The Johns Hopkins University
Applied Physics Laboratory
Laurel, Maryland 20723-6099

Enclosure (3) to:
TSSD-18263

SEM-1-1499
February 11, 1997

TO: J. W. Hunt

FROM: A. C. Sadilek

SUBJECT: ACE Spacecraft Optical Mapping Results

ATTACHMENTS:
(1) ACE Spacecraft Optical Mapping Data and Results
(2) Adcole Corporation DSAD Alignment Fixture Calibration Report
(3) Star Camera Roll Mapping Fixture Calibration
(4) ACE Star Tracker Acceptance Procedure Data Sheets - Boresight Mapping

On 24 January 1997, the ACE Spacecraft was mapped to determine the orientation of the star camera (tracker) and the four DSADs. First the Spacecraft was leveled by autocollimating off faces A and B of the master optical cube. The spacecraft was jacked until the theodolite recorded the elevation of face A = 90° 01′ 55″ and the elevation of face B = 90° 02′ 44″. This aligned the Spacecraft +Z axis with local vertical. Then all following theodolite elevation readings were in spacecraft coordinates. Face A of the master optical cube was used as the azimuth reference, and azimuth values were computed from the Spacecraft +X axis. This setup is shown on page 1 of the ACE Spacecraft Optical Mapping Results attached to this memo. The star camera lens (protective window) was used as a boresight reference. and roll about the boresight was measured using a special fixture with an optical flat epoxied to its side. All four DSADs were mapped using an Adcole DSAD Alignment Fixture. This fixture had been calibrated at Adcole. and its calibration report is attached. The results of the Optical Mapping are as follows:

Star Camera (Tracker);
Boresight Azimuth = 225.0125° from +Xs/c Axis
Boresight Elevation = 89.9561° from +Zs/c Axis
Rotation about Boresight axis = +0.0797°

(A) DSAD # 630;
Boresight Azimuth = 225.0133° from +Xs/c Axis
Boresight Elevation = 124.9754° from +Zs/c Axis
Rotation about DSAD Boresight axis = +0.0962°

(B) DSAD # 631;
Boresight Azimuth = 224.9889° from +Xs/c Axis
Boresight Elevation = 124.9634° from +Zs/c Axis
Rotation about DSAD Boresight axis = –0.0496°

(A) DSAD # 1130;
Rotation of DSAD coordinate system = 225.0354° from +Xs/c Axis
Boresight = –0.0549° from +Zs/c Axis about –X/–Ys/c Axis
= –0.0370° from +Zs/c Axis about –X/+Ys/c Axis

(B) DSAD # 1131;
Rotation of DSAD coordinate system = 224.9732° from +Xs/c Axis
Boresight = –0.0824° from +Zs/c Axis about –X/–Ys/c Axis
= –0.0182° from +Zs/c Axis about –X/+Ys/c Axis

All of the results are within 0.1 degree of nominal values, and the actual values can be used if more accurate attitude determination is required.

Albert C Sadilek
Albert C. Sadilek

Distribution:
MCChiu
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JMRoberts
TGSholar
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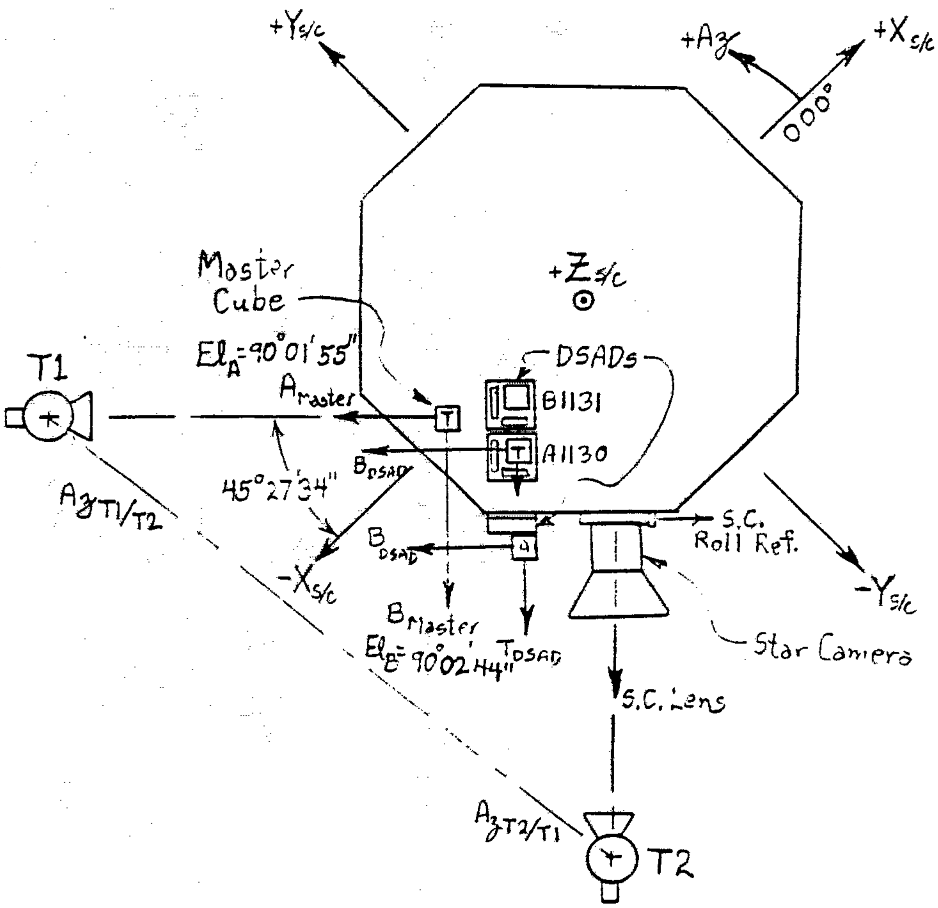
JPStaiger
TEStrikwerda
CEWilley
SEM Files

