

SPECTRON ENGINEERING HUD SIMULATOR CALIBRATION PROCEDURE

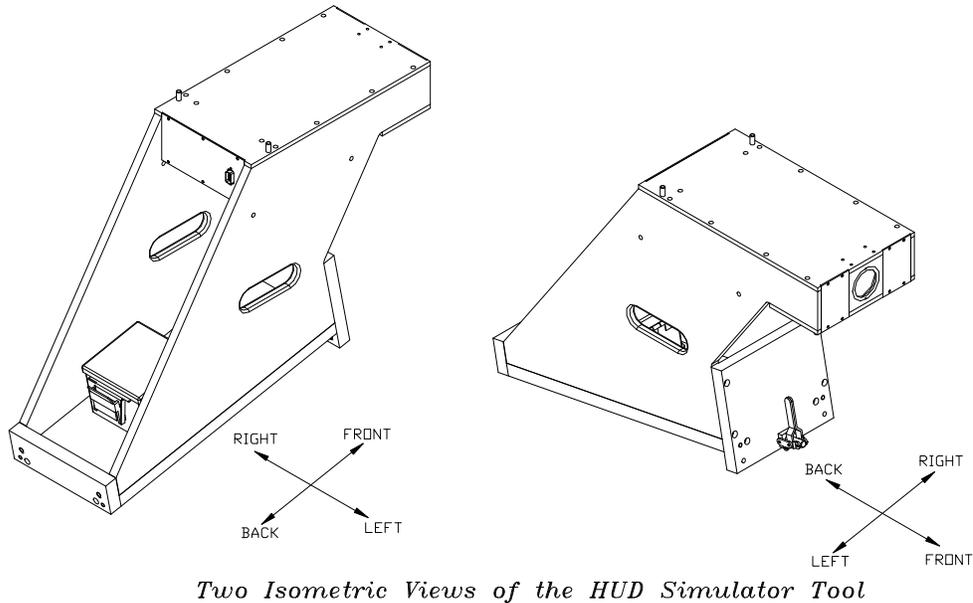


Figure 1. Two Isometric Views of the HUD Simulator Tool

General Discussion.

The calibration procedure which follows is used to verify the relationship of the alignment pins and bushings to the optical features of this unit. This is the only relationship needed to position the HUD (Head Up Display) Simulator. No other face or surface on the unit should be assumed to be qualified.

In Sections A, B and C, the relationships of the mounting pins are verified. The source of the front and back pin position specifications may be found in the configuration prints for the F-15 WFOV (Wide Field Of View) HUD and the F-15 Dual Combiner HUD. The pins located in the top of the HUD Simulator are defined by Spectron Engineering, Inc., and are used in making side position measurements.

In Sections D through L, the HUD Simulator is placed on gage blocks and the elevation of the reference collimator is measured as well as any roll component. This is done in two configurations which are then averaged.

In Sections M through Q, the HUD Simulator is turned onto each of its sides and placed on gage blocks. The gage blocks required are based on the pin spacings calculated in sections A, B and C. In this position, the Azimuth of the reference collimator is measured.

Sections R through U are used to check the calibration and determine the calibration factors. Verification is done through comparing the empirical data

collected and calculated to the factory calibration. Calibration numbers are then created.

Tools required:

1. Granite Surface Plate 24" x 36" or larger
2. Micrometer 0-1 ", 0.0001" resolution.
3. Micrometer 5-6 ", 0.0001" resolution.
4. Micrometer 6-7 ", 0.0001" resolution.
5. Precision Master Level, 0.0005"/10" resolution.
6. Gage block set, 81 piece, Grade 3.
7. Theodolite¹ calibrated to NIST standards, with adjustable height tripod. It is recommended that an aperture of approximately 1/4" to 3/8" diameter be fitted to the Theodolite telescope to reduce focus problems.
8. Two pair of calibration pins, $\varnothing 0.2495$ x 1.5 inch long. These are included with the HUD Simulator.
9. Measuring tape.

