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Test Report

Herschel

Title: **Herschel Instrument Alignment w.r.t. CVV Test Report**

CI-No: 120 000

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1 INTRODUCTION

1.1 Scope

This document describes the alignment measurements performed with the Herschel PFM instruments after integration onto the Herschel Optical Bench. The related test procedure with the filled in test results is appended to this document

1.2 Objective

The alignment measurements documented here shall demonstrate that the positions and orientations of the Herschel PFM instruments HIFI, PACS and SPIRE within the Herschel CVV are within their specified envelopes.

It has to be noted that the evaluation presented in this document relies on the assumption that the telescope, when mounted, reaches its nominal position.

After the telescope has been integrated its alignment will be checked wrt. the same CVV reference cube as the instruments. The calculation concerning overall alignment will then be repeated taking into account final alignment data.

The Telescope Mounting Structure (TMS) has already been integrated earlier. As reference for the respective activities, the plane of the upper–bulkhead interface flange was used. In order to have the same reference also for alignment measurements and for later telescope integration the relation of the primary reference cube on the CVV (CVVRC4) and the UB interface flange plane had to be determined.

Finally, along with above mentioned tasks it was verified, that the HIFI FPU AD orientation is not influenced when a harness rail is mounted to the FPU.

2 Applicable Documents

2.1 Applicable Documents

[AD 1]	Procedure for PFM Alignment of Herschel Instruments wrt. PLM, HP-2-ASED-TP-0111, Issue 1, 20.07.2007
[AD 2]	HP-2-ASED-SD-0177: HIFI AD Stability Check after Harness Rail Final Fixation.
[AD 3]	HP-2-ASED-SD-0179: Determination of CVV Flange Orientation
[AD 4	H-EPLM Requirement Specification H-P-2-ASPI-SP-0250, Issue 3.3, 20.10.2004

2.2 Reference Documents

[RD 1]	Herschel Telescope User Manual, HER.NT.1034.T.ASTR, Issue 1, 15.12.2006
[RD 2]	Alignment Method, Plan & Results HP-2-ASED-TN-0097, Issue 2
[RD 3]	Inputs to System Level Alignment PACS-ME-TN-069, Issue 3
[RD 4]	SPIRE FPU External Alignment Report SPIRE-RAL-REP-002948, Issue 1
[RD 5]	HIFI FPU External Ads Alignment Test Reults FPSS-01068, Issue 3
[RD 6]	SPIRE Alignment Data Summary SPIRE-RAL-REP-002876, Issue 1
[RD 7]	Alignment Results of HIFI FPU Flight Model FPSS-00963 Issue 1

3 Report Summary

The tests describe in this document have been carried out between August 2nd, 2007 and August 6th, 2007. Details can be seen from the “as run procedure” appended to this document. There date and time of the individual measurements have been recorded.

3.1 Test Article

Herschel PFM instruments HIFI, PACS and SPIRE integrated onto Optical Bench. CVV upper bulkhead not mounted. PLM mounted on rotary table.

3.2 Applied Procedure

The Herschel instrument alignment tests have been performed according to:
Procedure for PFM Alignment of Herschel Instruments wrt. PLM,
HP-2-ASED-TP-0111

Two additional tasks had to be performed along with the instrument alignment. Since these were not part of the original procedure, dedicated activity control sheets were prepared:

- HP-2-ASED-SD-0177: HIFI AD Stability Check after Harness Rail Final Fixation.
- HP-2-ASED-SD-0179: Determination of CVV Flange Orientation.

3.3 Reviews

The test readiness review was held on 31.07.2007. See HP-2-ASED-MN-1378.

The post-test review was held on 08.08.2007. See HP-2-ASED-MN-1383.

3.4 Procedure Variations:

No 1: Change of measurements sequence, in order to minimize time for set-up re-configuration. However, since the procedure has a modular structure, there is no impact on objective, methods or results.

No. 2: Installation of a second Angle Transfer Prism (ATP): In order to simplify continuous check of prime ATP stability (also time saving). No impact on measurement objective, methods or results.

No 3: This is not a formal procedure variation, only clarifying remark concerning nominal values: The “nominal values” called up by the original procedure still contain biases which have to be determined according to the measurements of activity control sheet HP-2-ASED-SD-0179. For comparison of measured and nominal values, theses biases have to be taken into account. The related calculation will be part of this final report.

3.5 Non-Conformance Summary:

One minor NCR raised: HP-121000-ASED-NC3516:

- OB position slightly exceeds position tolerance: Limit. 1 mm, measured 1.01mm.
- Rotation of OB about X exceeds angle tolerance of 0.0333 deg, measured 0.1015 deg. This value has been defined by ASED assuming that the instrument FPUs are nominally aligned wrt. OB. This is, however, not the case. The actual FPU alignments are all in spec, apart from PACS.
- Rotation of OB about Z exceeds tolerance of 0.0333 deg (measured 0.0442 deg). Here the same argument as above is valid.
- PACS rotation about X exceeds tolerance of 0.0389 deg (measured 0.0 564 deg). Allowed tolerance was derived from alignment budget. Excess rotation reduces overall margin, but margin is still positive

Note: The NC concerns only tolerances which have been derived in order to establish an overall budget. So, not achieving individual values only reduces the margin, but does not violate an overall alignment budget.

3.6 Open work:

None

4 Alignment Activities Description

The positions and orientations of the Herschel Instruments have been measured wrt. the external CVV coordinate systems represented by a primary CVV reference cube CVVRC4, mounted on the outer side of the CVV in +Y direction. The three instruments HIFI, PACS and SPIRE where represented by their instrument reference cubes (RC) mounted at known positions on the instruments themselves.

The positions of the instruments (reference cubes) were determined using a Linear Measurement Device which allows to measure directly horizontal or vertical distances between two given points. With this device the separations between CVVRC4 (or auxiliary reference cube CVVRC2 on the –Z side of the CVV) and the respective instrument reference points were measured. In all cases, at least three measurements were made, from which mean values were calculated and further used in the data evaluation.

The orientations of the instruments were determined by auto-collimation measurements according to the following principle: The auto-collimation direction to a selected face of a prime reference is determined by means of an auto-collimation theodolite. Relative to this direction, an Angle Transfer Prism (ATP) is set up at a known orientation, generally at 90 deg (left) to the prime RC direction. For further measurements, the direction to the ATP can be accessed by the theodolite and taken as zero-reference for the determination of the direction to an instrument cube auto-collimation direction, then representing the instrument's orientation. Again, at least three angle measurements were made to determine instrument orientations as mean value of the individual measurements.

Also the Optical Bench was equipped with a reference cube which was used as described above for the instruments. However, this cube is not used as a reference in further alignment related activities. Therefore, we report here the measurements made with this cube, but the related data are not further used. Using OB data as reference would mean to introduce an additional (intermediate) reference and, therefore, an additional error. The instrument data are directly linked to the prime references on the outer side of the CVV, which are accessible at later stages of the AIT sequence, e. g., when the telescope will be integrated onto the CVV and measured to the same reference cube.

In an earlier AIT phase, the Telescope Mounting Structure (TMS) had to be mounted onto the upper bulkhead a measurement of the TMS position and orientation had to be made. As reference for this measurement (which was carried out on a 3D measuring machine) the plane of the mounting flange was used.

In order, to have a common reference for later alignment measurements along with the instrument positions and orientations, we have also determined the relation of the mounting plane of the upper bulkhead wrt. the primary reference CVVRC4. This measurement is reflected in AD 3.

Finally the occasion of freely accessible instruments was used to perform a further check. A harness rail had to be integrated onto the HIFI FPU in order to accommodate and mechanically support a harness. Since the mechanical fixation of this rail is close to the structure carrying the HIFI FPU ADs, a check had to be made, demonstrating that mounting the rail and tightening related bolts has no impact on the orientation of the HIFI FPU ADs. This alignment check is described in AD 2.

The determination of the CVV flange orientation and the AD stability check have not been part of the original instrument alignment procedure. Therefore, dedicated Activity Control Sheets have been prepared according to which these tasks were performed.

As far as procedure variations had to be implemented, these have recorded in the related Procedure Variation Sheets of the “As run procedure” (Sect. 11.1). Similarly, non-conformances have been documented (Sect. 11.2).

5 Alignment Measurement Data

All measurement data are compiled in this chapter (copied from an EXCEL file which was established during the measurements). Also included are the measurements of the OB orientation and position. As already mentioned above in Sect. 4 the data for orientation and position of the OB have been recorded, but will not be further used in this document.

The subsequent tables use the following descriptions/symbols:

Step:	Step no. of applicable procedure (HP-2-ASED-TP-0111, Issue 1, 20.07.2007)
Cube:	ID of used opt. reference cube
from side:	Relative position of theodolite
dir:	Viewing direction of theodolite
dim:	Dimension of measured quantity
Meas 1, 2, 3:	Measurement no. 1, no. 2, no. 3
Mean:	Mean of (three) measurements
Std dev:	Standard deviation of measurements

5.1 Data: Check of OB position

Step	Cube	from side	dir	dim	Meas 1	Meas 2	Meas 3	Mean	STD dev
Check of OB alignment									
9	CVVRC4	+y	x	mm	0	0	0	**0**	0
11	CVV I/F	+y	x	mm	57,33	57,43	57,41	**57,39**	0,052915
13	OB	+y	x	mm	560,84	560,73	560,79	**560,7867**	0,055076
20	CVVRC4	+y	z	mm	0	0	0	**0**	0
23	OB	+y	z	mm	71,52	71,38	71,47	**71,45667**	0,070946
31	CVVRC4	+z	y	mm	0	0	0	**0**	0
34	OB	+z	y	mm	257,65	257,74	257,75	**257,7133**	0,055076

Table 5-1: OB vertical position measurements

5.2 Data: Check of OB orientation

Step	Cube	from side	dir	dim	Meas 1	Meas 2	Meas 3	Mean	STD dev
41	CVVRC4	+y	HZ	deg	360,0001	360,0005	360,001	**360,0005**	0,000451
			V	deg	90,3333	90,3329	90,3332	**90,33313**	0,000208
45	OB	+y	HZ	deg	359,8194	359,8207	359,8208	**359,8203**	0,000781
			V	deg	90,0256	90,0253	90,0254	**90,02543**	0,000153
50	CVVRC4	+z	HZ	deg	359,9985	359,9998	359,9985	**359,9989**	0,000751
			V	deg	90,0055	90,0053	90,0054	**90,0054**	1E-04
54	OB	+z	HZ	deg	359,8209	359,8221	359,82	**359,821**	0,001054
			V	deg	89,9006	89,9007	89,9006	**89,90063**	5,77E-05

Table 5-2: OB orientation (Rx, RZ) measurements

5.3 Data: Instrument orientation from +Y side

Step	Cube	from side	dir	dim	Meas 1	Meas 2	Meas 3	Mean	STD dev
Angular alignment HIFI									
61	HIFI	+y	HZ	deg	359,9614	359,9595	359,9605	**359,9605**	0,00095
			V	deg	89,9838	89,9837	89,9839	**89,9838**	0,0001
Angular Alignment PACS									
64	PACS	+y	HZ	deg	359,8932	359,8936	359,8932	**359,8933**	0,000231
			V	deg	90,0437	90,0427	90,0441	**90,0435**	0,000721
Angular Alignment SPIRE									
67	SPIRE	+y	HZ	deg	359,3617	359,359	359,3584	**359,3597**	0,001758
			V	deg	89,9904	89,9901	89,9899	**89,99013**	0,000252
Angular Alignment CVVRC2									
70	CVVRC2	+y	HZ	deg	360,0192	360,019	360,0189	**360,019**	0,000153
			V	deg	90,0031	90,0028	90,0028	**90,0029**	0,000173

Table 5-3: Instrument orientation (Rz) measurements

5.4 Data: Instrument orientation from +Z side

Step	Cube	from side	dir	dim	Meas 1	Meas 2	Meas 3	Mean	STD dev
Angular Alignment HIFI									
74	HIFI	+z	HZ	deg	359,9611	359,9615	359,961	**359,9612**	0,000265
			V	deg	89,9872	89,9869	89,9871	**89,98707**	0,000153
Angular Alignment PACS									
77	PACS	+z	HZ	deg	359,8939	359,8945	359,8943	**359,8942**	0,000306
			V	deg	89,9876	89,9885	89,9885	**89,9882**	0,00052
Angular Alignment SPIRE									
80	SPIRE	+z	HZ	deg	359,3613	359,3613	359,3616	**359,3614**	0,000173
			V	deg	90,035	90,0348	90,0349	**90,0349**	1E-04
Angular Alignment CVVRC4									
83	CVVRC4	+z	HZ	deg	359,9985	359,9998	359,9985	**359,9989**	0,000751
			V	deg	90,0055	90,0053	90,0054	**90,0054**	1E-04

Table 5-4: Instrument orientation (Ry) measurements

5.5 Data: Orientation of reference cube CVVRC2 from –Z side

Step	Cube	from side	dir	dim	Meas 1	Meas 2	Meas 3	Mean	STD dev
Angular Alignment CVVRC2									
86	CVVRC2	-z	HZ	deg	0,0231	0,0221	0,0235	**0,0229**	0,000721
			V	deg	90,03	90,0302	90,0299	**90,03003**	0,000153

Table 5-5: CVVRC2 orientation wrt. CVVRC4

5.6 Data: Horizontal distance measurements from +Y side

Step	Cube	from side	dir	dim	Meas 1	Meas 2	Meas 3	Mean	STD dev
Horizontal distance Measurement on +y side									
94	CVVRC4	+y	z	mm	0	0	0	**0**	0
99	HIFI	+y	z	mm	72,04	71,97	71,97	**71,99333**	0,040415
104	PACS	+y	z	mm	6,8	6,87	6,8	**6,823333**	0,040415
109	SPIRE	+y	z	mm	128,13	128,14	128,14	**128,1367**	0,005774

Table 5-6: Instrument horizontal distance (Tz) measurements

5.7 Data: Horizontal distance measurements from +Z side

Step	Cube	from side	dir	dim	Meas 1	Meas 2	Meas 3	**Mean**	STD dev
Horizontal distance Measurement on +z side									
116	CVVRC4	+z	y	mm	0	0	0	**0**	0
121	HIFI	+z	y	mm	1089,15	1089,12	1089,11	**1089,127**	0,020817
126	PACS	+z	y	mm	853,32	853,31	853,29	853,3067	0,015275
131	SPIRE	+z	y	mm	862,97	863,04	863,03	863,0133	0,037859

Table 5-7: Instrument horizontal distance (Ty) measurements

5.8 Data: Vertical distance measurements from +Y side

Step	Cube	from side	dir	dim	Meas 1	Meas 2	Meas 3	**Mean**	STD dev
Vertical distance Measurement on +y side									
137	CVVRC4	+y	x	mm	0	0	0	**0**	0
139	HIFI	+y	x	mm	902,68	902,64	902,63	**902,65**	0,026458
141	PACS	+y	x	mm	1000,66	1000,71	1000,69	**1000,687**	0,025166
143	SPIRE	+y	x	mm	1020,92	1020,94	1020,97	**1020,943**	0,025166

Table 5-8: Instrument vertical distance (Tx) measurements

5.9 Data: Vertical distance measurements of CVVRC2 from -Z side

Step	Cube	from side	dir	dim	Meas 1	Meas 2	Meas 3	Mean	STD dev
Vertical distance Measurement on -z side									
147	CVVRC2	-z	x	mm	0,01	0,07	0,01	0,03	0,034641

Table 5-9: CVVRC2 vertical distance (Tx) measurements wrt. CVVRC4

5.10 Data: Angular offset between primary reference CVVRC4 and the mechanical system (TTAP)

The related measurements have been performed according to Activity Control Sheet HP-2-ASED-SD-0179: Determination of CVV Flange Orientation.

Step	Cube	from side	dir	dim	Meas 1	Meas 2	Meas 3	Mean	STD dev
Definition of y axis for Rx with Rotary Table and TTAP y-axis mark									
ACS 0179	CVVRC4	+y	Hz	deg	359,9685	359,9653	359,9664	**359,9667**	0,001626

Table 5-10: Angular offset between systems of CVVRC4 and TTAP: RX (AD 3)

5.11 Data: Orientation of flange of Upper Bulkhead wrt. CVVRC4

The related measurements have been performed according to Activity Control Sheet HP-2-ASED-SD-0179: Determination of CVV Flange Orientation.

Step	Cube	from side	Meas 1	Meas 2	Meas 3	**Mean**	STD dev
CVV Flange orientation w.r.t. CVVRC4							
ACS 0179		+y Centre	90,0078	90,0075	90,0081	90,0078	0,0003
		+y Left	90,0068	90,0068	90,0071	90,0069	0,000173
		+y Right	89,998	89,9986	89,9985	89,99837	0,000321
					Mean Rz	**90,00436**	0,005206
CVV Flange orientation w.r.t. CVVRC4							
ACS 0179		+z Centre	90,0073	90,0082	90,0083	90,00793	0,000551
		+z Left	90,0059	90,006	90,0061	90,006	0,0001
		+z Right	90,0039	90,0042	90,0043	90,00413	0,000208
					Mean Ry	**90,00602**	0,0019

Table 5-11: Orientation of UB Interface Flange wrt. CVVRC4: Ry, Rz

5.12 Data: Check of HIFI FPU AD stability wrt. fixation of harness rail

The related measurements have been performed according to Activity Control Sheet HP-2-ASED-SD-0177: HIFI AD Stability Check after Harness Rail Final Fixation.

Step	Cube	from side	dir	dim	Meas 1	Meas 2	Meas 3	Mean	STD dev
HIFI AD Stability check									
	Before harness rail fixation								
ACS 0177	AD +z	-y	HZ	deg	0,0034	0,0027	0,0027	**0,002933**	0,000404
	AD +z	-y	V	deg	89,9957	89,9952	89,9953	**89,9954**	0,000265
	AD -z	-y	HZ	deg	0,0218	0,0211	0,0206	**0,021167**	0,000603
	AD -z	-y	V	deg	89,9937	89,9948	89,9952	**89,99457**	0,000777
	After harness rail fixation								
	AD -z	-y	HZ	deg	0,0176	0,0179	0,02	**0,0185**	0,001308
	AD -z	-y	V	deg	89,9951	89,9968	89,9945	**89,99547**	0,001193
	AD +z	-y	HZ	deg	359,9995	360,0006	360,0003	**360,0001**	0,000569
	AD +z	-y	V	deg	89,9953	89,9961	89,9958	**89,99573**	0,000404

Table 5-12: Check of HIFI FPU AD stability wrt. harness-rail fixation

6 Data Evaluation and Results

From the measured data as compiled in Sect. 5, we find the following results

6.1 S/C mechanical Interface (Flange of Upper Bulkhead)

In order, to have a common reference for later alignment measurements along with the instrument positions and orientations, we have determined the relation of the mounting plane of the upper bulkhead wrt. the primary reference CVVRC4. (Measurement data see Table 5-11).

Furthermore, the Rot X relation of CVVRC4 wrt. a S/C mechanical system engraved in the TTAP has been determined (Measurement data see Table 5-10)

From the respective tables 5-11 and 5-10, we find

Mounting flange upper bulkhead:

Tilt about Y:	Rot Y = 90.0060 deg
Tilt about Z:	Rot Z = 90.0044 deg
Angle S/C syst – CVVRC4:	Rot X = 359.9667 deg

Remark: In the following, we assume that values for LOS and around LOS are represented by the measured instrument interface orientations.

6.2 Instrument Tilts

6.2.1 (Rot X)

	Rot X Cube wrt CVVRC4	Rot X Cube wrt. (S/C I/F)	Rot X instr. I/F wrt. (S/C I/F)
HIFI	+2.4 arcmin	+4.4 arcmin	+4.4 arcmin
PACS	6.4 arcmin	+8.4 arcmin	+10.5 arcmin
SPIRE	38.4.arcmin	40.4 arcmin	Not known
OB	10.8 arcmin	+12.8 arcmin	+10.1 arcmin

Table 6-1: Orientation of instrument wrt. CVVRC4 and S/C mechanical system
Here, column 1 is the direct measurement of instrument cube wrt. CVVRC4.
Column 2 takes into account the rotation of CVVRC4 wrt. S/C (2 arcmin).
Column 3 takes into account the offset between instrument cube and instrument mechanical I/F (as provided by the instruments).

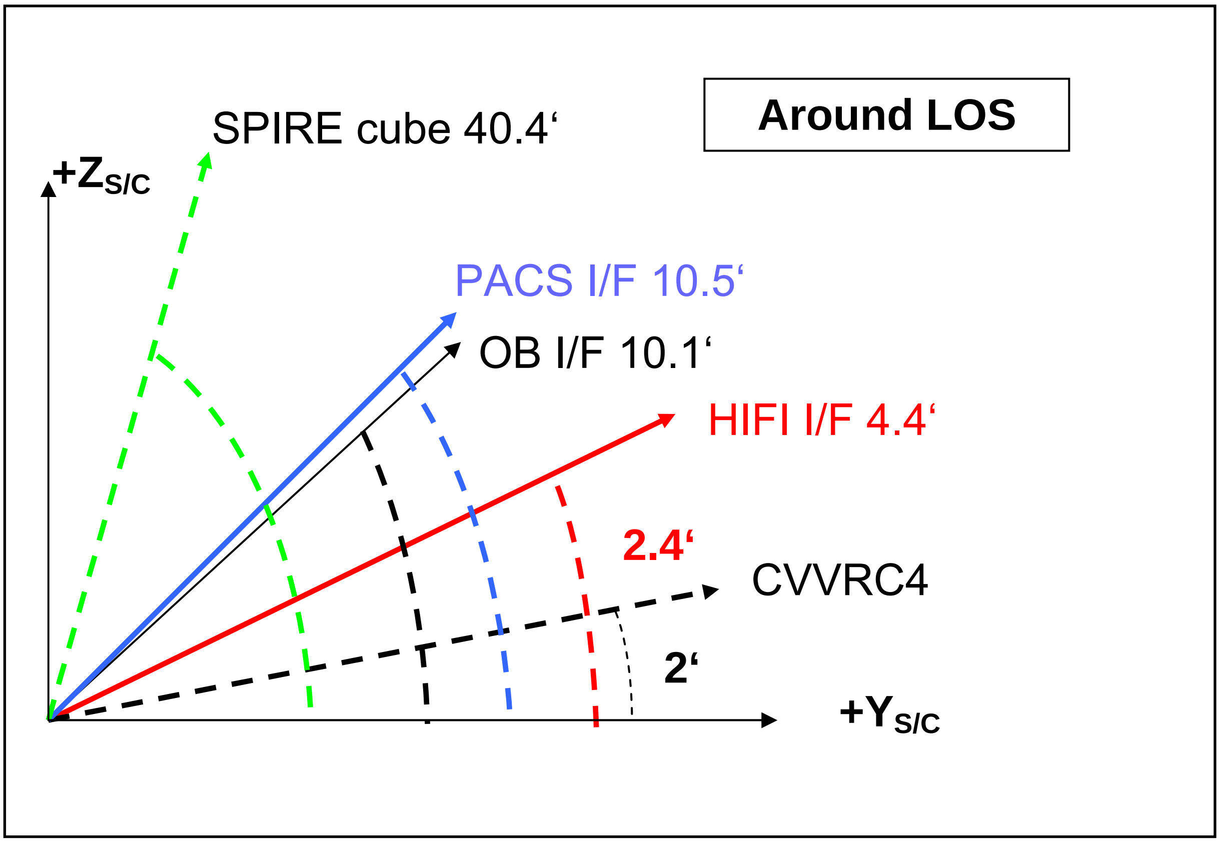

Figure 6-1: Graphic representation of Rot X values.

The around-line-of-sight values are shown here for instrument interfaces corresponding to columns 1 and 2 of above table.

The figure shows the rotations of the instrument cubes wrt. CVVRC4 (instr RC) and the rotation of the cubes wrt. S/C mechanical interface (instr. I/F). In order to find the rotation of the instrument I/F wrt. S/C interface, the instrument internal bias has to be added. (compiled in Table 14-2 of the “as run” procedure).

6.2.2 Rotation about Y-axis: Rot Y

	Rot Y (cube) wrt S/C I/F	Rot Y (mech I/F) wrt S/C I/F	Remark
HIFI	-1.13 arcmin	+0.13 arcmin	
PACS	-1.07 arcmin	-2.32 arcmin	
SPIRE	+1.73 arcmin	-5.57 arcmin	
OB	-6.32 arcmin	-1.70 arcmin	

Table 6-2: Orientation of instrument cube and Instrument I/F wrt. S/C mechanical system

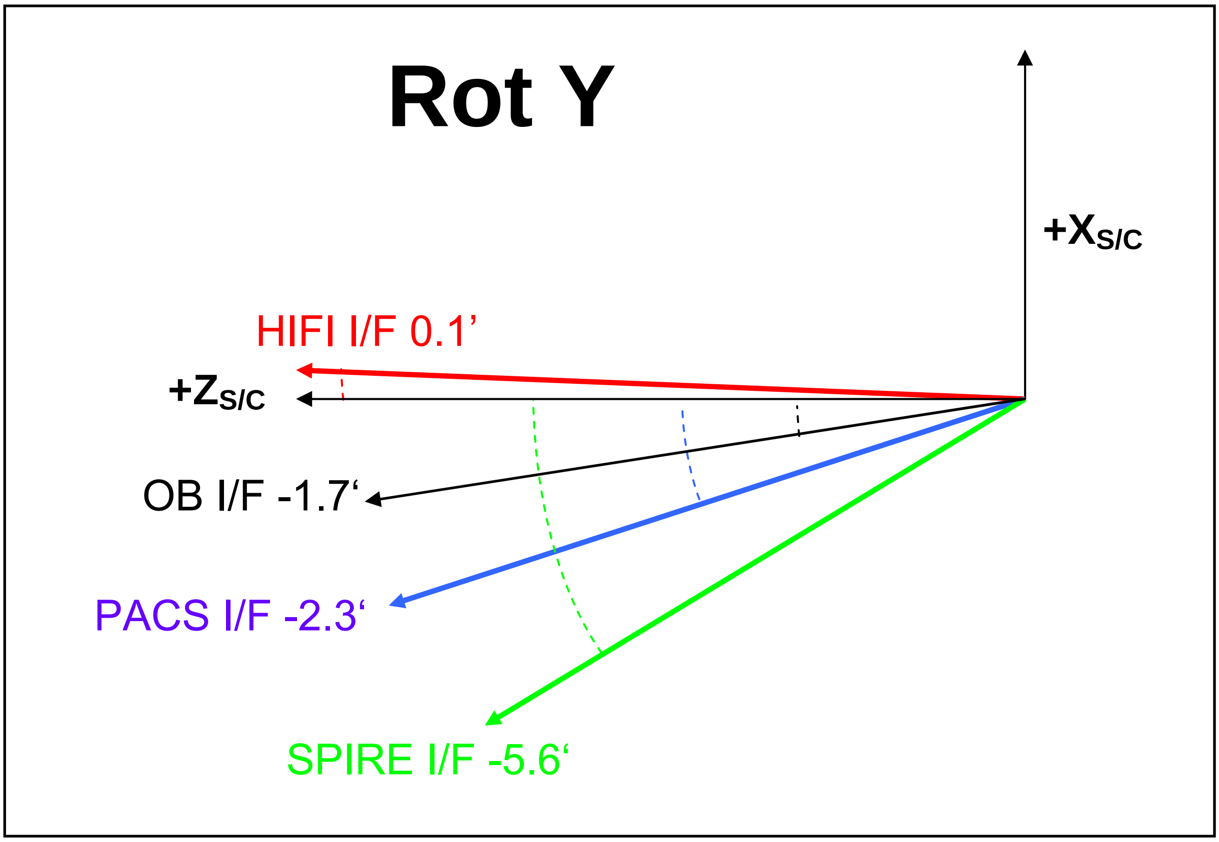

Figure 6-2: Graphic representation of Rot Y values.

The Rot Y values are shown here for instrument cubes and instrument interfaces.

The angular offsets between instrument cubes and interfaces are collected in Sect 14 of the “as run procedure” appended to this document.