ACE Spacecraft Optical Mapping Results

Data of January 24, 1997



Star Camera:

T1/T2 Az = 357 ° 51 ' 27 "
– T1 Az = – 330 ° 55 ' 12 "
ΔAz1 = 26 ° 56 ' 15 "

T2 Az = 227 ° 07 ' 33 "
– T2/T1 Az = – 164 ° 31 ' 37 "
ΔAz2 = 62 ° 35 ' 56 "

ΔAz cube face A/star cam. lens = 180 – ΔAz1 – ΔAz2 = 90 ° 27 ' 49 "

Star cam. lens Az = 180 – 45° 27' 34" + ΔAz cube face A/star cam lens

= 225 ° 00 ' 15 "

Star camera Boresight Az = Star Cam. lens Az + (Az cal. offset = +30 arcsec)

= 225 ° 00 ' 45 " = 225.0125 ° from +Xs/c Axis

Star cam. lens El = 90 ° 01 ' 57 "

Star camera Boresight El =180° – Star cam. lens El + (El cal. offset = –41 arcsec)

= 89 ° 57 ' 22 " = 89.9561 ° from +Zs/c Axis

Star cam. roll; Roll fixture El = 90 ° 03 ' 22 "

Star cam. roll El = Roll fixture El + 0° 01' 25" = 90 ° 04 ' 47 "

Star camera roll = 180° – Star cam. roll El = 89 ° 55 ' 13 "

= 89.9203 ° from +Zs/c Axis

= +0.0797 ° Rotation about S.C. Boresight Axis

ACE Spacecraft Optical Mapping Results

Data of January 24, 1997

DSAD Optical Mapping:

(A) DSAD #630:

T1/T2 Az = 346° 19' 50"
– T1 Az = – 330° 55' 11"
ΔAz1 = 15° 24' 39"

T2 face T Az = 254° 17' 26"
– T2/T1 Az = – 180° 10' 20"
ΔAz2 = 74° 07' 06"

ΔAz cube face A/fixt. face T = 180 – ΔAz1 – ΔAz2 = 90° 28' 15"
Fixture face T Az = 180 – 45° 27' 34" + ΔAz cube face A/fixt. face T
= 225° 00' 41" = 225.0114°
DSAD #630 Boresight Az = Fixt. face T Az + (Az cal. offset = +0.0019°)
= 225.0133° from +Xs/c Axis

Fixture face T El = 55° 01' 37" = 55.0269°
DSAD #630 Boresight El =180° – Fixt. face T El + (El cal. offset = +0.0023°)
= 124.9754° from +Zs/c Axis

DSAD roll offset; Fixture face B El = 90° 05' 45"
DSAD roll = 180° – Fixt. face B El + (roll El cal. offset = –0.0004°) from +Zs/c Axis
DSAD #630 roll offset = 90° – DSAD roll = +0.0962° about DSAD Boresight.