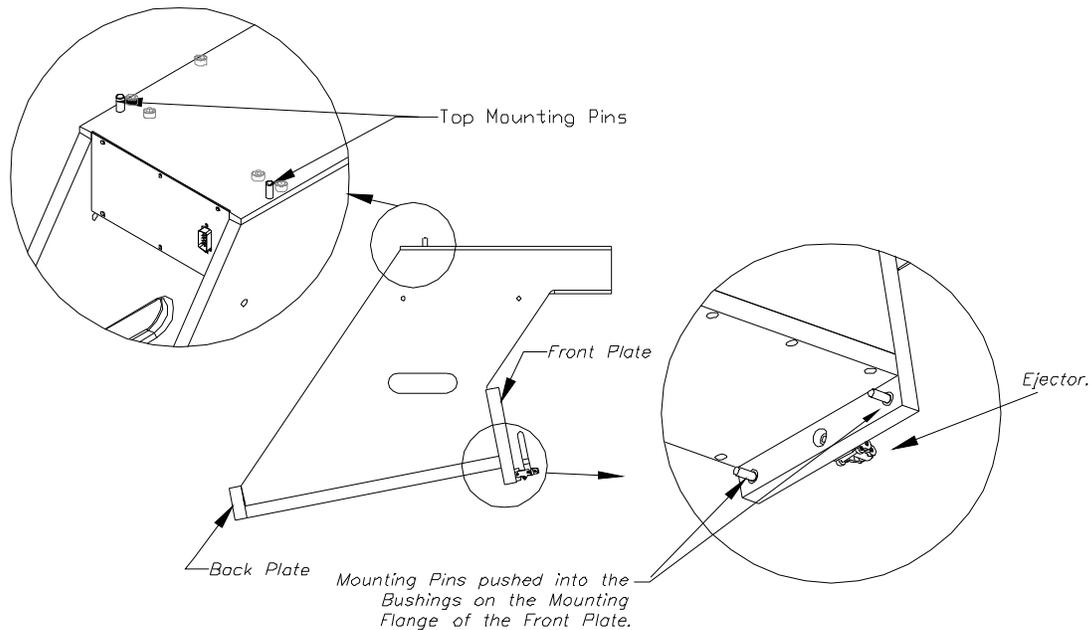


Figure 2. Left Hand Side Shown

- A. Insert the calibration pins into the bushings in the mounting flange of the HUD Simulator. Push the calibration pin in until it is flush with the front of the HUD Simulator. Do **NOT** use force. These should be removable by hand. See Figure 2. Measure with a micrometer, the diameter of the 2 mounting pins. Measure the outside to outside distance and calculate the center to center distance of the pins. Record the measurements below.

A1. _____ Diameter of Left Pin.
 A2. _____ Diameter of Right Pin.
 A3. _____ Outside to Outside Distance.
 A4. _____ Center to Center Distance = $A3 - ((A1 + A2) / 2)$.
 The Center to Center dimension should = 5.8825 ± 0.0025 inch.²

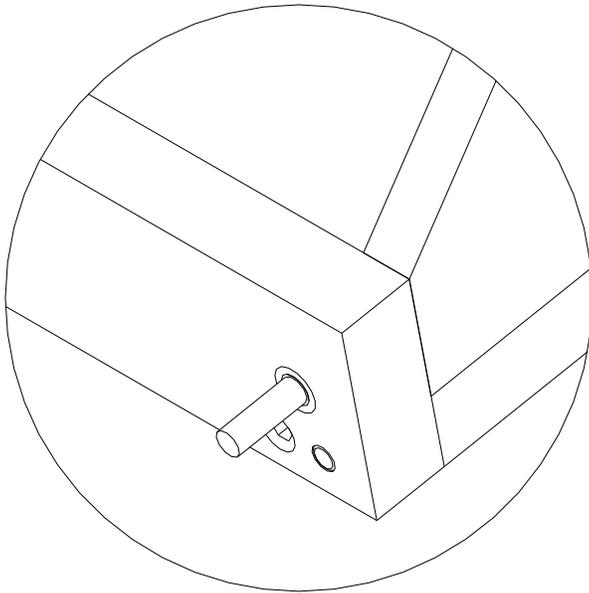


Figure 3. Close-up view of HUD Simulator calibration pin position

- B. Insert the Calibration Pins into the Bushings in the back plate of the HUD Simulator. Push the calibration pin in until it is flush with the inside surface of the HUD Simulator. Do **NOT** use force. These should be removable by hand. See Figure #3. Measure with a micrometer, the diameter of the 2 mounting pins. Measure the outside to outside distance and calculate the center to center distance of the pins. Record the measurements below.

