AT/39.3/083

Triton antenna surveys

B.Parsons, B.Wilcockson & M.Kesteven

July 30, 1998

1 Summary

The four 16m Triton antennas were surveyed and adjusted over the period 12 july 1998 to 25 july 1998. The final surveys show that a setting accuracy of better than 0.25mm (rms) was achieved in each case.

2 Introduction

These antennas were built and erected by SES P/L on behalf of Clough Engineering. For the purposes of this report it is sufficient to note that the reflecting surface consists of 84 panels arranged in 4 concentric rings, 12 panels in the first ring, and 24 panels in all the other rings. Each panel is attached to the backup structure by means of studs which connect to gussets at each panel corner.

The survey operation is designed to assist the engineers in setting the reflector surface to the shape specified by the designers. We survey targets placed at the corner of each panel, and from this data we compute the adjustments required at the panel mounting bolts.

Two survey/adjust iterations were required on each antenna before the 0.25mm (rms) accuracy was achieved.

Section 3 describes the survey procedures, and section 4 gives the detailed results.

3 Survey Procedure

3.1 Overview

At the centre of the antenna (at the vertex) we install a rigid beam with a theodolite mounting bracket (a "Tribrach"). This bracket is used by SES in installing the panels, and by us in the survey.

We mark a set of targets on the reflector surface. The targets are disposed in rings which are concentric with the theodolite axis; every target is close to a panel corner (and to a mounting stud).

We observe every target with the theodolite - the difference between the observed elevation (angle) and the elevation expected for a perfect reflector is a measure of the panel setting error.

3.2 The Targets

Every target is at an accurately known arc distance from the theodolite axis. We have a semi-rigid steel tape, 1mm thick and 20mm wide, to which we attach a set of cursors. Each cursor is located at an accurately measured distance from the tape end, and is used for all the targets of a given ring. The target is a pencil mark made on the reflector surface, using the cursor as a guide for the pencil. The marks are 5mm long, at right angles to the tape. One end of the tape is attached to a rotating collar installed on the theodolite axis, 140mm below the theodolite's trunion axis. The assembly is installed in the tribrach which ensures that the collar is co-axial with the theodolite's azimuth axis.

The tape is laid on the surface along a radial line of panel edges. We mark either side of the tape, one target for each panel corner.

There are two factors which ensure that the arclength will reliably lead us to the true target's coordinates -

1. since the reflector is already close to the specified radial profile, an error in any target is normal to the surface, and thus to first order will not affect the other targets; in addition, the targets are re-marked after the first round of adjustments.

2. targets are marked at 8 different radii; and therefore there is only one set of elevation angles which is consistent with the given arclengths and the designed profile. (The procedure would fail with just one radial target, and would be unreliable with 2-3).

This procedure is robust:

- a temperature change (between when the tape was measured and when the targets were marked) will affect tape and antenna in the same way. The scale size of the antenna might change by a few parts in 10000, but the shape will not change.

- small errors in the positioning of the targets will lead to an error in the panel setting; however, the ratio (arclength error to setting error) is roughly 4:1 for these antennas (averaged over the full aperture).

3.3 Target Prediction Tables

The prediction of each target's elevation angle is based on :

a. The target arclength and the specified reflector (radial) profile;

b. The height of the theodolite above the reflector vertex;

c. A gravitational bias that ensures that the reflector has the specified radial profile at the "look" angle of 45 degrees. A correction is necessary because the antenna deforms as it tips from the zenith to the horizon. If the surface is perfect at the look angle it will not be perfect at the zenith. Yet the survey and adjustments are done with the antenna pointing to the zenith.

d. A correction is also made to account for any manufacturing error in the panel. The surface of every panel was measured at the factory to check that it conformed to the design shape; every panel had a surface accuracy of around 0.12mm (rms). These same measurements also provide us with an estimate of the offset between the mean panel profile and the actual surface at the corners. Suppose that a corner were bent up by 1 mm above the mean profile; then we should ensure that in the panel setting operation, that corner be raised by 1 mm so that the bulk of the panel sits on the specified profile.

Table 1 has the mean surface error for all the panels in each ring.

