HIRDLS

TC-OXF-185

HIGH RESOLUTION DYNAMICS LIMB SOUNDER

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Subject/Title: **BASELINE SCAN PATTERNS FOR HIRDLS DESIGN & TEST**

Description/Summary/Contents:

ANGLES ARE SPECIFIED AS MECHANICAL SHAFT ANGLES

This document defines typical and extreme-case scan patterns which should be used as a basis for HIRDLS design and test purposes.

The parameters needed to describe a complete scan cycle are complex, and the actual-motion profile is dependent on the behaviour of the Scanner Control System. For these reasons it is not appropriate to define a given pattern simply by means of a diagram.

Instead, the pattern is defined by a numerical control table of the kind envisaged for operational use. The parameters used in the table take into account some important behavioural features of the proposed Control System in order to achieve as closely as possible the desired actual motion.

A single table is inadequate to define the necessary design and test cases. At least two tables are required to cover worst-case situations - three if a typical case is required for test purposes. This document includes examples of control tables for two types of scan sub-mode in order to assist in modelling and evaluating the implications of both constant-angular-rate and constant-tangent-height-rate sub-modes. There are thus six tables in all.

Keywords: Scan; LOS; test; elevation; azimuth;

Purpose of this Document: Adjunct to ITS

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INTRODUCTION

Six numerical scan control tables are included in this document, corresponding to the six operational scenarios described by the following Table:

	"Typical" case	"Lowest" extreme case	"Highest" extreme case
Constant tangent height rate scan	Table 1	Table 2	Table 3
Constant angular rate (elevation)	Table 4	Table 5	Table 6

The alternative scan sub-modes, i.e. constant angular rate and constant tangent height rate, are included since they are both potentially required in operation, and it is therefore desirable to verify the correct operation of the Scanner Control System in both sub-modes. The "constant tangent height rate" profile is achieved by specifying certain intervals and rates, and assuming that the Scanner Control System will interpolate over the specified intervals in the manner described to John Barnett by Alain Carrier. This assumption - which needs to be confirmed - must eventually appear in the appropriate specification document.

For worst-case design purposes relating to power consumption, heat dissipation, peak torques, torque profiles, disturbances, viewing aperture clearance, etc., one "lowest" or one "highest" extreme case should be selected. Which is chosen depends on which parameter is being considered.

For test purposes, different considerations will apply, but again the appropriate case or cases will need to be selected.

In what follows, the elevation scan cycles may be thought of as having a "DC" component and two "AC" components, the latter being at the elevation scan rate and the orbit rate respectively.

The "DC" component is represented by fixed offsets or biases from "nominal" in the elevation angle due for example to an "incorrect" orbit height, or a "fixed" offset in spacecraft pitch attitude. It should be noted however that even the terms "DC" and "fixed" are relative, in the sense that a spacecraft pitch attitude bias may be constant for weeks or months, and may then be changed by command for some operational reason; orbit height will slowly decay and may be boosted up from time to time, etc.. So in this context "DC" implies "over a large number of orbits".

In Global Mode, the peak-to-peak angular range for individual elevation scans will be fairly constant, but the "envelope" will slowly migrate up and down between larger peak values as the mean ILOS angle is adjusted around the orbit - as well as over longer periods - so that the tangent-point height tracks the oblateness of the earth, and corrections are made for the eccentricity of the orbit and the slow precession of its perigee, etc..

Orbit-rate and slower cycles of this kind will be sufficiently slow that variations in peak disturbance torques, scanner temperature, etc. will in general not average out. For this reason some of them are treated in what follows as contributing to the "extreme case" conditions, e.g. earth oblateness effects. Details of this kind need further consideration from the design and test points of view.

NOTES ON NUMERICAL TABLES

1) The first column gives the point in the sequence marked on figure 1; columns 2-5 are those required by the scanner (possibly modified in some way); column 6 (boresight height) is given for information only. Blank lines are inserted for clarity.

