

NOTE - Dec  
2 SETS OF ADDRESSEES!

FAX COVER PAGE

CALIFORNIA INSTITUTE OF TECHNOLOGY

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|               |                     |
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| REFER TO:     | LIGO-T970105-00-B   |
| SUBJECT:      | Rogers measurements |

|   |   |
|---|---|
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NOTE: My calcs. on evaluating Rogers' field notes. Do you have any time preferences for the alignment meeting today?

*FAX COVER PAGE*

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|               |                |
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|   |                     |
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| FROM:   | Larry Jones         |
| ORGANIZATION:                                     | LIGO Project        |
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# SETTING UP ELEVATION REFERENCE READINGS

(FROM ROGERS FIELD BOOK #665)

Jan 4/8/9

WILD NA 30003 w/ BAR CODE RAD

4/5/97

## LEVEL LOOP READINGS

MOVING SOUTHEAST

MOVING NORTHWEST

TRANSFER LEVELS INSIDE

| STATION       | ELEV, FT | DESCRIP.       |    | ELEV, FT | Δ, FT | DESCRIP. | STATION | ELEV, FT | ELEV, FT |
|---------------|----------|----------------|----|----------|-------|----------|---------|----------|----------|
| TBM<br>ST/NEG | 100.000  |                |    |          |       |          |         |          |          |
| TP-1          | 99.974   | CONCR. SCRIBE  |    | 99.981   | .007  |          | TBM     | 99.775   | 99.776   |
| TP-2          | 99.775   | DOOR #1 REBAR  | 62 | 99.782   | .007  |          | 65      | 99.974   |          |
| -3            | 99.955   | DOOR #2 REBAR  | 60 | 99.958   | .003  | DOOR #2  | 3       | 99.955   | 99.956   |
| -4            | 100.120  |                | 59 | 100.123  | .003  |          | 66      | 100.136  |          |
| -5            | 100.099  | DOOR #3 REBAR  | 58 | 100.100  | .001  | DOOR #3  | 5       | 100.099  | 100.099  |
| -6            | 100.215  |                | 57 | 100.215  | .000  |          | 67      | 100.303  |          |
| -7            | 100.112  | DOOR #4 REBAR  | 56 | 100.112  | .000  | DOOR #4  | 7       | 100.112  | 100.113  |
| -8            | 100.421  |                | 55 | 100.424  | .003  |          | 68      | 100.453  |          |
| -9            | 100.446  | DOOR #5 REBAR  | 54 | 100.443  | .003  | DOOR #5  | 9       | 100.446  | 100.445  |
| -10           | 100.563  |                | 53 | 100.567  | .004  |          | 69      | 100.614  |          |
| -11           | 100.470  | DOOR #6 REBAR  | 52 | 100.473  | .003  | DOOR #6  | 11      | 100.470  | 100.471  |
| -12           | 100.768  | SN             | 51 | 100.772  | .004  |          | 70      | 100.753  |          |
| -13           | 100.636  | DOOR #7 REBAR  | 50 | 100.639  | .003  | DOOR #7  | 13      | 100.636  | 100.637  |
| -14           | 100.868  |                | 49 | 100.870  | .002  |          | 71      | 100.927  |          |
| -15           | 100.852  | DOOR #8 REBAR  | 48 | 100.853  | .001  | DOOR #8  | 15      | 100.852  | 100.852  |
| -16           | 101.098  |                | 47 | 101.097  | .001  |          | 72      | 101.092  |          |
| -17           | 101.002  | DOOR #9 REBAR  | 46 | 101.003  | .001  | DOOR #9  | 17      | 101.002  | 101.001  |
| -18           | 101.232  |                | 45 | 101.230  | .002  |          | 73      | 101.272  |          |
| -19           | 101.291  | DOOR #10 REBAR | 44 | 101.287  | .004  | DOOR #10 | 19      | 101.291  | 101.291  |
| -20           | 101.429  |                | 43 | 101.427  | .002  |          | 74      | 101.484  |          |
| -21           | 101.447  | DOOR #11 REBAR | 42 | 101.446  | .001  | DOOR #11 | 21      | 101.447  | 101.449  |
| -22           | 101.651  |                | 41 | 101.648  | .003  |          | 75      | 101.680  |          |
| -23           | 101.705  | DOOR #12 REBAR | 40 | 101.701  | .004  | DOOR #12 | 23      | 101.705  | 101.707  |
| -24           | 101.915  | SN             | 39 | 101.914  | .001  |          | 76      | 101.888  |          |
| -25           | 101.914  | DOOR #13 REBAR | 38 | 101.913  | .001  | DOOR #13 | 25      | 101.914  | 101.915  |
| -26           | 102.154  | SN             | 37 | 102.152  | .002  |          | 77      | 102.086  |          |
| -27           | 102.125  | DOOR #14 REBAR | 36 | 102.123  | .002  | DOOR #14 | 27      | 102.125  | 102.123  |
| -28           | 102.297  | SN             | 35 | 102.295  | .002  |          | 78      | 102.320  |          |
| -29           | 102.256  | DOOR #15 REBAR | 34 | 102.255  | .001  | DOOR #15 | 29      | 102.256  | 102.255  |
| -30           | 102.596  |                | 33 | 102.594  | .002  |          | 79      | 102.531  |          |
| -31           | 102.747  |                | 32 | 102.748  | .001  |          | 30      | 102.596  | 102.596  |
| BT/ES         | 102.982  |                |    |          |       | ??       | 80      | 102.670  |          |
|               |          | SN             | 61 | 99.936   | N/A   | ??       | 31      | 102.747  | 102.749  |
|               |          |                |    |          |       |          | 81      | 102.924  |          |