Table 1: Panel Manufacturing errors

Ring #	rms (mm)
1	0.13
2	0.11
3	0.11
4	0.14

3.4 Analysis

In essence, the analysis amounts to comparing the observed and predicted elevation angles for each target, and converting the difference to a panel setting error. There are two preliminary processing steps that we apply before computing the setting errors: we look for the signature of a theodolite axis tilt as well as the signature of a vertical shift in the theodolite trunion axis. It is, after all, simpler to move the theodolite than to reposition every panel. The magnitudes are modest - a few tenths of mm, and a few arcsces.

4 The Surveys

The surveys are summarised in table 2.

Table 2: Survey Results

antenna	surface error (rms in mm)	survey date
1 (α)	2.05	14/7/1998
	1.30	18/7/1998
	0.22	22/7/1998
2 (β)	2.68	14/7/1998
	0.52	17/7/1998
	0.17	21/7/1998
3 (C)	2.73	13/7/1998
	0.73	16/7/1998
	0.23	20/7/1998
4 (δ)	2.53	12/7/1998
	1.01	15/7/1998
	0.16	17/7/1998

An additional round of adjustments was undertaken after the final survey: the small number of panels with errors exceeding 0.3mm were reset. We have estimated the rms that will have resulted - assuming that the panels were repositioned with an error of 0.3mm (rms).

We conclude that every antenna has now been adjusted to better than 0.16mm (rms).

07-22-1998 23:52:23

Files to be used :

C:\survey\triton1\jul22\R1INNER.001
C:\survey\triton1\jul22\R1OUTER.001
C:\survey\triton1\jul22\R2INNER.001
C:\survey\triton1\jul22\R2OUTER.001
C:\survey\triton1\jul22\R3INNER.001
C:\survey\triton1\jul22\R3OUTER.001
C:\survey\triton1\jul22\R4INNER.001
C:\survey\triton1\jul22\R4OUTER.001

ring 1 INNER
Theodolite tilt : 15.0 arc secs
tilt direction 185.21 degrees
Theodolite height error : -0.48 mm

ring 1 OUTER
Theodolite tilt : 11.0 arc secs
tilt direction 37.31 degrees
Theodolite height error : -0.31 mm

ring 2 INNER
Theodolite tilt : 5.4 arc secs
tilt direction 2.88 degrees
Theodolite height error : -0.39 mm

ring 2 OUTER
Theodolite tilt : 14.8 arc secs
tilt direction 23.15 degrees
Theodolite height error : -0.41 mm

ring 3 INNER
Theodolite tilt : 10.2 arc secs
tilt direction 11.96 degrees
Theodolite height error : -0.25 mm

ring 3 OUTER
Theodolite tilt : 13.0 arc secs
tilt direction 30.80 degrees
Theodolite height error : -0.30 mm

ring 4 INNER
Theodolite tilt : 10.6 arc secs
tilt direction 45.48 degrees
Theodolite height error : -0.38 mm

ring 4 OUTER
Theodolite tilt : 13.6 arc secs
tilt direction 30.47 degrees
Theodolite height error : -0.40 mm

mean tilt : 10.21 arc secs
mean azimuth : 30.28 degrees
mean height error : -0.37 mm; if <0, raise theodolite

data CORRECTED for tilt and height

Negative means adjust DOWN

Ring 1

Panel Inner Outer

	left	right	left	right
		(all adjustments in mm)		
11	0.3	-0.1	0.2	-0.2
25	0.0	0.1	-0.0	-0.1
15	-0.0	0.1	-0.3	0.0
32	1.0	-0.2	0.0	0.0
18	-0.2	0.4	-0.1	-0.2
13	-0.4	-0.0	-0.1	-0.1
39	0.3	0.1	0.0	0.2
21	-0.1	0.1	-0.3	0.0
33	0.0	0.2	-0.1	-0.2
30	-0.2	0.1	0.0	-0.2
20	0.1	0.1	0.1	0.2
24	0.2	0.9	-0.1	-0.3

RMS Setting error for this ring : 0.25 mm
RMS half-path error for this ring : 0.25 mm