2) The elevation shaft angle for the IFC view is given as TBD; its value does not affect the generation of the tables. The azimuth shaft angle is assumed to be 29 deg, but the exact value is not critical.

3) Tables 1-3 and 4-6 are based on the nominal case plus the two extremes given in TC-OXF-76C, namely:

   i) Nominal case, with mean Earth radius of 6371 km; in this case a 25.3 km tangent point height for the centre of the IFOV corresponds to 25.32 deg elevation angle relative to the ICRF.

   ii) Extreme low case; here the elevation shaft angles have lower values than the nominal because the Earth's radius is a maximum (6378.4 km), the spacecraft radius is lowest (7046 km), and the spacecraft attitude and alignment errors of -0.3 deg are such as to compound the problem; in this case a 25.3 km tangent point height corresponds to 24.35 deg elevation angle relative to the ICRF.

   iii) Extreme high case; reverse of case (ii) with the Earth radius set to 6356.9 km, spacecraft radius to 7106 km, and an attitude plus alignment error of +0.3 deg; in this case a 25.3 km tangent point height corresponds to 26.39 deg elevation angle relative to the ICRF.

   These extremes should not be considered unlikely; the Earth radius variation and a large proportion of the orbit radius variation are certain to occur and in no sense represent errors. It may be noticed that the extreme high and low cases are not symmetric about the nominal; this is primarily because the extremes of the Earth radii are not symmetric about the mean value normally used, and also because of non-linearity in the conversion between elevation angle and tangent height.

4) The scan assumes 6 atmospheric profiles equally spaced in azimuth between +20.5 deg LOS -41.8 deg LOS; this range is necessary for the extreme low case so that the tangent point tracks of the end profiles lie over each other on successive southbound orbits at the equator (for northbound the range could be reduced by about 1.6 deg). No allowance is made for yaw error since, to an adequate approximation, the coverage lost on one side matches that gained on the other.

5) In Tables 1, 2 and 3 an elevation scan at a constant rate of tangent height per unit time is being specified in the atmospheric segment of each elevation scan (-27 to +103 km tangent point altitude). The rate is set to be 0.2 km per 1/84 sec, i.e. 130 km in 7.738 sec. This constant height rate scan is achieved by specifying the atmospheric part at three shaft angles (two end points and a mid point) with the elevation rates set accordingly. Since this may introduce unnecessary complications during testing, a second set is defined in Tables 4, 5 and 6. In these the atmospheric segment of each elevation scan is set to be at a constant angular rate, and this to be the same mean rate at used in Tables 1, 2 and 3 (the atmospheric section requires the same time of 7.738 seconds). The total cycle time of the sequence varies slightly between 64.475 and 64.984 sec. This variation is caused by high order effects (primarily the non-linearity of the elevation angle to tangent height relation), and is not indicative of an error.

6) Certain arbitrary assumptions have been made, and can be changed if necessary subject to the constraint that an overall cycle time of no more than 66 sec is required (and scientifically a shorter time would be advantageous). These arbitrary assumptions are listed in notes (7) to (13) below:

7) The dwell time at the IFC has been taken to be 0.5 sec; from considerations of radiometric noise 0.25 sec would be adequate, but some allowance has been made for the scanner to settle mechanically. It may be desirable to trade some of the additional 0.25 sec with the slew time, to reduce the peak acceleration needed.

8) A time of 1 sec has been assumed for the scanner to move in azimuth between one elevation profile and the next, corresponding to an acceleration of 25.2 deg/sec/sec. It should be noted that poorer line of sight stability could be tolerated at the space view end of the scan than at the bottom, hence it might be appropriate to increase this time or insert a short delay on the 3 occasions when the azimuth step is at the bottom limit (-27 km boresight altitude) at the expense of decreasing it on the 2 occasions at the space view end (137 km). This refinement has not been included in the attached tables.

9) Acceleration rates lower than 25.2 deg/sec/sec have been assumed for the azimuth movements to and from the IFC, to assist in meeting one of the GIRD angular momentum requirements.

