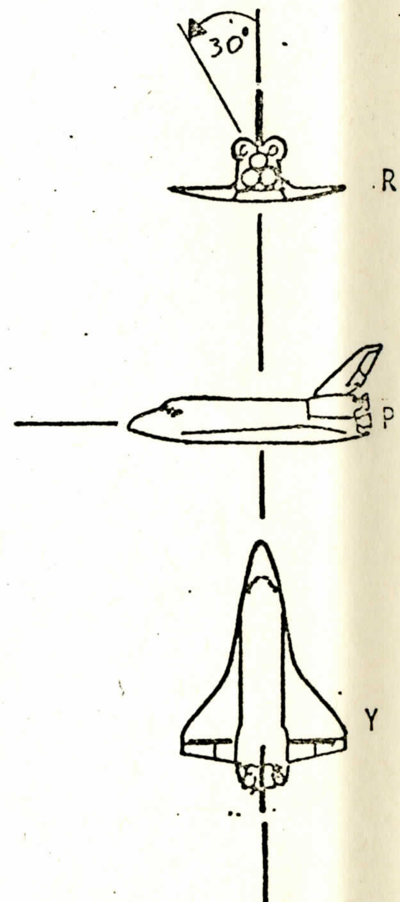
AFT FDAI MOVEMENT

(0, 0, 30)



FRONT RHC

AFT RHC



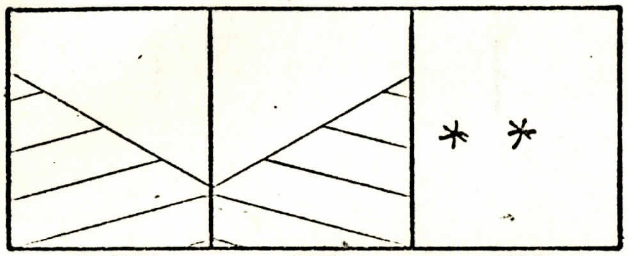
ORBITER MOVEMENT

AFT STATION

DESCRIPTION

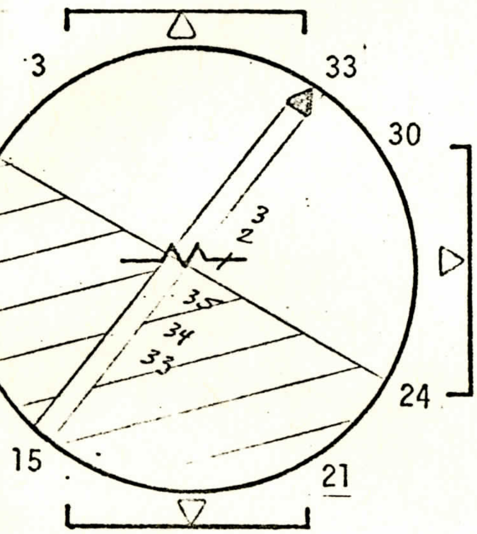
- Pilot places sense switch back to -x, leaving the orbiter in previous attitud

- Inertial orientation of +X control axis = (330°, 0°, 0°)



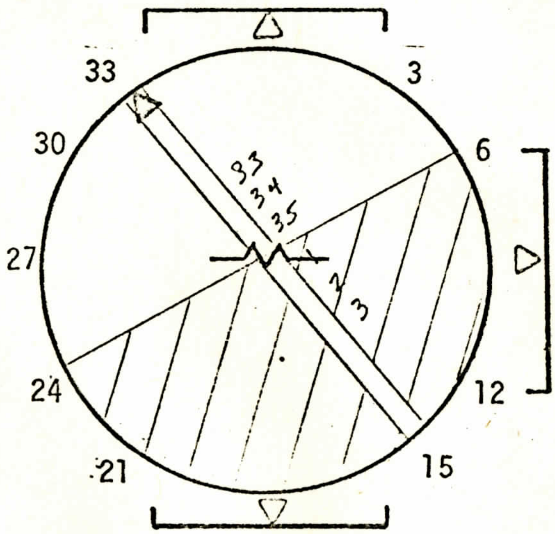
FRONT AFT TOP

WIDOW VIEW



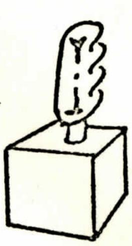
FRONT FDAI MOVEMENT

(330, 0, 0)

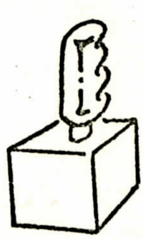


AFT FDAI MOVEMENT

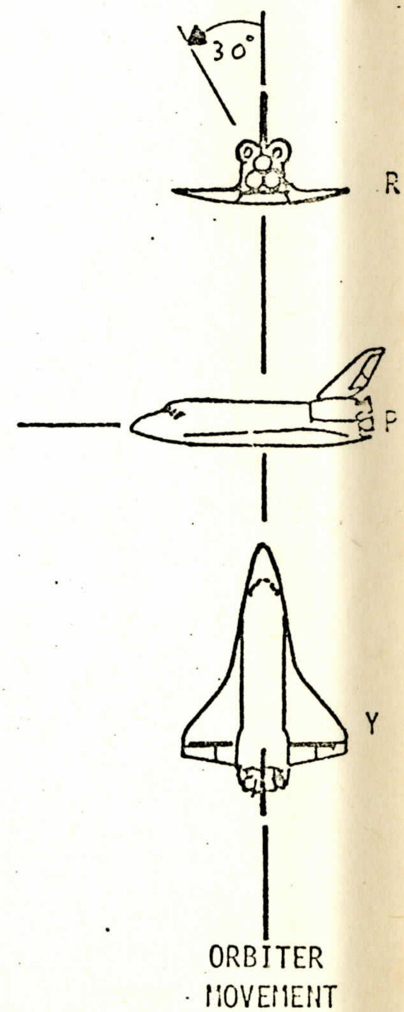
(330, 0, 0)



FRONT RHC



AFT RHC



ORBITER MOVEMENT