Negative means adjust DOWN

Ring 2

Panel	Inner		Outer	
	left	right	left	right
		(all adjustments in mm)		
19	-0.0	0.0	-0.3	-0.0
41	-0.1	-0.1	0.0	-0.1
50	0.2	0.2	0.0	-0.0
39	0.1	-0.1	-0.1	-0.4
24	0.1	0.3	0.0	-0.0
33	0.1	0.1	-0.1	0.0
76	-0.0	-0.0	0.2	0.1
37	0.2	0.1	0.1	0.1
72	0.3	0.4	0.3	0.2
32	0.2	0.1	-0.0	-0.1
66	0.1	-0.4	0.2	0.1
53	0.0	-0.1	0.2	0.1
59	0.2	0.0	0.2	0.3
46	0.3	-0.1	0.1	0.1
34	-1.8	0.2	0.1	-0.1
51	0.1	-0.1	0.0	0.2
21	0.0	-0.1	0.0	0.2
87	-0.3	0.2	-0.0	0.1
47	0.1	0.0	0.1	0.0
18	0.0	0.2	0.1	0.1
57	0.1	-0.0	-0.1	0.1
40	0.0	-0.0	-0.0	-0.1
27	0.1	-0.1	-0.1	-0.2
25	0.0	0.2	0.1	-0.1

RMS Setting error for this ring : 0.23 mm
RMS half-path error for this ring : 0.22 mm

Negative means adjust DOWN

Ring 3

Panel	Inner		Outer	
	left	right	left	right
		(all adjustments in mm)		
37	-0.0	-0.0	-0.1	-0.4
36	-0.1	-0.1	-0.0	-0.1
54	0.1	-0.1	0.0	0.1
16	-0.1	-0.1	-0.5	-0.2
32	-0.2	-0.1	0.0	-0.4
46	0.0	-0.2	-0.6	0.1
50	0.0	-0.1	0.1	-0.0
64	0.2	0.1	0.1	0.2

51	-0.2	-0.1	0.0	-0.2
59	-0.4	-0.1	-0.4	-0.0
13	0.1	-0.3	0.1	-0.1
3	-0.3	-0.0	-0.2	0.1
10	0.1	-0.0	0.0	-0.1
58	-0.2	-0.1	-0.1	0.1
53	-0.3	-0.2	0.2	-0.1
40	-0.0	-0.1	-0.0	0.0
17	-0.0	-0.1	0.0	0.1
52	-0.3	-0.1	0.1	0.1
33	-0.3	-0.2	-0.1	-0.1
4	-0.2	-0.2	0.0	-0.2
57	-0.3	-0.3	-0.1	-0.1
35	-0.3	-0.6	-0.1	-0.2
43	-0.2	-0.1	-0.4	-0.0
93	-0.0	-0.2	-0.0	-0.1

RMS Setting error for this ring : 0.20 mm
RMS half-path error for this ring : 0.17 mm

Negative means adjust DOWN

Ring 4

Panel	Inner		Outer	
	left	right	left	right
	(all adjustments in mm)			
44	0.0	0.3	0.2	0.1
50	0.2	0.0	0.2	-0.1
47	0.2	0.3	-0.1	-0.1
45	0.2	0.0	-1.0	0.2
9	-0.0	-0.5	0.0	-0.1
51	-0.1	-0.8	-0.1	-0.0
56	-0.2	-0.3	-0.2	-0.1
15	-0.0	0.0	0.1	-0.1
20	-0.1	-0.2	0.1	0.3
62	-0.0	0.0	0.1	0.3
49	0.0	0.1	0.1	0.0
48	-0.0	0.0	-0.2	0.2
53	0.1	0.1	0.1	0.4
98	-0.1	0.0	0.1	0.1
30	0.0	0.1	-0.1	0.1
55	0.1	0.1	0.2	0.4
38	0.2	0.1	0.0	0.4
37	0.1	-0.2	0.2	0.1
41	-0.1	0.0	0.2	-0.3
35	0.1	0.0	0.1	0.1
19	0.0	-0.1	-0.1	-0.3
32	0.1	0.1	-0.1	-0.2
59	0.0	0.1	-0.1	-0.0
69	-0.2	0.3	-0.0	0.1

RMS Setting error for this ring : 0.21 mm
RMS half-path error for this ring : 0.17 mm

Overall RMS setting error : 0.22 mm

Overall RMS half-path error : 0.20 mm

07-22-1998 00:44:17

Files to be used :