10) The space view part of the vertical profile has been scanned in elevation at twice the angular rate of the atmospheric part of the scan.

11) A transition time of 0.1 sec has been assumed for the rate to change between the atmospheric and space view parts of the scan. For the rates involved here and assuming constant acceleration this corresponds to approximately 2.5 km in tangent point altitude.

12) The fly-back following the IFC view and immediately prior to the first elevation scan has been performed at constant elevation angle, i.e. at the nominal space view tangent point altitude of 137 km, and not at constant elevation shaft angle - which would not represent the expected operational case.

13) Azimuth rates are zero at the beginning and end of every segment except during the azimuth fly-back, where the fly-back is divided into a series of segments in order to specify a varying elevation shaft angle. A constant acceleration of 10.8 deg/sec/sec is arbitrarily assumed up to the mid point of this fly-back, followed by a constant deceleration at the same rate. By chance one of the points for which we have already calculated the elevation shaft angle corresponding to 137 km tangent happens to be very close to the mid point, and this coincidence has been used to simplify the calculation.

Table 1

Nominal elevation offset.
Post launch sequence with atmospheric scan at constant rate of tangent height unit time.

	Elev shaft angle (deg)	Elev shaft rate (deg/s)	Azimuth shaft angle (deg)	Azimuth shaft rate (deg/s)	Time (s)	Boresight height (km)	
A	TBD	0.0000	29.00	0	0.000	N/A	Start at IFC view
B	-1.1110	0.0000	10.25	-20.1	1.868	137.0	Azimuth scan at space view elevation
C	-1.0959	0.0293	4.02	-23.2	2.156	137.0	
D	-1.0940	-0.0147	-2.21	-20.0	2.444	137.0	
E	-1.1052	-0.0457	-8.44	-16.4	2.786	137.0	
F	-1.1301	-0.0427	-14.67	-11.6	3.232	137.0	
G	-1.1702	0.3608	-20.9	0	4.309	137.0	Elevation scan 1 (down)
H	-0.8271	0.3608	-20.9	0	5.260	105.5	
I	-0.8001	0.1804	-20.9	0	5.360	103.0	
	-0.1193	0.1718	-20.9	0	9.229	38.0	
J	0.5307	0.1644	-20.9	0	13.098	-27.0	
K	0.5125	-0.1587	-14.67	0	14.098	-27.0	Elevation scan 2 (up)
	-0.1152	-0.1659	-14.67	0	17.967	38.0	
L	-0.7726	-0.1742	-14.67	0	21.836	103.0	
M	-0.7988	-0.3484	-14.67	0	21.936	105.5	
N	-1.1301	-0.3484	-14.67	0	22.887	137.0	
O	-1.1052	0.3407	-8.44	0	23.887	137.0	Elevation scan 3 (down)
P	-0.7812	0.3407	-8.44	0	24.838	105.5	
Q	-0.7556	0.1704	-8.44	0	24.938	103.0	
	-0.1126	0.1622	-8.44	0	28.807	38.0	
R	0.5012	0.1552	-8.44	0	32.676	-27.0	
S	0.4961	-0.1537	-2.21	0	33.676	-27.0	Elevation scan 4 (up)
	-0.1115	-0.1606	-2.21	0	37.545	38.0	
T	-0.7480	-0.1686	-2.21	0	41.414	103.0	
U	-0.7733	-0.3373	-2.21	0	41.514	105.5	
V	-1.0940	-0.3373	-2.21	0	42.465	137.0	
W	-1.0959	0.3379	4.02	0	43.465	137.0	Elevation scan 5 (down)
X	-0.7746	0.3379	4.02	0	44.416	105.5	
Y	-0.7493	0.1689	4.02	0	44.516	103.0	
	-0.1117	0.1609	4.02	0	48.385	38.0	
Z	0.4970	0.1539	4.02	0	52.254	-27.0	
AA	0.5038	-0.1560	10.25	0	53.254	-27.0	Elevation scan 6 (up)
	-0.1132	-0.1631	10.25	0	57.123	38.0	
AB	-0.7596	-0.1712	10.25	0	60.992	103.0	
AC	-0.7853	-0.3425	10.25	0	61.092	105.5	
AD	-1.1110	-0.3425	10.25	0	62.043	137.0	
AE	TBD	0.0000	29.00	0	64.478	N/A	Dwell at IFC view for 0.5 sec
A	TBD	0.0000	29.00	0	64.978	N/A	

Table 2.