TP = TURNING POINT

ELEVATION CLOSURE ERRORS (2.1mm MAX, OVER 2 KM!)

CALCULATION OF VERTICAL ALIGNMENT OFFSETS

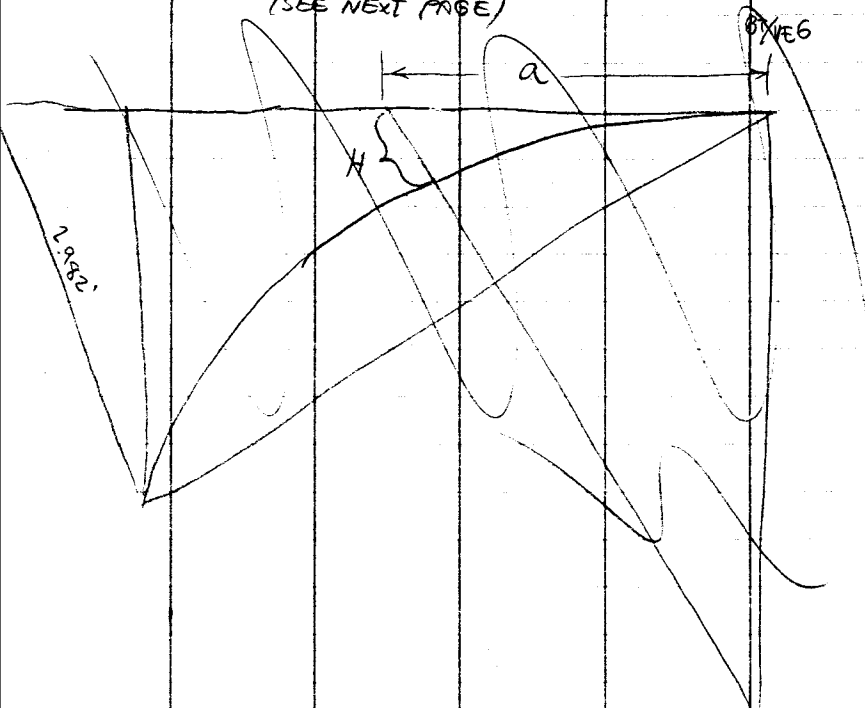
4/8/97

VERTICAL ERROR, MM

$H_m$   
D. RAD = 2.375'