C:\survey\triton2\jul21\R1INNER.001
C:\survey\triton2\jul21\R1OUTER.001
C:\survey\triton2\jul21\R2INNER.001
C:\survey\triton2\jul21\R2OUTER.001
C:\survey\triton2\jul21\R3INNER.001
C:\survey\triton2\jul21\R3OUTER.001
C:\survey\triton2\jul21\R4INNER.001
C:\survey\triton2\jul21\R4OUTER.001

ring 1 INNER
Theodolite tilt : 8.2 arc secs
tilt direction 236.91 degrees
Theodolite height error : -1.01 mm

ring 1 OUTER
Theodolite tilt : 10.4 arc secs
tilt direction 331.15 degrees
Theodolite height error : -1.06 mm

ring 2 INNER
Theodolite tilt : 7.8 arc secs
tilt direction 337.49 degrees
Theodolite height error : -1.11 mm

ring 2 OUTER
Theodolite tilt : 15.5 arc secs
tilt direction 343.13 degrees
Theodolite height error : -1.11 mm

ring 3 INNER
Theodolite tilt : 12.6 arc secs
tilt direction 347.77 degrees
Theodolite height error : -1.01 mm

ring 3 OUTER
Theodolite tilt : 15.8 arc secs
tilt direction 332.95 degrees
Theodolite height error : -1.05 mm

ring 4 INNER
Theodolite tilt : 16.2 arc secs
tilt direction 336.24 degrees
Theodolite height error : -1.05 mm

ring 4 OUTER
Theodolite tilt : 16.6 arc secs
tilt direction 335.23 degrees
Theodolite height error : -1.06 mm

mean tilt : 13.76 arc secs
mean azimuth : 336.33 degrees
mean height error : -1.05 mm; if <0, raise theodolite

data CORRECTED for tilt and height

Negative means adjust DOWN

Ring 1

Panel	Inner	Outer

	left	right	left	right
		(all adjustments in mm)		
6	0.3	0.2	-0.0	-0.0
10	0.1	-0.3	0.0	-0.1
7	-0.1	0.0	0.1	-0.0
5	-0.2	-0.1	0.1	0.0
1	-0.1	-0.2	0.0	-0.2
44	-0.1	0.0	0.0	-0.0
16	-0.1	-0.1	-0.1	0.0
27	-0.1	-0.0	-0.0	0.1
28	-0.1	-0.3	-0.1	-0.0
17	-0.0	-0.1	-0.3	0.2
9	-0.1	-0.1	0.2	-0.1
8	0.0	0.2	0.2	0.1

RMS Setting error for this ring : 0.13 mm
RMS half-path error for this ring : 0.13 mm

Negative means adjust DOWN

Ring 2

Panel	Inner		Outer	
	left	right	left	right
		(all adjustments in mm)		
67	-0.0	-0.0	-0.1	-0.0
22	1.1	-0.2	0.1	-0.0
62	0.0	0.0	-0.2	0.0
73	0.1	0.2	0.1	-0.1
10	0.3	0.1	0.0	-0.0
55	-0.1	0.1	0.1	0.0
13	-0.0	0.0	0.1	-0.0
68	0.2	0.1	0.2	0.2
64	-0.0	0.0	0.0	0.1
20	-0.0	0.0	0.1	-0.0
52	-1.1	0.1	-0.1	0.2
58	0.1	0.1	0.2	0.2
31	-0.1	-0.0	0.1	0.1
91	0.1	0.1	0.1	0.2
48	0.0	0.0	-0.0	0.1
95	0.2	-0.0	0.1	0.1
45	0.1	0.0	0.1	0.1
23	0.4	0.2	0.6	0.0
43	-0.0	0.1	-0.1	0.1
4	0.1	0.0	0.2	-0.3
49	-0.0	0.2	-0.1	0.1
9	0.2	0.3	0.2	0.2
26	0.0	-0.2	0.1	-0.1
60	0.0	0.0	0.1	0.2

RMS Setting error for this ring : 0.21 mm
RMS half-path error for this ring : 0.20 mm

Negative means adjust DOWN

Ring 3

Panel	Inner		Outer	
	left	right	left	right
		(all adjustments in mm)		
2	-0.1	0.1	-0.0	0.0
77	-0.1	0.0	0.0	-0.0
49	0.0	0.0	0.2	0.2
38	-0.3	-0.1	0.1	-0.0
5	-0.2	-0.2	-0.1	0.0
12	-0.2	-0.3	-0.3	0.2
18	-0.2	-0.2	0.2	-0.2
9	-0.1	0.1	0.0	-0.2