(B) DSAD #631:

T1/T2 Az = 349° 10' 05"
– T1 Az = – 330° 55' 12"
ΔAz1 = 18° 14' 53"

T2 face T Az = 252° 35' 10"
– T2/T1 Az = – 181° 16' 50"
ΔAz2 = 71° 18' 20"

ΔAz cube face A/fixt. face T = 180 – ΔAz1 – ΔAz2 = 90° 26' 47"
Fixture face T Az = 180 – 45° 27' 34" + ΔAz cube face A/fixt. face T
= 224° 59' 13" = 224.9870°
DSAD #631 Boresight Az = Fixt. face T Az + (Az cal. offset = +0.0019°)
= 224.9889° from +Xs/c Axis

Fixture face T El = 55° 02' 20" = 55.0389°
DSAD #631 Boresight El =180° – Fixt. face T El + (El cal. offset = +0.0023°)
= 124.9634° from +Zs/c Axis

DSAD roll offset; Fixture face B El = 89° 57' 00"
DSAD roll = 180° – Fixt. face B El + (roll El cal. offset = –0.0004°) from +Zs/c Axis
DSAD #631 roll offset = 90° – DSAD roll = –0.0496° about DSAD Boresight.

ACE Spacecraft Optical Mapping Results

Data of January 24, 1997

(A) DSAD #1130: 360

T1/T2 Az = 10° 14' 43"
–T1 Az = –330° 55' 07"
ΔAz1 = 39° 19' 36"

T2 face C Az = 233° 08' 12"
–T2/T1 Az = – 182° 57' 28"
ΔAz2 = 50° 10' 44"

ΔAz cube face A/fixt. face C = 180 – ΔAz1 – ΔAz2 = 90° 29' 40"
Fixture face C Az = 180 – 45° 27' 34" + ΔAz cube face A/fixt. face C
= 225° 02' 06" = 225.0350° from +Xs/c Axis
DSAD #1130 roll = Fixt. face C Az + (roll cal. offset = +0.0004°)
= $\boxed{225.0354^\circ \text{ from +Xs/c Axis}}$
DSAD #1130 roll offset = DSAD #1130 roll – 225°
= +0.0354° about +Zs/c Axis from –X/–Ys/c Axis
Fixture face B El = 90° 03' 12" = 90.0533°
DSAD face/B Dir. = 180° – Fixt. face B El + (El cal. offset = –0.0016°)
= 89.9451° from +Zs/c Axis about –X/–Ys/c Axis
DSAD #1130 Boresight = DSAD face/B Dir. – 90°
= $\boxed{-0.0549^\circ \text{ from +Zs/c Axis about –X/–Ys/c Axis}}$
Fixture face C El = 90° 02' 22" = 90.0394°
DSAD face/C Dir. = 180° – Fixt. face C El + (El cal. offset = +0.0024°)
= 89.9629° from +Zs/c Axis about –X/+Ys/c Axis
DSAD #1130 Boresight = DSAD face/C Dir. – 90°
= $\boxed{-0.0370^\circ \text{ from +Zs/c Axis about –X/+Ys/c Axis}}$