Low extreme for elevation offset
Post launch sequence with atmospheric scan at constant rate of tangent height per unit time.

	Elev shaft angle (deg)	Elev shaft rate (deg/s)	Azimuth shaft angle (deg)	Azimuth shaft rate (deg/s)	Time (s)	Boresight height (km)	
A	TBD	0.0000	29.00	0	0.000	N/A	Start at IFC view
B	-1.6373	0.0000	10.25	-20.1	1.868	137.0	Azimuth scan at space view elevation
C	-1.6152	0.0432	4.02	-23.2	2.156	137.0	
D	-1.6124	-0.0217	-2.21	-20.0	2.444	137.0	
E	-1.6288	-0.0674	-8.44	-16.4	2.786	137.0	
F	-1.6655	-0.0629	-14.67	-11.6	3.232	137.0	
G	-1.7247	0.3728	-20.9	0	4.309	137.0	Elevation scan 1 (down)
H	-1.3697	0.3728	-20.9	0	5.261	105.5	
I	-1.3418	0.1864	-20.9	0	5.361	103.0	
	-0.6393	0.1770	-20.9	0	9.230	38.0	
J	0.0293	0.1689	-20.9	0	13.099	-27.0	
K	0.0283	-0.1631	-14.67	0	14.099	-27.0	Elevation scan 2 (up)
	-0.6174	-0.1709	-14.67	0	17.968	38.0	
L	-1.2957	-0.1800	-14.67	0	21.837	103.0	
M	-1.3227	-0.3600	-14.67	0	21.937	105.5	
N	-1.6655	-0.3600	-14.67	0	22.889	137.0	
O	-1.6288	0.3521	-8.44	0	23.889	137.0	Elevation scan 3 (down)
P	-1.2936	0.3521	-8.44	0	24.841	105.5	
Q	-1.2672	0.1761	-8.44	0	24.941	103.0	
	-0.6038	0.1671	-8.44	0	28.810	38.0	
R	0.0277	0.1595	-8.44	0	32.679	-27.0	
S	0.0274	-0.1579	-2.21	0	33.679	-27.0	Elevation scan 4 (up)
	-0.5977	-0.1654	-2.21	0	37.548	38.0	
T	-1.2544	-0.1743	-2.21	0	41.417	103.0	
U	-1.2806	-0.3486	-2.21	0	41.517	105.5	
V	-1.6124	-0.3486	-2.21	0	42.469	137.0	
W	-1.6152	0.3492	4.02	0	43.469	137.0	Elevation scan 5 (down)
X	-1.2828	0.3492	4.02	0	44.421	105.5	
Y	-1.2566	0.1746	4.02	0	44.521	103.0	
	-0.5987	0.1657	4.02	0	48.390	38.0	
Z	0.0274	0.1582	4.02	0	52.259	-27.0	
AA	0.0278	-0.1603	10.25	0	53.259	-27.0	Elevation scan 6 (up)
	-0.6070	-0.1680	10.25	0	57.128	38.0	
AB	-1.2738	-0.1770	10.25	0	60.997	103.0	
AC	-1.3004	-0.3539	10.25	0	61.097	105.5	
AD	-1.6373	-0.3539	10.25	0	62.049	137.0	
AE	TBD	0.0000	29.00	0	64.484	N/A	Dwell at IFC view for 0.5 sec
A	TBD	0.0000	29.00	0	64.984	N/A	

Table 3.

High extreme case for elevation offset.
Post launch sequence with atmospheric scan at constant rate of tangent height per unit time.