14	0.0	-0.1	0.1	0.3
24	-0.1	-0.0	0.3	-0.1
8	-0.2	-0.2	0.1	-0.1
15	0.2	-0.0	0.0	0.2
11	-0.0	0.1	0.0	0.2
22	0.1	-0.2	-0.2	0.2
56	-0.1	0.0	0.1	0.1
41	0.1	-0.0	0.1	0.1
86	-0.0	0.1	-0.1	-0.2
73	-0.1	-0.2	-0.1	-0.1
39	-0.1	-0.0	-0.1	-0.2
89	-0.1	-0.0	-0.1	0.1
84	0.4	-0.0	0.1	-0.3
23	0.1	-0.2	-0.1	-0.2
68	0.1	0.1	-0.1	-0.2
70	0.0	0.0	-0.2	0.1

RMS Setting error for this ring : 0.15 mm
RMS half-path error for this ring : 0.13 mm

Negative means adjust DOWN

Ring 4

Panel	Inner		Outer	
	left	right	left	right
	(all adjustments in mm)			
83	-0.2	0.1	-0.4	-0.2
81	-0.1	0.0	0.0	0.0
84	-0.0	-0.1	-0.0	0.0
18	-0.1	-0.1	-0.0	0.2
17	0.0	-0.2	0.1	-0.0
88	-0.0	0.2	-0.0	-0.0
26	0.1	0.1	0.1	0.0
87	0.1	0.0	0.1	0.3
14	0.1	-0.3	0.1	-0.3
31	-0.1	0.8	0.3	0.2
58	-0.0	0.1	0.1	0.1
21	0.0	0.1	0.1	-0.0
67	-0.0	-0.1	0.2	-0.0
52	-0.0	0.0	0.3	-0.0
77	0.1	-0.0	0.2	-0.1
4	-0.0	0.1	0.1	0.3
5	-0.1	-0.0	-0.2	-0.2
70	0.2	-0.1	0.2	-0.0
76	-0.1	-0.1	0.2	-0.2
73	-0.1	0.1	0.0	-0.1
82	-0.0	-0.1	-0.5	0.1
86	-0.0	-0.1	-0.2	-0.1
85	-0.0	-0.1	-0.1	-0.0
23	-0.2	-0.2	-0.3	-0.2

RMS Setting error for this ring : 0.16 mm
RMS half-path error for this ring : 0.13 mm

Overall RMS setting error : 0.17 mm

Overall RMS half-path error : 0.15 mm

07-20-1998 23:57:16

Files to be used :

C:\survey\triton3\jul20\R1INNER.001
C:\survey\triton3\jul20\R1OUTER.001
C:\survey\triton3\jul20\R2INNER.001
C:\survey\triton3\jul20\R2OUTER.001
C:\survey\triton3\jul20\R3INNER.001
C:\survey\triton3\jul20\R3OUTER.001
C:\survey\triton3\jul20\R4INNER.001
C:\survey\triton3\jul20\R4OUTER.001

ring 1 INNER
Theodolite tilt : 24.6 arc secs
tilt direction 30.41 degrees
Theodolite height error : -0.04 mm

ring 1 OUTER
Theodolite tilt : 28.0 arc secs
tilt direction 331.55 degrees
Theodolite height error : 0.09 mm

ring 2 INNER
Theodolite tilt : 29.8 arc secs
tilt direction 333.43 degrees
Theodolite height error : -0.01 mm

ring 2 OUTER
Theodolite tilt : 31.9 arc secs
tilt direction 324.93 degrees
Theodolite height error : -0.04 mm

ring 3 INNER
Theodolite tilt : 28.5 arc secs
tilt direction 340.27 degrees
Theodolite height error : 0.09 mm

ring 3 OUTER
Theodolite tilt : 30.0 arc secs
tilt direction 333.63 degrees
Theodolite height error : 0.01 mm

ring 4 INNER
Theodolite tilt : 29.2 arc secs
tilt direction 332.80 degrees
Theodolite height error : 0.00 mm