B1. _____ Diameter of Left Pin.
 B2. _____ Diameter of Right Pin.
 B3. _____ Outside to Outside Distance.
 B4. _____ Center to Center Distance = $B3 - ((B1 + B2) / 2)$.
 The Center to Center dimension should = 5.6225 ± 0.0025 inch.³

C. Measure with a micrometer, the diameter of the 2 mounting pins on the top plate of the HUD Simulator. See Figure #2. Measure the outside to outside distance. Record the measurements below.

- C1. _____ Diameter of Left Pin.
 - C2. _____ Diameter of Right Pin.
 - C3. _____ Outside to Outside Distance.
- This measurement will be used in step M.

D. Place the HUD Simulator upright on the surface plate. Using a Precision Master Level, level the surface plate, ± 10 arc-seconds.

E. Set up the HUD Simulator with gage blocks under both front pins and under the right back pin as seen in Figure #4. The gage block size is indicated below.⁴

Front Pin Gage Blocks: $2.0847 - 1.56 - ((A1 + A2) / 4) = \underline{\hspace{2cm}}$
 Back Pin Gage Block: $2.0847 - ((B1 + B2) / 4) = \underline{\hspace{2cm}}$

F. Set up the Theodolite at the position indicated in Figure 4.

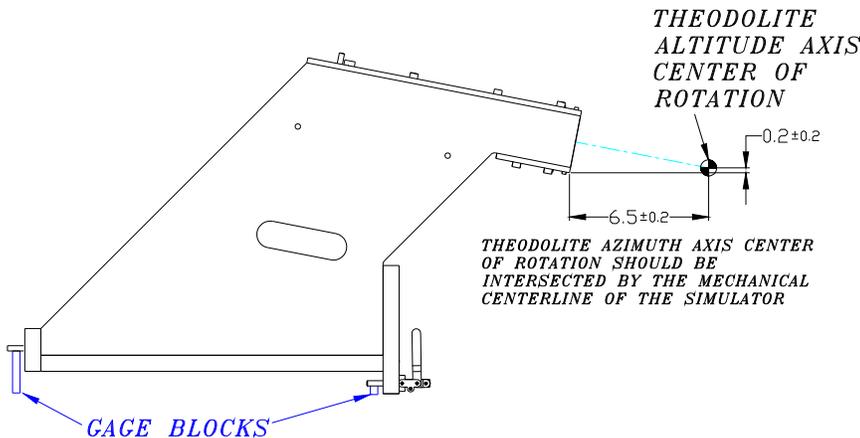


Figure 4. Side view of HUD Simulator in upright position

G. Level the Theodolite, ± 10 arc-seconds. Set the Theodolite Azimuth Circle to $\sim 90^\circ$.

H. Now rotate the theodolite up $\sim 11^\circ$ and find the center crosshair of the collimator. Rotate $\sim 4.5^\circ$ to the left to find the left cross-hair. Measure each edge of the vertical slit at the intersection with the horizontal slit, then measure both edges of the horizontal slit at the intersection of the vertical slit. Repeat for the right crosshair. Now plunge and reverse⁵ the theodolite and repeat the measurements.

- Original Face
- Left Crosshair
 - H1. _____ Horizontal Slit first edge.
 - H2. _____ Horizontal Slit second edge.

- H3. _____ Vertical Slit first edge.
- H4. _____ Vertical Slit second edge
- Right Crosshair
- H5. _____ Horizontal Slit first edge.
- H6. _____ Horizontal Slit second edge.
- H7. _____ Vertical Slit first edge.
- H8. _____ Vertical Slit second edge

Opposite Face

- Left Crosshair
- H9. _____ Horizontal Slit first edge.
- H10. _____ Horizontal Slit second edge.
- H11. _____ Vertical Slit first edge.
- H12. _____ Vertical Slit second edge
- Right Crosshair
- H13. _____ Horizontal Slit first edge.
- H14. _____ Horizontal Slit second edge.
- H15. _____ Vertical Slit first edge.
- H16. _____ Vertical Slit second edge

- I. Return the theodolite to its configuration at the beginning of section H and move the back gage blocks to under the left back pin. The Theodolite and Granite Surface Plate should not be moved except to set the theodolite back to its original configuration. Repeat the measurements done in step H.