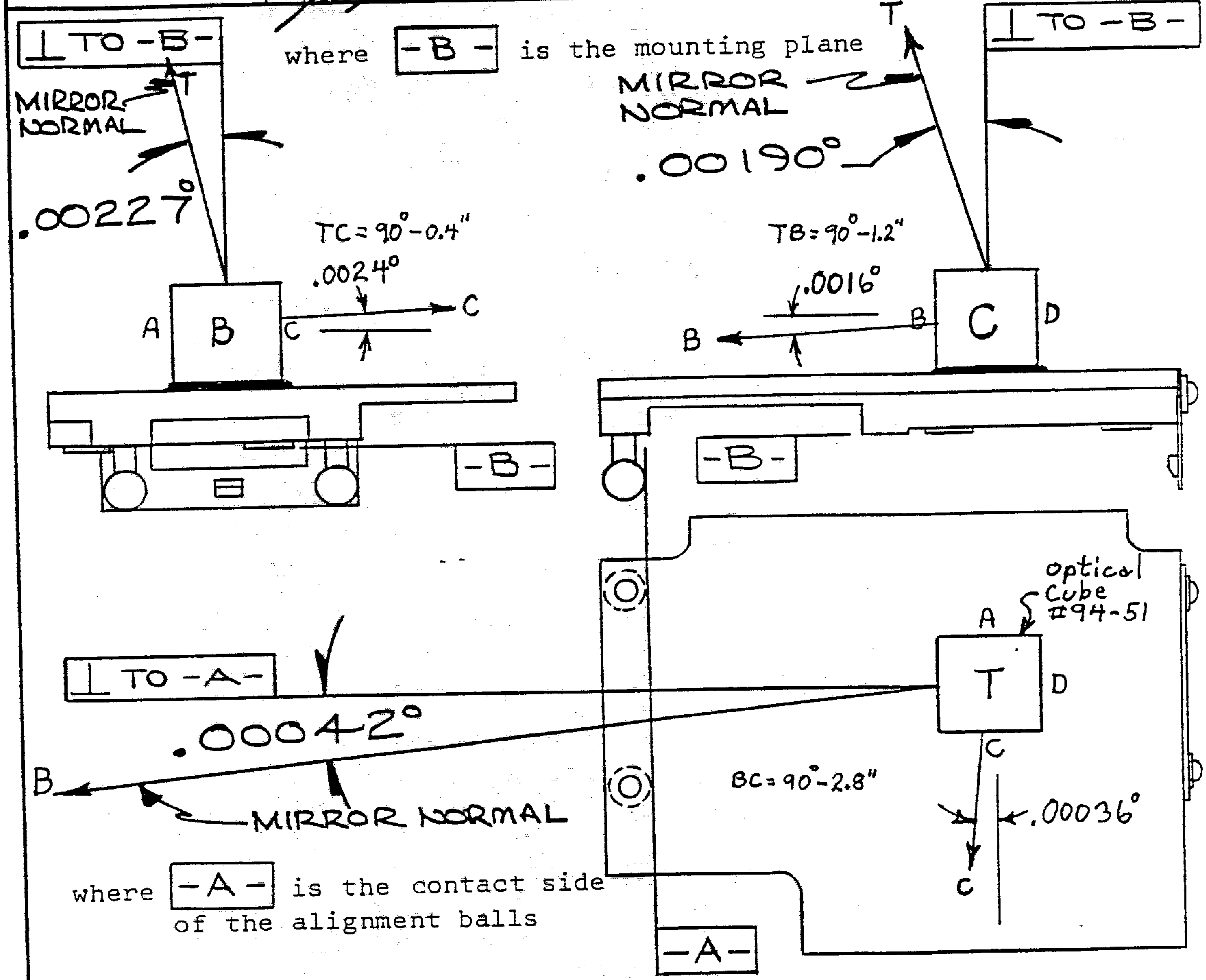
(B) DSAD #1131: 360

T1/T2 Az = 10° 14' 43"
–T1 Az = –330° 55' 07"
ΔAz1 = 39° 19' 36"

T2 face C Az = 233° 11' 45"
–T2/T1 Az = –182° 57' 17"
ΔAz2 = 50° 14' 28"

ΔAz cube face A/fixt. face C = 180 – ΔAz1 – ΔAz2 = 90° 25' 56"
Fixture face C Az = 180 – 45° 27' 34" + ΔAz cube face A/fixt. face C
= 224° 58' 22" = 224.9728° from +Xs/c Axis
DSAD #1131 roll = Fixt. face C Az + (roll cal. offset = +0.0004°)
= $\boxed{224.9732^\circ \text{ from +Xs/c Axis}}$
DSAD #1131 roll offset = DSAD #1131 roll – 225°
= –0.0268° about +Zs/c Axis from –X/–Ys/c Axis
Fixture face B El = 90° 04' 51" = 90.0808°
DSAD face/B Dir. = 180° – Fixt. face B El + (El cal. offset = –0.0016°)
= 89.9176° from +Zs/c Axis about –X/–Ys/c Axis
DSAD #1131 Boresight = DSAD face/B Dir. – 90°
= $\boxed{-0.0824^\circ \text{ from +Zs/c Axis about –X/–Ys/c Axis}}$
Fixture face C El = 90° 01' 14" = 90.0206°
DSAD face/C Dir. = 180° – Fixt. face C El + (El cal. offset = +0.0024°)
= 89.9818° from +Zs/c Axis about –X/+Ys/c Axis
DSAD #1131 Boresight = DSAD face/C Dir. – 90°
= $\boxed{-0.0182^\circ \text{ from +Zs/c Axis about –X/+Ys/c Axis}}$