| STATION | ELEV, FT<br>(RING TOP) | ELEV, FT<br>E | DIST FROM<br>BT/VE6, FT | $a_x$<br>$\frac{a_x}{a_c} \times 2.0050$<br>FT | $H_{XL}$ | $H_{XS}$<br>$\sqrt{R^2 - a_x^2} - R$<br>FT (CURVATURE CORRECTION) | $H_x$<br>$(H_{XL} + H_{XS})$<br>+ 103.468<br>FT D | $H_m - H_x$<br>(VERT. OFFSET), FT | VERTICAL ERROR, MM |
|---------|------------------------|---------------|-------------------------|--|----------|---|---|-----------------------------------|--------------------|
| TP 65   | 99.974                 | =             | N/A                     |  |          |   |   |                                   |                    |
| BT/VE6  | 103.468                | ①             | 0                       | 0  | 0        | 0   | 103.468   | 0                                 | 0 (BY DEFINITION)  |
| SR# 99  | (105.791)              | 103.416       | 53.6                    | .0167  | 0        | 0   | 103.4847  | -.0687                            | -20.9              |
| SR# 98  | (105.821)              | 103.446       | 97.8                    | .0305  | 0        | 0   | 103.4985  | -.0525                            | -16.0              |
| SR# 97  | (105.853)              | 103.478       | 165.7                   | .0516  | 0        | 0   | 103.5196  | -.0416                            | -12.7              |
| SR# 96  | (105.891)              | 103.516       | 227.8                   | .0710  | .0012    |   | 103.5402  | -.0242                            | -7.4               |
| SR# 95  | (105.899)              | 103.524       | 295.7                   | .0921  | .0021    |   | 103.5622  | -.0382                            | -11.7              |
| SR# 94  | (105.929)              | 103.554       | 357.9                   | .1115  | .0031    |   | 103.5826  | -.0286                            | -8.7               |
| SR# 93  | (105.939)              | 103.564       | 425.7                   | .1326  | .0043    |   | 103.6049  | -.0409                            | -12.5              |
| TP 66   | 100.143                | =             | N/A                     |  |          |   |   |                                   |                    |
| PRIOR = | 100.136                | =             | N/A                     |  |          |   |   |                                   |                    |
| BT/VE5  | 106.464                | ②             | 6435.377                | 2.0050   | 0.9912   |   | 106.4642  | -.0002                            | -0.05 (CHECK)      |

(SEE NEXT PAGE)