Original Face

- Left Crosshair
- I1. _____ Horizontal Slit first edge.
- I2. _____ Horizontal Slit second edge.
- I3. _____ Vertical Slit first edge.
- I4. _____ Vertical Slit second edge
- Right Crosshair
- I5. _____ Horizontal Slit first edge.
- I6. _____ Horizontal Slit second edge.
- I7. _____ Vertical Slit first edge.
- I8. _____ Vertical Slit second edge

Opposite Face

- Left Crosshair
- I9. _____ Horizontal Slit first edge.
- I10. _____ Horizontal Slit second edge.
- I11. _____ Vertical Slit first edge.
- I12. _____ Vertical Slit second edge
- Right Crosshair
- I13. _____ Horizontal Slit first edge.
- I14. _____ Horizontal Slit second edge.

- I15. _____ Vertical Slit first edge.
 I16. _____ Vertical Slit second edge

J. Compute the average Readings:

Gage Blocks Under Right Rear Side:

$$\begin{aligned} \text{Left Cross Horizontal average} &= \{[90^\circ - ((H1 + H2)/2)] + [((H9 + H10)/2) - 270^\circ]\}/2 \\ &= \{[90^\circ - ((\text{_____} + \text{_____})/2)] + [((\text{_____} + \text{_____})/2) - 270^\circ]\}/2 \\ \text{J1.} &= \text{_____} \end{aligned}$$

$$\begin{aligned} \text{Left Cross Vertical average} &= \{(H3 + H4)/2 + [(H11 + H12)/2 - 180^\circ]\}/2 \\ &= \{(\text{_____} + \text{_____})/2 + [(\text{_____} + \text{_____})/2 - 180^\circ]\}/2 \\ \text{J2.} &= \text{_____} \end{aligned}$$

$$\begin{aligned} \text{Right Cross Horizontal average} &= \{[90^\circ - ((H5 + H6)/2)] + [((H13 + H14)/2) - 270^\circ]\}/2 \\ &= \{[90^\circ - ((\text{_____} + \text{_____})/2)] + [((\text{_____} + \text{_____})/2) - 270^\circ]\}/2 \\ \text{J3.} &= \text{_____} \end{aligned}$$

$$\begin{aligned} \text{Right Crosshair Vertical average} &= \{(H7 + H8)/2 + [(H15 + H16)/2 - 180^\circ]\}/2 \\ &= \{(\text{_____} + \text{_____})/2 + [(\text{_____} + \text{_____})/2 - 180^\circ]\}/2 \\ \text{J4.} &= \text{_____} \end{aligned}$$

Gage Blocks Under Left Rear Side:

$$\begin{aligned} \text{Left Cross Horizontal average} &= \{[90^\circ - ((I1 + I2)/2)] + [((I9 + I10)/2) - 270^\circ]\}/2 \\ &= \{[90^\circ - ((\text{_____} + \text{_____})/2)] + [((\text{_____} + \text{_____})/2) - 270^\circ]\}/2 \\ \text{J5.} &= \text{_____} \end{aligned}$$

$$\begin{aligned} \text{Left Cross Vertical average} &= \{(I3 + I4)/2 + [(I11 + I12)/2 - 180^\circ]\}/2 \\ &= \{(\text{_____} + \text{_____})/2 + [(\text{_____} + \text{_____})/2 - 180^\circ]\}/2 \\ \text{J6.} &= \text{_____} \end{aligned}$$

$$\begin{aligned} \text{Right Cross Horizontal average} &= \{[90^\circ - ((I5 + I6)/2)] + [((I13 + I14)/2) - 270^\circ]\}/2 \\ &= \{[90^\circ - ((\text{_____} + \text{_____})/2)] + [((\text{_____} + \text{_____})/2) - 270^\circ]\}/2 \\ \text{J7.} &= \text{_____} \end{aligned}$$

$$\begin{aligned} \text{Right Crosshair Vertical average} &= \{(I7 + I8)/2 + [(I15 + I16)/2 - 180^\circ]\}/2 \\ &= \{(\text{_____} + \text{_____})/2 + [(\text{_____} + \text{_____})/2 - 180^\circ]\}/2 \\ \text{J8.} &= \text{_____} \end{aligned}$$