ADCOLE CORPORATION			**TEST REPORT**		
Description	Calibration Report		**Instruction No.**	26136	
Part Name	Alignment Fixture		**Page**	7 of 7	
Part Number	Model 26100				
Tested By		**Date of Test**	9/13/95	**Serial No.**	009



where -B- is the mounting plane

where -A- is the contact side of the alignment balls

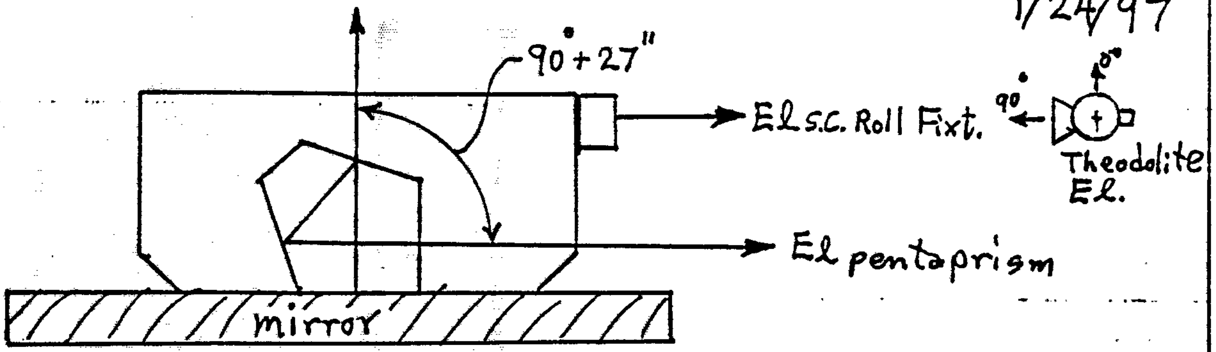
Angles shall not exceed 0.005°

FIGURE 2 - ALINGMENT FIXTURE CALIBRATION REPORT

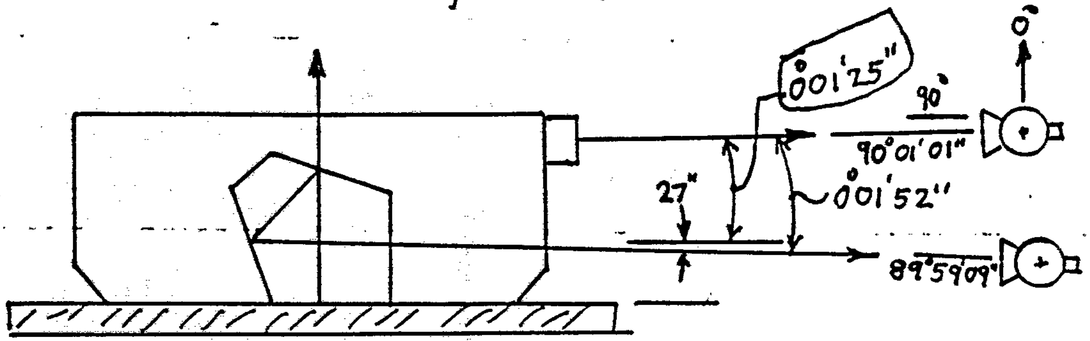
Revision					
ERN No.					
Date					
Approved By					

Calibration of ACE Star Camera Roll Mapping Fixture

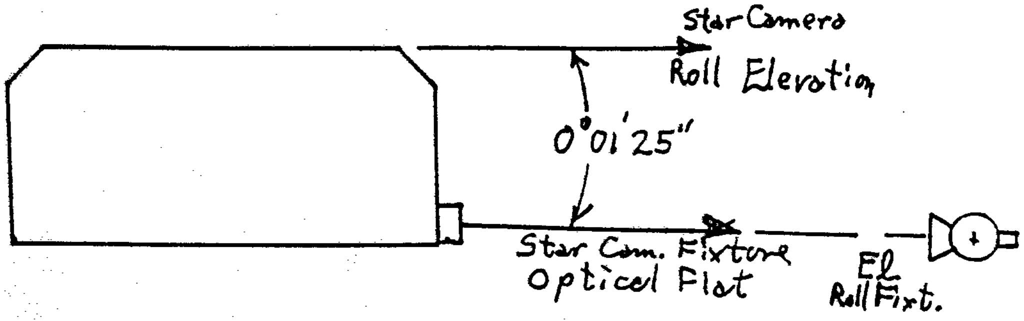
1/24/97



	El sc. Roll Fixture	El pentaprism
	90° 01' 05"	89° 59' 10"
	90° 01' 00"	89° 59' 06"
	90° 00' 57"	89° 59' 10"
Avg.	90° 01' 01"	89° 59' 09"



∴ When Fixture is in use:



Star Camera Roll Elevation = S.C. Roll Fixt. El + 0° 01' 25"

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

c. The test conductor shall document the non conformance on the Cert Log Action Item List (AIL) and immediately contact the cognizant Project Engineer Quality Assurance (PEQA).

d. The PEQA will review the discrepancy, initiate Material Review Board (MRB) action, as appropriate and notify the customer. See Quality Assurance Program Plan for additional failure reporting information.

e. Upon receipt of an MRB disposition, actions to comply with the disposition may be taken.