ring 4 OUTER
Theodolite tilt : 32.7 arc secs
tilt direction 330.86 degrees
Theodolite height error : -0.01 mm

mean tilt : 29.49 arc secs
mean azimuth : 334.39 degrees
mean height error : 0.01 mm; if <0, raise theodolite

data CORRECTED for tilt and height

Negative means adjust DOWN

Ring 1

Panel	Inner	Outer

	Inner		Outer	
	left	right	left	right
	(all adjustments in mm)			
29	0.0	-0.0	-0.1	-0.2
14	0.0	-0.0	0.0	-0.1
31	-0.1	-0.1	-0.1	0.2
34	0.0	0.0	-0.1	0.1
42	-0.1	0.1	-0.3	-0.2
23	-0.0	0.0	0.1	-0.2
22	-0.1	-0.1	-0.2	-0.1
45	-0.2	0.0	-0.2	-0.2
38	0.1	1.3	0.0	0.0
35	0.0	0.3	0.1	-0.1
37	-0.2	0.1	-0.1	-0.2
36	0.1	-0.0	-0.1	-0.0

RMS Setting error for this ring : 0.22 mm
RMS half-path error for this ring : 0.22 mm

Negative means adjust DOWN

Ring 2

Panel	Inner		Outer	
	left	right	left	right
	(all adjustments in mm)			
61	0.1	0.2	0.0	0.1
75	-0.1	0.0	-0.2	0.0
94	0.2	0.0	-0.0	0.2
69	-0.1	0.0	0.0	1.4
96	-0.0	0.1	0.1	-0.1
54	0.0	0.1	-0.1	-0.0
74	-0.0	0.3	-0.0	0.8
14	0.1	0.2	0.6	-0.1
89	-0.1	-0.2	0.0	0.1
77	-0.1	-0.1	0.2	-0.1
88	-0.2	-0.0	-0.1	-0.0
79	0.0	0.1	0.0	0.1
71	-0.1	-0.0	-0.0	0.1
93	0.1	-0.1	0.1	0.0
7	0.0	0.1	0.0	-0.2
97	-0.0	-0.1	-0.1	-0.1
78	0.0	-0.0	-0.0	-0.3
56	0.2	0.1	-0.1	0.0
38	0.1	0.0	-0.1	-0.0
65	0.1	-0.0	0.0	0.1
16	-0.1	-0.0	-0.2	0.0
35	-0.1	-0.1	-0.0	-0.0
36	0.0	-0.3	-0.0	-0.2
70	-0.1	-0.0	0.2	-0.1

RMS Setting error for this ring : 0.20 mm
RMS half-path error for this ring : 0.18 mm

Negative means adjust DOWN

Ring 3

Panel	Inner		Outer	
	left	right	left	right
	(all adjustments in mm)			
92	-0.1	-0.2	-0.0	-0.0
20	0.0	0.0	-0.1	0.1
81	-0.1	-0.0	-0.0	-0.2
80	-0.2	-0.2	-0.1	0.0
74	-0.2	-0.1	-0.1	-0.1
94	-0.0	-0.2	1.1	-0.1
95	-0.2	-0.3	-0.1	0.0
21	-0.3	-0.2	-0.0	-0.1

1	-0.2	0.1	-0.0	-0.3
75	-0.3	0.0	-0.3	0.1
6	-0.2	-0.1	0.0	-0.2
91	0.1	-0.1	-0.1	0.1
97	-0.3	-0.1	0.1	0.0
85	-0.1	0.0	0.2	0.3
26	-0.0	0.0	-0.1	0.0
44	-0.2	-0.0	0.1	-0.0
90	-0.0	-0.3	0.1	-0.0
29	-0.1	-0.0	-0.1	-0.0
76	0.9	-0.0	-0.1	-0.3
42	0.2	-0.3	0.1	0.0
63	-0.2	-0.2	-0.1	-0.0
78	-0.1	0.1	-0.1	0.0
19	-0.1	-0.5	0.0	-0.1
27	-0.3	0.4	-0.0	0.0

RMS Setting error for this ring : 0.21 mm
RMS half-path error for this ring : 0.18 mm