6.2.3 Rotation about Z-axis: Rot Z

	Rot Z (cube) wrt S/C I/F	Rot Z (mech I/F) wrt S/C I/F	Remark
HIFI	+1.24 arcmin	+1.35 arcmin	
PACS	-2.35 arcmin	-3.38 arcmin	
SPIRE	+0.86 arcmin	-2.84 arcmin	
OB	-1.26 arcmin	+2.65 arcmin	

Table 6-3: Orientation of instrument cube and Instrument I/F wrt. S/C mechanical system

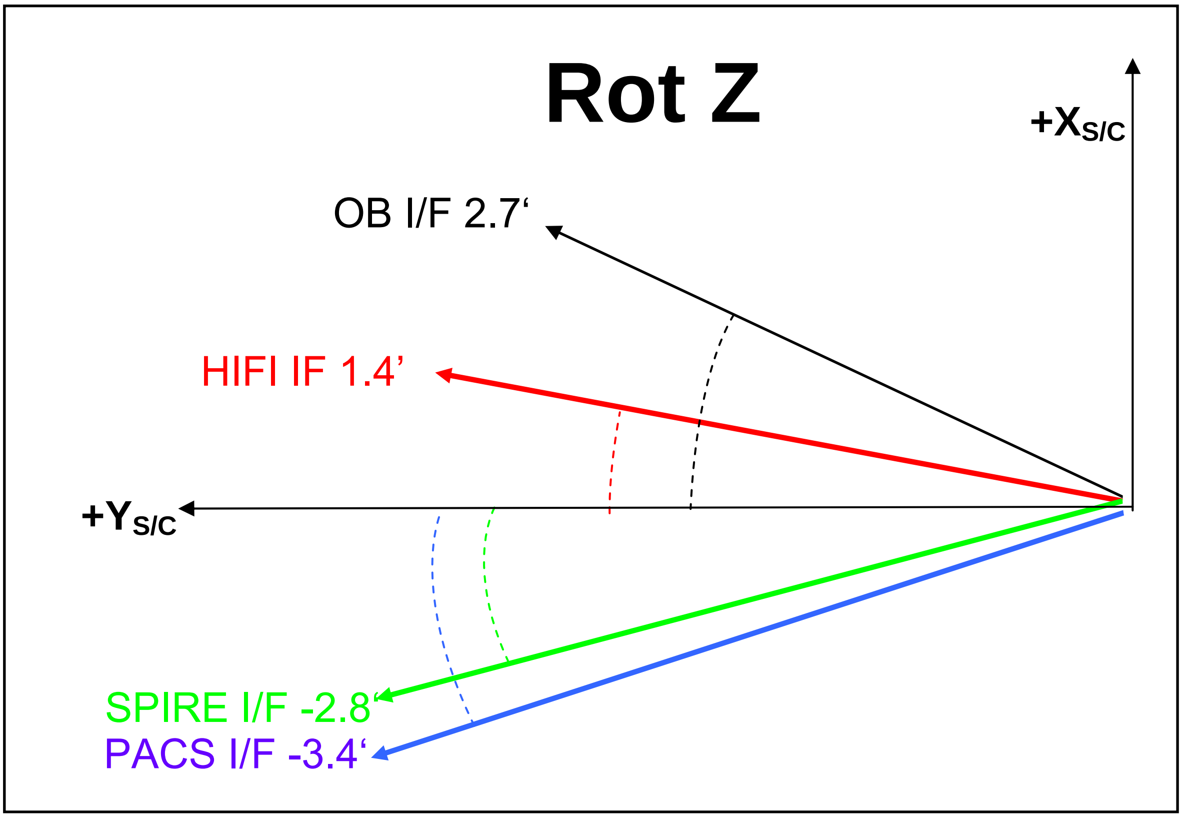

Figure 6-3: Graphic representation of Rot Z values.

The Rot Z values are shown here for instrument cubes and instrument interfaces.

The angular offsets between instrument cubes and interfaces are collected in Sect 14 of the “as run procedure” appended to this document.

6.3 Focus

The defocus contributions are shown in the following table and compared to the focus requirements:

	Measured position bias	Instrument internal uncertainty	Telescope uncertainty	CVV Uncertainty
HIFI	-0.65 mm	±4.7 mm (0riginal allocation)	±3 mm (RD 1)	±1.1 mm (RD 2)
PACS	+0.09 mm	±1.0 mm (RD 3)	±3 mm (RD 1)	±1.1 mm (RD 2)
SPIRE	-0.06 mm	±2.25 mm (RD 6)	±3 mm (RD 1)	±1.1 mm (RD 2)

Table 6-4: Defocus position and uncertainty contributions

	Thermoelastic Effects
HIFI	± 0.1 mm
PACS	± 0.1 mm
SPIRE	± 0.1 mm

Table 6-5: Defocus position: Influence of thermoelastic effects
According to RD 2: Original allocations of instruments

From above two tables, we find the focus positions and the related uncertainties:

	Overall focus position	Requirement ΔX	Margin
HIFI	**-0.75 mm ± 5.7 mm**	± 8.5 mm	2.1
PACS	**+0.19 mm ± 3.3 mm**	± 7.0 mm	3.5
SPIRE	**-0.16 mm ± 3.9 mm**	± 7.7 mm	3.7

Table 6-6: Final focus positions and tolerances

The table shows that the focus requirements are well fulfilled for all instruments

6.4 Pupil Mismatch

From the Rot Y and Rot Z values of Section 6.2 we find the resulting individual tilt-related pupil mismatches $\Delta Y = - e \tan(\text{Rot } Z)$ and $\Delta Z = - e \tan(\text{Rot } Y)$, where e = 2638 mm represents the M1-M2 mirror separation (vertex distance). To find the total pupil mismatches, the lateral FPU displacements have to be added accordingly.

	Rot Y	Rot Z	ΔY(Pupil) at M2	ΔZ(Pupil) at M2
HIFI	+0.13 arcmin	+1.35 arcmin	**+1.04 mm**	**-0.10 mm**
PACS	-2.31 arcmin	-3.38 arcmin	**-2.60 mm**	**+1.78 mm**
SPIRE	-5.56 arcmin	-2.84 arcmin	**-2.19 mm**	**+4.28 mm**

Table 6-7: Instrument-tilt components of pupil mismatches

	ΔY	ΔZ
HIFI	-1.03 mm	+0.01 mm
PACS	-0.81 mm	+0.88 mm
SPIRE	-1.21 mm	+0.26 mm

Table 6-8: Pupil mismatch: Measured instrument lateral shifts

	Internal Position Error		Thermoelastic Effects	
	ΔY Int	**ΔZ Int**	**ΔY TE**	**ΔZ TE**
HIFI 1)			4)	4)
Channel 1	-2 mm ± 2	+2 mm ± 2	±0.1 mm	±0.1 mm
Channel 2	-3 mm ± 2	+2 mm ± 2	±0.1 mm	±0.1 mm
Channel 3	+5 mm ± 2	0 mm ± 2	±0.1 mm	±0.1 mm
Channel 4	0 mm ± 2	-6.5 mm ± 2	±0.1 mm	±0.1 mm
Channel 5	-5 mm ± 2	+0.5 mm ± 2	±0.1 mm	±0.1 mm
Channel 6	0 mm ± 2	0 mm ± 2	±0.1 mm	±0.1 mm
Channel 6b	-4 mm ± 2	+4.0 mm ± 2	±0.1 mm	±0.1 mm
PACS 2)	0.0 mm ± 0.6	0.0 mm± 0.6	±0.1 mm	±0.1 mm
SPIRE 3)	-1.70 mm ±0.5	-0.70 mm ±0.5	+0.8 mm	+0.2 mm

Table 6-9: Pupil mismatch: Instrument internal errors and thermoelastic effects

1) From RD 7
2) From RD 3 (but uncertainty scaled for 2σ)
3) From RD 6
4) 0,1mm taken from RD 2 (original allocation as given by the instruments)

	ΔY	ΔZ	Remark
Telescope	-0.45 mm ± 0.5	-0.60 mm ± 0.5	According to RD 1

Table 6-10: Telescope lateral shift

	ΔY	ΔZ	Uncertainty	Tolerance
HIFI				**24 mm**
Channel 1	-1.64 mm	+2.61 mm	±2.34 mm	
Channel 2	-2.64 mm	+2.61 mm	±2.34 mm	
Channel 3	+5.56 mm	+0.61 mm	±2.34 mm	
Channel 4	+0.56 mm	-6.09 mm	±2.34 mm	
Channel 5	-0.14 mm	+1.11 mm	±2.34 mm	
Channel 6	+0.56 mm	+0.61 mm	±2.34 mm	
Channel 6b	-3.64 mm	+4.61 mm	±2.34 mm	
PACS	-3.06 mm	+3.36 mm	±1.35 mm	**7 mm**
SPIRE	-5.45 mm	+4.64 mm	±1.32 mm	**9.5 mm**

Table 6-11: Total pupil mismatch

Note: SPIRE: Thermoelastic effects for the instruments have been provided without sign. Therefore, these are added linearly as worst case to the absolute value of the total bias (see RD 6).
For the other Instruments, values have been taken from RD 2 as originally allocated by the instruments and used as with SPIRE.

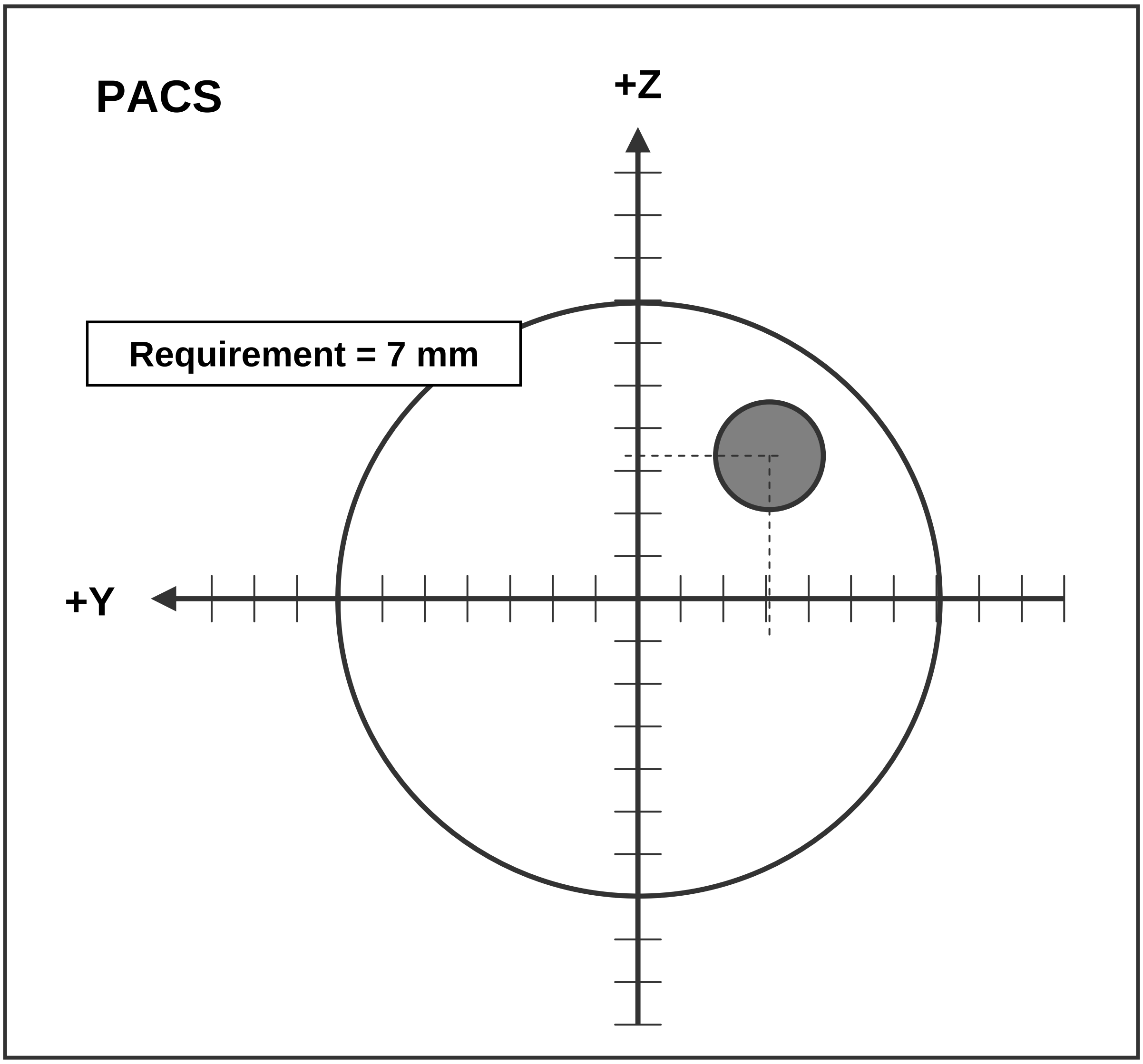

Figure 6-4: Pupil mismatch and uncertainty of PACS wrt. related requirement

The grey circle shows the uncertainty region.

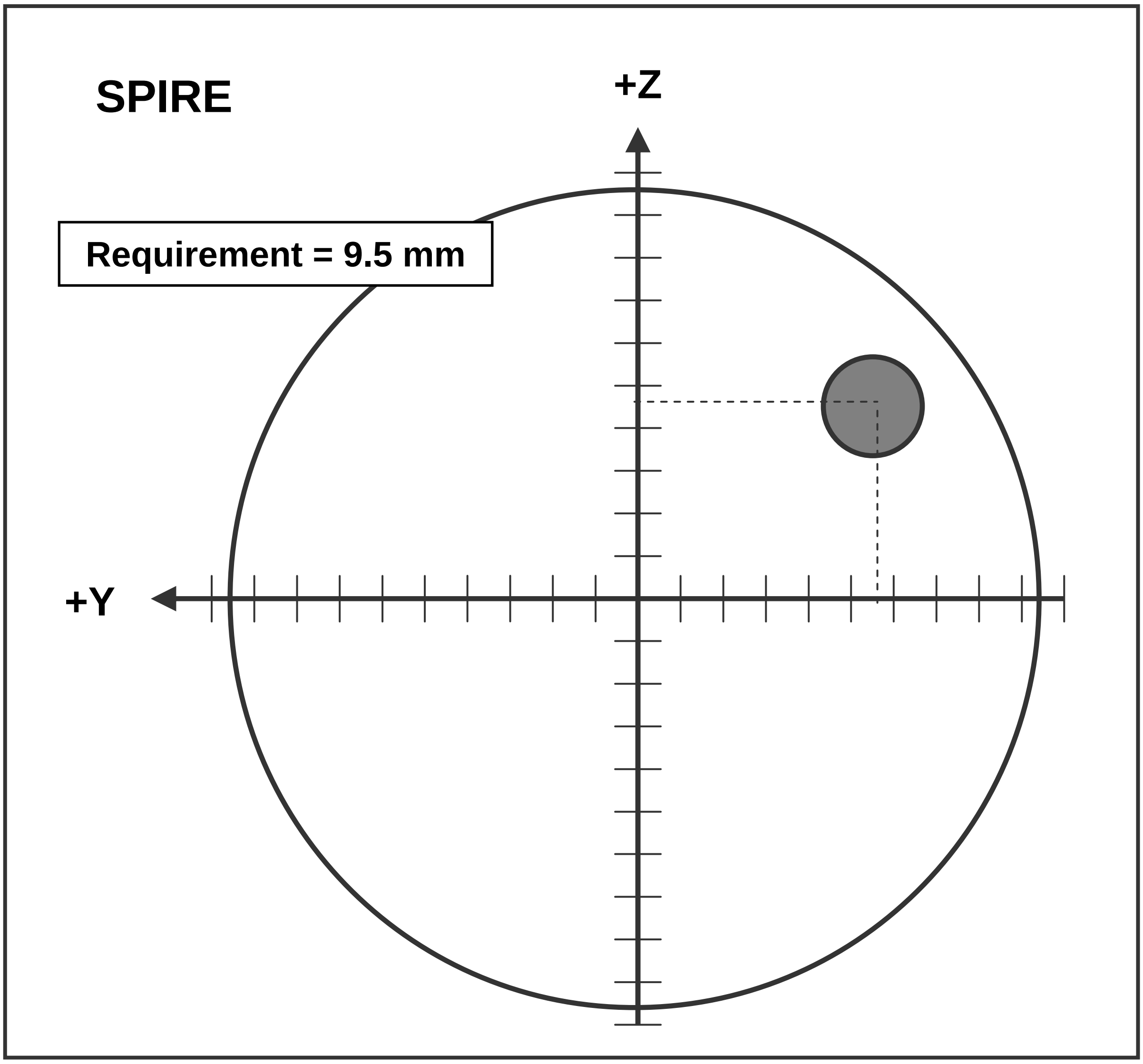

Figure 6-5: Pupil mismatch and uncertainty of SPIRE wrt. related requirement.

The grey circle shows the uncertainty region.

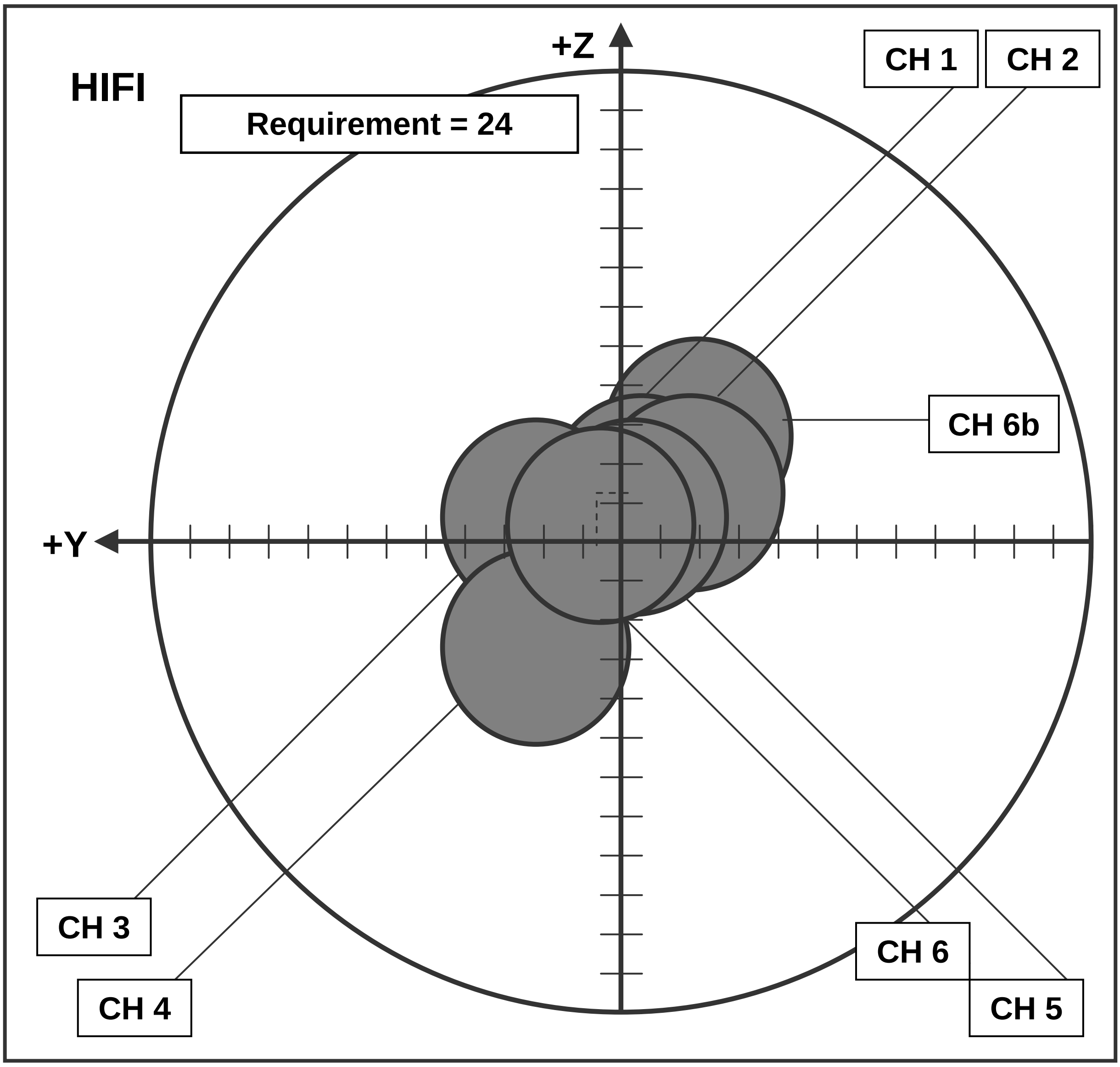

Figure 6-6: Pupil mismatch and uncertainty of HIFI wrt. related requirement

The grey circles show the uncertainty regions.

The Tables and Figures above demonstrate that the pupil mismatches of all instruments are within specified limits, although margins for PACS and SPIRE are not very large.

6.5 Potential Vignetting of LO-Beams by CVV windows

The tilt of the HIFI FPU leads t a certain lateral offset between the LO beam paths from the LOAs and their related CVV windows which might imply vignetting. Therefore, in the following we check the amount of lateral deviation between LO channels and CVV windows due to the Rot X, Y, Z values of the HIFI FPU. The HIFI beam diameter is 30mm, the CVV Window diameter is 34mm.

With the following denominations/numbers

dx, dy, dz: Measured lateral (linear) deviations of the FPU (represented by its reference cube)

RCVV: Radius of CVV = 950 mm

RCube: Radial position of reference cube = 116 mm

DWin: Distance of outermost window centres = 401 mm

we find:

ΔX (Rot Z) = dx(FPU) + (RCVV – RCube) tan Rot Z

ΔX (Rot Z) = -0.65 mm + (950 – 116) mm tan 0.0025° = -0.32 mm

ΔZ (Rot X) = dz(FPU) - (RCVV – RCube) tan Rot X

ΔZ (Rot X) = 0.01 mm – (950 – 116) mm tan 0.073° = -1.1 mm

ΔX (Rot Y) = dy (FPU) – (DWin) tan Rot Y

ΔX (Rot Y) = 0 + (401) mm tan 0.0022° = 0.015 mm [negligible]

The total lateral deviation between the LOU beams and the windows is

$\Delta = [\Delta x^2 + \Delta z^2]^{1/2} = 1.15$ mm

Compared to the overall margin of ± 2 mm we conclude, that from the above determined HIFI FPU tilts no intolerable vignetting by the CVV windows will occur.

Note:

The above assessment will not be the sole basis for the assumption of sufficient freedom from LOU beam vignetting. A final decision on this question will be made during a forthcoming AIT period where the upper bulkhead will be temporarily closed.

This period will be used to perform a real measurement of the relative lateral positioning of CVV Windows and FPU ADs thus directly determining potential LOU Window vignetting.

6.6 Stability wrt. harness rail fixation

In the course of the instrument AIT, a harness rail had to be attached on the HIFI FPU structure close to the area of the FPU Alignment Devices (AD). Therefore, a check was requested which should demonstrate that the mounting of the harness rail has no impact on the AD orientation.

As the measurement data from Table 8-12 show the residual impact of the mentioned activities onto the AD orientation is:

	+ Z Hz	**+Z V**	**- Z - Hz**	**-Z V**
before screw fixation	0.0029 deg	89.9954 deg	0.0211 deg	89.9946
after screw fixation	0.0001 deg	89.9957 deg	0.0185 deg	89.9954
Difference	0.0028 deg **10.1 arcsec**	0.0003 deg **1.1 arcsec**	0.0026 deg **9.4 arc sec**	0.0008 deg **2.9 arcsec**

Table 6-12: HIFI FPU AD stability wrt. harness rail fixation

The table shows that the stability of the ADs was far better than the required limit of 20 arcsec.

7 Conclusions

From the above presented evaluation of the Herschel instrument alignment, we conclude, that all instruments are within their specified envelopes.

For focus alignment (x direction) there is comfortable margin for all three instruments (see Table 6-6).

For pupil mismatch the margin is very comfortable for HIFI (see Fig. 6-6). For PACS and SPIRE the margin is appr. 1.5mm in y and z direction and can be taken directly from Figures 6-4 and 6-5.
Please note, that for these calculations it was assumed that the telescope, when mounted at a later stage, reaches its nominal position. This must be confirmed by an alignment check after telescope integration. Here the telescope cubes will be measured to the same CVV reference as the Instruments.

The vignetting calculation presented in chapter 6.5 shows that there is no intolerable vignetting of the LOU beams by the CVV windows. There is still margin left compared to the CVV windows oversize of ± 2 mm.
When the upper bulkhead is mounted it is planned to measure directly the position of the HIFI ADs w.r.t. the CVV window position. This measurement shall confirm the calculation from chapter 6.5.

As demonstrated in chapter 6.6 the HIFI FPU ADs have remained stable under fixation of harness rail.

8 Attachment

1. “As Run” Procedure for PFM Alignment of Herschel Instruments wrt. PLM
2. “As Run” Activity Control Sheet: HIFI AD Stability Check after Harness rail Final Fixation: HP-2-ASED-SD-0177
3. “As Run” Activity Control Sheet: Determination of CVV Flange Orientation HP-2-ASED-SD-0179

Hs Run

02.08.2007

Title: **Procedure for PFM Alignment of Herschel Instruments wrt. PLM**

CI-No: 120000

Prepared by:	E. Hölzle / D. Schink	Date: 23.7.2007
Checked by:	S. Idler	23.07.07
Product Assurance:	R. Stritter	24.07.07
Configuration Control:	W. Wietbrock	25.07.07
Project Management:	Dr. W. Fricke	26/07/2007

Distribution: See Distribution List (last page)

AS Run PFM

Issue	Date	Sheet	Description of Change	Release
1	20.07.07	All	First formal issue	

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1 INTRODUCTION

1.1 Scope

This document describes the instrument level alignment measurements to be made after instrument integration onto OB. These measurements shall verify the correct positioning of the OB wrt. the CVV and of the instruments wrt. each other and wrt. the CVV/OB. The procedure for performing these activities is reflected in chapter 10 of this document.

Alignment adjustments and measurements have to be performed with the PFM.

The guidelines and requirements applicable to the PFM alignment activities are explained in [RD 1].

Lessons learned with the STM and EQM have been implemented for the PFM.

1.2 Objective

The alignment adjustment and verification measurements with the flight hardware are required in order to show that the alignment requirements specified in [AD 1] are met.

The alignment requirements as specified in [AD 1] are applicable for in-orbit conditions if not stated otherwise. The final verification of these requirements is a combination of on-ground alignment measurements and calculations taking into account in-orbit effects and launch loads. This analysis is performed in [RD 1] whereas this procedure covers the alignment activities for on-ground verification measurements.

Alignment measurements are carried out on several stages during the H-EPLM qualification and acceptance testing. A test plan and sequence for PFM is given in [RD 1], [RD 5] and [RD 6].

2 Applicable Documents

2.1 Applicable Documents

[AD 1]	H-EPLM requirements Specification (HERS) H-P-2-ASPI-SP-0250, issue 3.3, dated 20.10.2004
[AD 2]	Instrument Interface Document IID Part A SCI-PT-IIDA-04624, issue 4.0, dated 30.04.2006
[AD 3]	Instrument Interface Document Part B, Instrument HIFI SCI-PT-IIDB/HIFI-02125, issue 3.3, dated 21.10.2005
[AD 4]	Instrument Interface Document Part B, Instrument PACS SCI-PT-IIDB/PACS-02126, issue 4.0, dated 02.06.2006
[AD 5]	Instrument Interface Document Part B, Instrument SPIRE SCI-PT-IIDB/SPIRE-02124, issue 4.0, dated 01.04.2006
[AD 6]	FIRST Telescope Specification SCI-PT-RS-04671, issue 7.0, dated 26.07.2004

2.2 Reference Documents

[RD 1]	Alignment Method, Plan & Results HP-2-ASED-TN-0097
[RD 2]	Herschel System Alignment Plan H-P-2-ASPI-PL-0276
[RD 3]	HIFI – LOU Alignment Plan (Annex 2 in IID Part A, SCI-PT-IIDA-04624, Issue 1/0, dated 1.09.2000)
[RD 4]	Satellite AIT Plan (Part 1: STM Qualification Phase) HP-2-ASED-PL-0025
[RD 5]	Herschel Satellite AIT Plan (Part 2: PFM Acceptance Phase) HP-2-ASED-PL-0026
[RD 6]	Handling and Integration Procedure, Herschel EPLM Support Structures & SVM Thermal Shield HP-2-ECAS-PR-0001
[RD 7]	HIFI Alignment Camera System User Manual HP-2-TER-MA-0001
[RD 8]	Herschel Optical Bench Assembly Dimensional Check Report HP-2-SEN-TR-0009, Issue 1_3, dated 28.10.04
[RD 9]	HP-2-ECAS-PR-0014, Issue 02
[RD 10]	Report of the Measurements of the HIFI External Alignment Devices; FPSS-01068 Issue 3.0
[RD 11]	Distance Measurements Validity Check HP-2-ASED-TR-0174, Issue 1-0
[RD 12]	Inputs to System Level Alignment PACS-ME-TN-069, Issue 3
[RD 13]	SPIRE FPU External Alignment Report SPIRE-RAL-PEP-002946, Issue 1

3 Requirements to be verified

With this alignment procedure the on-ground alignment contribution of instruments and OB to the overall alignment requirement as specified in [AD 1] will be verified. The overall verification of the alignment requirements can only be performed per analysis and will be provided with an update of [RD 1] after the on-ground alignment activities have been performed including the HACS and videogrammetry measurements during TB/TV testing.

- HERS 0680 Alignment cubes
  The H-EPLM shall be equipped with at least 2 optical cubes (1 nominal, 1 for redundancy). They shall represent the H-EPLM optical reference frame.

- HERS 1240 Visibility of Alignment Cubes
  The optical references used for focal plane alignment shall be accessible during module and system AIT operations.

- HERS 1220 Focus Alignment
  The absolute in-orbit focus alignment shall be less than:

Instrument	Absolute alignment requirement
PACS	±7.0 mm
SPIRE	±7.7 mm
HIFI	±8.5 mm

- HERS 1230 Pupil Mismatch

Instrument	Absolute alignment requirement
PACS	±7.0 mm
SPIRE	±9.5 mm
HIFI	±24.0 mm

- HERS 0640 PACS LOS Bias
  The alignment bias of PACS Line of Sight with regard to the PLM-SVM interface frame shall be lower than ±5 arcmin (including ground and in-orbit effects).