4.2 Test setup. The test conductor will connect the test equipment in accordance with the requirements of this procedure. The Ball QA monitor will verify the cabling hookup before testing begins. In cases where a series of tests will be performed with a single setup, the QA monitor may seal the cabling for future reference.

4.3 Redlining. Redline changes may be made to the test procedure, when required during testing, by the Test Engineer. Redlining shall be accomplished in accordance with E.P. 3.06 Controlled Redline Print System.

5. TEST DESCRIPTIONS

5.1 CT-631 system. The CT-631 system consists of a CT-631 Star Tracker and a Light Shade. The Light Shade shall be mounted to the ST, and formal testing will be performed on the full system as shown in Figure 1.

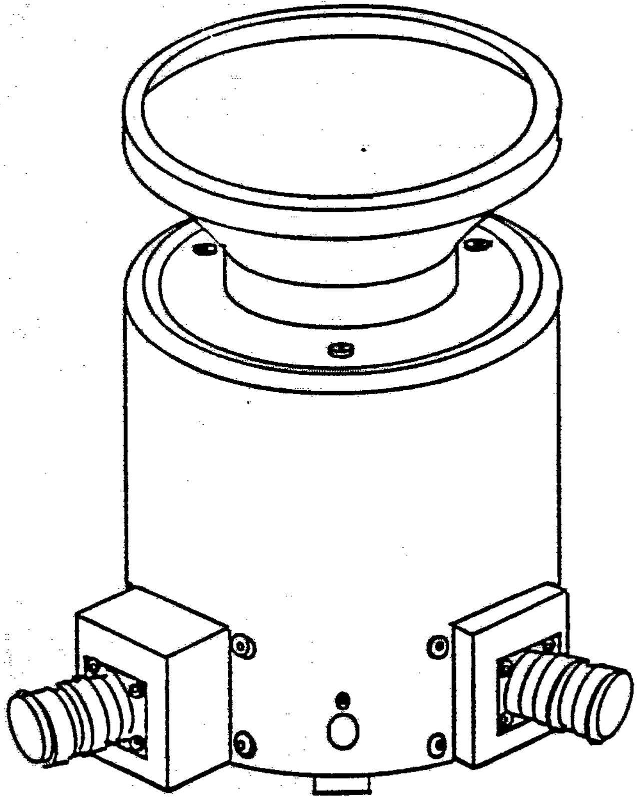


Figure 1 ACE Scanner Assembly

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5.2 ST axis definition. The ST axis and coordinate system is defined in Figure 2.