	Elev shaft angle (deg)	Elev shaft rate (deg/s)	Azimuth shaft angle (deg)	Azimuth shaft rate (deg/s)	Time (s)	Boresight height (km)	
A	TBD	0.0000	29.00	0	0.000	N/A	Start at IFC view
B	-0.5308	0.0000	10.25	-20.1	1.868	137.0	Azimuth scan at space view elevation
C	-0.5236	0.0140	4.02	-23.2	2.156	137.0	
D	-0.5227	-0.0070	-2.21	-20.0	2.444	137.0	
E	-0.5280	-0.0218	-8.44	-16.4	2.786	137.0	
F	-0.5399	-0.0204	-14.67	-11.6	3.232	137.0	
G	-0.5591	0.3480	-20.90	0	4.309	137.0	Elevation scan 1 (down)
H	-0.2285	0.3480	-20.9	0	5.259	105.5	
I	-0.2024	0.1740	-20.9	0	5.359	103.0	
	0.4556	0.1663	-20.9	0	9.228	38.0	
J	1.0856	0.1595	-20.9	0	13.097	-27.0	
K	1.0483	-0.1541	-14.67	0	14.097	-27.0	Elevation scan 2 (up)
	0.4399	-0.1606	-14.67	0	17.966	38.0	
L	-0.1954	-0.1680	-14.67	0	21.835	103.0	
M	-0.2206	-0.3361	-14.67	0	21.935	105.5	
N	-0.5399	-0.3361	-14.67	0	22.885	137.0	
O	-0.5280	0.3287	-8.44	0	23.885	137.0	Elevation scan 3 (down)
P	-0.2158	0.3287	-8.44	0	24.835	105.5	
Q	-0.1911	0.1643	-8.44	0	24.935	103.0	
	0.4302	0.1570	-8.44	0	28.804	38.0	
R	1.0252	0.1507	-8.44	0	32.673	-27.0	
S	1.0149	-0.1492	-2.21	0	33.673	-27.0	Elevation scan 4 (up)
	0.4259	-0.1554	-2.21	0	37.542	38.0	
T	-0.1892	-0.1627	-2.21	0	41.411	103.0	
U	-0.2136	-0.3254	-2.21	0	41.511	105.5	
V	-0.5227	-0.3254	-2.21	0	42.461	137.0	
W	-0.5236	0.3259	4.02	0	43.461	137.0	Elevation scan 5 (down)
X	-0.2140	0.3259	4.02	0	44.411	105.5	
Y	-0.1895	0.1630	4.02	0	44.511	103.0	
	0.4266	0.1557	4.02	0	48.380	38.0	
Z	1.0166	0.1494	4.02	0	52.249	-27.0	
AA	1.0306	-0.1515	10.25	0	53.249	-27.0	Elevation scan 6 (up)
	0.4325	-0.1578	10.25	0	57.118	38.0	
AB	-0.1921	-0.1652	10.25	0	60.987	103.0	
AC	-0.2169	-0.3304	10.25	0	61.087	105.5	
AD	-0.5308	-0.3304	10.25	0	62.037	137.0	
AE	TBD	0.0000	29.00	0	64.472	N/A	Dwell at IFC view for 0.5 sec
A	TBD	0.0000	29.00	0	64.972	N/A	

Table 4.

Nominal elevation offset.
Pre launch test sequence with atmospheric scan at constant rate of elevation shaft angle per unit time.