- K. Calculate the Roll component from the left and right averages . $\text{Arctan}((J3+J7-J1-J5)/((J4+ J8-J2-J6)*\text{COS } 11^\circ))$
 $= \text{Arctan}((\underline{\hspace{1cm}} + \underline{\hspace{1cm}} - \underline{\hspace{1cm}} - \underline{\hspace{1cm}})/((\underline{\hspace{1cm}} + \underline{\hspace{1cm}} - \underline{\hspace{1cm}} - \underline{\hspace{1cm}})*0.9816))$
 K1. = $\underline{\hspace{1cm}}$ °
- L. Calculate Great Circle correction. $11*(1-\text{COS}((J4+J8-J2-J6)/4))$
 $11*(1-\text{COS}((\underline{\hspace{1cm}} + \underline{\hspace{1cm}} - \underline{\hspace{1cm}} - \underline{\hspace{1cm}})/4))$
 L1. = $\underline{\hspace{1cm}}$ °

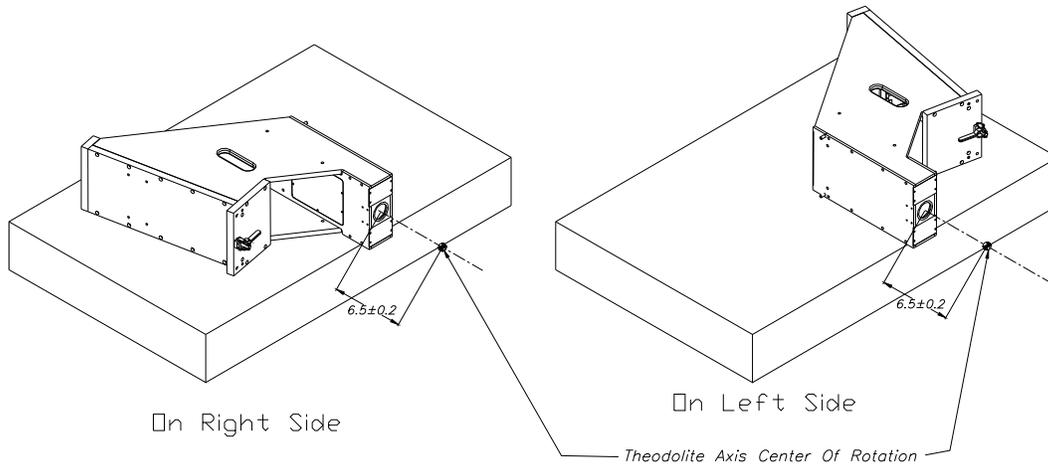


Figure 5 HUD Simulator views keeping the center line stationary.

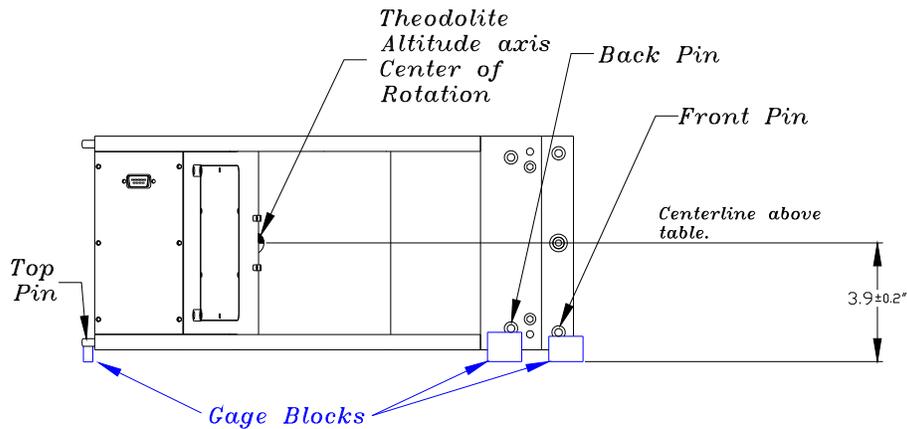


Figure 6. HUD Simulator in side position (View from back)

- M. Remove the gage blocks and turn the HUD Simulator onto its right side on one side of the granite plate. See Figures #5 and #6. (Later in the procedure, the HUD simulator will need to be turned over while keeping the alignment of the crosshairs and theodolite the same. It is, therefore, necessary to place the HUD Simulator to one side as seen in Figure #5.) Set up the HUD Simulator with gage blocks under the front pin, back pin and top pin. Calculate the gage block size below:

Back Pin Gage Block: $3.886 - (B3/2) =$ _____

Front Pin Gage Block: $3.886 - (A3/2) =$ _____

Top Pin Gage Block: $3.886 - (C3/2) =$ _____

- N. Reposition the height of the Theodolite to be level with the mechanical centerline in the new position. See Figures #5 and #6 for proper position. Level the Theodolite, ± 10 arc-second.
- O. Find the Center Crosshair of the Collimator then rotate the theodolite about 4.5° down to find the lower cross-hair. Record the Horizontal readings only. Do the same with the upper crosshairs. Now plunge and reverse the theodolite and repeat the measurements. Record the Horizontal⁶ readings only.

Original Face:

Lower Crosshair

O1. _____ Horizontal Slit first edge.

O2. _____ Horizontal Slit second edge.

Upper Crosshair

O3. _____ Horizontal Slit first edge.

O4. _____ Horizontal Slit second edge.

Opposite Face:

Lower Crosshair

O5. _____ Horizontal Slit first edge.

O6. _____ Horizontal Slit second edge.

Upper Crosshair

O7. _____ Horizontal Slit first edge.

O8. _____ Horizontal Slit second edge.

- P. Do a plunge and reverse to put the theodolite back in its configuration from the beginning of section O. Without moving the theodolite or surface plate, place the HUD simulator on it's left side then repeat the measurements done on the right side. Use the same gage blocks as those calculated for the right side. (The HUD simulator should be turned over while keeping the alignment of the crosshairs and theodolite the same. See Figures #5, and #6.)

Original Face:

Lower Crosshair

P1. _____ Horizontal Slit first edge.

P2. _____ Horizontal Slit second edge.

Upper Crosshair

P3. _____ Horizontal Slit first edge.

P4. _____ Horizontal Slit second edge.

Opposite Face:

Lower Crosshair

P5. _____ Horizontal Slit first edge.

P6. _____ Horizontal Slit second edge.

Upper Crosshair

P7. _____ Horizontal Slit first edge.

P8. _____ Horizontal Slit second edge.

Q. Compute the average readings:

Right Side:

$$\begin{aligned} \text{Right Cross Horizontal average.} &= \{[90^\circ - ((O1 + O2)/2)] + [((O5 + O6)/2) - 270^\circ]\} / (-2) \\ &= \{[90^\circ - ((______ + ______)/2)] + [((______ + ______)/2) - 270^\circ]\} / (-2) \\ \text{Q1.} &= ______ \end{aligned}$$

$$\begin{aligned} \text{Left Cross Horizontal average.} &= \{[90^\circ - ((O3 + O4)/2)] + [((O7 + O8)/2) - 270^\circ]\} / (-2) \\ &= \{[90^\circ - ((______ + ______)/2)] + [((______ + ______)/2) - 270^\circ]\} / (-2) \\ \text{Q2.} &= ______ \end{aligned}$$

Left Side:

$$\begin{aligned} \text{Left Cross Horizontal average.} &= \{[90^\circ - ((P1 + P2)/2)] + [((P5 + P6)/2) - 270^\circ]\} / 2 \\ &= \{[90^\circ - ((______ + ______)/2)] + [((______ + ______)/2) - 270^\circ]\} / 2 \\ \text{Q3.} &= ______ \end{aligned}$$

$$\begin{aligned} \text{Right Cross Horizontal average.} &= \{[90^\circ - ((P3 + P4)/2)] + [((P7 + P8)/2) - 270^\circ]\} / 2 \\ &= \{[90^\circ - ((______ + ______)/2)] + [((______ + ______)/2) - 270^\circ]\} / 2 \\ \text{Q4.} &= ______ \end{aligned}$$

$$\begin{aligned} \text{Skew angle} &= (Q1 + Q2 + Q3 + Q4) / 4 \\ &= (______ + ______ + ______ + ______) / 4 \\ \text{Q5.} &= ______ \end{aligned}$$

$$\begin{aligned} \text{Skew Roll} &= (Q5 * .192) \\ &= (______ * 0.192) \\ \text{Q6.} &= ______ \end{aligned}$$