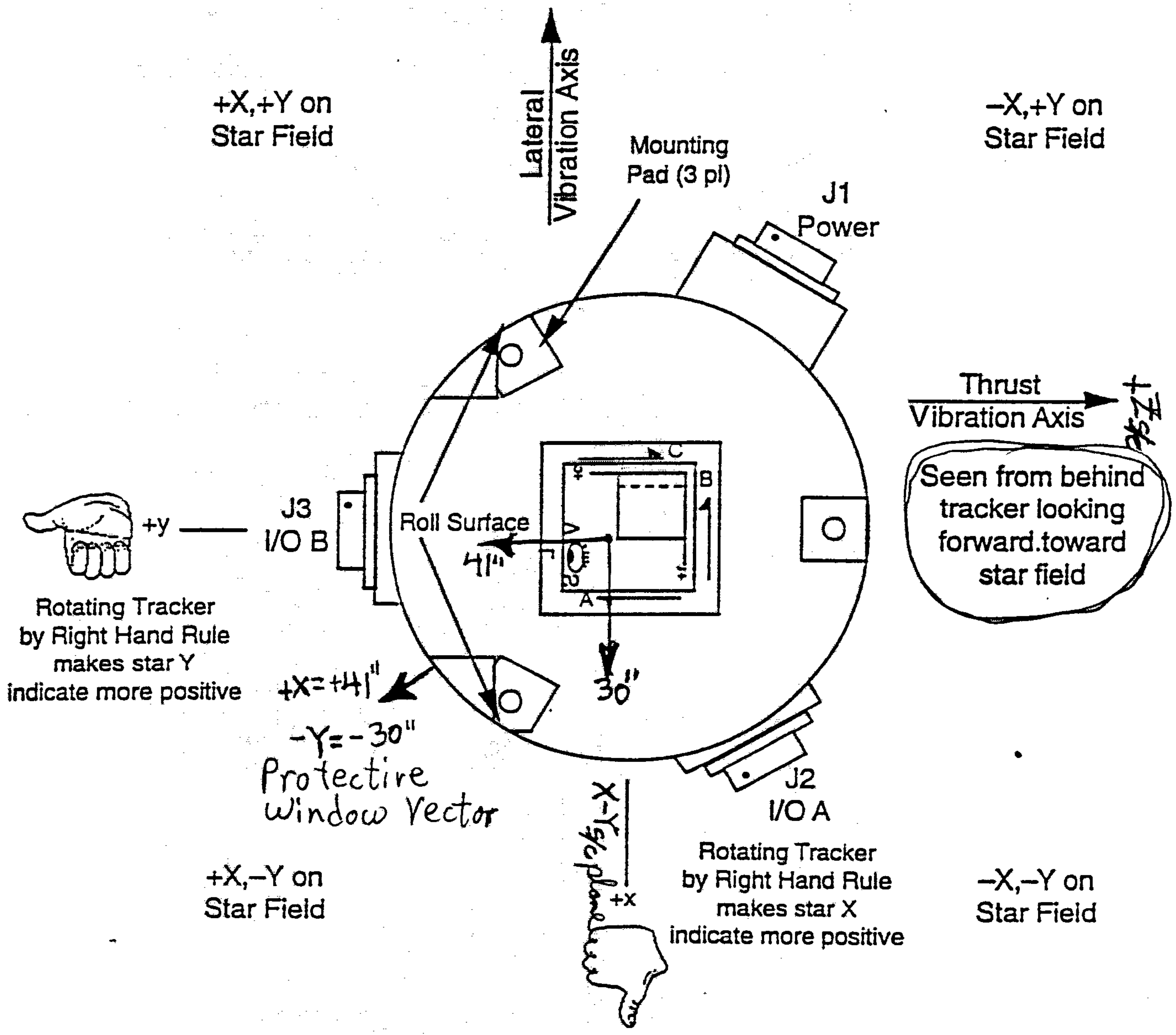

Figure 2 ST axis and coordinate definition

∴ for S.C. A_z Boresight,
Add 30 sec to A_z loc
for S.C. Boresight ∠ from +Z axis
subtract 41 sec from
El loc ∠ from +Z axis

2. Start two roll screws and note the running torque.
3. Torque the two roll screws to 20 inch pounds over the running torque.
4. Torque the three mounting bolts to 20 inch pounds over the running torque.
5. Torque the three mounting bolts to 40 inch pounds over the running torque.
6. Torque the three mounting bolts to 62 to 68 inch pounds over the running torque.

8.2.2 Test procedure.

a. Place the CT-631 on the optical bench with its boresight parallel to the bench.

b. Place an optical flat, adjustable in 2 axes, in front of the ST as shown in Figure 9.