	Elev shaft angle (deg)	Elev shaft rate (deg/s)	Azimuth shaft angle (deg)	Azimuth shaft rate (deg/s)	Time (s)	Boresight height (km)	
A	TBD	0.0000	29.00	0	0.000	N/A	Start at IFC view
B	-1.1110	0.0000	10.25	-20.1	1.868	137.0	Azimuth scan at space view
C	-1.0959	0.0293	4.02	-23.2	2.156	137.0	elevation
D	-1.0940	-0.0147	-2.21	-20.0	2.444	137.0	
E	-1.1052	-0.0457	-8.44	-16.4	2.786	137.0	
F	-1.1301	-0.0427	-14.67	-11.6	3.232	137.0	
G	-1.1702	0.3440	-20.90	0	4.309	137.0	Elevation scan 1 (down)
H	-0.8259	0.3440	-20.9	0	5.310	105.4	
I	-0.8001	0.1720	-20.9	0	5.410	103.0	
J	0.5307	0.1720	-20.9	0	13.148	-27.0	
K	0.5125	-0.1661	-14.67	0	14.148	-27.0	Elevation scan 2 (up)
L	-0.7726	-0.1661	-14.67	0	21.886	103.0	
M	-0.7975	-0.3322	-14.67	0	21.986	105.4	
N	-1.1301	-0.3322	-14.67	0	22.987	137.0	
O	-1.1052	0.3248	-8.44	0	23.987	137.0	Elevation scan 3 (down)
P	-0.7800	0.3248	-8.44	0	24.988	105.4	
Q	-0.7556	0.1624	-8.44	0	25.088	103.0	
R	0.5012	0.1624	-8.44	0	32.826	-27.0	
S	0.4961	-0.1608	-2.21	0	33.826	-27.0	Elevation scan 4 (up)
T	-0.7480	-0.1608	-2.21	0	41.565	103.0	
U	-0.7721	-0.3216	-2.21	0	41.665	105.4	
V	-1.0940	-0.3216	-2.21	0	42.666	137.0	
W	-1.0959	0.3221	4.02	0	43.666	137.0	Elevation scan 5 (down)
X	-0.7734	0.3221	4.02	0	44.667	105.4	
Y	-0.7493	0.1611	4.02	0	44.767	103.0	
Z	0.4970	0.1611	4.02	0	52.505	-27.0	
AA	0.5038	-0.1633	10.25	0	53.505	-27.0	Elevation scan 6 (up)
AB	-0.7596	-0.1633	10.25	0	61.243	103.0	
AC	-0.7841	-0.3265	10.25	0	61.343	105.4	
AD	-1.1110	-0.3265	10.25	0	62.344	137.0	
AE	TBD	0.0000	29.00	0	64.779	N/A	Dwell at IFC view for
A	TBD	0.0000	29.00	0	65.279	N/A	0.5 sec

Table 5.

Low extreme for elevation offset.
Pre launch test sequence with atmospheric scan at constant rate of elevation shaft angle per unit time.

	Elev shaft angle (deg)	Elev shaft rate (deg/s)	Azimuth shaft angle (deg)	Azimuth shaft rate (deg/s)	Time (s)	Boresight height (km)	
A	TBD	0.0000	29.00	0	0.000	N/A	Start at IFC view
B	-1.6373	0.0000	10.25	-20.1	1.868	137.0	Azimuth scan at space view
C	-1.6152	0.0432	4.02	-23.2	2.156	137.0	elevation
D	-1.6124	-0.0217	-2.21	-20.0	2.444	137.0	
E	-1.6288	-0.0674	-8.44	-16.4	2.786	137.0	
F	-1.6655	-0.0629	-14.67	-11.6	3.232	137.0	
G	-1.7247	0.3544	-20.90	0	4.309	137.0	Elevation scan 1 (down)
H	-1.3684	0.3544	-20.9	0	5.314	105.4	
I	-1.3418	0.1772	-20.9	0	5.414	103.0	
J	0.0293	0.1772	-20.9	0	13.152	-27.0	
K	0.0283	-0.1711	-14.67	0	14.152	-27.0	Elevation scan 2 (up)
L	-1.2957	-0.1711	-14.67	0	21.891	103.0	
M	-1.3214	-0.3422	-14.67	0	21.991	105.4	
N	-1.6655	-0.3422	-14.67	0	22.996	137.0	
O	-1.6288	0.3347	-8.44	0	23.996	137.0	Elevation scan 3 (down)
P	-1.2923	0.3347	-8.44	0	25.001	105.4	
Q	-1.2672	0.1673	-8.44	0	25.101	103.0	
R	0.0277	0.1673	-8.44	0	32.840	-27.0	
S	0.0274	-0.1657	-2.21	0	33.840	-27.0	Elevation scan 4 (up)
T	-1.2544	-0.1657	-2.21	0	41.578	103.0	
U	-1.2793	-0.3313	-2.21	0	41.678	105.4	
V	-1.6124	-0.3313	-2.21	0	42.683	137.0	
W	-1.6152	0.3319	4.02	0	43.683	137.0	Elevation scan 5 (down)
X	-1.2815	0.3319	4.02	0	44.689	105.4	
Y	-1.2566	0.1659	4.02	0	44.789	103.0	
Z	0.0274	0.1659	4.02	0	52.527	-27.0	
AA	0.0278	-0.1682	10.25	0	53.527	-27.0	Elevation scan 6 (up)
AB	-1.2738	-0.1682	10.25	0	61.265	103.0	
AC	-1.2991	-0.3364	10.25	0	61.365	105.4	
AD	-1.6373	-0.3364	10.25	0	62.370	137.0	
AE	TBD	0.0000	29.00	0	64.805	N/A	Dwell at IFC view for
A	TBD	0.0000	29.00	0	65.305	N/A	0.5 sec