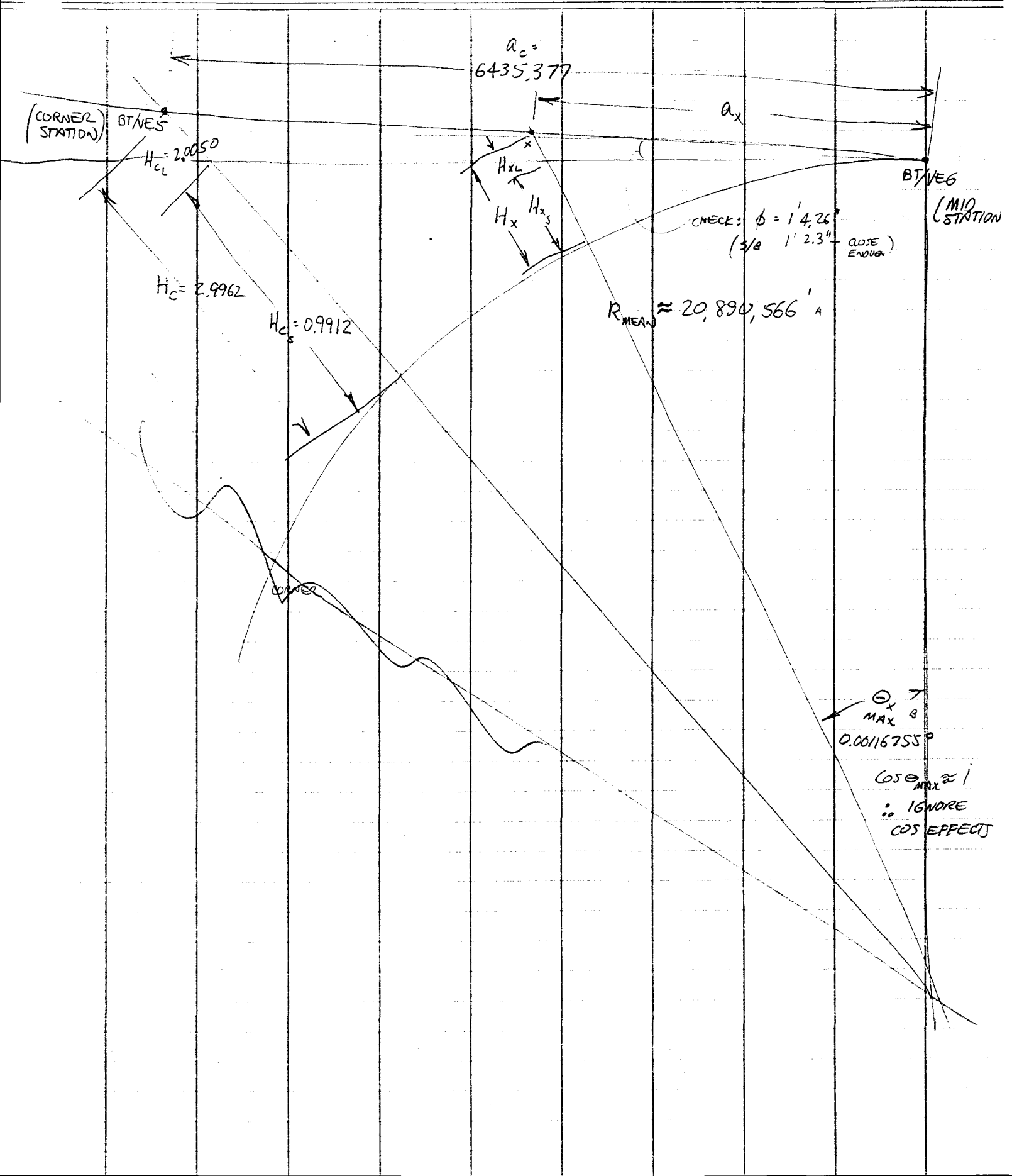


①  $100.000 + \frac{41.61}{12} = 103.4675$   
 ②  $102.982 + \frac{41.78}{12} = 106.4637$   
 $\Delta 2.9962$

SR = SUPPORT RING

SUBSCRIPTS : L = LINEAR PORTION  
S = SPHERICAL (CIRCULAR) PORTION

(SKETCH FOR PG 2 - VERT. ALIGNMENT OFFSETS) 4/8/9: *JH*



CHECK:  $\phi = 1' 4.26''$   
(3/8 1' 2.3" CLOSE ENOUGH)

$R_{MEAN} \approx 20,890,566'$

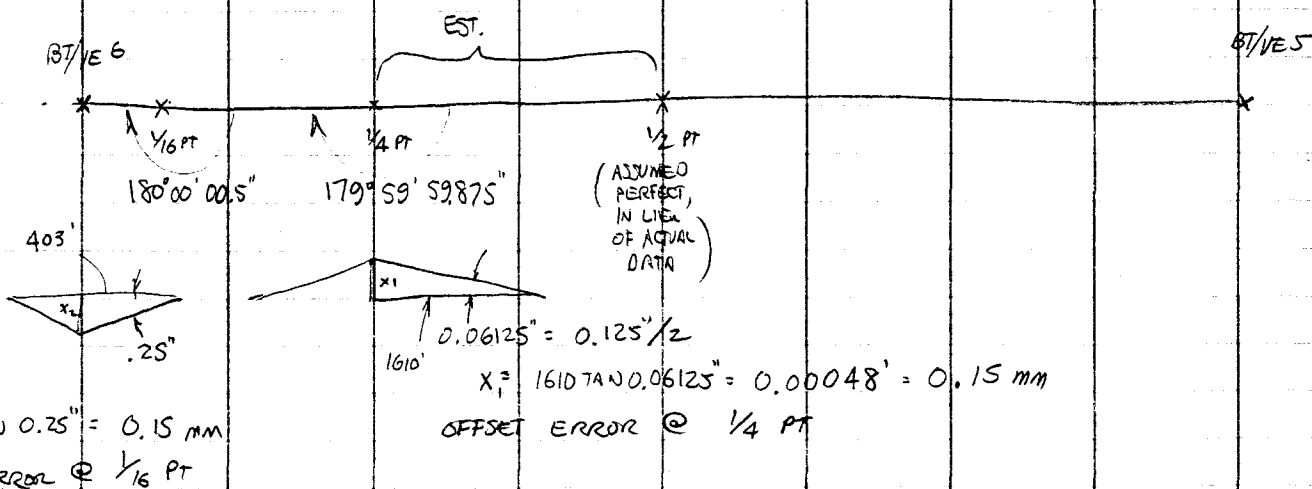
$\theta_x \approx 7$   
MAX  $\theta$   
0.0616755°