- HERS 0645 Around-LOS Bias
  The maximum around-LOS alignment bias of each instrument with regard to PLM-SVM interface shall not exceed 12 arcmin (including on-ground positioning accuracy, thermoelastic behaviour).

- HERS 0650a SPIRE and HIFI LOS w.r.t. PACS LOS
  SPIRE and HIFI in-orbit LOS shall be known with regard to PACS LOS with an accuracy better than ±6arcsec (2σ) each axis (including on-ground alignment knowledge, in-orbit stability knowledge). In addition ASED's RfD 'HP-2-ASED-RD-0006 Issue 2.0' has to be considered.

  Note: This requirement is related to the in-orbit knowledge accuracy of HIFI (resp. SPIRE) FPU cube w.r.t. the PACS FPU cube. it includes:

  - On-ground relative position knowledge accuracy (y-z plane)
  - In-orbit relative stability knowledge during cool (y-z plane)
  - In-orbit thermoelastic behaviour (y-z plane)
  - The relation between the yz instrument relative position knowledge and relative in-orbit LOS is the worst case length of the Telescope.

- HERS 0660 Around LOS Knowledge
  The around LOS alignment of each instrument with regard to the PLMSVM interface frame shall be known with an accuracy better than ±0.5 arcmin at 68 % confidence level (including on-ground alignment knowledge, in-orbit stability knowledge):

NOTE:

From the above description, it is clear that this document covers only instrument to OB and CVV alignment and will, therefore, provide only inputs for the verification of the above compiled requirements.

At the time of preparation of this procedure, specific measured FPU reference cube positions and orientations are only available for OB, HIFI and PACS. Based on these measured data, nominal values for positions and orientations of these units have been calculated and will be used for comparison with the measurements as defined in this procedure.

For SPIRE, only measured rotations about y and z-axis exist. Therefore, for displacements, the "as designed values" together with the related tolerances for system level alignment as given in RD 13 have been used to derive "nominal values" for comparison with the measurements.

Should FPU data become available at a later point in time, even after integration, these measured alignment data can still be used to perform a detailed evaluation of the PLM alignment a posteriori, if desired. The data used for above mentioned position/orientation determination and the resulting values are compiled in Section 14.

4 Alignment Activities Description

4.1 Alignment Overview

The purpose of the instrument alignment is to precisely adjust the OBA, i. e. OB with the three Herschel instruments HIFI, PACS and SPIRE with respect to the CVV and hence with the telescope focus. For instrument position and orientation, the procedure defines certain tolerances (see. Sect 10 and its sub-sections).These tolerances are compatible with the performance budget. A part of the margin of the alignment budget (focus, pupil mismatch) is allocated to final OB misalignment tolerance: ± 1mm.

The LOU must be aligned very precisely to the HIFI FPU. Both elements are aligned to each other by a specific activity (covered by a dedicated LOU alignment procedure HP-2-ASED-TP-0112, tbi). The mounting tolerances (i. e. position/orientation deviations) mentioned above, therefore, do not apply to the HIFI FPU/LOU configuration. i. e., they have no impact on HIFI performance aspects.

During the Herschel integration, however, the telescope is the last subsystem which will be mounted onto the cryostat. At this integration stage the cryostat cover is already closed and therefore the optical reference cubes from the instruments can no longer be seen. Consequently the instruments must be aligned to a common intermediate optical reference, the CVV cubes, to which the telescope is aligned later on (covered by a separate telescope related procedure).

This procedure covers the following alignment tasks:

- Alignment of OB w.r.t. CVV
- Alignment measurements of instruments w.r.t. CVV alignment cubes

Main Integration and Alignment Steps:

1. Mounting of a reference cube at the optical bench (OB manufacturer) and CVV cubes at the CVV.

2. Integration of the OB into the cryostat.

3. Adjustment of the OB wrt. CVV.

4. Integration of the three instruments onto the optical bench. Each instrument is equipped with an alignment cube, in principle representing the instrument's internal alignment (see AD 3, 4, 5).
   Instruments, for which presently no specific measured alignment data exist (SPIRE) will be aligned to their nominal position (as per ICD) on the OB and their relation to the CVV reference cubes will be measured. When specific

FPU data become available, the alignment measurements will used to evaluate the PLM alignment a posteriori.

5. Alignment of the instruments is measured w.r.t. the CVV reference cube No 4 (CVVRC4) as shown in Figure 14-2 to obtain the knowledge about the actual orientation (position and angle), from which their relation to the OB reference cube is obtained (see step 6 below). 1)

 1) According to IID-A the instruments shall be delivered with dowel pins. This is actually the case for PACS and HIFI. For SPIRE special screws will be used. That means, that the actual lateral position will be measured w.r.t. the OB and CVV but shimming is only possible in x direction. The instrument internal alignment error must be compliant with this alignment strategy.

6. Alignment measurement of OB reference cube w.r.t. a reference cube mounted outside the CVV (see Figure 14-2). If necessary correction of OB via the tank straps.

NOTE:
Initially, all instruments/PLM related alignment measurements are made wrt. the CVVRC: CVVRC2 and CVVRC4. After mounting the PLM to the SVM, the final transfer to S/C coordinate system is then performed by measuring the relation of the CVVRCs wrt. the SVM related master reference cubes MRC3 (and MRC 4) and applying the appropriate transfer matrices computed in the MRC3 coordinate system. The determination of S/C axis will be performed by TAS-F.

The complete integration, alignment and test logic flow for PFM is shown in the Satellite AIT Plan, RD 5.

To compensate instrument internal dimensional tolerances, the instruments will be delivered with shimming plates. It is assumed, that the instruments will be delivered with adapted shims, i. e. a potential instrument internal misalignment is directly corrected by the correspondingly modified shims.

Dowel pins mounted at the OB shall serve as alignment reference to allow to find the alignment position again after removing of the instruments (e.g. for reproducible re-integration).

This procedure is valid for the PFM. The filled in test procedure establishes the main part of the alignment test report.

Instruments and OB will be delivered with alignment references and will be internally aligned w.r.t. these references (already performed before integration).

For the CVV the alignment reference cubes have been mounted during STM alignment activities according to the positions as shown in the annex.

The alignment methods are described in detail in RD 1. Here only a short overview is given for completeness of this document. Two types of alignment measurements are needed to perform all alignment tasks.

- Angle measurements between alignment cubes (using an auto-collimation theodolite and an angle transfer prism).
- Distance measurements between cross hairs marked at the surface of the alignment cubes (Linear Measurement Device along with theodolite and an angle transfer prism).

4.2 Adjustment Capabilities

For actual correction of the instrument alignment the following adjustment capabilities are foreseen:

1. Shimming plates for each instrument
   - PACS shim thickness ±3mm in x direction
   - HIFI shim adjustment range ± 3mm in x direction
   - SPIRE: No Shimming plates are foreseen

2. Optical Bench adjustment range in each direction 1.5mm via the 16 tank straps. Additional ±2mm in x direction using shimming plates between OB and upper Spatial Frame Work.

4.3 Angle Measurements of Alignment cubes

The Angle measurements between different alignment cubes are based on the principle of auto-collimation. A theodolite with illuminated cross hair is used as autocollimator. The cross hair image is projected on a flat mirror (face of alignment cube) the angular orientation of which has to be determined. When the line of sight of the theodolite is parallel to the flat mirror normal, the reflected image of the cross hair is refocused in the cross hair plane and coincides with the theodolite cross hair. The corresponding azimuth and elevation angle from the flat mirror normal can than be read from the theodolite scales.

In the vertical plane this reading is related to the earth gravity field. The horizontal reading has to be related to a reference direction, for which an Angle Transfer Prism (ATP) will be used.

Since the alignment cubes are mounted on different heights the theodolite can be moved vertically on an alignment stand (see Figure 6-1).

4.4 Distance Measurements

The distance measurements are based on measurements using the Linear Measurement Device (LMD).

4.4.1 Linear Measurement Device

A scale tape (steel) is mounted onto a rail under a defined mechanical tension. On the tape surface engraved code bars which provide an absolute linear position code. The actual length is defined by aiming sequentially at position reference cubes with cross hair and an alignment target at the linear measurement device with a theodolite. The actual position is read by a scanning head mounted at the LMD (see Figure 6-3).
A validity check was performed with the LMD to demonstrate that the device is a tool adequate for distance measurements within the Herschel PFM AIT programme. Details of the validity check (re-qualification) are given in RD 11.

4.5 Alignment Procedure

An alignment sequence consists of the following steps:

- Measurement process, auto-collimation or distance measurement. For an angular measurement the elevation and azimuth angles will be measured w.r.t. the alignment cube axes.
- Determination of the unit misalignment w.r.t. the nominal position and orientation and comparison to the alignment requirement.
- Final alignment check (only necessary if corrections, e. g. by shimming, have been made).

4.5.1 Theodolite Readings

The theodolite defines the reference frame for the elevation angles (internal levelling of the theodolite). For the azimuth the reference frame will be determined by an Angular Transfer Prism (ATP). This ATP defines the zero for the azimuth reading.

The elevation can vary between 0 and 180 degree and the azimuth is between 0 and 360 degree. The definition for elevation and azimuth is given in the following figures.

Each normal to a reference cube surface is defined by the elevation and the azimuth angle as shown in Figure 4-1 and 4-2. These are the raw measurement data that will be provided with the filled in Test Procedure.

The X, Y and Z-axis are here represented by the respective normals of the cube faces of CVVRC4.

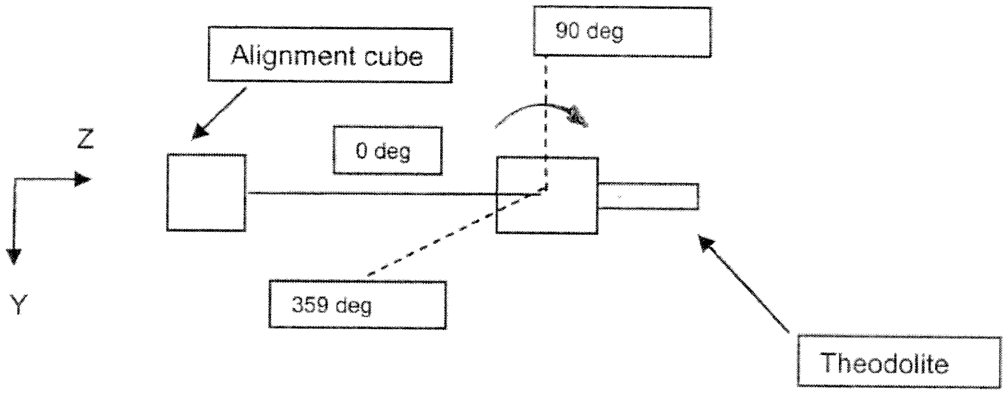


Figure 4-1: Azimuth Reading

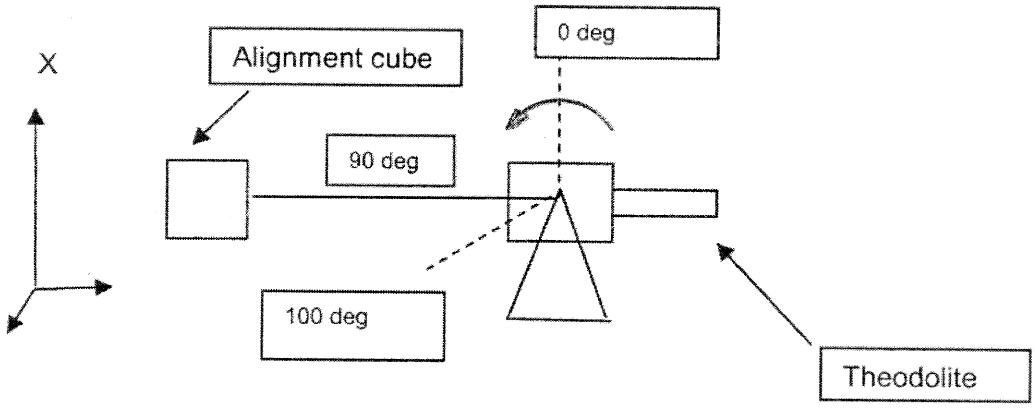


Figure 4-2: Elevation Reading

5 Test Article Description

Figure 5-1 shows the Herschel Optical Bench Assembly (OBA). The OBA is mounted in the centre of the CVV. For optical reference measurements it is equipped with a reference cube. With the upper bulkhead still open, the instrument positions can be measured wrt. the OBA reference cube. The OBA reference cube can be measured wrt. the outer CVV reference cubes. By the thus established relations between instruments and the CVV references further relations, e. g. wrt. TMS and telescope can be established later, when the upper bulkhead is closed.
After closure of upper bulkhead PACS and SPIRE are no longer accessible. Their position and orientation is considered being represented by the HIFI FPU AD which can be viewed via two alignment windows close to the LOU windows. In this way, the position of the telescope relative to PACS and SPIRE can be determined via measurements of the relation of HIFI's LOU wrt. FPU.
The LOU is mounted on the outer –y side of the CVV.

The involved alignment reference locations are compiled in Annex 1

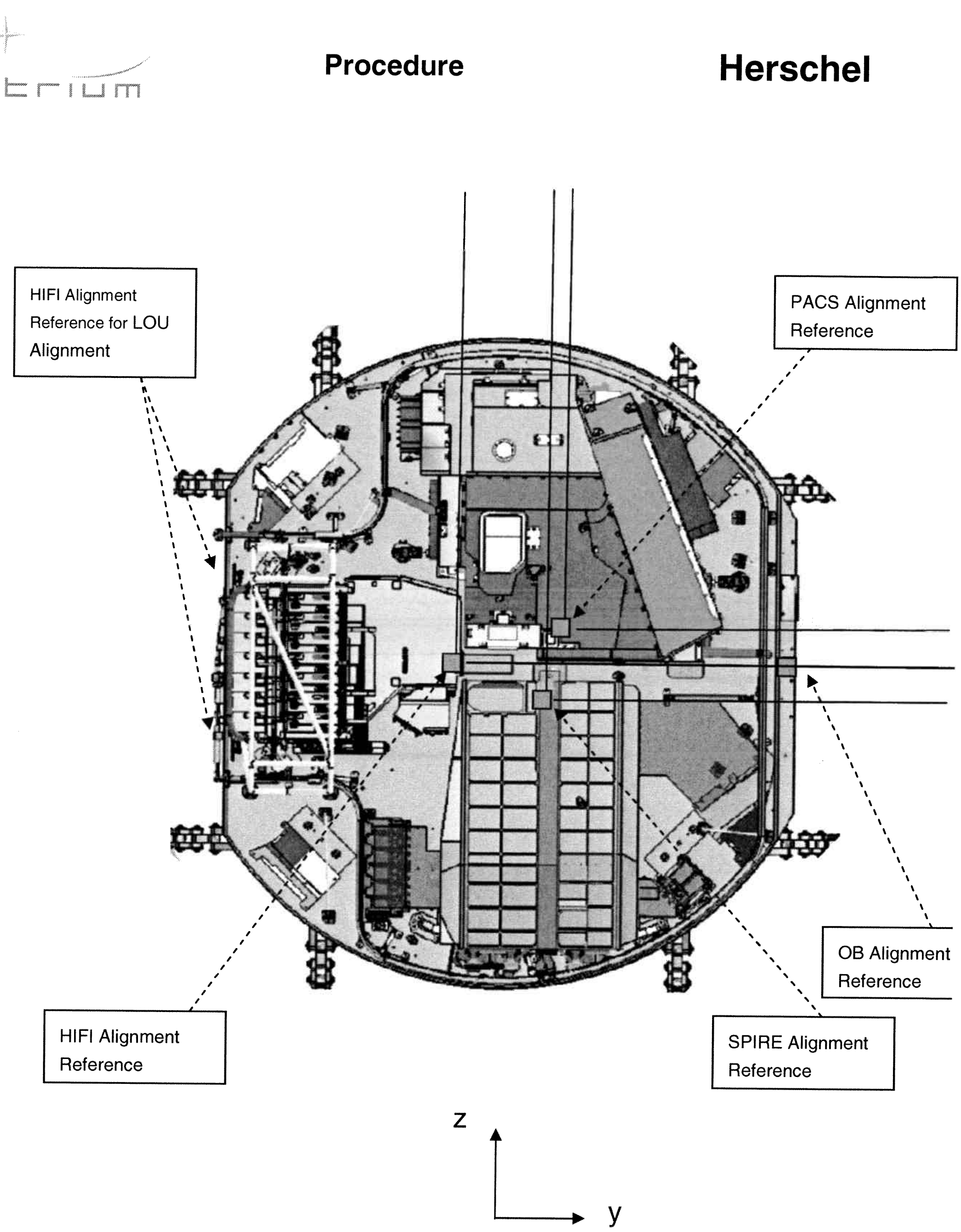


Figure 5-1: Herschel OBA with alignment references
The OBA and instrument positions will be measured wrt. the outer CVV reference cubes (not shown here) on +y and –z side of the CVV. By the thus established relations between instruments and the CVV references, further relations, e. g. wrt. TMS and telescope can be established later (after CVV is closed).
Solid lines indicate optical access (of theodolite) to the individual reference cubes.

6 Test Set-Up Configuration

The configuration of the test set-up for the PFM is shown in a principle Sketch in Figure 6-1

The EPLM is shown on the rotary table with the upper bulkhead not yet mounted. The right side shows the theodolite adjustable to the required working heights by vertical and horizontal shifts along guiding rails of the tripod.

For the purpose of the measurements of this procedure, the PLM is not mounted on the SVM but on the TTAP. The TTAP is equipped with a coordinate system, which makes sure that the PLM is mounted in one unique relation to the TTAP.

The alignment stand is located at a convenient distance (appr. 1 - 5m from the EPLM). Auto-collimation will be performed to the CVV reference cube and each unit equipped with an alignment reference, such as OB and instruments.

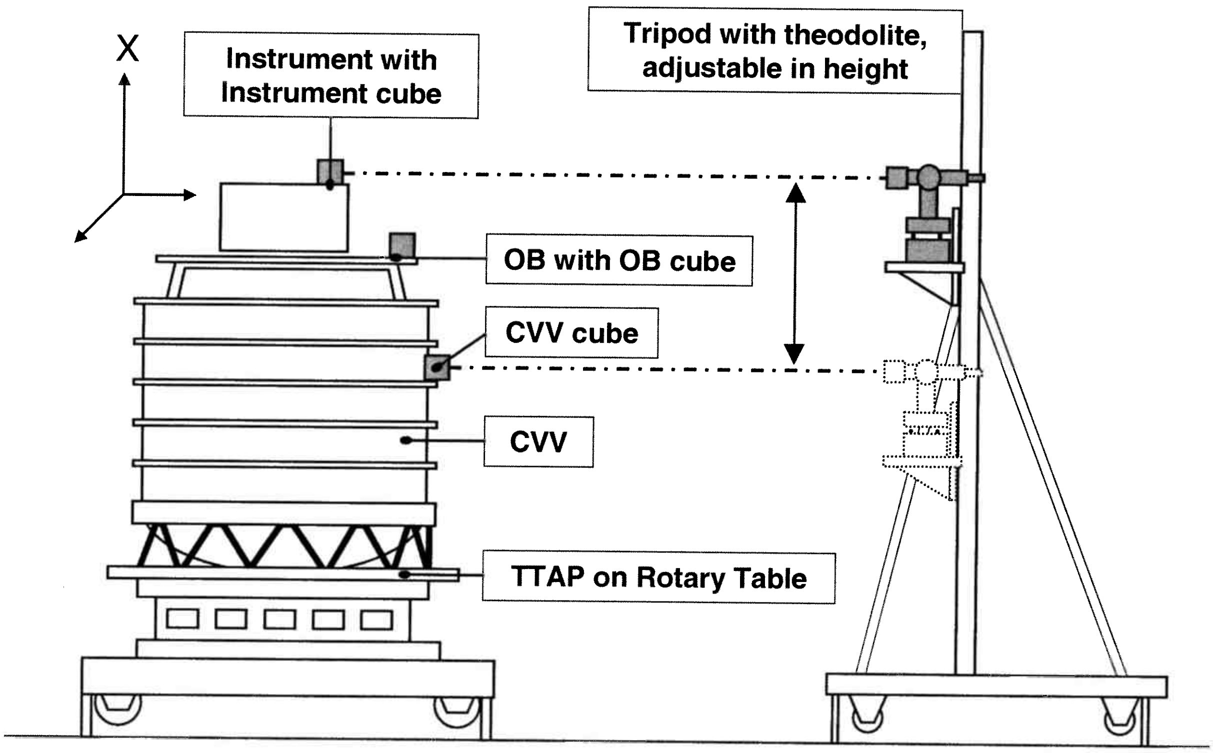


Figure 6-1: Principle Sketch: Alignment Measurement Test Set-Up

Figure 6-2 and Figure 6-3 show a typical set-up for the Linear Measurement Device.

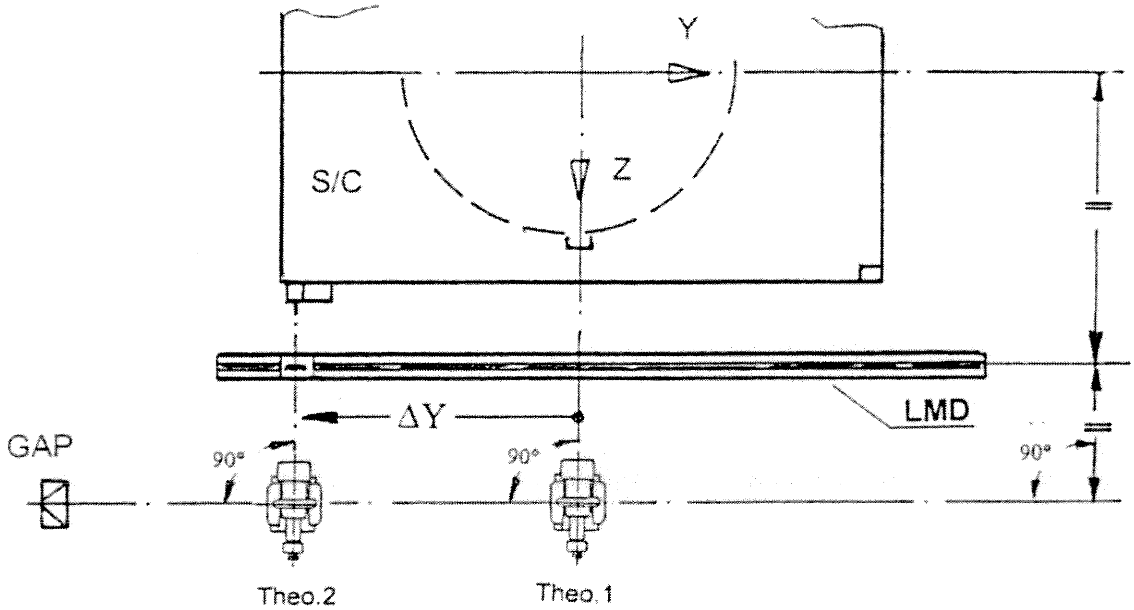


Figure 6-2: Lateral Distance Measurement with LMD

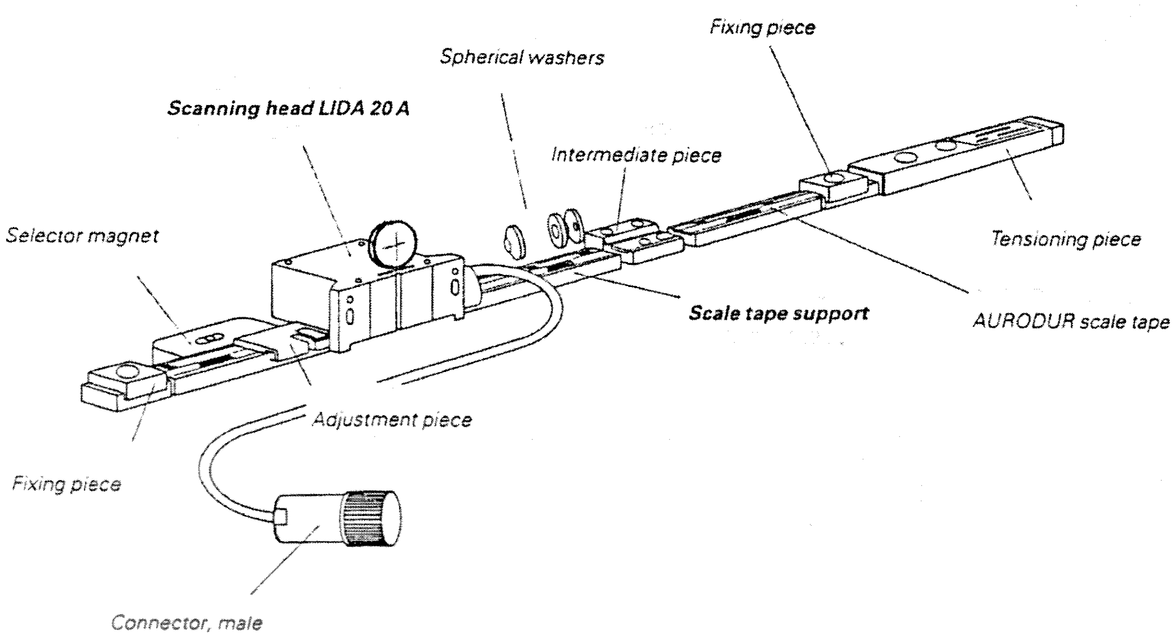


Figure 6-3: Linear Measurement Device

Configuration PLM relative to TTAP:

To be noted prior to begin of measurements:

The determination of the mechanical y-axis w.r.t. the CUVRC4 has been performed according to the Activity Control sheet: HP-2-ASED-SD-0179.
The y-axis was determined using the rotary table centre pin and the TTAP +y mark and than transferred to CUVRC4.
This measurement was also performed for the STM campaign. The agreement of both measurements is within 14.4 arcsec for CUVRC4.

7 Test Equipment

In the following table the main equipment needed for Herschel instrument level alignment activities is shown.

Nr.	Qty	Equipment	Description	Remark
1	2	Theodolite	Wild T2000 S or equivalent	
2	1	Linear Measurement Device	For axial and lateral distance measurements	
3	2	Angular Transfer Prism	As reference for azimuth	
5	3	Alignment reference cubes	1 on OB, 2 on CVV cylinder. part	1)
6	1	Support Structure for LMD	For vertical and horizontal measurements	
7	1	Alignment Stand	For Theodolite Height appr. 7,5m	Metop Equipment
8	1	Adjustable support for PLM or use of a rotary	For precise levelling of the PLM	
9	1	Adapter	For SVM I/F	
10	1	Adapter	For PLM I/F	
11	1	Rotary Table		

Table 7-1: Alignment Equipment List

1 pair of theodolite/ATP will be used for measurements, the other pair is foreseen as back-up.

The units to be aligned (instruments) will be delivered already with alignment cubes mounted. Their relation to the unit has to be determined by the manufacturer.

The CVV is equipped with 4 master reference cubes with the following characteristics:

- Flatness better than lambda/4
- The reflecting surfaces are orthogonal to each other with an angle of 90° ± 10arcsec
- Reflectivity better than 75%
- Material characteristics to survive environmental testing without performance degradation.
- The alignment cubes are protected by caps.

1) The CVV is equipped with 4 reference cubes (MRC). Two of them (nominal and redundant cube) will be mounted on the cylindrical part of the CVV: CVVRC2 and CVVRC4). The other two CVVRC 1 and CVVRC3 (auxiliary cubes) are mounted at the upper bulkhead for back up reasons (instability of nominal cube after re-tensioning of struts).

During the STM alignment a stability test was already performed. During integration of the instruments onto the OB only CVVRC2 and CVVRC 4 are available.
After re-tensioning of the straps (after cool down) the alignment of HIFI – and hence also of the OB – will be checked using the alignment devices of HIFI as references.

All measurements will be made relative to CVVRC4 as "Master Reference Cube". Thus, at later stages, e. g. after the CVV has been closed the positional relation of all aligned units can be retrieved by measurements referenced to CVVRC4.

Since CVVRC4 (and CVVRC2) is not fully accessible at system level alignment activities (obstruction by other equipment) additional references have to be introduced at later project stages, e.g. before the obstructing external cryo-equipment and cabling is mounted to the CVV after integration of the upper bulkhead with two reference cubes CVVRC1 and CVVRC3. By measuring their relation to CVVRC4, CVVRC 1, 3 will provide full knowledge of the alignment relations of other equipment such as TMS or telescope wrt. the OB and instruments.

7.1 Used Test Equipment

The theodolites and ATPs used for the alignment measurements are identified in the following table. The Table shall be filled in prior to test, when the actually used equipment has been prepared.

Equipment	Short designation/calibration	Serial No.
Theodolite	Theo A	310518
Theodolite	Theo B	310455 not used
Angle Transfer Prism	ATP A	69962 Master
Angle Transfer Prism	ATP B	69967 see page 76

Table 7-2: Identification of used Optical Alignment Equipment

8 Test Conditions

8.1 Environmental Conditions

Environmental	Nominal	Remark
Clean Room Class	100 100000	CVV open CVV closed
Temperature	22°C ± 3°C	
Rel. Humidity	40% - 60%	
Pressure	Ambient	

Table 8-1: Environmental Conditions

8.2 Other conditions

The alignment shall be performed on a stable, vibration free floor.