Negative means adjust DOWN

Ring 4

Panel	Inner		Outer	
	left	right	left	right
	(all adjustments in mm)			
89	0.0	0.2	-0.1	-0.2
39	-0.1	0.1	-0.1	-0.2
63	0.1	0.2	-0.6	-0.1
93	0.1	0.0	0.5	-0.3
97	-0.0	-0.0	-0.4	1.5
91	0.2	-0.1	-0.1	0.1
95	-0.3	-0.0	-0.3	1.0
1	0.1	-0.1	-0.3	0.7
24	-0.2	0.1	0.0	0.0
96	-0.1	0.1	-0.0	0.3
75	0.1	0.2	0.3	0.1
61	0.0	0.0	0.1	-0.0
34	-0.0	0.1	-0.1	0.7
33	-0.1	0.0	0.0	-0.1
36	-0.0	-0.3	-0.2	-0.0
60	0.0	-0.2	-0.4	0.1
66	0.1	0.1	-0.1	-0.3
16	-0.1	-0.1	-0.1	-0.2
10	-0.1	-0.1	-0.2	-0.1
54	0.1	0.1	0.1	0.2
29	-0.1	-0.1	-0.1	-0.1
8	-0.0	-0.1	-0.0	-0.0
7	0.1	0.0	-0.1	-0.3
13	0.1	-0.0	-0.3	0.6

RMS Setting error for this ring : 0.27 mm
RMS half-path error for this ring : 0.21 mm

Overall RMS setting error : 0.23 mm

Overall RMS half-path error : 0.20 mm

07-20-1998 11:17:30

Files to be used :

C:\survey\triton4\jul17\R1INNER.001
C:\survey\triton4\jul17\R1OUTER.001
C:\survey\triton4\jul17\R2INNER.001
C:\survey\triton4\jul17\R2OUTER.001
C:\survey\triton4\jul17\R3INNER.001
C:\survey\triton4\jul17\R3OUTER.001
C:\survey\triton4\jul17\R4INNER.001
C:\survey\triton4\jul17\R4OUTER.001

ring 1 INNER
Theodolite tilt : 22.9 arc secs
tilt direction 233.85 degrees
Theodolite height error : 0.77 mm

ring 1 OUTER
Theodolite tilt : 7.5 arc secs
tilt direction 342.77 degrees
Theodolite height error : 0.83 mm

ring 2 INNER
Theodolite tilt : 11.9 arc secs
tilt direction 333.69 degrees
Theodolite height error : 0.79 mm

ring 2 OUTER
Theodolite tilt : 11.0 arc secs
tilt direction 337.16 degrees
Theodolite height error : 0.85 mm

ring 3 INNER
Theodolite tilt : 13.4 arc secs
tilt direction 348.79 degrees
Theodolite height error : 0.84 mm

ring 3 OUTER
Theodolite tilt : 12.4 arc secs
tilt direction 347.16 degrees
Theodolite height error : 0.82 mm

ring 4 INNER
Theodolite tilt : 12.3 arc secs
tilt direction 349.40 degrees
Theodolite height error : 0.87 mm

ring 4 OUTER
Theodolite tilt : 11.2 arc secs
tilt direction 341.96 degrees
Theodolite height error : 0.84 mm

mean tilt : 11.07 arc secs
mean azimuth : 339.95 degrees
mean height error : 0.82 mm; if <0, raise theodolite

data CORRECTED for tilt and height

Negative means adjust DOWN

Ring 1

Panel	Inner	Outer

	left	right	left	right
		(all adjustments in mm)		
49	0.1	0.3	-0.0	0.1
26	0.1	0.5	-0.0	0.1
41	-0.0	0.1	-0.0	-0.1
46	0.2	0.0	0.1	-0.0
19	-0.0	0.1	-0.2	-0.0
43	-0.1	-0.0	-0.1	-0.0
48	-0.0	-0.1	-0.1	-0.0
2	-0.0	-0.1	-0.1	-0.0
4	-0.1	-0.1	0.1	0.1
3	0.0	0.0	-0.1	-0.0
40	0.1	0.0	-0.0	0.1
47	0.1	0.2	0.1	0.0

RMS Setting error for this ring : 0.12 mm
RMS half-path error for this ring : 0.12 mm