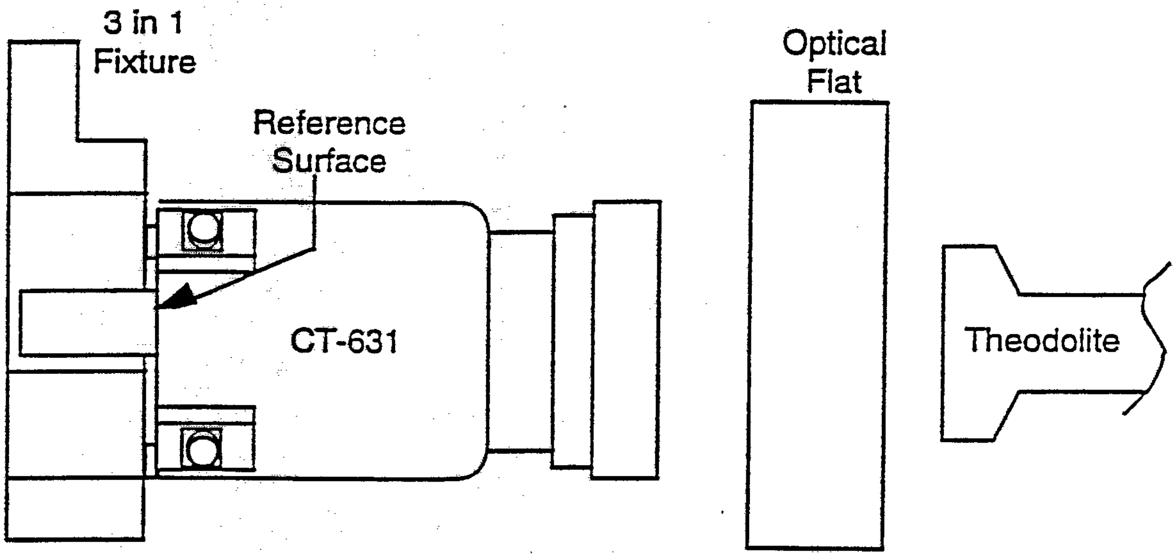

Figure 9 XY reference setup

NOTE

Use a quality quartz flat with parallel surfaces. Do not use a pyrex flat which can produce multiple images and refract the image from the reference surface. A quartz flat has clear edges, whereas the edges of a pyrex flat appear light green in color.

c. Position and focus the theodolite to view the 3-in-1 fixture reference surface.

d. Adjust the position of the optical flat until the return image from the flat overlays the return image from the 3-in-1 fixture reference surface.

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e. Move the theodolite to view the return image from the CT-631 protective window.

f. Record the theodolite AZ and EL readings for the optical flat image on the data sheet. If necessary, insert a sheet of paper between the optical flat and the ST to eliminate the ST return.

g. Record the theodolite reading for the ST protective window image on the data sheet.

h. Repeat steps f and g to achieve three independent readings. If the three readings meet the standard deviation requirement, calculate the average and proceed.

i. Perform the necessary calculations on the data sheet to determine the AZ and EL angles between the protective window and the ST mounting plane.

NOTE

A final result of 0,0 would indicate that a vector perpendicular to the CT-631 protective window is also perpendicular to the mounting pads. A final result of +X, +Y would indicate the protective window vector points into the +X, +Y quadrant of the star field as depicted in Figure 2.

Boresight Orientation

8.2.3 Data reduction. None required.

8.3 Baseline performance tests. The purpose of this test is:

a. To verify that the ST communicates (executes commands and provides data), functions (searches, acquires, and tracks stars), and performs to the specified accuracy.

b. To establish a reference against which subsequent interim test results may be compared.

The baseline test consists of a STAR test per paragraph 8.4, star matrix per paragraph 8.5, and power consumption per paragraph 8.6. These tests shall be performed in the sequence shown in Figure 10. The star matrix parameters are:

Temperature (°C)	–30, +20, +50 °C
Star Intensity (M_I)	+3.5, +2.0, +0.1
Dimension	7 x 7

SERNO 0001

FORMAL TEST PROCEDURE
ACE STAR SCANNER ASSEMBLY

8.2.2 X and Y Reference Angles

f. Optical Flat (AZ) 306° 27' 31.2" Reading #1
h. 306° 27' 30.0" Reading #2
306° 27' 30.1" Reading #3
Standard Deviation = 0.67" ≤ 4 arc-sec
Average A = 306° 27' 30.4" Ref.

f. Optical Flat (EL) 90° 12' 51.0" Reading #1
h. 90° 12' 51.4" Reading #2
90° 12' 51.4" Reading #3
Standard Deviation = 0.23" ≤ 4 arc-sec
Average B = 90° 12' 51.3" Ref.

g. CT-631 Protective Window (AZ) 306° 26' 53.0" Reading #1
h. 306° 26' 52.8" Reading #2
306° 26' 52.7" Reading #3
Standard Deviation = 0.15" ≤ 4 arc-sec
Average C = 306° 26' 52.8" Ref.

g. CT-631 Protective Window (EL) 90° 12' 21.8" Reading #1
h. 90° 12' 21.7" Reading #2
90° 12' 22.4" Reading #3
Standard Deviation = 0.38" ≤ 4 arc-sec
Average D = 90° 12' 22.0" Ref.

i. ST X Coordinate

P.89:

Average A – Average C = +37.6" Ref. +44.7"

ST Y Coordinate

Average D – Average B = -29.3" Ref. -31.0"

ST X-Coord. avg = +41 arcsec
ST Y-Coord. avg = -30 arcsec

TEST CONDUCTOR DATE 3-29-96
QA 115 DATE 3-29-94

Aerospace Systems Group Electro-Optics/Cryogenics Division P.O. Box 1062 Boulder, Colorado 80306	SIZE A	CAGE CODE 13993	DWG NO. 533114 265	REV —
	SCALE	NONE		SHEET 63