8.3 Personnel

The following personnel is required to perform the alignment measurements.

Responsibility	Name
Test Manager	S. Idler
Handling and Integration Engineer	T. Boyer / H. Geiger
Alignment Engineers (2 Persons)	E. Hölzle / D. Schink
PA Responsible	T. Schmidt

Table 8-2: Personnel

8.4 General and Special Precautions/Safety

The following shall be considered:

The handling of the test set-up shall be in accordance with controlled procedure only.

Handling, mechanical and electrical, has to be done only by qualified personnel.

- The test personnel should pay attention that the complete test is carried out following the procedure steps exactly. This will be confirmed by a signature on the corresponding procedure sheet.
- Correct set-up of the test equipment has to be checked carefully prior to the test.
- Any changes to the alignment sequence have to be recorded in the procedure variation sheet.
- Wherever nominal values and dedicated tolerances are defined, actual measured values shall be recorded to document that the test step was successful. If any actual measured value is out-of-limits or if any step cannot be completed correctly, a Non-Conformance-Report (NCR) shall be written. All deviations during the integration have to be handled with NCR's and have to be noted in the NCR summary table.

  Please note: There is one exception to the above rule: In Sect. 10.2 and 10.3 the position and orientation of the OB is measured. Since at this stage, the OB need not necessarily be precisely adjusted, the procedure calls for a re-adjustment and a corresponding re-measurement. Also, in case the re-measurement (Sect. 10.4, 10.5) does not yet yield the desired position and accuracy, another re-adjustment may become necessary. All re-measurements after re-adjustment activities will be recorded and appended to the “as run procedure”. Thus a complete visibility of all measurements and adjustment steps is guaranteed.

9 Specific Conditions for PFM Instrument Alignment

The involved instruments will be mounted according to their relevant integration procedures. All instruments and the OB have their optical reference cubes or mirrors already mounted.

10 Test Procedures

This chapter describes the necessary steps to perform the angular and distance measurements as described in chapter 4. The principal measurement steps are analogous for all cubes.

The angular and distance measurements as described in Section 4.3 and 4.4 shall be performed for each alignment cube (surface) as listed in Table 14-1 (Appendix).

Measurements:

1. For each measurement (position and orientation) the measurement is performed three times.
    a. For position, the LMD reticle is set in position again, the theodolite is re-adjusted accordingly.
    b. For orientation, the theodolite is set into auto-collimation wrt. the ATP and re-orientated back to the reference cube.
2. The standard deviation between the three measurements shall be within the measurement accuracy (see below).
3. The mean value of the three measurements shall be within the specified tolerance (e. g. ± 1mm of OB).

Measurement Accuracies:

For the tasks to be performed according to this procedure, the following accuracies shall be considered (**2 σ-values**) for a single measurement:

Linear measurements with LMD:	**± 0.4 mm**
Angle measurements:	**± 20 arcsec.**

To achieve the requested measurement accuracy, the theodolites have to be levelled adequately before the measurements. The typical levelling accuracy is ≤ 2 arcsec.

Zero-Points of Linear Distance Measurements:

For the linear distance measurements, usually the first of the two reference points to be measured is defined as zero-point, i. e., its coordinate is set to zero. The procedure contains tables, to record also these values. Although these values will be (typically) zero throughout the measurements, they are recorded in order to make sure, that the measurement was performed correctly, i. e. that no reset of the zero-point was erroneously omitted.

Checks of ATP Position:

The positioning of the ATP will be checked after each measurement (as far as relevant), i. e., after angle measurements.

With the linear distance measurements, such a check is only helpful when the LMD is horizontal. For vertical measurements, the only relevant measurement reference is the theodolite-internal plumb-line.

Before Begin of alignment measurements:

0. Complete form "**Configuration PLM relative to TTAP**" in Sect 6 and Table 7-2 in Sect 7.

Please read procedure variation sheet on page 76 before review.

10.1 Rotary Table Levelling

1. Place the rotary table on the foreseen place at the test floor.
2. Connect the operating and read out electronics
3. Adjust (levelling) the rotation axis as per rotary table manual. The aimed accuracy is ± 2 arcsecs for any position.

Rotary table levelling:	Level1	A 0° 00' 00"
	Level2	B 0° 00' 00"
Date/Time: 2.08.07/16:12		

Explaination for A and B w.r.t. the alignment stand is given on last page.

10.2 Check of OB Position

See Fig. 10-1.

4. Mount LMD vertically close to CVVRC4 +Y face. The distance to the OB cube shall be in the range of (approximately) 1 – 5 m. Check verticality with water balance on two orthogonal sides of the LMD beam. Deviations from verticality shall not be larger than ± 0.5 deg.

LMD verticality:	Elevation1	Ry = 89.9°
	Elevation2	Rz = 89.8°
Date/Time: 2.08.07/16:00		

5. Mount theodolite such that CVVRC4 +Y face can be viewed in auto-collimation.
6. Achieve auto-collimation with CVVRC4, and set theodolite Hz reading to 0.0000 deg. Rotate theodolite to the left until 270.0000 azimuth is reached. Mount ATP such that theodolite achieves auto-collimation wrt. ATP. Rotate theodolite back to CVVRC4 and achieve auto-collimation. Theodolite reading must be Hz = 0.0000 deg. ± 10 arcsec. If this is not the case, repeat step 6 until condition is fulfilled.

7. Direct theodolite towards CVVRV4, set V = 90.0000 deg. and adjust theodolite height with x translation stage to centre of reticle. Rotate theodolite towards LMD.

8. Move the scanning head of the LMD until the elevation bar of the cross hair coincides with the elevation bar of theodolite cross hair.

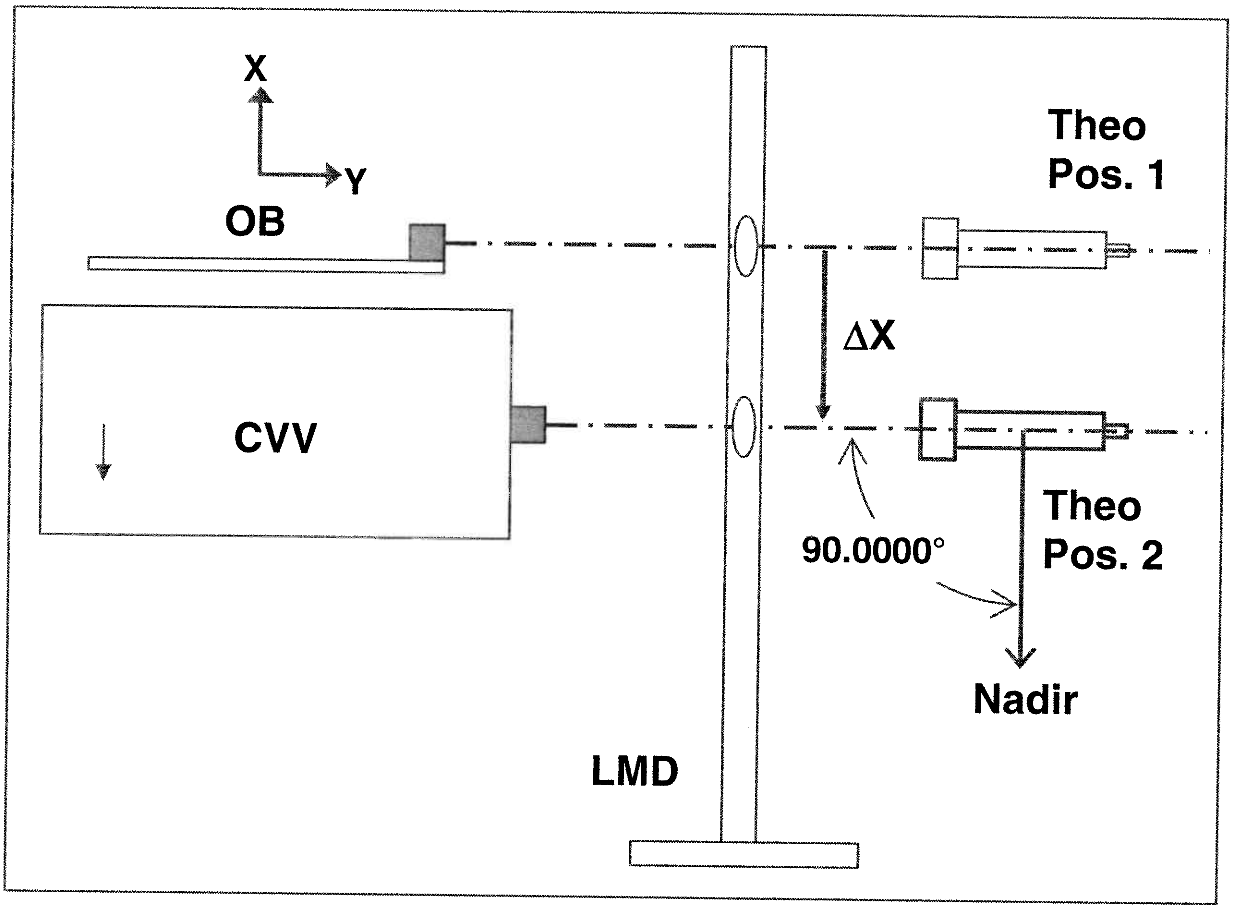


Figure 10-1: Principle set up for vertical distance measurement with LMD from +Y

9. Set the LMD reading to zero at this point. Record the following value:

CVVR4 +Y Linear Position in X				Mean
X(CVVRC4+Y)	0	0	0	
Measurement Date:	2.08.07		Time: 16:20	

10. Adjust theodolite with elevation set to 90.0000 deg. in height to upper edge of CVV I/F flange and rotate theodolite towards LMD.

11. Move the scanning head of the LMD until the upper edge of the I/F-flange coincides with the elevation bar of theodolite cross hair. Record the following

value:

CVV I/F flange plane Linear Position in X			Mean
X(CVV I/F) 57.33	57.43	57.41	57.39 mm
Measurement Date: 2.08.07		Time: 16:25	

12. Adjust theodolite with lateral stages to the centre of the next reference point: OB RC + Y side and rotate theodolite towards LMD.

13. Move the scanning head of the LMD until the elevation bar of the cross hair coincides with the elevation bar of the theodolite cross hair and record the following value:

OB+y face Linear Position in X			Mean
X(OB+y) 560.84	560.73	560.79	560.79 mm
Measurement Date: 2.08.07		Time: 17:40	

Re-check LMD orientation:	Elevation1	Ry = 89.9°
	Elevation2	Rz = 89.9°
Date/Time: 2.08.07 / 17:40		

Re-check Rotary table levelling:	Level1	A = 0° 00' 00"
	Level2	B = 0° 00' 00"
Date/Time: 2.08.07 / 17:40		

Check of OB position in Z-direction

See Fig. 10-2.

14. Mount LMD horizontal in front of +Y side. Set theodolite in front of LMD reference mirror and direct theodolite towards ATP. Achieve auto-collimation with ATP and set theodolite azimuth reading to Hz = 270.0000 deg. Rotate theodolite back to LMD reference mirror until azimuth 0.0000 deg. is reached. Adjust LMD such that auto-collimation mark from reference mirror is visible within theodolite's FoV. If this is achieved, the LMD is parallel to the Z-axis by better than ± 0.5 deg. Check horizontal orientation of LMD beam with water balance. Deviation from exact horizontal orientation shall be less than ± 0.5 deg.

LMD horizonztality:	~~Elevation1~~ Azimuth	Rx = 0.17°
	Elevation~~2~~	Ry = 0.11°
Date/Time: 3.08.07 / 12:00		

15. Switch on the LMD display according to the LMD manual.

16. Check the levelling of the theodolite. Level if necessary.

17. Direct theodolite towards ATP, achieve auto-collimation and set Hz = 270.0000.

18. Rotate theodolite back to Hz = 0.0000 deg. and adjust theodolite with lateral stage to azimuth bar of cross hair of CVVRC4 +y face.

19. Move the scanning head of the LMD until the azimuth of the cross hair coincides with the azimuth of theodolite cross hair.

20. Set the LMD reading to zero at this point. Record the following value:

CVVRC4 Linear Position in Z				Mean
Z(CVVRC4+y)	0	0	0	
Measurement Date:	3.08.07		Time: 12:00	

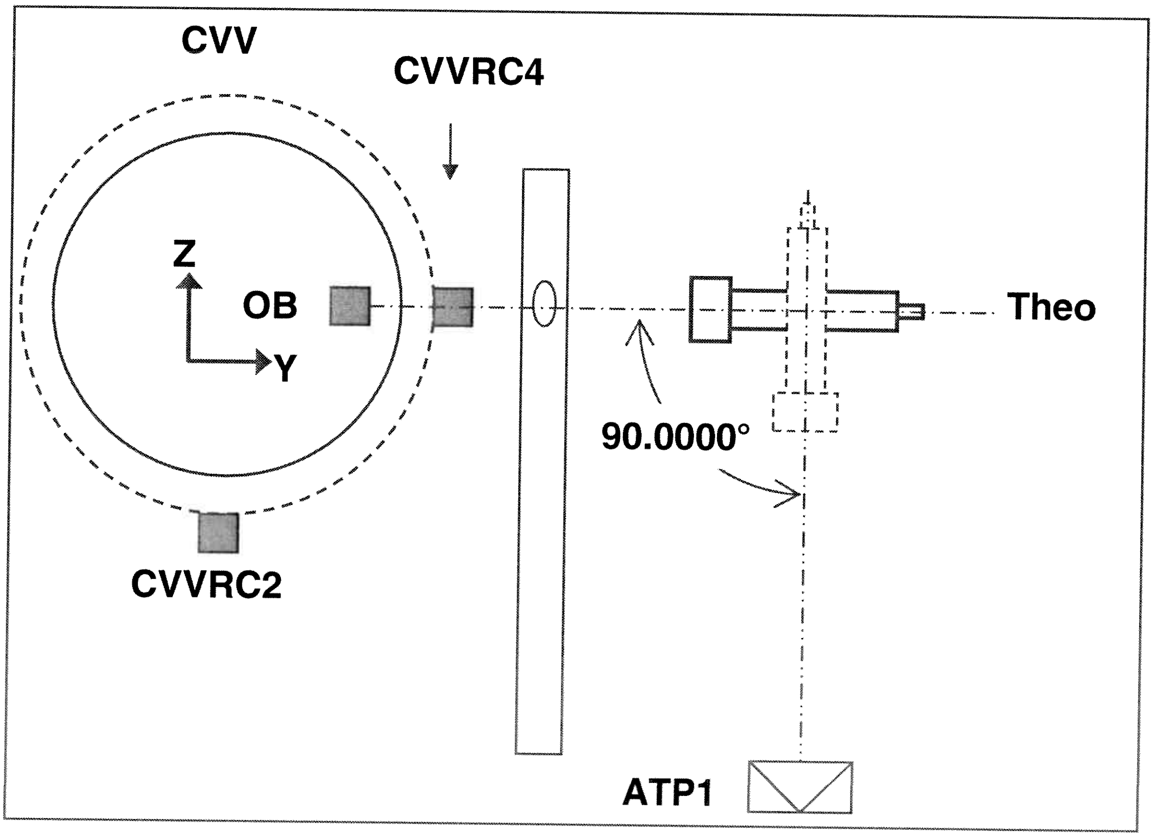


Figure 10-2: Principle set up for horizontal distance measurement from +Y.

21. Move the theodolite to the next reference: OB RC, check the levelling in this position. Level if necessary.

22. Move the scanning head of the LMD until the azimuth cross of the hair coincides with the azimuth of the theodolite cross hair.

23. Read-out the LMD display. Record the following value:

OB +y face Linear Position in Z				Mean
Z(OB+y)	71.52	71.38	71.47	71.46 mm
Measurement Date:	3.08.07		Time: 13:05	

24. Check ATP position:

ATP Position: Hz =	270.0001°
Date: 3.08.07	Time: 13:05

Re-check LMD orientation:	Azimuth:	0.17°
	Elevation	0.12°
Date/Time: 3.08.07 / 13:05		

Re-check Rotary table levelling:	Level1	A = -0° 00' 01"
	Level2	B = 0° 00' 01"
Date/Time: 3.08.07 / 13:05		

Check of OB position in Y-direction

See Fig. 10-3:

25. Rotate PLM such that +Z side points towards theodolite and check Rotary Table levelling

Rotary table levelling:	Level1	A = -0° 00' 01"
	Level2	B = 0° 00' 00"
Date/Time: 3.08.07 / 12:00		

26. Adjust theodolite with lateral stage to the centre of the first reference point: CVVRC4 + Z side and achieve auto-collimation.

27. Set theodolite reading to Hz = 0.0000 deg. Rotate theodolite through 90 deg. to the left until theodolite reading Hz = 270.0000 deg. is reached

28. Check that ATP is in auto-collimation, adjust if necessary. Set Hz = 270.0000 deg.

29. Rotate theodolite back to Hz = 0.0000 deg. and adjust theodolite with lateral stage to azimuth bar of cross hair of CVVRC4 +z face.

Re-check LMD orientation:	Azimuth: Elevation	0.17° 0.12°
Date/Time: 3.08.07 / 13:05		

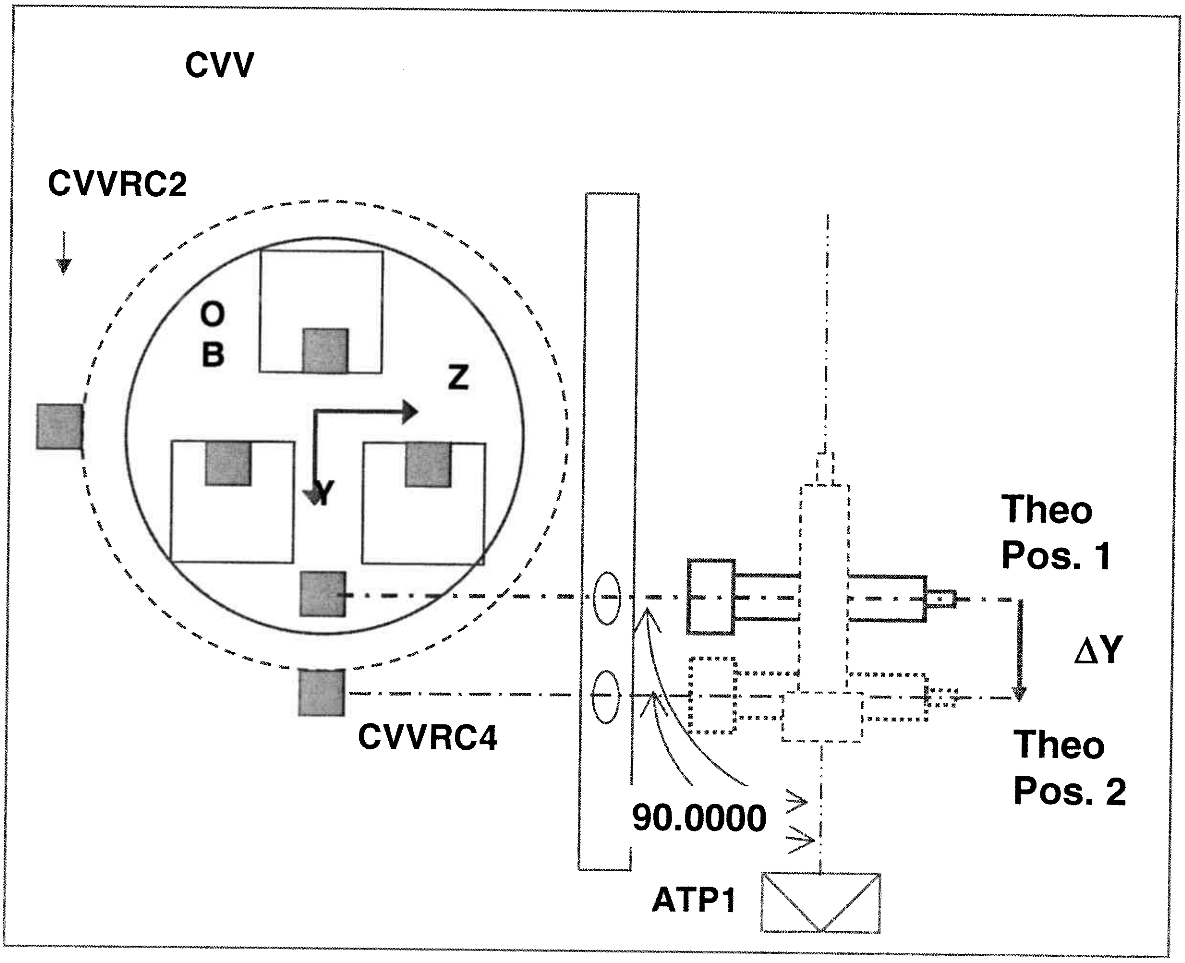


Figure 10-3: Principle set up for horizontal distance measurement from +Z.

30. Move the scanning head of the LMD until the azimuth of the cross hair coincides with the azimuth of theodolite cross hair.

31. Set the LMD reading to zero at this point. Record the following value:

CVVRC4+z face Linear Position in Y				Mean
Y(CVVRC4+z)	0	0	0	
Measurement Date:	3.08.07		Time:	17:00

32. Move the theodolite to the next reference: OB RC, check the levelling in this position. Level if necessary.

33. Move the scanning head of the LMD until the azimuth bar of the cross hair coincides with the azimuth of the theodolite cross hair in the OB position.

34. Read-out the LMD display. Record the following value:

OB +z face Linear Position in Y				Mean
Z(OB+z)	257.65	257.74	257.75	257.71 mm
Measurement Date:	3.08.07		Time:	17:20

35. Check ATP position:

ATP Position: Hz =	270.0000°
Date: 3.08.07	Time: 17:20

Re-check LMD orientation:	Azimuth:	0.17°
	Elevation	0.15°
Date/Time: 3.08.07 / 17:20		

Re-check Rotary table levelling:	Level1	A = 0° 00' 01"
	Level2	B = 0° 00' 00"
Date/Time: 3.08.07 / 17:20		

10.3 Check of OB Orientation from + Y-direction

See Fig 10-4:

36. Rotate PLM such that +Y side points towards theodolite and check Rotary Table levelling

Rotary table levelling:	Level1	A = 0° 00' 00"
	Level2	B = 0° 00' 01"
Date/Time: 3.08.07 / 15:25		

37. Point the theodolite to CVVRC4 and achieve auto-collimation.

38. Set theodolite reading to Hz = 0.0000 deg. Rotate theodolite through 90 deg. to the left until theodolite reading Hz = 270.0000 is reached.

39. Place ATP such that it can be viewed from theodolite at 270.0000 deg. position and level it.

40. Adjust ATP such that theodolite achieves auto-collimation.

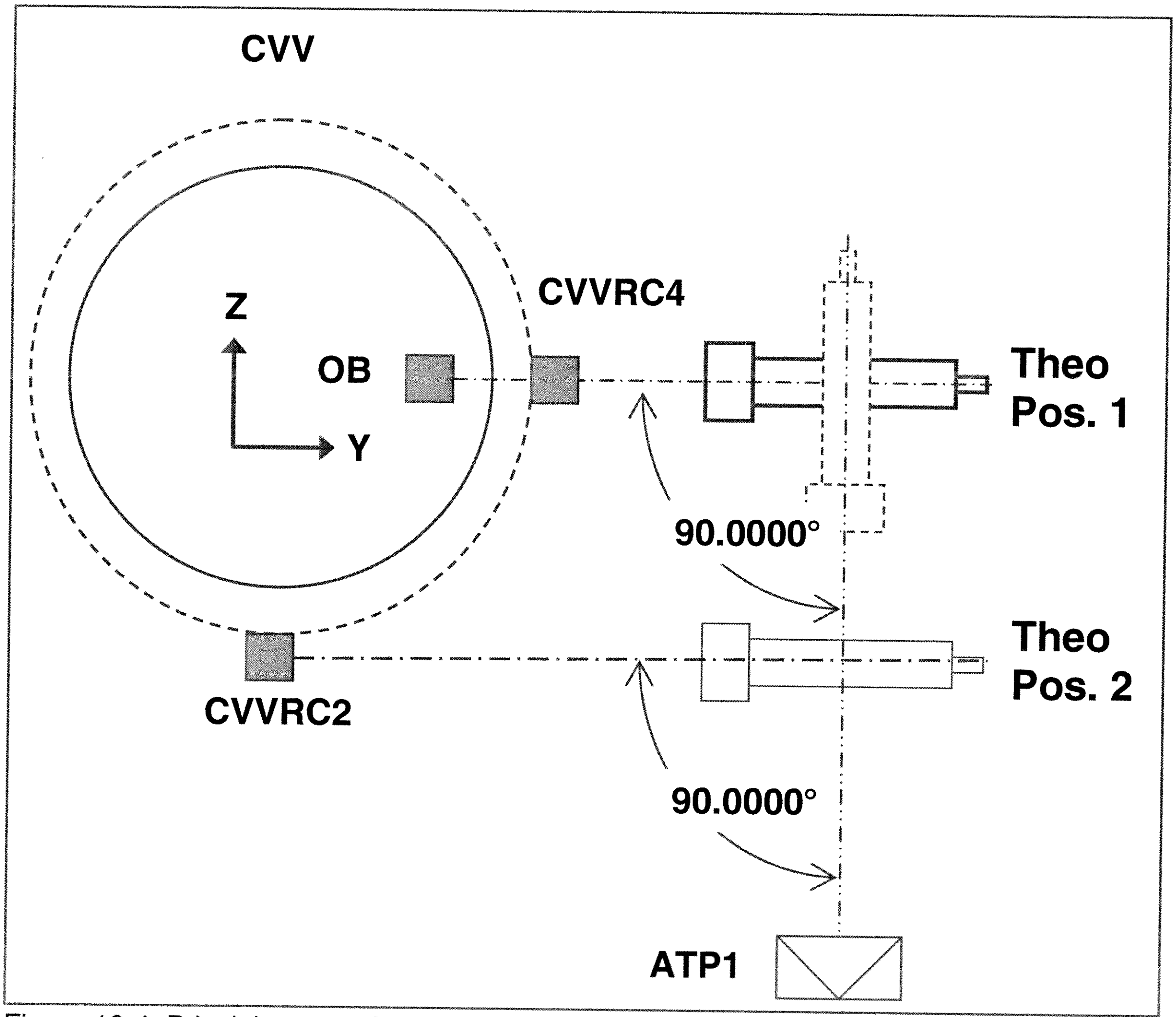


Figure 10-4: Principle set up for angle measurement from +Y.

41. Rotate theodolite back to CVVRC4 until auto-collimation is achieved. Theodolite reading shall be Hz = 0.0000 deg. ± 10 arcsec. If this is not the case, repeat steps 37 - 43 until this condition is fulfilled. Record the following values:

CVVRC4+y face				Mean
HZ =	0.0001°	0.0005°	0.0010°	0.0005°
V =	90.3333°	90.3329°	90.3332°	90.3331°
	Measurement Date: 3.08.07		Measurement Time: 10:50	

42. Check ATP position:

ATP Position: Hz =	270.0000°
Date: 3.08.07	Time: 10:50

43. Set up theodolite in front of OB RC face +y such that ATP can be viewed from this position and level theodolite.
44. Direct theodolite to the ATP, achieve auto-collimation and set theodolite reading to Hz = 270.0000 deg.
45. Rotate theodolite back to OB RC, achieve auto-collimation and record the following values:

OB +y face				Mean
HZ =	359.8194°	359.8207°	359.8208°	359.8203°
V =	90.0256°	90.0253°	90.0254°	90.0254°
	Measurement Date: 3.08.07		Measurement Time: 15:45	

46. Check ATP position:

ATP Position: Hz =	270.0000°
Date: 3.08.07	Time: 15:45

Re-check Rotary table levelling:	Level1	A = 0° 00' 00"
	Level2	B = 0° 00' 01"
Date/Time: 3.08.07 / 15:45		

Check of OB orientation from +Z-direction

See Fig 10-5.

47. Rotate Rotary table through 90.0000 deg., such that PLM + Z side points towards theodolite and check Rotary Table levelling.