$\cos \theta_{MAX} \approx 1$   
 $\therefore$  IGNORE COS EFFECTS

O. RAD = 2.375

|         | DIST. FT<br>(RANGE 066) | LATERAL<br>OFFSET, FT | LATERAL<br>ERROR, MM |                 | VERTICAL<br>ERROR, MM<br>(FROM PG 2) | OVERALL<br>ERROR, MM |
|---------|-------------------------|-----------------------|----------------------|-----------------|--------------------------------------|----------------------|
| BT/VE 6 | 4.000                   | 0                     | 0                    | (BY DEFINITION) | 0                                    | 0                    |
| SR#99   | (1.627)                 | + .002                | + 0.6                |                 | - 20.9                               | 20.9                 |
| SR#98   | (1.639)                 | + .014                | + 4.3                |                 | - 16.0                               | 16.6                 |
| SR#97   | (1.648)                 | + .023                | + 7.0                |                 | - 12.7                               | 14.5                 |
| SR#96   | (1.662)                 | + .037                | + 11.3               |                 | - 7.4                                | 13.5                 |
| SR#95   | (1.648)                 | + .023                | + 7.0                |                 | - 11.7                               | 13.6                 |
| SR#94   | (1.657)                 | + .032                | + 9.8                |                 | - 8.7                                | 13.1                 |
| SR#93   | (1.631)                 | + .006                | + 1.8                |                 | - 12.5                               | 12.6                 |
| BT/VE 5 | 4.000                   | 0                     | 0                    | (BY DEFINITION) | 0                                    | 0                    |

CHECK THE EFFECT OF ERRORS IN "WIGGLE-IN"



- THESE ERRORS HAPPEN TO CANCEL EACH OTHER
- THEY ARE ALSO INSIGNIFICANT, EVEN IF THEY WERE ADDITIVE
- IT'S DOUBTFUL THAT THE  $\frac{1}{2}$  PT ERROR (IF SIMILAR TECHNIQUES WERE USED) WOULD BE OTHERWISE.

CHECK OF ARM LENGTHS CALCD. FROM LAT/LONG

*[Signature]*  
4/8/97

|               | LAT $\phi$         | LONG $\lambda$      | HT $h$         |
|---------------|--------------------|---------------------|----------------|
| 35            | 46° 27' 17.652298" | 119° 24' 29.309585" | 141.498        |
| 38            | 46° 26' 02.578424" | 119° 26' 58.709275" | 142.798        |
| 25            | 46° 27' 19.733097" | 119° 24' 28.832703" | 141.470 m      |
| 28            | 46° 29' 03.072631" | 119° 26' 17.476116" | 140.264 m      |
|               | <u>25</u>          | <u>28</u>           | <u>35</u>      |
| $\lambda$ (A) | 119.4080091        | 119.4381878         | 119.4081416    |
| $\phi$ (B)    | 46.45548142        | 46.48417018         | 46.45490342    |
| $a$ (C)       | 6,378,137          |                     |                |
| $b$ (D)       | 6,356,752.31       |                     |                |
| $f$           | 0.00336409         |                     |                |
| $\Sigma^2$    | 0.006716864        |                     |                |
| $h$ (E)       | 141.470            | 140.264             | 141.498        |
| $N(\phi)$ (F) | 6,389,383.185      | 6,389,393.917       | 6,389,382.969  |
| X             | -2,161,424.871     | -2,162,307.559      | -2,161,456.615 |
| Y             | 3,834,657.756      | 3,831,504.444       | 3,834,693.347  |
| Z             | 4,600,270.949      | 4,602,466.493       | 4,600,226.706  |
| $\Delta X$    | 882.68777          |                     | 3603362        |
| $\Delta Y$    | 3153.34167         |                     | 102875         |
| $\Delta Z$    | 2195.54425         |                     | 159637108      |
| Calc. L       | 3942.476 m         |                     | 3942.487 m     |
| ROGERS "TRUE" | 3942.502 m         |                     | 3942.501 m     |
| $\Delta$      | 26 mm ✓            |                     | 14 mm ✓        |

$$f = \frac{a-b}{b} \quad \Sigma^2 = 2f - f^2 \quad N(\phi) = \frac{a^2}{\sqrt{a^2 \cos^2 \phi + b^2 \sin^2 \phi}}$$

$$\begin{aligned} X &= (N(\phi) + h) \cos \phi \cos \lambda \\ Y &= (N(\phi) + h) \cos \phi \sin \lambda \\ Z &= [(1 - \Sigma^2) N(\phi) + h] \sin \phi \end{aligned}$$