Table 6.

High extreme case for elevation offset.
Pre launch test sequence with atmospheric scan at constant rate of elevation shaft angle per unit time.

	Elev shaft angle (deg)	Elev shaft rate (deg/s)	Azimuth shaft angle (deg)	Azimuth shaft rate (deg/s)	Time (s)	Boresight height (km)	
A	TBD	0.0000	29.00	0	0.000	N/A	Start at IFC view
B	-0.5308	0.0000	10.25	-20.1	1.868	137.0	Azimuth scan at space view
C	-0.5236	0.0140	4.02	-23.2	2.156	137.0	elevation
D	-0.5227	-0.0070	-2.21	-20.0	2.444	137.0	
E	-0.5280	-0.0218	-8.44	-16.4	2.786	137.0	
F	-0.5399	-0.0204	-14.67	-11.6	3.232	137.0	
G	-0.5591	0.3329	-20.90	0	4.309	137.0	Elevation scan 1 (down)
H	-0.2273	0.3329	-20.9	0	5.306	105.4	
I	-0.2024	0.1664	-20.9	0	5.406	103.0	
J	1.0856	0.1664	-20.9	0	13.144	-27.0	
K	1.0483	-0.1607	-14.67	0	14.144	-27.0	Elevation scan 2 (up)
L	-0.1954	-0.1607	-14.67	0	21.882	103.0	
M	-0.2195	-0.3215	-14.67	0	21.982	105.4	
N	-0.5399	-0.3215	-14.67	0	22.978	137.0	
O	-0.5280	0.3144	-8.44	0	23.978	137.0	Elevation scan 3 (down)
P	-0.2147	0.3144	-8.44	0	24.975	105.4	
Q	-0.1911	0.1572	-8.44	0	25.075	103.0	
R	1.0252	0.1572	-8.44	0	32.813	-27.0	
S	1.0149	-0.1556	-2.21	0	33.813	-27.0	Elevation scan 4 (up)
T	-0.1892	-0.1556	-2.21	0	41.551	103.0	
U	-0.2125	-0.3112	-2.21	0	41.651	105.4	
V	-0.5227	-0.3112	-2.21	0	42.648	137.0	
W	-0.5236	0.3117	4.02	0	43.648	137.0	Elevation scan 5 (down)
X	-0.2129	0.3117	4.02	0	44.644	105.4	
Y	-0.1895	0.1559	4.02	0	44.744	103.0	
Z	1.0166	0.1559	4.02	0	52.482	-27.0	
AA	1.0306	-0.1580	10.25	0	53.482	-27.0	Elevation scan 6 (up)
AB	-0.1921	-0.1580	10.25	0	61.220	103.0	
AC	-0.2158	-0.3160	10.25	0	61.320	105.4	
AD	-0.5308	-0.3160	10.25	0	62.317	137.0	
AE	TBD	0.0000	29.00	0	64.752	N/A	Dwell at IFC view for
A	TBD	0.0000	29.00	0	65.252	N/A	0.5 sec