Re-check Rotary table levelling:	Level1	A = 0° 00' 01"	
Date/Time: 4.08.07 / 10:40	Level2	B = 0° 00' 00"	

48. Set up theodolite in front of CVV RC 4 such that ATP can be viewed from this position and level theodolite.

49. Direct theodolite towards ATP and achieve auto-collimation. Set Hz = 270.0000 deg.

50. Rotate theodolite back to CVVRC4 until auto-collimation occurs. and record the following values:

+Z face

CVVRC4~~+y~~ face				Mean
HZ =	359.9985°	359.9998°	359.9985°	359.9989°
V =	90.0055°	90.0053°	90.0054°	90.0054°
	Measurement Date: 4.08.07		Measurement Time: 10:40	

51. Check ATP position:

ATP Position: Hz =	270.00000
Date: 4.08.07	Time: 10:40

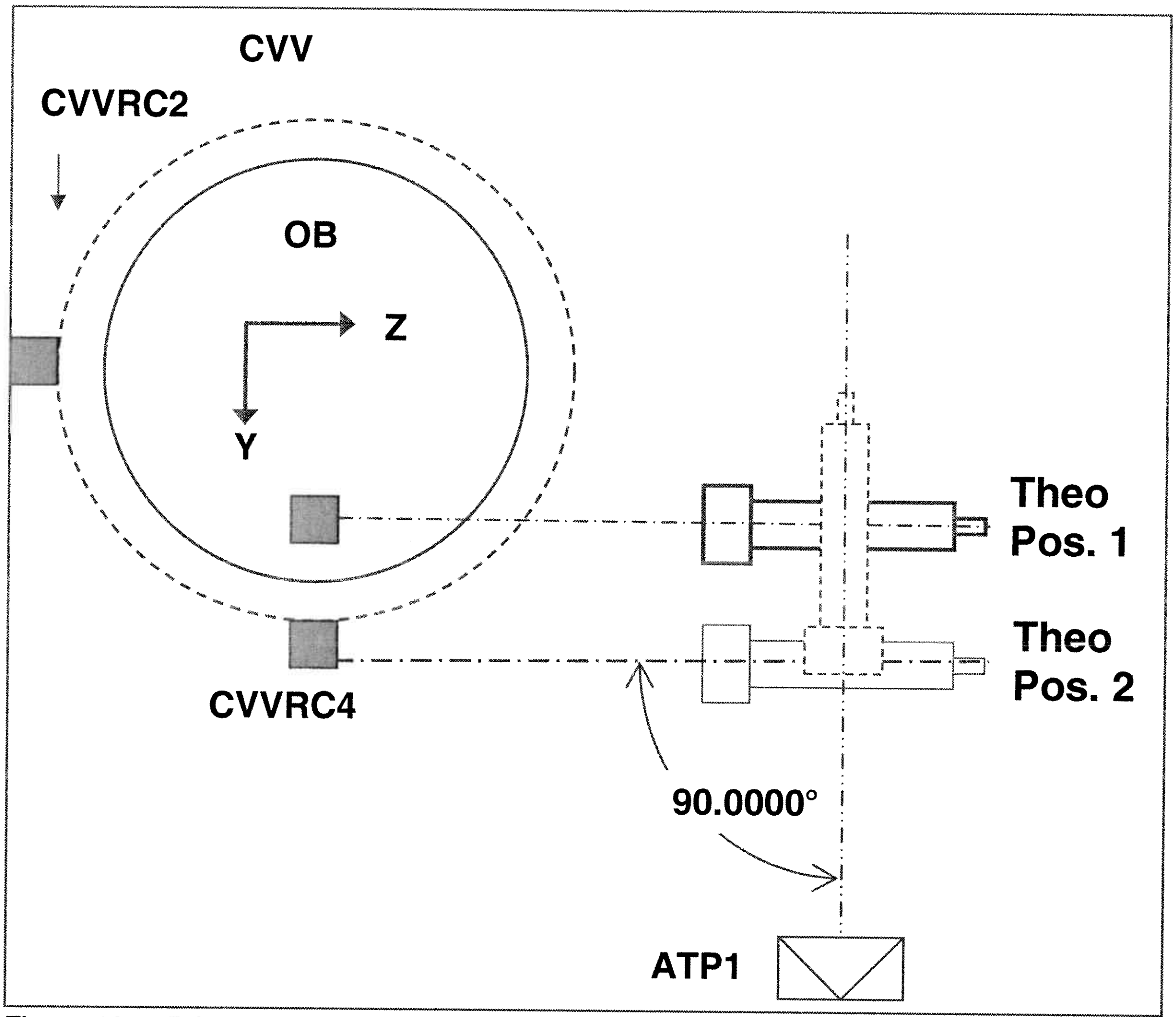


Figure 10-5: Principle set up for angle measurement from +Z.

52. Move theodolite to the next reference: OB RC, check the levelling in this position. Level if necessary.
53. Direct theodolite to the ATP, achieve auto-collimation and set theodolite reading to Hz = 270.0000 deg.
54. Rotate theodolite back to OB RC, achieve auto-collimation and record the following values:

OB +z face				Mean
HZ =	359.8209°	359.8221°	359.8200°	359.8210°
V =	89.9006°	89.9007°	89.9006°	89.9006°
	Measurement Date: 3.08.07		Measurement Time: 16:10	

55. Check ATP position:

ATP Position: Hz =	270.0000 °
Date: 3.08.07	Time: 16:10

Re-check Rotary table levelling:	Level1	A = 0° 00' 014"
	Level2	B = 0° 00' 00"
Date/Time: 3.08.07 / 16:10		

56. Compare the values measured in steps 4 through 55 to their target values. If any of the measured values is not reached within its given tolerance range, the OB has to be adjusted accordingly and the measurement steps 4 through 55have to be repeated. The re-adjustment will be made by the mechanical integration personnel (according to company-internal procedure).

Value Comparison: **ΔX of CVV I/F Flange**	Value OK	Value not OK
Measured Distance to CVVRC4: **ΔX =** 57.4 **mm** Nominal Distance to CVVRC4: **ΔX = 57.5 mm ± 1 mm** If value is not achieved adjust OB to above value and repeat steps 4 – 56.	✓	

Value Comparison: **ΔX of OB +Y face**	Value OK	Value not OK
Measured Distance to CVVRC4: **ΔX =** 560.8 **mm** Nominal Distance to CVVRC4: **ΔX = 560.5 mm ± 1 mm** If value is not achieved adjust OB to above value and repeat steps 4 – 56.	✓	

Value Comparison: **ΔZ of OB +y face**	Value OK	Value not OK
Measured Distance to CVVRC4: **ΔZ =** 71.5 **mm** Nominal Distance to CVVRC4: **ΔZ = 72.1 mm ± 1.0 mm** If value is not achieved adjust OB to above value and repeat steps 4 – 56.	✓	

Value Comparison: ΔY **of OB +Z face**	Value OK	Value not OK
Measured Distance to CVVRC4: **ΔY =** 257.7 **mm** Nominal Distance to CVVRC4: **ΔY = 256.7 mm ± 1.0 mm** If value is not achieved adjust OB to above value and repeat steps 4 - 56	✓	

Value Comparison: **Rot of OB +Y face**	Value OK	Value not OK
Hz = 359.8203 deg. V = 90.0254 deg. Nominal theodolite readings shall be: **Hz = 359.9551 deg. ± 120 arcsec** **V = 90.0652 deg. ± 120 arcsec** If value is not achieved adjust OB to above value and repeat steps 4 – 56.	see	page 77

Value Comparison: **Rot of OB +Z face**	Value OK	Value not OK
Measured theodolite readings: Hz = 359.8210 deg. V = 89.9006 deg. Nominal theodolite readings shall be: **Hz = 359.9547 deg. ± 120 arcsec** **V = 89.9229 deg. ± 120 arcsec** If value is not achieved adjust OB to above value and repeat steps 4 – 56.	see	page 77

The subsequent Sections 10.4 and 10.5 are intended for

REPETION OF MEASUREMENTS OF OB POSITION AND ORIENTATION AFTER OB-ADJUSTMENT

If an adjustment of the OB is not necessary, these two sections shall be omitted.

There was no need to adjust the OB.
Therefore, section 10.4 and 10.5 need not to be filled-in.

10.4 OB Position Measurement: Repetition after OB Re-Adjustment

See Fig. 10-6.

4. Mount LMD vertically close to CVVRC4 +Y face. The distance to the OB cube shall be in the range of (approximately) 1 – 5 m. Check verticality with water balance on two orthogonal sides of the LMD beam. Deviations from verticality shall not be larger than 0.5 deg.

LMD verticality:	Elevation1 Elevation2
Date/Time:	

5. Mount theodolite such that CVVRC4 +Y face can be viewed in auto-collimation.

6. Achieve auto-collimation with CVVRC4, and set theodolite reading to Hz = 0.0000 deg. Rotate theodolite to the left until Hz = 270.0000 is reached. Mount ATP such that theodolite achieves auto-collimation wrt. ATP. Rotate theodolite back to CVVRC4 and achieve auto-collimation. Theodolite reading must be Hz = 0.0000 deg. ± 10 arcsec. If this is not the case, repeat step 6 until condition is fulfilled.

7. Direct theodolite towards CVVRV4, set V = 90.0000 deg. and adjust theodolite height with x translation stage to centre of reticle. Rotate theodolite towards LMD.

8. Move the scanning head of the LMD until the elevation bar of the cross hair coincides with the elevation bar of theodolite cross hair.

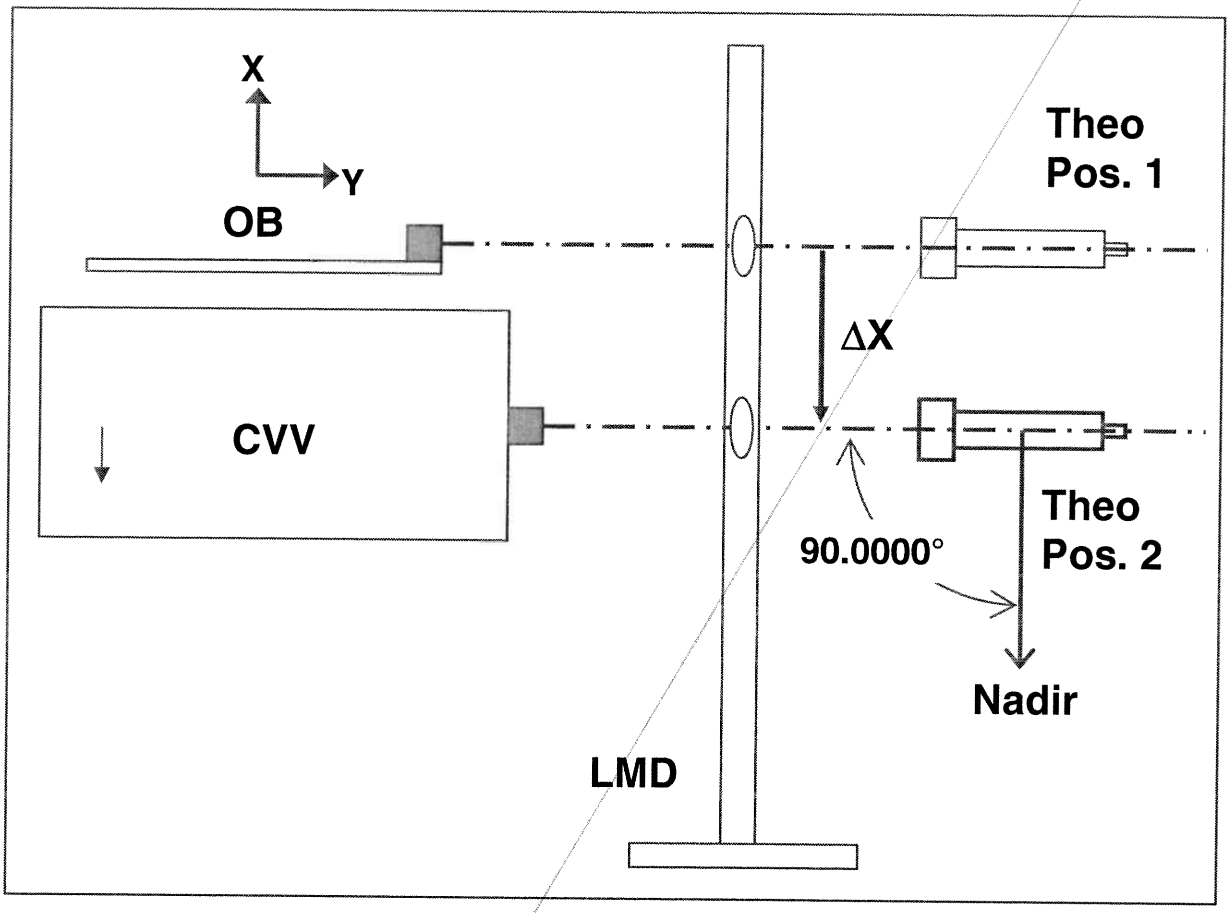


Figure 10-6: (Analogous to Fig 10-1) Principle set up for vertical distance measurement with LMD from +Y

9. Set the LMD reading to zero at this point. Record the following value:

CVVR4 +Y Linear Position in X				Mean
X(CVVRC4+Y)				
Measurement Date:			Time:	

10. Adjust theodolite with elevation set to 90.0000 deg. in height to upper edge of CVV I/F flange and rotate theodolite towards LMD.

11. Move the scanning head of the LMD until the upper edge of the I/F-flange coincides with the elevation bar of theodolite cross hair. Record the following value:

CVV I/F flange plane Linear Position in X				Mean
X(CVV I/F)				
Measurement Date:			Time:	

12. Adjust theodolite with lateral stages to the centre of the next reference point: OB RC + Y side and rotate theodolite towards LMD..

13. Move the scanning head of the LMD until the elevation bar of the cross hair coincides with the azimuth bar of the theodolite cross hair and record the following value:

OB+y face Linear Position in X				Mean
X(OB+y)				
Measurement Date:			Time:	

Re-check LMD orientation:	Azimuth: Elevation
Date/Time:	

Re-check Rotary table levelling:	Level1 Level2
Date/Time:	

Check of OB position in Z-direction

See Fig. 10-7.

14. Mount LMD horizontal in front of +Y side. Set theodolite in front of auto-LMD reference mirror and direct theodolite towards ATP. Achieve auto-collimation with ATP and set theodolite azimuth reading to Hz = 270.0000 deg. Rotate theodolite back to LMD reference mirror until azimuth 0.0000 deg. is reached. Adjust LMD such that auto-collimation mark from reference mirroris visible within theodolite's FoV. If this is achieved, the LMD is parallel to the Z-axis by better than ±0.5 deg. Check horizontal orientation of LMD beam with water balance. Deviation from exact horizontal orientation shall be less than ±0.5 deg.

LMD horizonztality:	Elevation1 Elevation2
Date/Time:	

15. Switch on the LMD display according to the LMD manual.

16. Check the levelling of the theodolite. Level if necessary.

17. Direct theodolite towards ATP, achieve auto-collimation and set Hz = 270.0000.

18. Rotate theodolite back to Hz = 0.0000 deg. and adjust theodolite with lateral stage to azimuth bar of cross hair of CVVRC4 +y face.

19. Move the scanning head of the LMD until the azimuth of the cross hair coincides with the azimuth of theodolite cross hair.

20. Set the LMD reading to zero at this point. Record the following value:

CVVRC4 Linear Position in Z				Mean
Z(CVVRC4+y)				
Measurement Date:			Time:	

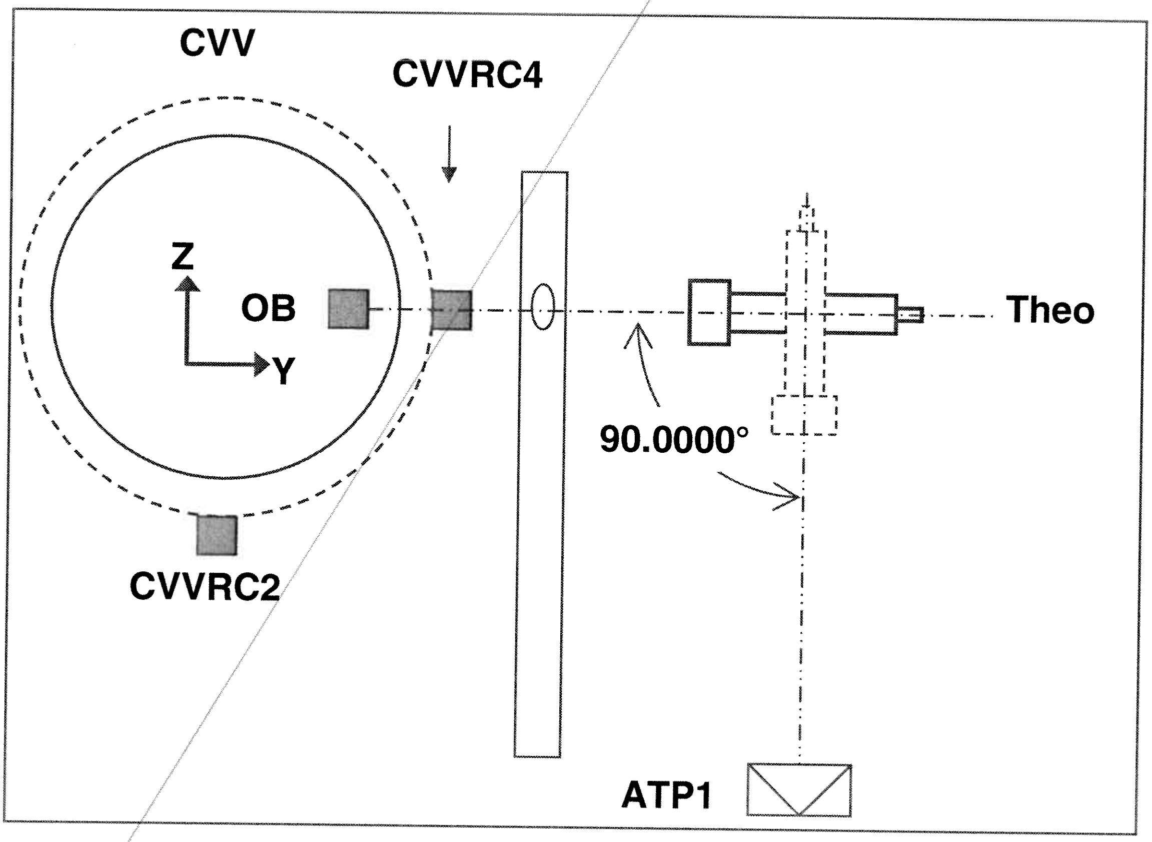


Figure 10-7: (Analogous to Fig 10-2) Principle set up for horizontal distance measurement from +Y.

21. Move the theodolite to the next reference: OB RC, check the levelling in this position. Level if necessary.

22. Move the scanning head of the LMD until the azimuth cross of the hair coincides with the azimuth of the theodolite cross hair

23. Read-out the LMD display. Record the following value:

OB +y face Linear Position in Z				Mean
Z(OB+y)				
Measurement Date:			Time:	

24. Check ATP position:

ATP Position: Hz =	
Date:	Time:

Re-check LMD orientation: Date/Time:	Azimuth: Elevation

Re-check Rotary table levelling: Date/Time:	Level1 Level2

Check of OB position in Y-direction

See Fig. 10-8:

25. Rotate PLM such that +Z side points towards theodolite and check Rotary Table levelling

Rotary table levelling: Date/Time:	Level1 Level2

26. Adjust theodolite with lateral stage to the centre of the first reference point: CVVRC4 + Z side and achieve auto-collimation.

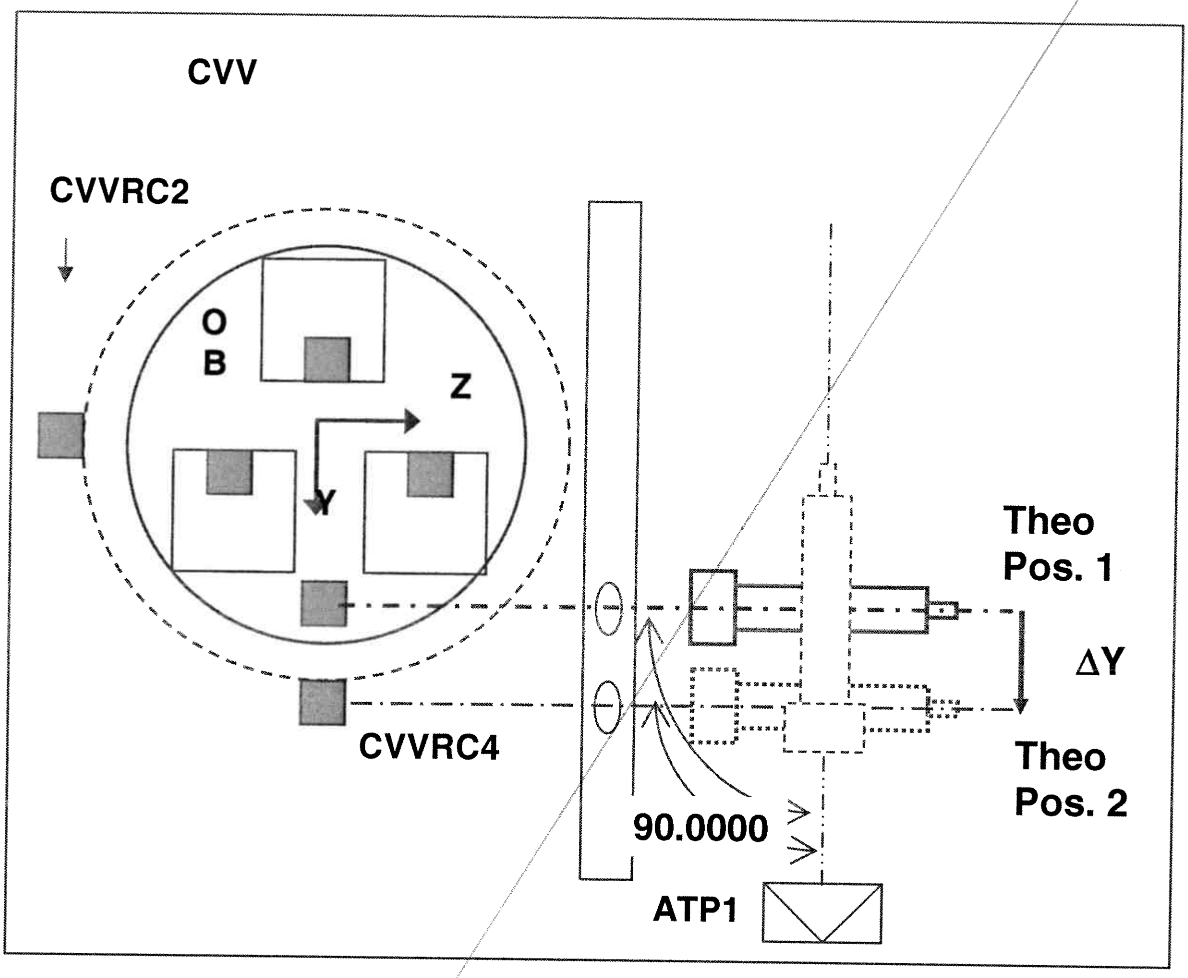


Figure 10-8: (Analogous to Fig 10-3) Principle set up for horizontal distance measurement from +Z.

27. Set theodolite reading to Hz = 0.0000 deg. Rotate theodolite through 90 deg. to the left until theodolite reading Hz = 270.0000 deg is reached.

28. Check that ATP is in auto-collimation, adjust if necessary. Set Hz = 270.0000 deg.

29. Rotate theodolite back to Hz = 0.0000 deg. and adjust theodolite with lateral stage to azimuth bar of cross hair of CVVRC4 +z face.

Re-check LMD orientation:	Azimuth: Elevation
Date/Time:	

30. Move the scanning head of the LMD until the azimuth of the cross hair coincides with the azimuth of theodolite cross hair.

31. Set the LMD reading to zero at this point. Record the following value:

CVVRC4+z face Linear Position in Y				Mean
Y(CVVRC4+z)				
Measurement Date:			Time:	

32. Move the theodolite to the next reference: OB RC, check the levelling in this position. Level if necessary.

33. Move the scanning head of the LMD until the azimuth bar of the cross hair coincides with the azimuth of the theodolite cross hair in the OB position.

34. Read-out the LMD display. Record the following value:

OB +z face Linear Position in Y				Mean
Z(OB+z)				
Measurement Date:			Time:	

35. Check ATP position:

ATP Position: Hz =	
Date:	Time:

Re-check LMD orientation:	Azimuth: Elevation
Date/Time:	

Re-check Rotary table levelling:	Level1 Level2
Date/Time:	

10.5 Check of OB Orientation from +y-direction

See Fig 10-9:

36. Rotate PLM such that +Y side points towards theodolite and check Rotary Table levelling

Rotary table levelling:	Level1 Level2
Date/Time:	

37. Point the theodolite to CVVRC4 and achieve auto-collimation.
38. Set theodolite reading to Hz = 0.000 deg. Rotate theodolite through 90 deg. to the left until theodolite reading Hz = 270.0000 deg. is reached.
39. Place ATP such that it can be viewed from theodolite at Hz = 270.0000 deg. position and level it.
40. Adjust ATP such that theodolite achieves auto-collimation.

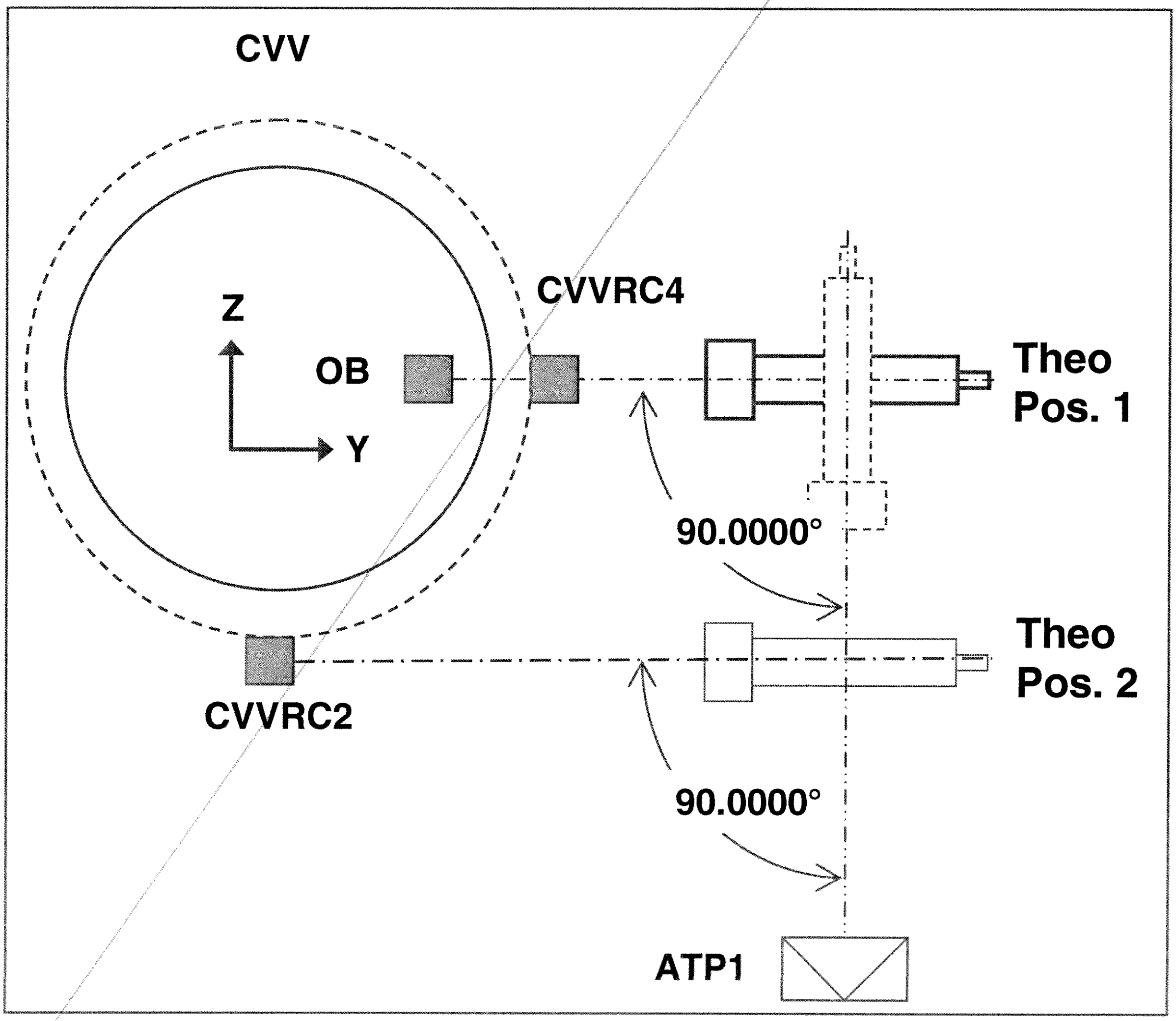


Figure 10-9: (Analogous to Fig 10-4) Principle set up for angle measurement from +Y.

41. Rotate theodolite back to CVVRC4 until auto-collimation is achieved. Theodolite reading shall be Hz = 0.0000 deg. ± 10 arcsec. If this is not the case, repeat steps 37 - 41 until this condition is fulfilled and record the following values:

CVVRC4+y face				Mean
HZ =				
V =				
	Measurement Date:		Measurement Time:	

42. Check ATP position:

ATP Position: Hz =	
Date:	Time:

43. Set up theodolite in front of OB RC face +y such that ATP can be viewed from this position and level theodolite.
44. Direct theodolite to the ATP, achieve auto-collimation and set theodolite reading to Hz = 270.0000 deg.
45. Rotate theodolite back to OB RC, achieve auto-collimation and record the following values:

OB +y face				Mean
HZ =				
V =				
	Measurement Date:		Measurement Time:	

46. Check ATP position:

ATP Position: Hz =	
Date:	Time:

Re-check Rotary table levelling:	Level1 Level2
Date/Time:	

Check OB orientation from +Z-direction

See Fig 10-10.

47. Rotate Rotary table through 90.0000 deg., such that PLM + Z side points towards theodolite and check Rotary Table levelling.