(POSITIVE IS AWAY FROM END)

(POSITIVE IS TOWARD ROAD)

4/9/97

|    |   | ROGERS LATERAL | FIXED LATERAL OFFSET (FROM ROGERS) | CB1 "A3" FIXED OFFSETS | ROGERS VERTICAL | FIXED VERTICAL OFFSET (FROM ROGERS) | CB1 "H" FIXED VERTICAL OFFSET |
|----|---|----------------|------------------------------------|------------------------|-----------------|-------------------------------------|-------------------------------|
| 99 | G | 0.6            | -                                  | -                      | -20.9           | -                                   | -                             |
| 98 | F | 4.3            | +0.5                               | +2                     | -16.0           | +0.8                                | +2                            |
| 97 | G | 7.0            | -                                  | -                      | -12.7           | -                                   | -                             |
| 96 | F | 11.3           | +4.3                               | -5                     | -7.4            | +4.8                                | +5                            |
| 95 | G | 7.0            | -                                  | -                      | -11.7           | -                                   | -                             |
| 94 | F | 9.8            | +5.4                               | -5                     | -8.7            | +3.4                                | +4                            |
| 93 | G | 1.8            | -                                  | -                      | -12.5           | -                                   | -                             |

CHECK SIGN CONVENTION W/ STEVE ✓ (SEE ABOVE)

CONCLUSIONS -

- ~~DEPENDING UPON SIGN CONVENTION~~, THIS ~~COULD BE~~ <sup>IS</sup> A VERY GOOD AGREEMENT ON RELATIVE POSITIONS OF THE FIXED VS. GUIDED
- NOTE - NONE OF THESE USED GPS READINGS
- APPARENTLY CB1'S POLICY IS NOT TO CENTER FIXED SUPPORT RINGS BETWEEN ADJACENT GUIDED SUPPORT RINGS - (CONFIRM THIS)



IN THIS CASE,  
ON BOTH CBI & ROGERS  
(POSITIVE IS TOWARD ROAD)

JD  
4/9/97

ACTUALS-Y  
(mm)

ACTUALS-Z  
(mm)

|    | CBI | ROGERS | $\Delta$ (CBI-ROG)<br>MM | CBI | ROGERS | $\Delta$ (CBI-ROG)<br>MM |
|----|-----|--------|--------------------------|-----|--------|--------------------------|
| 99 | 4   | -0.6   | 4.6                      | -1  | -20.9  | 19.9                     |
| 98 | 3   | -4.3   | 7.3                      | 2   | -16.0  | 18.0                     |
| 97 | 2   | -7.0   | 9.0                      | 0   | -12.7  | 12.7                     |
| 96 | -1  | -11.3  | 10.3                     | 1   | -7.4   | 8.4                      |
| 95 | 0   | -7.0   | 7.0                      | 0   | -11.7  | 11.7                     |
| 94 | -1  | -9.8   | 8.8                      | 0   | -8.7   | 8.7                      |
| 93 | 4   | -1.8   | 5.8                      | 0   | -12.5  | 12.5                     |

ASSUMING ROGERS  
READINGS ARE CORRECT,

AVERAGE ERROR = 7.5

(DITD) = 13.1

|    | ROGERS<br>$a_x$ , FT | m      | CBI<br>$a_x$ , m | (ROG - CBI)<br>$\Delta$ |
|----|----------------------|--------|------------------|-------------------------|
| 99 | 53.6                 | 16.34  | 16.32            | .02                     |
| 98 | 97.8                 | 29.81  | 29.77            | .04                     |
| 97 | 165.7                | 50.51  | 50.46            | .05                     |
| 96 | 227.8                | 69.43  | 69.40            | .03                     |
| 95 | 295.7                | 90.13  | 90.08            | .05                     |
| 94 | 357.9                | 109.09 | 109.02           | .07                     |
| 93 | 425.7                | 129.75 | 129.71           | .04                     |

$a_x$  = DIST TO BT/VEG