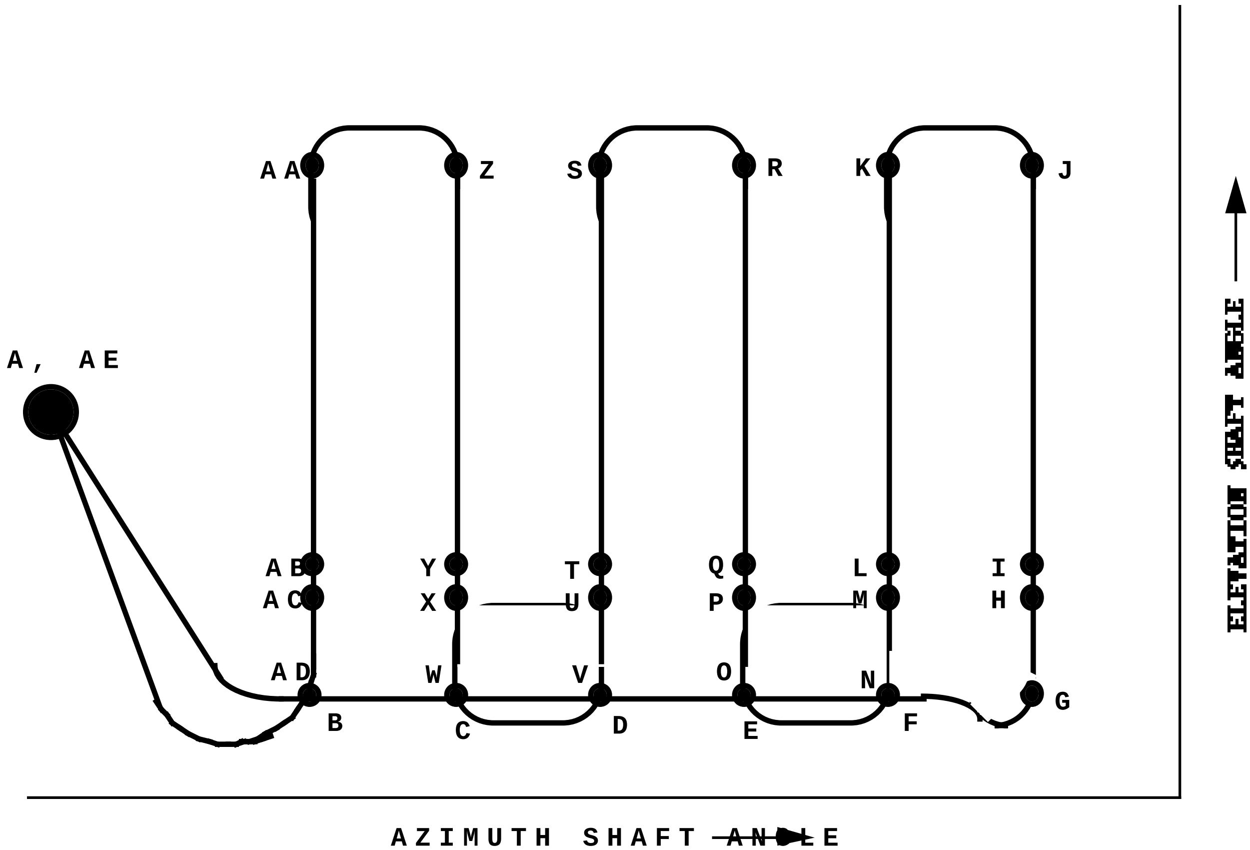

Figure 1

Schematic showing the sequence of elevation shaft angle vs azimuth shaft angle position, with points on the sequence (A, B, C ... AE) that correspond to tables 1-6. Increasing azimuth shaft angle (away from the IFC view) is to the right, and increasing elevation shaft angle (towards the earth) is upwards.