Re-check Rotary table levelling:	Level1 Level2
Date/Time:	

48. Set up theodolite in front of CVV RC 4 such that ATP can be viewed from this position and level theodolite

49. Direct theodolite towards ATP and achieve auto-collimation. Set Hz = 270.0000 deg

50. Rotate theodolite back to CVVRC4 and achieve auto-collimation. Record the following values:

CVVRC4+z face				Mean
HZ =				
V =				
	Measurement Date:		Measurement Time:	

51. Check ATP position:

ATP Position: Hz =	
Date:	Time:

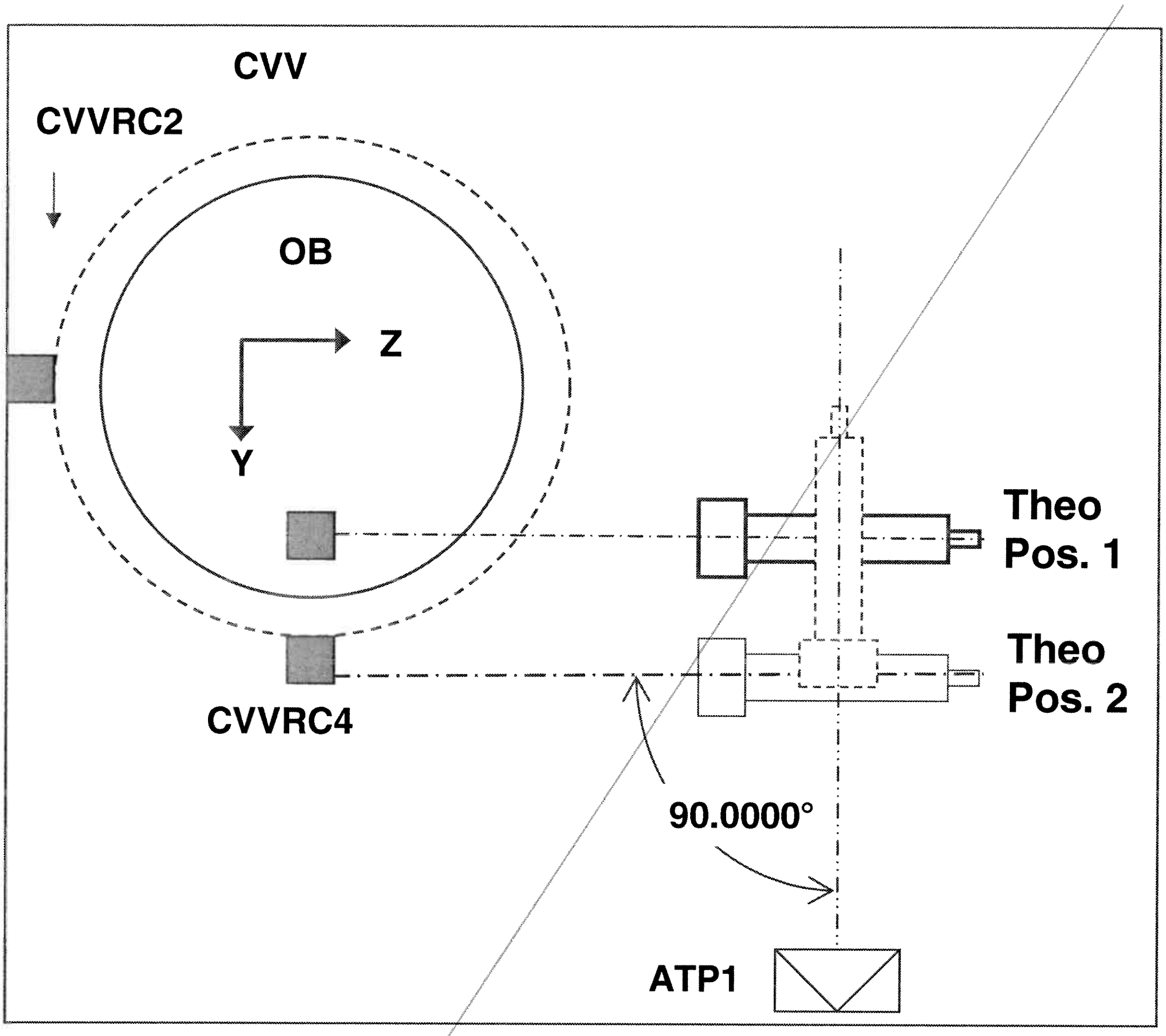


Figure 10-10: (Analogous to Fig 10-5) Principle set up for angle measurement from +Z.

52. Move theodolite to the next reference: OB RC, check the levelling in this position. Level if necessary.

53. Direct theodolite to the ATP, achieve auto-collimation and set theodolite reading to Hz = 270.0000 deg.

54. Rotate theodolite back to OB RC, achieve auto-collimation and record the following values:

OB +z face				Mean
HZ =				
V =				
	Measurement Date:		Measurement Time:	

55. Check ATP position:

ATP Position: Hz =	
Date:	Time:

Re-check Rotary table levelling: Level1 Level2 Date/Time:

56. Compare the values measured in steps 4 through 55 to their target values. If any of the measured values is not reached within its given tolerance range, the OB has to be adjusted accordingly and the measurement steps 4 through 53have to be repeated. The re-adjustment will be made by the mechanical integration personnel (according to company-internal procedure).

Value Comparison: **ΔX of CVV I/F Flange**	Value OK	Value not OK
Measured Distance to CVVRC4: **ΔX = mm** Nominal Distance to CVVRC4: **ΔX = 57.5 mm ± 1 mm** If value is not achieved adjust OB to above value and repeat steps 4 – 56.		

Value Comparison: **ΔX of OB +Y face**	Value OK	Value not OK
Measured Distance to CVVRC4: **ΔX = mm** Nominal Distance to CVVRC4: **ΔX = 560.5 mm ± 1 mm** If value is not achieved adjust OB to above value and repeat steps 4 – 56.		

Value Comparison: **ΔZ of OB +y face**	Value OK	Value not OK
Measured Distance to CVVRC4: **ΔZ = mm** Nominal Distance to CVVRC4: **ΔZ = 72.1 mm ± 1.0 mm** If value is not achieved adjust OB to above value and repeat steps 4 – 56.		

Value Comparison: **ΔY of OB +Z face**	Value OK	Value not OK
Measured Distance to CVVRC4: **ΔY = mm** Nominal Distance to CVVRC4: **ΔY = 256.7 mm ± 1.0 mm** If value is not achieved adjust OB to above value and repeat steps 4 - 56		

Value Comparison: **Rot of OB +Y face**	Value OK	Value not OK
Hz = deg. V = deg. Nominal theodolite readings shall be: **Hz = 359.9551 deg. ± 120 arcsec** **V = 90.0652 deg. ± 120 arcsec** If value is not achieved adjust OB to above value and repeat steps 4 – 56.		

Value Comparison: **Rot of OB +Z face**	Value OK	Value not OK
Measured theodolite readings: Hz = deg. V = deg. Nominal theodolite readings shall be: **Hz = 359.9547 deg. ± 120 arcsec** **V = 89.9229 deg. ± 120 arcsec** If value is not achieved adjust OB to above value and repeat steps 4 – 56.		

If the adjustment of the OB has become necessary again, the measurements shall be recorded on separate sheets and be appended to the "AS RUN PROCEDURE".

10.6 Angular Alignment Measurements of HIFI from + Y Side

57. Rotate PLM such that +Y side points towards theodolite and check Rotary Table levelling

Rotary table levelling:	Level1 Level2	A = 0° 00' 00" B = 0° 00' 01"
Date/Time: 3.08.07 / 14:25		

See Fig. 10-11.

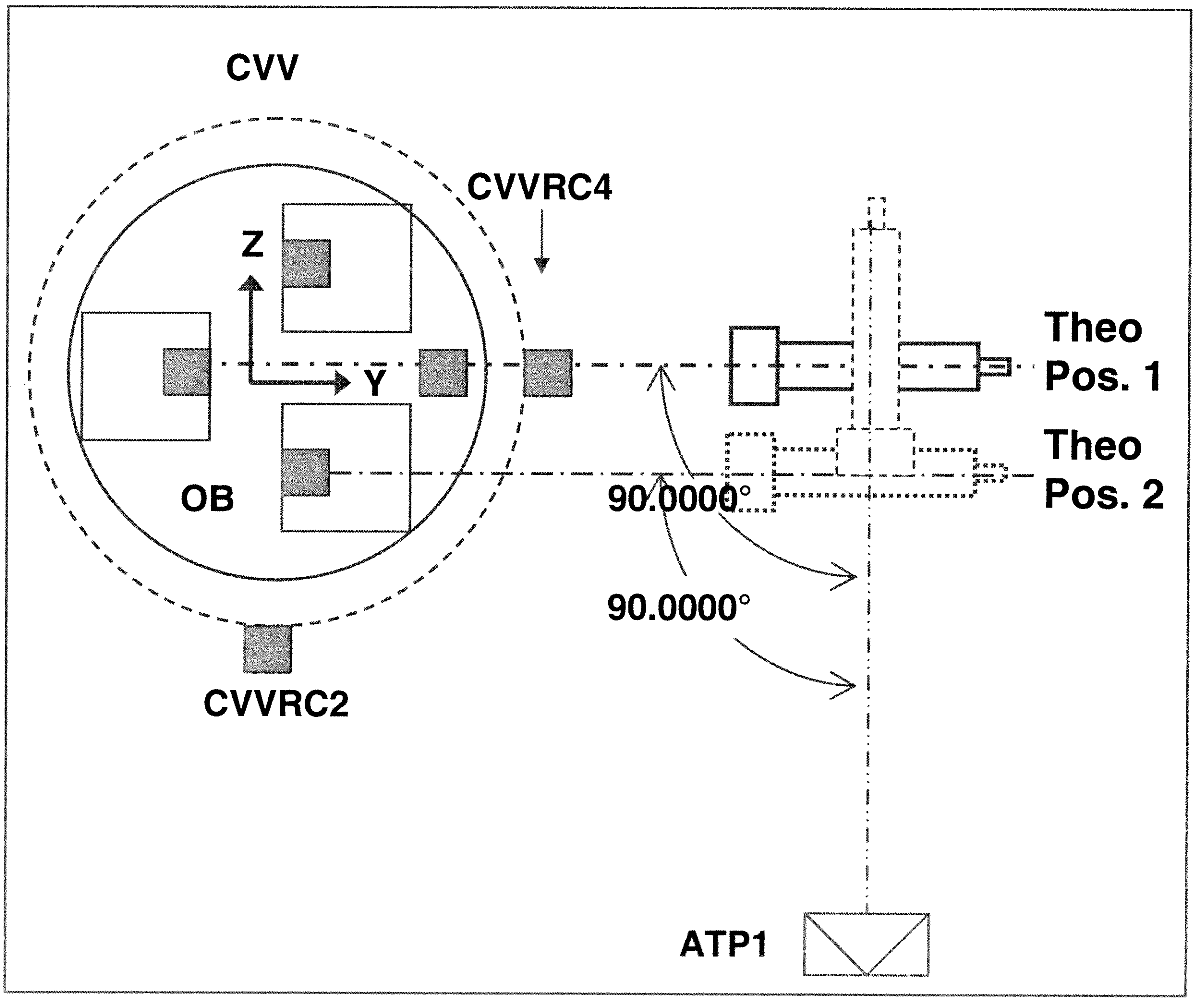


Figure 10-11: (Analogous to Fig 10-4) Principle set up for angle measurement from +Y.

58. This step has been cancelled.

59. Achieve auto-collimation with CVVRC4 and set Hz = 0.0000 deg.

60. Rotate the theodolite to the ATP and adjust it such that auto-collimation occurs. Set theodolite reading to Hz = 270.0000 deg.

61. Rotate theodolite back to HIFI +y face until auto-collimation occurs. Theodolite reading shall be Hz = 0.0000 deg. ± 10 arcsec. If this is not the case, repeat steps 58 - 61 until this condition is fulfilled and record the following values:

HIFI +y face				Mean
HZ =	359.9614°	359.9595°	359.9605°	359.9605°
V =	89.9838°	89.9837°	89.9839°	89.9838°
	Measurement Date: 3.08.07		Measurement Time: 15:25	

Measured theodolite readings: Hz = 359.9605°
V = 89.9838°

Nominal theodolite reading: Hz = 0.0011 ± 140 arcsec (incl. OB-offset)
V = 90.0019 ± 140 arcsec (incl. OB-offset)

62. Check ATP position

ATP Position: Hz =	270.0000°
Date: 3.08.07	Time: 15:25

Re-check Rotary table levelling:	Level1	A = 0° 00′ 00″
	Level2	B = 0° 00′ 01″
Date/Time: 3.08.07 / 15:25		

10.7 Angular Alignment Measurements of PACS from + Y Side

See Fig. 10-11

63. Set up theodolite in front of PACS cube surface +y such that ATP can be viewed from this position in auto-collimation.

64. Rotate the theodolite to the ATP achieve auto-collimation and set theodolite reading to Hz = 270.0000 deg. Rotate theodolite back to +y face, achieve auto-collimation and record the following values:

PACS +y face				Mean
HZ =	359.8932°	359.8936°	359.8932°	359.8933°
V =	90.0437°	90.0427°	90.0441°	90.0435°
	Measurement Date: 3.08.07		Measurement Time: 14:50	

Measured theodolite readings: Hz = 359.89330°
V = 90.0435°

Nominal theodolite reading: **Hz = 0.0347 ± 140 arcsec** (incl. OB-offset)
V = 89.9828 ± 140arcsec (incl. OB-offset)

65. Check ATP position

ATP Position: Hz =	270.0000
Date: 3.08.07	Time: 14:50

Re-check Rotary table levelling:	Level1	A = 0° 00' 00"
	Level2	B = 0° 00' 01"
Date/Time: 3.08.07 / 14:50		

10.8 Angular Alignment Measurements of SPIRE from + Y Side

See Fig. 10-11

66. Set up theodolite in front of SPIRE cube surface +y such that ATP can be viewed from this position in auto-collimation.
67. Rotate theodolite to ATP achieve auto-collimation and set theodolite reading to Hz = 270.0000 deg. Rotate theodolite back to +y face, achieve auto-collimation and record the following values:

SPIRE +y face				Mean
HZ =	359.3617°	359.3590°	359.3584°	359.3597°
V =	89.9904°	89.9901°	89.9899°	89.9901°
	Measurement Date: 3.08.07		Measurement Time: 15:10	

Measured theodolite readings: Hz = 359.3597°
V = 89.9901°

Nominal theodolite reading: **Hz = not available**
V = 89.9383 deg. ± 8.8 arcmin

68. Check ATP position

ATP Position: Hz =	270.0000°
Date: 3.08.07	Time: 15:10

Re-check Rotary table levelling:	Level1	A = 0° 00' 00"
	Level2	B = 0° 00' 01"
Date/Time: 3.08.07 / 15:10		

10.9 Angular Alignment Measurements of CVVRC2 Cube from + Y Side

See Fig. 10-11

69. Set up theodolite in front of CVVRC2 surface +y such that ATP can be viewed from this position in auto-collimation and level theodolite.
70. Rotate the theodolite to the ATP achieve auto-collimation and set theodolite reading to Hz = 270.0000 deg. Rotate theodolite back to +y face, achieve auto-collimation and record the following values:

CVVRC2 +y				Mean
HZ =	0.0192°	0.0190°	0.0189°	0.0190°
V =	90.0031°	90.0028°	90.0028°	90.0029°
	Measurement Date: 4.08.07		Measurement Time: 11:20	

71. Check ATP position

ATP Position: Hz =	270.0000
Date: 4.08.07	Time: 11:20

Re-check Rotary table levelling:	Level1	A = 0° 00' 00"
	Level2	B = 0° 00' 01"
Date/Time: 4.08.07 / 11:20		

10.10 Angular Alignment Measurements of HIFI from + Z Side

See Fig 10-12.

72. Rotate PLM through 90.0000 deg. such that + Z axis points towards theodolite and check Rotary Table levelling:

Re-check Rotary table levelling:	Level1	A = 0° 00' 01"
	Level2	B = 0° 00' 00"
Date/Time: 4.08.07 / 9:15		

73. Set up theodolite in front of HIFI cube surface +z such that ATP can be viewed from this position in auto-collimation. Level theodolite.
74. Rotate the theodolite to the ATP achieve auto-collimation and set theodolite reading to Hz = 270.0000 deg. Rotate theodolite back to +z face, achieve auto-collimation and record the following values:

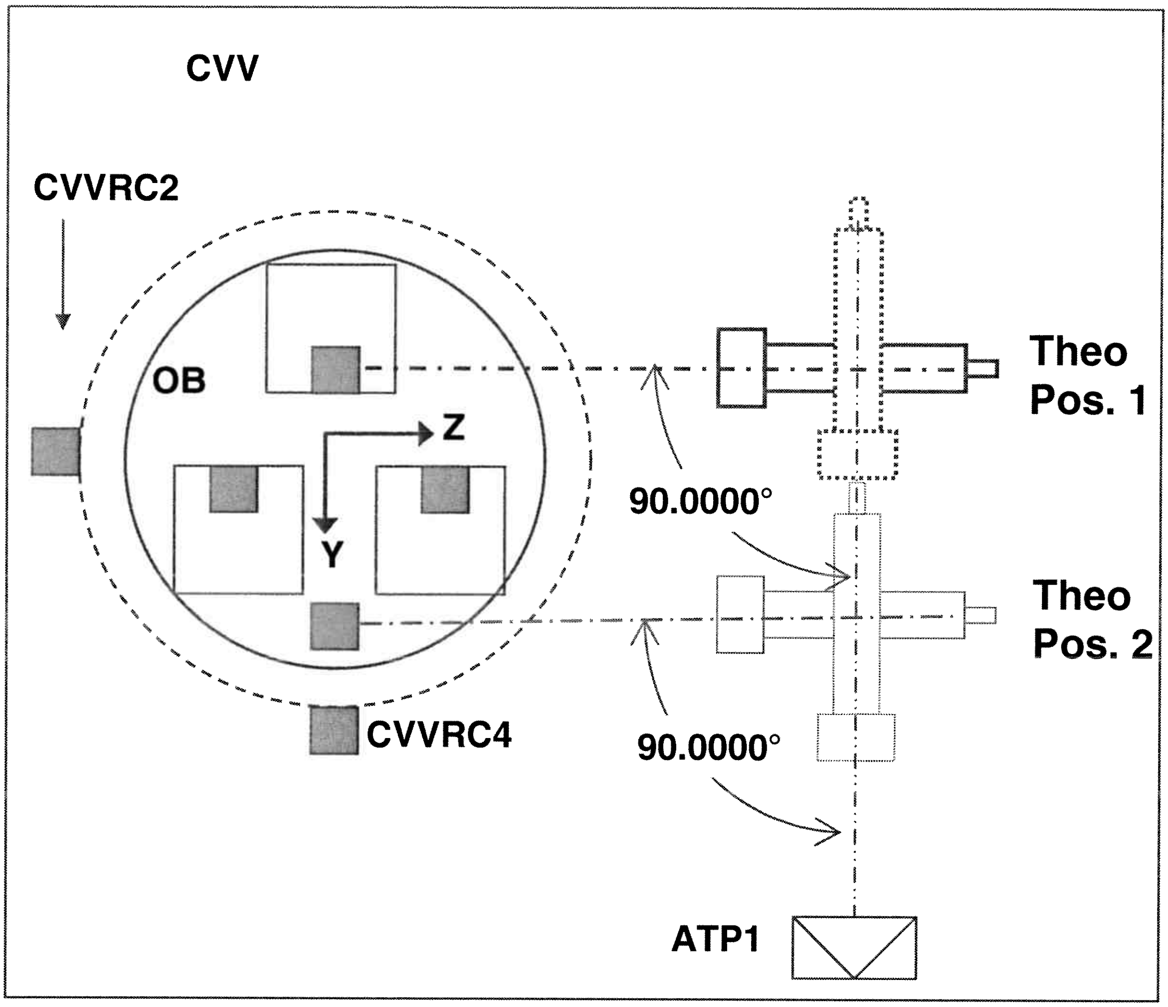


Figure 10-12: (Analogous to Fig. 10-5) Principle set up for angle measurement from +Z

HIFI +z face				Mean
HZ =	359.96110°	359.96150°	359.96100°	359.96120°
V =	89.98720°	89.98690°	89.98710°	89.98710°
	Measurement Date: 4.08.07		Measurement Time: 9:35	

Measured theodolite readings: Hz = 359.96120°
V = 89.98710°

Nominal theodolite reading: Hz = 0.0011 ± 140 arcsec (incl. OB-offset)
V = 89.9789 ± 140 arcsec (incl. OB-offset)

75. Check ATP position

ATP Position: Hz =	270.0000°
Date: 4.08.07	Time: 9:35

Re-check Rotary table levelling:	Level1	A =	0° 00' 01"
	Level2	B =	0° 00' 00"
Date/Time: 4.08.07 / 9:35			

10.11 Angular Alignment Measurements of PACS from + Z Side

See Fig 10-12.

76. Set up theodolite in front of PACS cube surface +z such that ATP can be viewed from this position in auto-collimation. Level theodolite.

77. Rotate the theodolite to the ATP achieve auto-collimation and set theodolite reading to Hz = 270.0000 deg. Rotate theodolite back to +z face, achieve auto-collimation and record the following values:

PACS +z face				Mean
HZ =	359.8939°	359.8945°	359.8943°	359.8942°
V =	89.9876°	89.9885°	89.9885°	89.9882°
	Measurement Date: 4.08.07		Measurement Time: 9:50	

Measured theodolite readings: Hz = 359.8942°
V = 89.9882°

Nominal theodolite reading: Hz = 0.0347 ± 140 arcsec (incl. OB-offset)
V = 90.0208 ± 140 arcsec (incl. OB-offset)

78. Check ATP position

ATP Position: Hz =	270.0000°
Date: 4.08.07	Time: 9:50

Re-check Rotary table levelling:	Level1	A =	0° 00' 01"
	Level2	B =	0° 00' 00"
Date/Time: 4.08.07 / 9:50			

10.12 Angular Alignment Measurements of SPIRE from + Z Side

See Fig 10-12.

79. Set up theodolite in front of SPIRE cube surface +z such that ATP can be viewed from this position in auto-collimation. Level theodolite.
80. Rotate the theodolite to the ATP achieve auto-collimation and set theodolite reading to Hz = 270.0000 deg. Rotate theodolite back to +z face, achieve auto-collimation and record the following values:

SPIRE +z face				Mean
HZ =	359.3613°	359.3613°	359.3616°	359.3614°
V =	90.0350°	90.0348°	90.0349°	90.0349°
	Measurement Date: 4.08.07		Measurement Time: 10:10	

Measured theodolite readings: Hz = 359.3614°
V = 90.0349°

Nominal theodolite reading: Hz = not available
V = 90.1217 deg. ± 8.8 arcmin

81. Check ATP position

ATP Position: Hz =	270.0000°
Date: 4.08.07	Time: 10:10

Rotary Table Level 1 A = 0° 00' 01"
Level 2 B = 0° 00' 00"

10.13 Angular Alignment Measurements of CVVRC4 Cube from + Z Side

See Fig 10-12.

82. Set up theodolite in front of CVVRC4 surface +z such that ATP can be viewed from this position in auto-collimation. Level theodolite.
83. Rotate the theodolite to the ATP achieve auto-collimation and set theodolite reading to Hz = 270.0000 deg. Rotate theodolite back to +z face, achieve auto-collimation and record the following values:

CVVRC4 +z				Mean
HZ =	359.9985°	359.9998°	359.9985°	359.9989°
V =	90.0055°	90.0053°	90.0054	90.0054°
	Measurement Date: 4.08.07		Measurement Time: 10:40	

84. Check ATP position

ATP Position: Hz =	270.0000°
Date: 4.08.07	Time: 10:40

Re-check Rotary table levelling:	Level1	A = 0° 00' 01"
	Level2	B = 0° 00' 00"
Date/Time: 4.08.07 / 10:40		

10.14 Angular Alignment Measurements of CVVRC2 from - Z Side

See Fig 10-13.

85. Rotate PLM through 180.0000 deg, such that –z points towards theodolite. Check Rotary Table levelling.

Re-check Rotary table levelling:	Level1	A = 0° 00' 01"
	Level2	B = 0° 00' 02"
Date/Time: 3.08.07 / 11:05		

86. Shift theodolite such that it can view front of CVVRC2 -z face and the ATP in auto-collimation. Level theodolite and set it in auto-collimation with ATP. Set azimuth reading to Hz = 270.0000 deg. Rotate theodolite back to CVVRC2 face -z, achieve auto-collimation and record the following values:

CVVRC2 -z face				Mean
HZ =	0.0231°	0.0221°	0.0235°	0.0229°
V =	90.0300°	90.0302°	90.0299°	90.0300°
	Measurement Date: 3.08.07		Measurement Time: 11:25	

87. Check ATP position

ATP Position: Hz =	270.0000°
Date: 3.08.07	Time: 11:25

Re-check Rotary table levelling:	Level1	A = 0° 00' 01"
	Level2	B = 0° 00' 02"
Date/Time: 3.08.07 / 11:25		

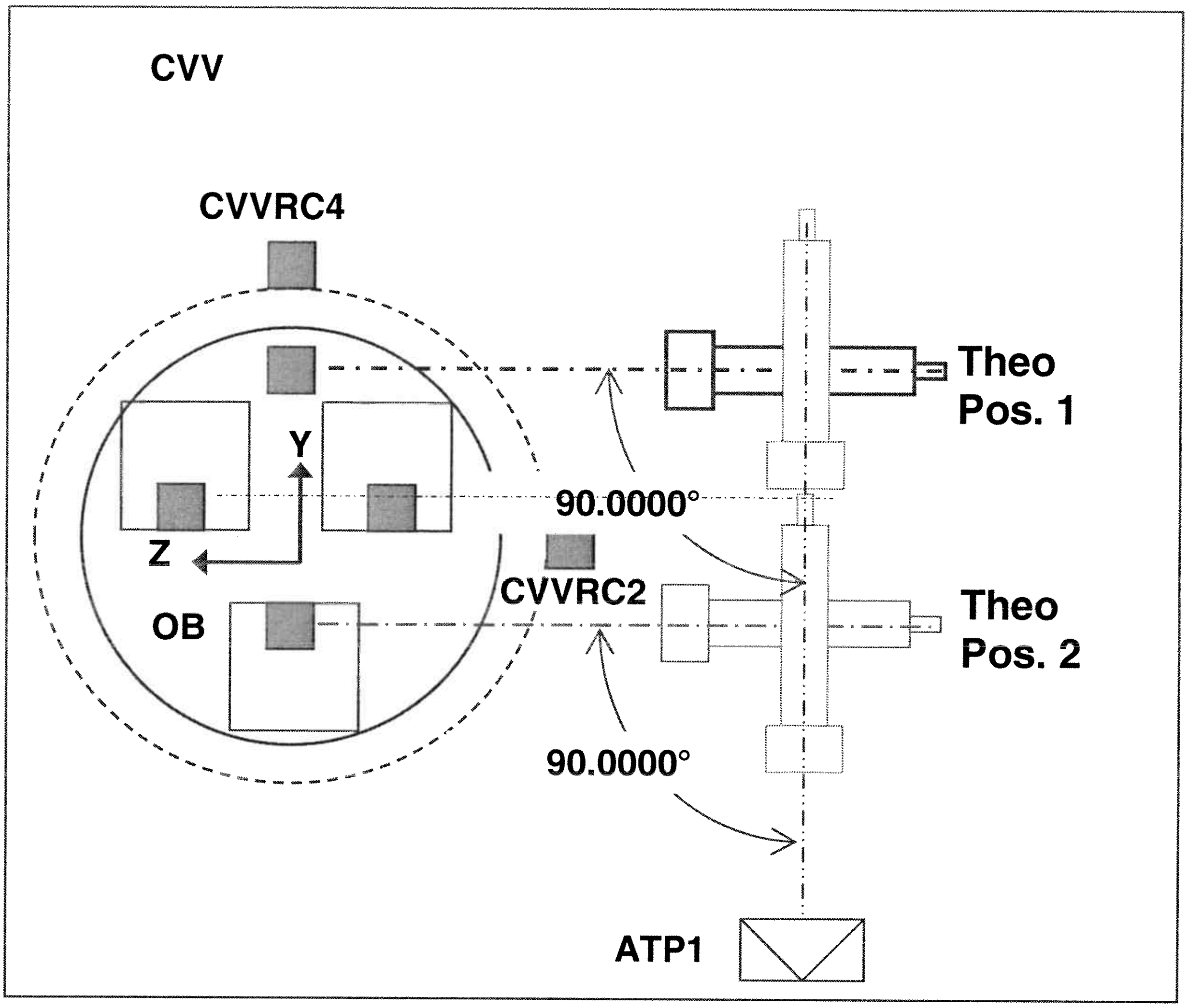


Figure 10-13: Principle set up for angle measurement from -Z

10.15 Horizontal Distance Measurements with LMD on + Y Side

See Fig 10-14.