Negative means adjust DOWN

Ring 2

Panel	Inner		Outer	
	left	right	left	right
		(all adjustments in mm)		
86	0.2	-0.1	0.0	-0.1
84	-0.6	-0.0	-0.1	-0.1
8	0.3	0.3	0.1	0.1
98	0.2	0.1	0.1	0.0
85	0.1	0.1	-0.0	-0.1
90	0.0	0.0	-0.1	-0.0
81	-0.0	0.0	-0.0	-0.1
83	0.0	0.0	0.1	0.0
5	0.0	-0.0	-0.1	0.1
2	0.1	0.1	-0.0	-0.1
63	-0.1	-0.1	0.1	-0.2
3	-0.1	0.2	-0.1	0.1
29	0.1	-0.2	-0.2	-0.0
28	0.1	-0.0	-0.0	-0.2
1	0.1	0.0	-0.1	-0.2
11	0.0	0.0	0.7	0.0
80	0.1	0.1	0.1	-0.2
92	0.0	0.0	0.0	0.0
30	0.1	-0.2	-0.1	-0.3
12	0.0	-0.0	-0.0	0.1
82	0.1	-0.6	-0.1	-0.2
17	0.1	0.1	0.1	-0.1
6	0.2	-0.1	-0.1	-0.1
44	0.2	0.2	-0.2	0.2

RMS Setting error for this ring : 0.16 mm
RMS half-path error for this ring : 0.15 mm

Negative means adjust DOWN

Ring 3

Panel	Inner		Outer	
	left	right	left	right
		(all adjustments in mm)		
67	-0.2	-0.1	-0.3	-0.4
28	-0.1	0.1	-0.3	-0.2
79	0.1	-0.0	-0.1	-0.0
55	-0.2	-0.0	-0.1	-0.1
65	-0.1	-0.0	-0.1	0.2
48	0.1	-0.1	-0.0	-0.0
82	-0.1	-0.2	0.0	-0.0
87	-0.2	0.2	0.2	0.6

61	-0.0	-0.1	0.1	-0.1
62	-0.1	0.0	-0.3	0.1
31	0.1	0.1	0.0	-0.0
47	-0.1	-0.1	-0.1	0.0
83	-0.0	0.0	0.0	0.1
88	0.1	-0.0	-0.0	0.0
60	0.2	0.2	0.1	0.3
25	0.0	-0.1	0.0	-0.2
96	0.1	-0.0	-0.2	-0.2
66	0.2	-0.0	0.1	0.2
69	0.0	0.1	0.3	0.1
34	-0.1	0.2	0.2	0.1
71	-0.3	-0.2	-0.0	-0.2
72	-0.1	0.2	0.1	0.1
30	-0.2	-0.1	0.0	0.2
45	-0.1	-0.0	-0.1	0.1

RMS Setting error for this ring : 0.15 mm
RMS half-path error for this ring : 0.13 mm

Negative means adjust DOWN

Ring 4

Panel	Inner		Outer	
	left	right	left	right
	(all adjustments in mm)			
92	-0.1	-0.3	-0.2	0.2
57	-0.2	-0.2	0.0	-0.0
22	-0.2	0.1	0.1	-0.1
72	-0.3	-0.2	-0.1	0.7
71	-0.0	0.2	0.0	-0.2
74	-0.1	-0.0	0.1	-0.1
3	-0.1	-0.1	-0.2	0.0
2	-0.0	-0.0	-0.0	-0.0
6	-0.1	-0.0	0.0	-0.0
78	0.1	-0.1	-0.2	0.0
90	-0.2	0.0	-0.2	-0.1
80	0.1	-0.1	-0.2	-0.1
27	-0.3	0.1	0.2	0.1
94	-0.0	0.1	-0.1	0.1
79	-0.2	0.0	0.0	-0.2
64	0.1	0.0	-0.0	0.3
25	-0.1	0.1	0.0	0.2
68	0.3	0.1	0.0	0.1
12	0.2	-0.0	0.2	0.0
65	0.0	-0.0	0.1	0.1
11	-0.1	0.1	-0.2	-0.0
43	-0.1	-0.1	-0.4	-0.3
40	-0.0	-0.2	-0.1	-0.2
42	-0.3	-0.1	-0.2	0.1

RMS Setting error for this ring : 0.17 mm
RMS half-path error for this ring : 0.13 mm

Overall RMS setting error : 0.16 mm

Overall RMS half-path error : 0.14 mm