R. Final analysis:

Mounting Pins to Boresight :

R1. Azimuth $= (Q1+Q2+Q3+Q4)/4 =$ _____ °

R2. Altitude $= (J1+J3+J5+J7)/4+L1 =$ _____ °

R3. Roll $= K1+Q6 =$ _____ °

Target position:

Mounting Pins to Boresight:

R4. Azimuth $= 0.000^\circ$

R5. Altitude $= 11.000^\circ$

R6. Roll $= 0.000^\circ$

S. Deltas:

S1. Azimuth $= R4 - R1 =$ _____ °

S2. Altitude $= R5 - R2 =$ _____ °

S3. Roll $= R6 - R3 =$ _____ °

T. Compare the empirical data to the factory reference values shown on the label on the back of the HUD Simulator.

T1. Azimuth difference $= (\text{nominal azimuth}) - S1 =$ _____ °*

T2. Altitude difference $= (\text{nominal altitude}) - S2 =$ _____ °*

T3. Roll difference $= (\text{nominal roll}) - S3 =$ _____ °**

*NOTE continue only if these values are less than $.01^\circ$ and greater than $-.01^\circ$.**NOTE continue only if these values are less than $.05^\circ$ and greater than $-.05^\circ$.

U. Convert to calibration numbers:

The first number in each set should indicate the sign. 0 (zero) indicates a positive number, 1 (one) indicates a negative number. The next part in each number set denotes the value in thousandths. See Figure #7 for an example.

First Part of number (sign digit):

U1a. Sign of S1 = ____

U2a. Sign of S2 = ____

U3a. Sign of S3 = ____

Second Part of number (quantity digit):

U1b. Integer value of $(S1*1000) =$ _____

U2b. Integer value of $(S2*1000) =$ _____

U3b. Integer value of $(S3*1000) =$ _____

Calibration:

Left Number = [U1a] and [U1b] = ____

Middle Number = [U2a] and [U2b] = ____

Right Number = [U3a] and [U3b] = ____

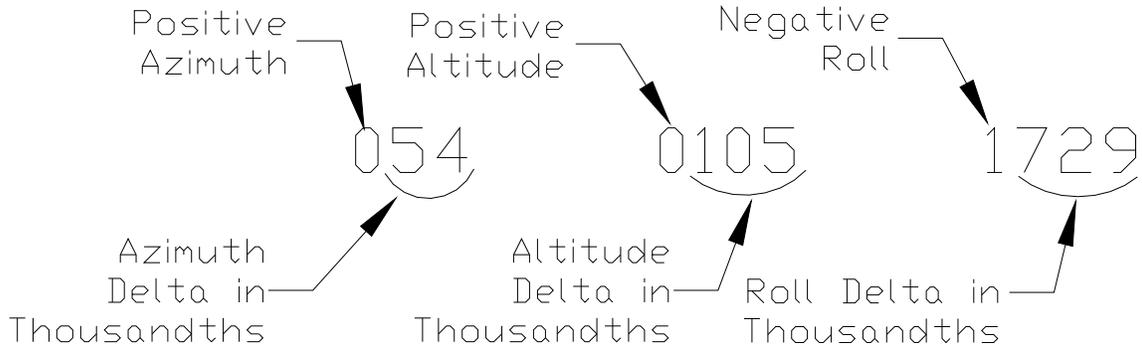


Figure 7. Example calibration numbers

Certification _____

<u>Item</u>	<u>Part Number</u>	<u>Serial Number</u>
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Date Completed _____

Completed By _____

Date Shipped _____

Shipped To _____

Reference

P.O. Number _____

Line Item(s) _____

Lot Number _____

Notes:

- ¹ For the purposes of this procedure, convert all Theodolite readings to decimal degrees.
- ² This dimension is the center to center distance of the mounting screws of the HUD.
- ³ This dimension is the center to center distance of the alignment bushings in the back of the HUD.
- ⁴ This front pin to back pin height difference is derived from the WFOV HUD configuration print.
- ⁵ Plunge and Reverse. Rotate the azimuth axis of the theodolite 180° and the elevation axis 180° and repeat the measurements. This process eliminates any concentricity error in the theodolite scales.
- ⁶ The horizontal lines in the HUD Simulator on this side were the Vertical lines in the previous position (The HUD Simulator in the upright position.)