88. Rotate PLM such that +Y side points towards theodolite position and check Rotary Table levelling:

Re-check Rotary table levelling:	Level1 Level2	Hz – 0° 00' 01" B = 0° 00' 00"
Date/Time: 3.08.07 / 12:00		

89. Level theodolite, direct it towards ATP and achieve auto-collimation. Set theodolite Hz = 270.0000 deg and rotate theodolite back to azimuth 0.0000 deg. Install the LMD in front of the S/C + Y side such that theodolite at 0.0000 deg azimuth is in auto-collimation with reference mirror on horizontal LMD beam (auto-collimation mark shall be within theodolite's FOV.) The LMD is then parallel to the PLM axes to better than ± 0.5 deg. Check horizontal orientation of LMD beam with water balance. Deviation from exact horizontal orientation shall be less than ± 0.5 deg.

90. Switch on the LMD display according to the LMD manual.

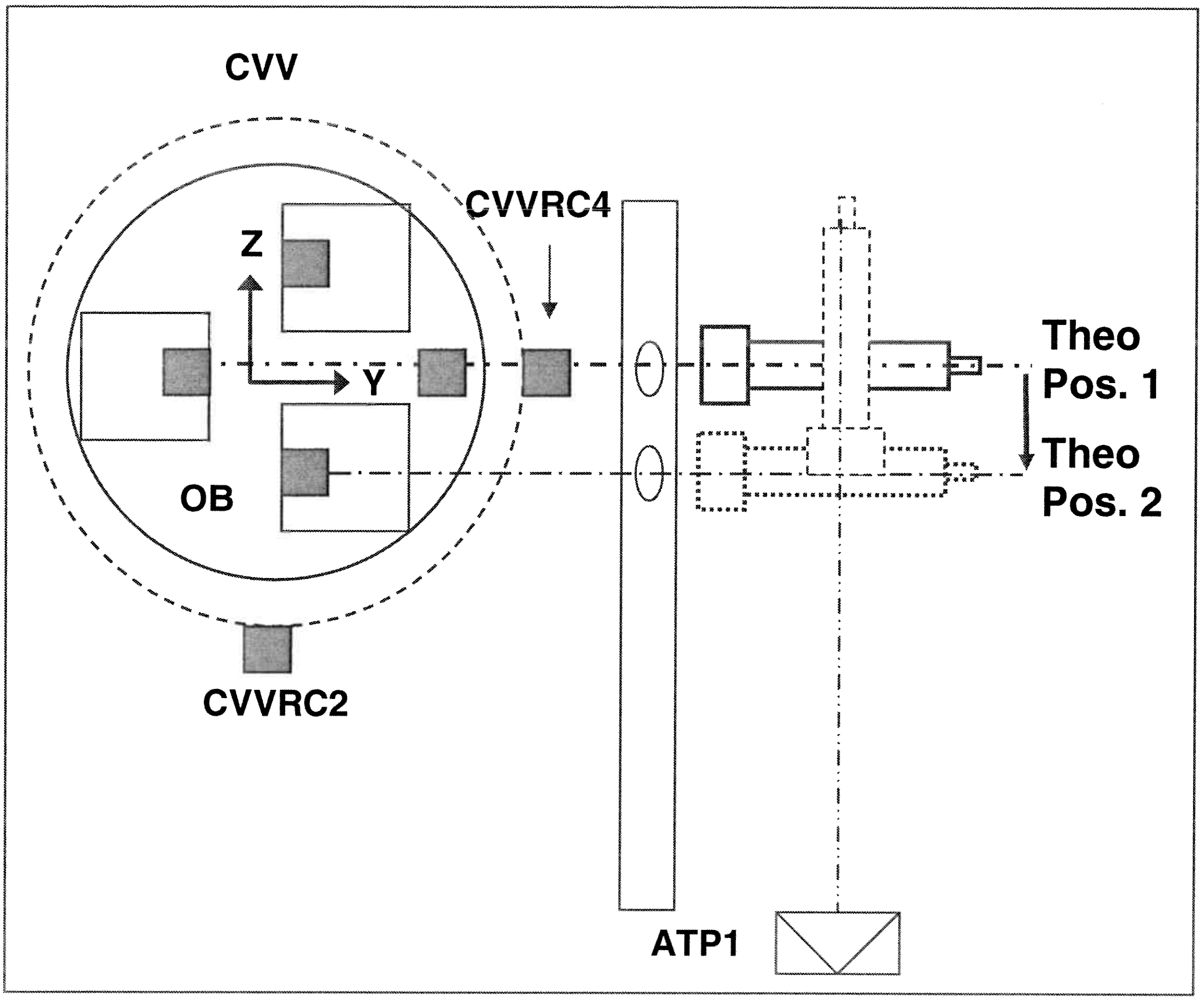


Figure 10-14: (Analogous to Fig. 10-2) Principle set up for distance measurements from +Y side

91. Direct theodolite to the first reference point: CVVRC4. Check the levelling of the theodolite, Level if necessary.

92. Direct theodolite towards ATP, achieve auto-collimation and set Hz = 270.0000 deg. and rotate theodolite back to Hz = 0.0000 deg. and adjust it with lateral stage to the centre of the first reference point: CVVRC4 + Y side.

93. Move the scanning head of the LMD until the azimuth of the cross hair coincides with the azimuth of theodolite cross hair.

94. Set the LMD reading to zero at this point. Record the following value:

CVVRC4 +Y face Linear Position in Z				Mean
Z(CVVRC4+y)	0	0	0	
Measurement Date: 3.08.07			Time: 12:00	

95. Check ATP Position:

ATP Position: Hz =	270.0000°
Date: 3.08.07	Time: 11:25

Re-check LMD orientation:	Azimuth:	0.170°
	Elevation	0.110°
Date/Time: 3.08.07 / 12:00		

Re-check Rotary table levelling:	Level1	A = -0° 00' 01"
	Level2	B = 0° 00' 00"
Date/Time: 3.08.07/12:00		

96. Move the theodolite to the next reference: HIFI, check the levelling in this position. Level if necessary.

97. Rotate theodolite towards ATP and achieve auto-collimation. Set Hz = 270.0000 deg. Rotate theodolite back to +y face of HIFI.

98. Move the scanning head of the LMD until the azimuth cross of the hair coincides with the azimuth of the theodolite cross hair in the HIFI position.

99. Read-out the LMD display. Record the following value:

HIFI + y face Linear Position in Z				Mean
Z(HIFI+y)	72.04	71.97	71.97	71.99 mm
Measurement Date: 3.08.07			Time: 13:50	

Measured distance to CVVRC4: **ΔZ =** 71.99 mm

Nominal distance to CVVRC4; **ΔZ = 72.0 ± 1.1 mm**

100. Check ATP Position:

ATP Position: Hz = 270.0001°	
Date: 3.08.07	Time: 13:50

Re-check LMD orientation:	Azimuth:	0.17°
	Elevation	0.12°
Date/Time: 3.08.07 / 13:50		

Re-check Rotary table levelling:	Level1	A = 0° 00' 01''
	Level2	B = 0° 00' 01''
Date/Time: 3.08.07 / 13:50		

101. Move the theodolite to the next reference: PACS, check the levelling in this position. Level if necessary.

102. Rotate theodolite towards ATP and achieve auto-collimation. Set Hz = 270.0000 deg. Rotate theodolite back to +y face of PACS.

103. Move the scanning head of the LMD until the azimuth of the cross hair coincides with the azimuth of the theodolite cross hair in the PACS position.

104. Read-out the LMD display. Record the following value:

PACS + y face Linear Position in Z				Mean
Z(PACS+y)	6.80	6.87	6.80	6.82 mm
Measurement Date:	3.08.07		Time: 14:25	

Measured distance to CVVRC4: **ΔZ =** 6.82 mm

Nominal distance to CVVRC4; **ΔZ = 7.7 ± 1.1 mm**

105. Check ATP Position:

ATP Position: Hz =	270.0005°
Date: 3.08.07	Time: 14:25

Re-check LMD orientation:	Azimuth:	0.17°
	Elevation	0.15°
Date/Time: 3.08.07 / 14:25		

Re-check Rotary table levelling:	Level1	A = 0° 00' 00"
	Level2	B = 0° 00' 01"
Date/Time: 3.08.07/14:25		

106. Move the theodolite to the next reference: SPIRE, check the levelling in this position. Level if necessary.

107. Rotate theodolite towards ATP and achieve auto-collimation. Set Hz = 270.0000 deg. Rotate theodolite back to +y face of SPIRE.

108. Move the scanning head of the LMD until the azimuth of the cross hair coincides with the azimuth of the theodolite cross hair in the SPIRE position.

109. Read-out the LMD display. Record the following value:

SPIRE + y face Linear Position Z				Mean
Z(SPIRE+y)	128.13	128.14	128.14	128.14 mm
Measurement Date: 3.08.07			Time: 13:35	

Measured distance to CVVRC4: **ΔZ =** 128.1 mm

Nominal distance to CVVRC4; **ΔZ = 128.4 mm ± 5.2 mm**

110. Check ATP Position:

ATP Position: Hz =	270.0002°
Date: 3.08.07	Time: 13:35

Re-check LMD orientation:	Azimuth:	0.17°
	Elevation	0.12°
Date/Time: 3.08.07 / 13:35		

Re-check Rotary table levelling:	Level1	A = -0° 00' 01"
	Level2	B = 0° 00' 01"
Date/Time: 3.08.07/13:35		

10.16 Horizontal Distance Measurements with LMD on +Z Side

See Fig. 10-15.

111. Rotate PLM such that +Z side points towards theodolite position and check Rotary Table levelling:

Rotary table levelling:	Level1	A = 0° 00' 01"
	Level2	B = 0° 00' 00"
Date/Time: 3.08.07 / 16:10		

112. Level theodolite, direct it towards ATP and achieve auto-collimation. Set theodolite azimuth to 270.0000 deg and rotate theodolite back to Hz = 0.0000 deg.

113. Rotate theodolite towards ATP and achieve auto-collimation. Set Hz = 270.0000 deg. Rotate theodolite back to +z face of CVVRC4.

114. Adjust theodolite with lateral stage to the centre of the first reference point: CVVRC4 + Z side.

115. Move the scanning head of the LMD until the azimuth of the cross hair coincides with the azimuth of theodolite cross hair.

116. Set the LMD reading to zero at this point. Record the following value:

CVVRC4 +z face Linear Position in Y				Mean
Y(CVVRC4+z)	0	0	0	
Measurement Date:	3.08.07		Time: 17:00	

117. Check ATP Position:

ATP Position: Hz =	270.0000°
Date: 3.08.07	Time: 16:10

Re-check LMD orientation:	Azimuth:	0.17°
	Elevation	0.15°
Date/Time: 3.08.07 / 16:10		

Re-check Rotary table levelling:	Level1	A = 0° 00' 01"
	Level2	B = 0° 00' 00"
Date/Time: 3.08.07 / 17:00		

118. Move the theodolite to the next reference: HIFI, check the levelling in this position. Level if necessary.

119. Rotate theodolite towards ATP and achieve auto-collimation. Set Hz = 270.0000 deg. Rotate theodolite back to +z face of HIFI

120. Move the scanning head of the LMD until the azimuth cross of the hair coincides with the azimuth of the theodolite cross hair in the HIFI position.

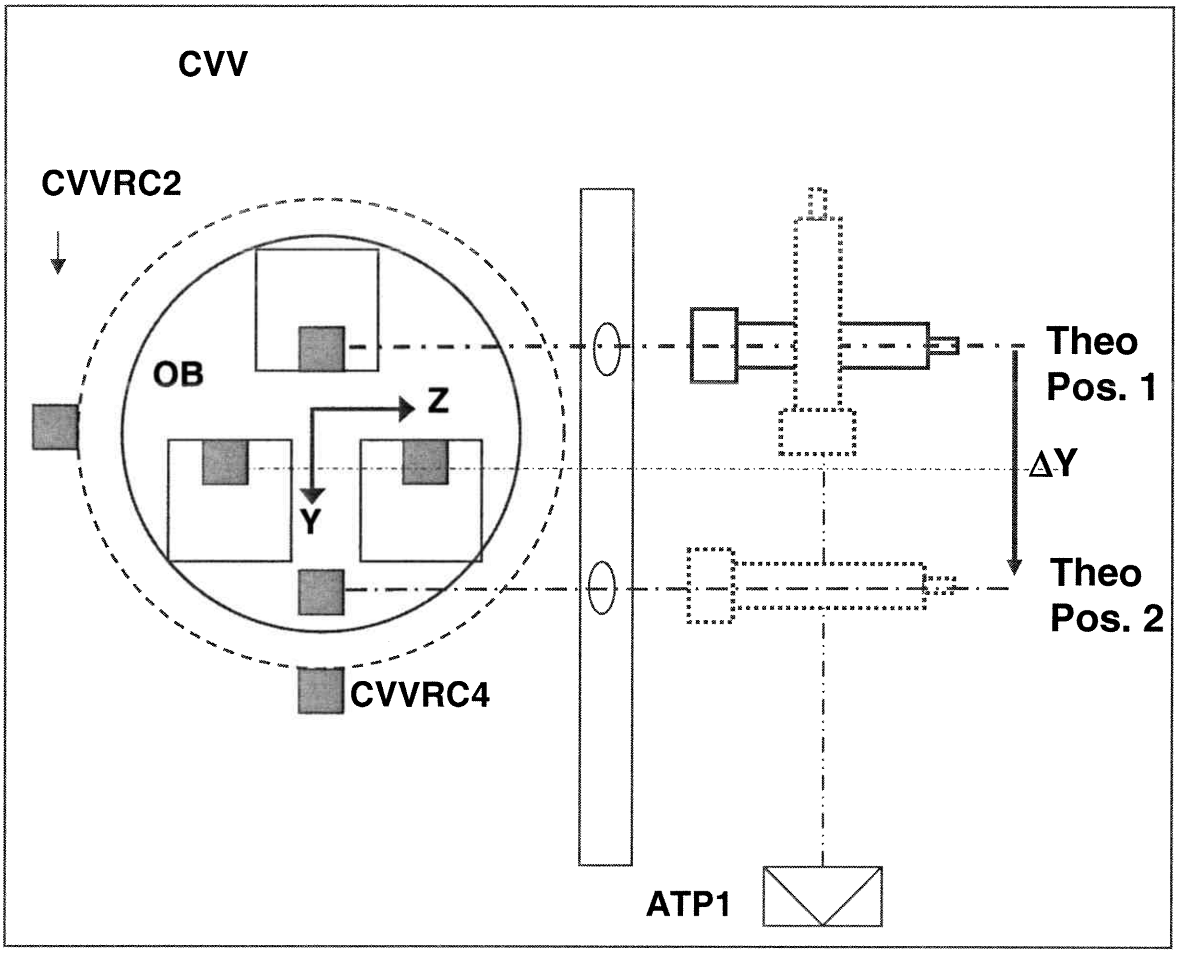


Figure 10-15: (Analogous to Fig. 10-3) Principle set up for distance measurements from +Z side

121. Read-out the LMD display. Record the following value:

HIFI + z face Linear Position in Y				Mean
Y(HIFI+z)	1089.15	1089.12	1089.11	1089.13 mm
Measurement Date: 3.08.07			Time: 18:25	

Measured distance to CVVRC4: ΔY = 1089.1 mm

Nominal distance to CVVRC4; **ΔY = 1088.1 ± 1.1mm**

122. Check ATP Position:

ATP Position: Hz =	270.0000°
Date: 3.08.07	Time: 18:25

Re-check LMD orientation:	Azimuth:	0.17°
	Elevation	0.14°
Date/Time: 3.08.07 / 18:25		

Re-check Rotary table levelling:	Level1	A = 0° 00' 01"
	Level2	B = 0° 00' 00"
Date/Time: 3.08.07 / 18:25		

123. Move the theodolite to the next reference: PACS, check the levelling in this position. Level if necessary.

124. Rotate theodolite towards ATP and achieve auto-collimation. Set Hz = 270.0000 deg. Rotate theodolite back to +z face of PACS.

125. Move the scanning head of the LMD until the azimuth of the cross hair coincides with the azimuth of the theodolite cross hair in the PACS position.

126. Read-out the LMD display. Record the following value:

PACS + z face Linear Position in Y				Mean
Y(PACS+z)	853.32	853.31	853.29	853.31 mm
Measurement Date: 3.08.07			Time: 17:55	

Measured distance to CVVRC4: ΔY = 853.3 mm

Nominal distance to CVVRC4; **ΔY = 852.5 ± 1.1mm**

127. Check ATP Position:

ATP Position: Hz =	270.0000°
Date: 3.08.07	Time: 17:55

Re-check LMD orientation:	Azimuth:	0.17°
	Elevation	0.12°
Date/Time: 3.08.07 / 17:55		

Re-check Rotary table levelling:	Level1	A = 0° 00' 014
	Level2	B = 0° 00' 004
Date/Time: 3.08.07 / 17:55		

128. Move the theodolite to the next reference: SPIRE, check the levelling in this position. Level if necessary.

129. Rotate theodolite towards ATP and achieve auto-collimation. Set Hz = 270.0000 deg. Rotate theodolite back to +z face of SPIRE.

130. Move the scanning head of the LMD until the azimuth of the cross hair coincides with the azimuth of the theodolite cross hair in the SPIRE position.

131. Read-out the LMD display. Record the following value:

SPIRE +z face Linear Position in Y				Mean
Y(SPIRE+z)	862.97	863.04	863.03	863.01 mm
Measurement Date: 3.08.07			Time: 17:55	

Measured distance to CVVRC4: **ΔY =** 863.0 mm

Nominal distance to CVVRC4; **ΔY = 861.8 mm ± 5.2 mm**

132. Check ATP Position:

ATP Position: Hz =	270.0000°
Date: 3.08.07	Time: 18:05

Re-check LMD orientation:	Azimuth:	0.17°
	Elevation	0.13°
Date/Time: 3.08.07 / 18:05		

Re-check Rotary table levelling:	Level1	A = 0° 00' 024
	Level2	B = 0° 00' 004
Date/Time: 3.08.07 / 18:05		

10.17 Vertical Distance Measurements with LMD

See Fig 10-16.

133. Rotate PLM+Y side towards theodolite and check Rotary Table levelling:

Re-check Rotary table levelling:	Level1	A = 0° 00' 00"
	Level2	B = 0° 00' 00"
Date/Time: 2.08.07 / 16:20		

134. Mount LMD vertical according to step 4 of this procedure.

LMD verticality:	Elevation1	Ry = 89.90
	Elevation2	Rz = 89.90
Date/Time: 2.08.07 / 16:20		

135. Direct theodolite towards CVVRV4 and level it, set V = 90.0000 deg. and adjust theodolite height with x translation stage to centre of reticle. Rotate theodolite towards LMD.

136. Move the scanning head of the LMD until the elevation bar of the cross hair coincides with the elevation bar of theodolite cross hair.

137. Set the LMD reading to zero at this point. Record the following value:

CVVR4 +Y Linear Position in X				Mean
X(CVVRC4+Y)	0	0	0	
Measurement Date:	2.08.07		Time: 16:20	

138. Adjust theodolite with translation stages to the centre of the next reference point: HIFI+ Y side and level it, set V = 90.0000 deg. and rotate theodolite towards LMD.

139. Move the scanning head of the LMD until the height mark of the cross hair coincides with the elevation bar of the theodolite cross hair and record the following value:

HIFI+Y vertical Position in X				Mean
X(HIFI+Y)	902.68	902.64	902.63	902.65 mm
Measurement Date:	2.08.07		Time: 16:40	

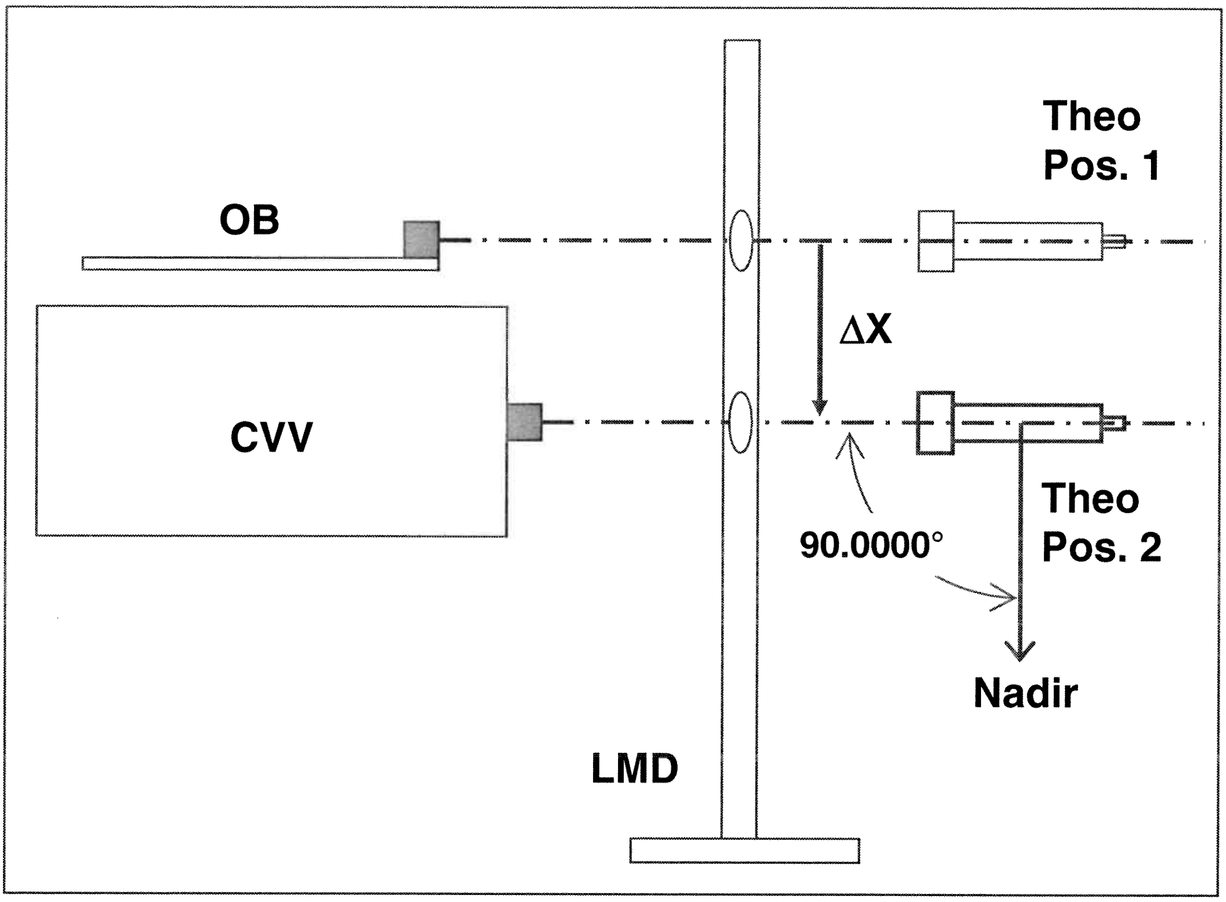


Figure 10-16: (Analogous to Fig. 10-1) Principle set up for vertical distance measurements with LMD from +y side.

Measured distance to CVVRC4: **ΔX =** 902.65 mm

Nominal distance to CVVRC4: **ΔX = 903.3 mm ± 1.1 mm**

Re-check LMD orientation:	Elevation1: Ry = 89.9°
	Elevation2: Rz = 89.9°
Date/Time: 2.08.07 / 16:40	

140. Adjust theodolite with translation stages to the centre of the next reference point: PACS+ Y side and level it, set V = 90.0000 deg. and rotate theodolite towards LMD.

141. Move the scanning head of the LMD until the height mark of the cross hair coincides with the elevation bar of the theodolite cross hair and record the following value:

PACS+Y vertical Position in X				Mean
X(PACS+Y)	1000.66	1000.71	1000.69	1000.69 mm
Measurement Date: 2.08.07			Time: 17:20	

Measured distance to CVVRC4: **ΔX =** 1000.69 mm

Nominal distance to CVVRC4: **ΔX = 1000.6 mm ± 1.1 mm**

Re-check LMD orientation:	Elevation1: Ry = 89.9° Elevation2: Rz = 89.9°
Date/Time: 2.08.07 / 17:20	

142. Adjust theodolite with translation stages to the centre of the next reference point: SPIRE + Y side and level it, set V = 90.0000 deg. and rotate theodolite towards LMD.

143. Move the scanning head of the LMD until the height mark of the cross hair coincides with the elevation bar of the theodolite cross hair and record the following value:

SPIRE+Y vertical Position in X				Mean
X(SPIRE+Y)	1020.92	1020.94	1020.97	1020.94 mm
Measurement Date: 2.08.07			Time: 17:00	

Measured distance to CVVRC4: **ΔX =** 1020.94 mm

Nominal distance to CVVRC4: **ΔX = 1021.0 mm ± 5.2 mm**

Re-check LMD orientation:	Elevation1: Ry = 89.9° Elevation2: Rz = 89.9°
Date/Time: 2.08.07 / 17:00	

Re-check Rotary table levelling:	Level1 ~~Ry = 89.9°~~ Level2 ~~Rz = 89.9°~~
Date/Time: 2.08.07 / 17:00	

A = 0° 00' 00"
B = 0° 00' 00"

10.18 Vertical Distance Measurements with LMD -Z Side

See Fig 10-16

Note: The following measurement will be performed for redundancy reasons only. For comparison, the measurement for CVVRC4 of section 10.17 will be used as reference.

144. Rotate PLM such that –z-axis points towards theodolite

145. Check Rotary Table levelling:

Re-check Rotary table levelling:	Level1 Level2	A = 0° 00' 01" B = 0° 00' 02"
Date/Time: 3.08.07 / 9:30		

146. Adjust theodolite with lateral stages to the centre of the next reference point: CVVRC2-Z side and level it, set V = 90.0000 deg. and rotate theodolite towards LMD.

147. Move the scanning head of the LMD until the elevation bar of the cross hair coincides with the elevation bar of the theodolite cross hair and record the following value:

CVVRC2-Z vertical Position in X				Mean
X(CVVRC2-Z)	0.01	0.07	0.01	0.03 mm
Measurement Date: 3.08.07			Time: 9:30	

Measured distance to CVVRC4: **ΔX =** 0 mm

Nominal distance to CVVRC4: **ΔX = 0mm ± 0.8mm**

Re-check LMD orientation:	Elevation1: Elevation2:	Ry = 89.9° Rz = 89.9°
Date/Time: 3.08.07 / 9:30		

11 Procedure Variation/NCR Summary

11.1 Procedure Variation Summary

No.	Page	Variation Description	Action required
1		Change of sequence of measurements	
		This procedure variation was raised during the alignment test in order to minimize the set-up re-configuration and to reduce the number of rotary table operations. Since the alignment procedure has a modular structure anyhow, this variation has no impact on measurement objective, methods and results.	No
2		Installation of a 2nd ATP	
		A 2nd ATP was mounted in front of the master ATP to improve the ATP stability	No

11 Procedure Variation/NCR Summary

11.1 Procedure Variation Summary

No.	Page	Variation Description	Action required
		Remark: This is not a formal procedure variation but only for clarification. Sections 10.2 - 10.3, 10.6 - 10.8 and 10.10 - 10.12 call for measurement values to be compared with nominal values. The measured values are referred to CVV RC4, however, these values include a bias w.r.t. the CVV flange. This bias has been determined under Activity Control Sheet HP-2-ASED-SD-0179. For comparison of measured and nominal values this must be taken into account. The respective calculation will be part of the final report.	

11.2 Non-Conformance Report (NCR) Summary

NCR No.	Non Conformance Description	Date generated	Originator	Date closed
→ HP-121000-ASED-NC-3516				
		8.08.07	D. Schink	
	The following non conformances have been observed: – 1. OB in y direction w.r.t. CVV RC4 slightly exceeds tolerance of 1mm (measured 1.01mm) – 2. Rotation around x of OB w.r.t. CVV exceeds tolerance of 0.0333 deg (measured 0.1015 deg). This value has been defined by ASED under the assumption that the Instrument FPUs are nominally aligned w.r.t. OB. This however is not the case. The actual FPU alignment w.r.t. the CVV are all in spec. apart from PACS (see below). – 3. OB rotation around Z-axis exceeds tolerance of 0.0333 deg (measured 0.0442 deg). See comment below. – 4. PACS rotation about z-axis exceeds tolerance of 0.0389 deg (measured 0.0564 deg). The allowed tolerance was derived from the alignment budget (TN-0097). Exceeding reduces available margin, but margin is still positive.			

11.2 Non-Conformance Report (NCR) Summary

NCR No.	Non Conformance Description	Date generated	Originator	Date closed
	5. PACS rotation about x-axis exceeds tolerance of 0.0389 deg (measured 0.1082 deg). This exceeding is within the overall budget (TN-0097).			

11.3 Test Configuration Record

1. Facility: ASED Cleanroom Class 100
2. Model: Herschel FM
3. Temperature: 19.8 °C
4. Humidity: 50.5 %
5. Test Start Date: 2.08.07
6. Test End Date: 4.08.07
7. Remarks:

12 Alignment Sign-off Sheet

The alignment has been performed according to this procedure. Deviations in the procedure and/or in the sequence are noted in the procedure variation sheets. Non conformances are listed in the NCR-Summary sheets.

	Date	Signature
Alignment Engineer	13.08.07 16.08.07	D. S[illegible] E. [illegible]
PA Responsible	17.08.07	[illegible]

13 Open Work Summary

No.	Page	Open Work Description	Closure Date
		None	

14 Annex 1: Position of Alignment Cubes

This chapter gives an overview about the positions of the alignment reference cubes for OB; Instruments and CVV.

14.1 Alignment Cube Reference Table

The angular and distance measurements as described in Section 4.3 and 4.4 shall be performed for each alignment cube (surface) as listed in Table 14-1.

No.	Alignment Cube (reference)	Surface ID	Angular Measurement	Distance Measurement	
1	**OB**	**+y** **+z**	**Rz, Rx** **Ry,** (Rx)	**Tz, Tx** **Ty**, (Tx)	
2	**HIFI**	**+y** **+z**	**Rz, Rx** **Ry,** (Rx)	**Tz, Tx** **Ty**, (Tx)	
3	**SPIRE**	**+y** **+z**	**Rz, Rx** **Ry,** (Rx)	**Tz, Tx** **Ty**, (Tx)	
4	**PACS**	**+y** **+z**	**Rz, Rx** **Ry,** (Rx)	**Tz, Tx** **Ty**, (Tx)	
5	**CVVRC2 (Bu 1)**	**-z** **+y**	**Ry, Rx** **Rz,** (Rx)	 **Tz,**	
6	**CVVRC4 (Bu 2)**	**+y** **+z**	**Rz, Rx** **Ry,** (Rx)	**Tz, Tx** **Ty**, (Tx)	

Table 14-1: Alignment Cube Identification

Explanation: +y: cube, surface visible from +y side
-z: cube visible from –z side
BU: Back up cube 1 and 2 (see Sect. 7)

The columns Angular and Distance Measurement indicate from which cube surface the measurements for Rx, Ry, Rz and Tx, Ty, and Tz shall be performed (Rx means rotation about the x axis; Tx distance measurement in x direction etc.).

Rx, Ry, Rz, Tx, Ty, TZ: These values are measured and will be used for test evaluation

(Rx), (Tx): These values will be measured, however, they are redundant and will not be used for test evaluation.

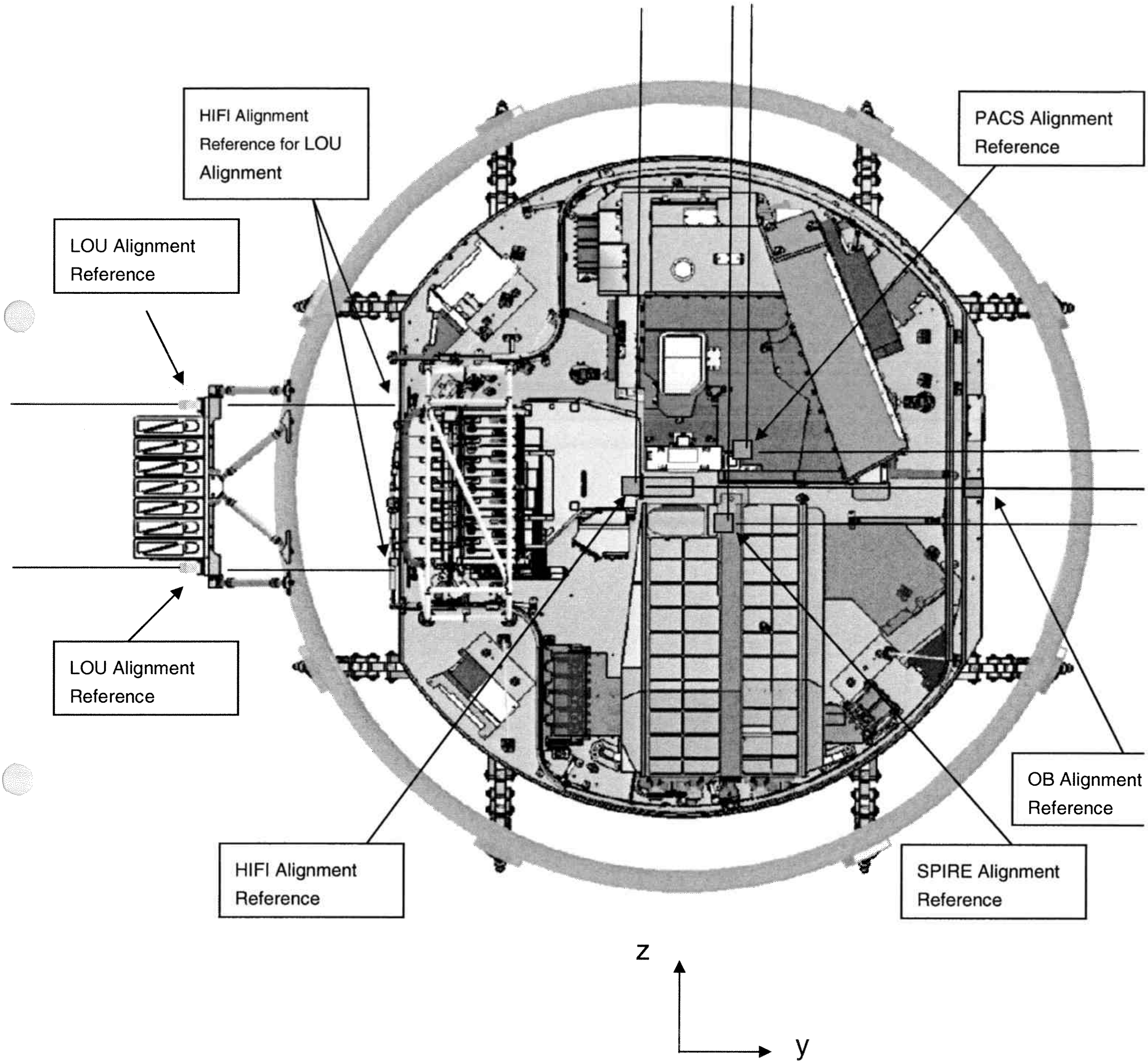


Figure 14-1: Alignment References for Instruments and Optical Bench

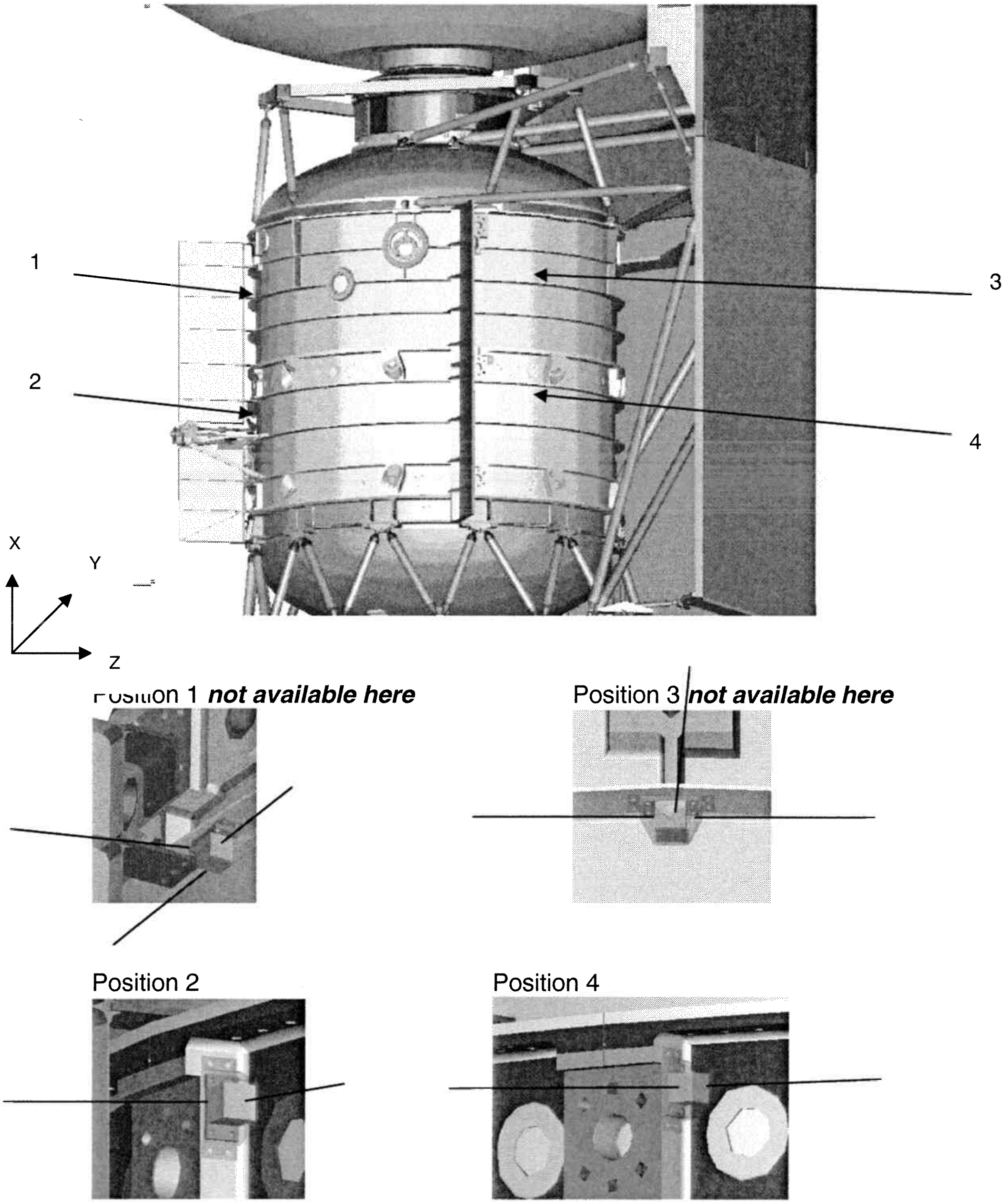


Figure 14-2: CVV Reference Cubes:

Only cubes in pos. 2 and 4 will be available here: CVVRC2 and CVVRC4.

Cube Positions and Orientations

Positions and orientations of the involved optical reference cubes are compiled below.

The related values of OB, HIFI and PACS are measured data, whereas the positions of the CVV reference cubes are design data (from CATIA model). For SPIRE, nominal positions have been taken from related ICD.

This means that for references, for which measured data are not available, alignment measurements will be performed wrt. their nominal positions (as per ICD) related to CVVRC4 as master reference. When FPU data become available at a later point in time, these will used to evaluate the PLM alignment a posteriori. For OB, HIFI and PACS actually measured data of alignment reference position and orientation are already included.

Cube	X	Y	Z	Remark
HIFI Transl. Measmt. error	**353.80 mm** ± 0.1 mm	**-116.30 mm** ± 0.1 mm	**0.00 mm** ± 0.1 mm	**RD 10**
HIFI Rotation. Measmt. error	**-4 arcsec** ± 20 arcsec	**-76 arcsec** ± 5 arcsec	**- 7 arcsec** ± 5 arcsec	**RD 10**
PACS Transl. Measmt. error	**451.10 mm** ± 0.1 mm	**119.28 mm** ± 0.1 mm	**64.27 mm** ± 0.1 mm	**RD 12**
PACS Rotation Measmt. error	**-125 arcsec** ± 20 arcsec	**75 arcsec** ± 20 arcsec	**62 arcsec** ± 20 arcsec	**RD 12**
SPIRE Transl.	**471.52 mm**	**110.00 mm**	**-56.41 mm**	**RD 13**
Spire Rotation Measmt. error	**Not measured**	**7.3 arcmin** ±0.5 arcmin	**3.7 arcmin** ±0.5 arcmin	**Measured RD 13**
OB -z face **+y face** **+z face**	**10.97 mm** **10.97 mm** **10.97 mm**	**715.08 mm** **725.08 mm** **715.08 mm**	**-10.05 mm** **-0.05 mm** **9.96 mm**	**RD 9 and Annex 2**
CVV I/F flange	**1479 mm**	**NA**	**NA**	**after CATIA data**
CVVRC2	**-549.50 mm**	**72.00 mm**	**-971.80 mm**	**after CATIA data**
CVVRC4	**-549.50 mm**	**971.80 mm**	**72.00 mm**	**after CATIA data**

Table 14-2: Alignment cube positions
Positions are w.r.t. OB coordinate system.
The coordinates are related to intersection point of cross hairs. Rotations are about indicated axes.

The positions and orientations of the cross hairs on the OB, HIFI and PACS reference cubes are measured values and have been taken from RD 9 (see Annex 2), RD 10 and RD 12

The positions of the cross hairs of the SPIRE reference cube are "as designed values", not measured values! Therefore, no measurement accuracy is given in above table. The values are taken from RD 13. The adjustment tolerances for SPIRE are as follows (see RD 13):
Displacements: ± 5.2 mm
Rotations: ± 8.8 arcmin
These tolerance values are used to define "success criteria" for the procedure above.

The instruments PACS and HIFI were mounted with dedicated shimming plates (delivered by the Instruments):
PACS: 1-way foot: 5.24mm; 2-way foot: 4.97mm; 3-way foot: 5.32mm (RD 12)

HIFI: Front feet: 16mm; rear feet: 10mm (e-mail from Robert Huisman, dated 13.07.07).

Translated into theodolite readings, the OB rotation values from annex 2/RD 9 become:

Cube OB	+Y sideX [deg.]	+Z side [deg.]	Remark
Theodolite Readings	**ΔV = 90.0652** **ΔHz = 359.9551**	**ΔV = 89.9229** **ΔHz = 359.9547**	RD 9

Table 14-3: Expected theodolite readings for OB ref. cube.
Based on actual ref. cube measurements (see RD 9/annex 2).

Translated into theodolite readings, the above HIFI rotation values from Table 14-2 become:

Cube HIFI	+Y side [deg.]	+Z side [deg.]	Remark
Theodolite Readings	**ΔV = 90.0019** **ΔHz = 0.0011**	**ΔV = 89.9789** **ΔHz = 0.0011**	RD 10

Table 14-4: Expected theodolite readings for HIFI FPU ref. cube
Based on actual HIFI ref. cube orientation according to RD 10.

Translated into theodolite readings, the above PACS rotation values from Table 14-2 become:

Cube PACS	+Y side [deg.]	+Z side [deg.]	Remark
Theodolite Readings	**ΔV = 89.9828** **ΔHz = 0.0347**	**ΔV = 90.0208** **ΔHz = 0.0347**	RD 12

Table 14-5: Expected theodolite readings for PACS ref. cubes.
Based on actual PACS ref.-cube orientation (taking into account PACS shims).

Cube SPIRE	+Y side [deg.]	+Z side [deg.]	Remark
Theodolite Readings	ΔV = 89.9383 ΔHz = not measured	ΔV = 90.1217 ΔHz = not measured	RD 13

Table 14-6: Expected theodolite readings for PACS ref. cube.
Based on actual PACS ref.-cube orientation (taking into account PACS shims).

From Table 14-2 and following ones we find the distances between certain references by determining the related coordinate differences.
Since all measurements are referred to the CVVRCs the distances are given in relation to CVVRC4 ("Master Reference Cube").
Some analogous values determined in relation to CVVRC2 are included for potential later use in the context of system alignment measurements.

Distances to Master Reference Cube CVVRC4				
Cube	**ΔX [mm]**	**ΔY [mm]**	**ΔZ [mm]**	**Remark**
HIFI actual	**903.30**	**1088.1**	**72.00**	**Based on measured instrument ref. data**
PACS actual	**1000.60**	**852.52**	**7.73**	
SPIRE	**1021.02**	**861.80**	**128.41**	**Based on nominal instr. ref. data (ICD)**
OB +y face	**560.47**	**---**	**72.05**	**Based on measured OB ref. data**
+z face	**560.47**	**256.72**	**----**	
CVV I/F flange	**57.50**	**NA**	**NA**	**CATIA model data**
Distances to Secondary Reference Cube CVVRC2 (for later use)				
HIFI	NA	NA	NA	Not accessible from –Z side
PACS	NA	NA	NA	
SPIRE	NA	NA	NA	
OB -z face	560.47	643.08	961.75	

Table 14-7: Expected distances of instrument and selected master references.

OB, HIFI and PACS data refer to measured positions of related reference cross hairs.

SPIRE data are based on nominal ICD values.

15 Annex 2: OB Cube Reference Data

The measured positions of the cross hair on OB reference cube have been taken from RD 9. The values as compiled in Fig. 15-1 are shown for EQM and PFM, however for the procedure, only PFM values are relevant.

6. MISCELLANEA

6.1 Coordinate System Marking

The OBA coordinate system is marked on the OBP (as per R-OBA-495).

6.2 Alignment Cube

The direction (normal to face) and position (cross hairs) of the optical active faces of the OBA alignment cube is presented in the following table:

Alignment Cube		Required				PFM Actual				EQM Actual			
		X	Y	Z	arc min	X	Y	Z	arc min	X	Y	Z	arc min
FACE -Z	Posit.					10.97	715.08	-10.05		11.18	714.96	-10.07	
	Dir.	0	0	-1	2.00	0.001377	0.000595	-1	5.16	0.000458	0.000832	-1	3.26
FACE +Y	Posit.					10.97	725.08	-0.05		11.18	724.97	-0.06	
	Dir.	0	1	0	2.00	0.001138	1	0.000783	4.75	0.000948	1	0.000771	4.20
FACE +Z	Posit.					10.97	715.08	9.96		11.18	714.96	9.95	
	Dir.	0	0	1	2.00	-0.001346	-0.000791	1	5.37	-0.000250	-0.000795	1.000000	2.86

The direction measurement accuracy is 20 arc sec w.r.t. each axis (10 arc sec required). The direction deviation after dismounting and mounting alignment cube onto OBP is less than 20 arc sec.

The position measurement accuracy is 0.003mm w.r.t. OBP coordinate system (0.1mm required). The position deviation after dismounting and mounting alignment cube onto OBP is 0.024mm (still less than required 0.1mm).

Figure 15-1: Measured positions of cross hair on OB reference cube

(Taken from HP-2-ECAS-PR-0014, Issue 02).

These figures are used to calculate "nominal positions" for the instruments in the sense that nominal (or measured for HIFI) instrument data are referred to the actual, i. e. measured OB data.

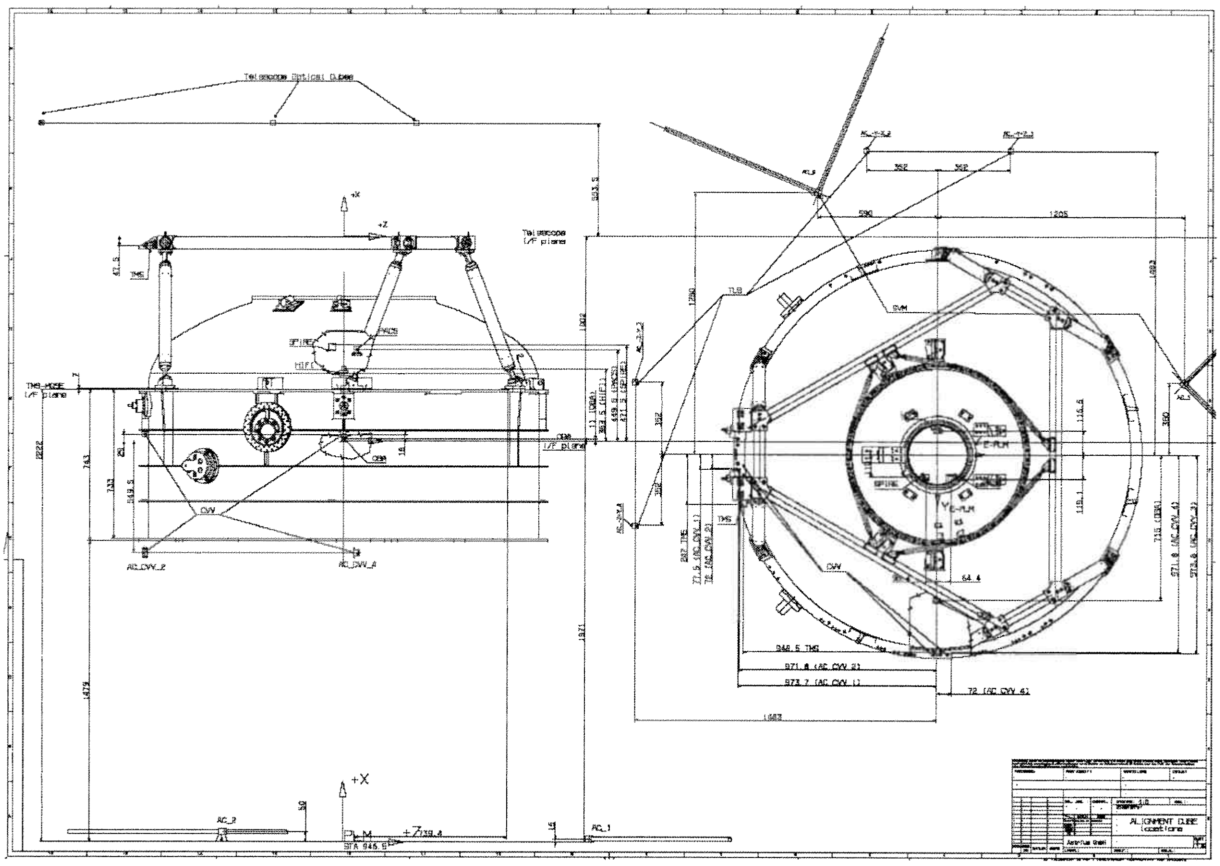


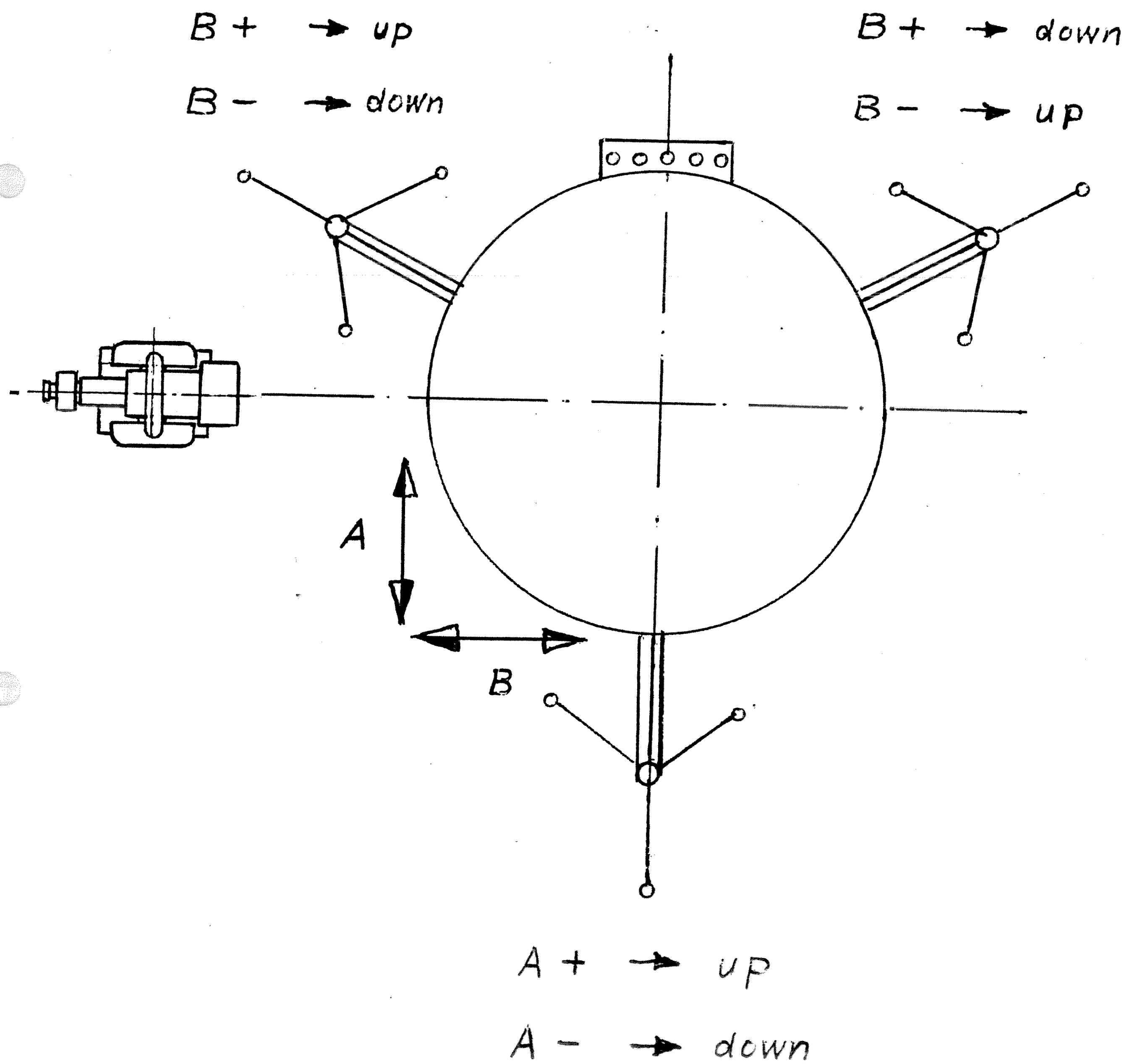
Figure 15-2: Nominal ("As Designed") Alignment Cube positions

Note. Drawing only gives design values (nominal).

Cube position from the above drawing are used to calculate the nominal distances related to CVVRC4 (and CVVRC2) and SPIRE.
For OB, HIFI and PACS measured positions/orientations are available and have been use throughout the procedure (Sect. 10 and subsections). The measured values of OB, HIFI and PACS are included in Tables 14-2 and in Fig 15-1.

STR leg correction in height

to adjust LEVELMETER reading to 0° 00' 00"



END OF DOCUMENT

	Name	Dep./Comp.		Name	Dep./Comp.
	Alberti von Mathias Dr.	ASG22		Schweickert Gunn	ASG22
	Baldock Richard	FAE12	x	Sonn Nico	ASG51
	Barlage Bernhard	AED13		Steininger Eric	AED32
x	Bayer Thomas	ASA42	x	Stritter Rene	AED11
	Brune Holger	ASA45		Suess Rudi	OTN/ASA44
	Edelhoff Dirk	AED2		Wagner Klaus	ASG22
	Fehringer Alexander	ASG13	x	Wietbrock Walter	AET12
x	Fricke Wolfgang Dr.	AED 65		Wöhler Hans	ASG22
	Geiger Hermann	ASA42		Wössner Ulrich	ASE252
	Grasl Andreas	OTN/ASA44			
	Grasshoff Brigitte	AET12			
	Hamer Simon	Terma			
	Hendry David	Terma			
	Hengstler Reinhold	ASA42			
	Hinger Jürgen	ASG22			
x	Hohn Rüdiger	AED65			
x	Hölzle Edgar Dr.	AED32			
	Huber Johann	ASA42			
	Hund Walter	ASE252			
x	Idler Siegmund	AED312			
	Ivády von András	FAE12			
	Jahn Gerd Dr.	ASG22			
	Kalde Clemens	ASM2			
	Kameter Rudolf	OTN/ASA42			
x	Kettner Bernhard	AET42			
	Knoblauch August	AET32	x	Thales Alenia Space Cannes	TAS-F
	Koelle Markus	ASA43		Thales Alenia Space Torino	TAS-I
x	Koppe Axel	AED312	x	ESA/ESTEC	ESA
x	Kroeker Jürgen	AED65			
	La Gioia Valentina	Terma		**Instruments:**	
	Lang Jürgen	ASE252	x	MPE (PACS)	MPE
	Langenstein Rolf	AED15	x	RAL (SPIRE)	RAL
	Langfermann Michael	ASA41	x	SRON (HIFI)	SRON
	Maukisch Jan	ASA43			
	Much Christoph	ASA43			
	Müller Jörg	ASA42		**Subcontractors:**	
x	Müller Martin	ASA43		Thales Alenia Space Antwerp	ABSP
	Peltz Heinz-Willi	ASG13		Austrian Aerospace	AAE
	Pietroboni Karin	AED65		Austrian Aerospace	AAEM
	Platzer Wilhelm	AED2		BOC Edwards	BOCE
	Reichle Konrad	ASA42		Dutch Space Solar Arrays	DSSA
	Runge Axel	OTN/ASA44		EADS Astrium Sub-Subsyst. & Equipment	ASSE
x	Schink Dietmar	AED32		EADS CASA Espacio	CASA
	Schlosser Christian	OTN/ASA44		EADS CASA Espacio	ECAS
	Schmidt Rudolf	FAE12		European Test Services	ETS
	Schmidt Thomas	ASA42		Patria New Technologies Oy	PANT
	Schuler Günter	ASA42		SENER Ingenieria SA	SEN

Location : FN	Title:HIFI AD Stability Check after Harness Rail final Fixation		
Facility : Class 100	Model: PFM	Subsystem: HIFI	Date: 2.08.07
	Test Conductor:		NCR Ref:
CI No 120000	Prepared By: E. Hölzle		CIL No:

Scope:
This Procedure covers the activities to perform: The HIFI AD stability check after Harness rail final fixation
This ACS shall be used in conjunction with the following Procedures and reference documents:
Procedure for PFM Alignment of Herschel Instruments w.r.t. PLM, HP-2-ASED-TP-0111

EGSE S/W reference and issue	**On-Board S/W** reference and Issue

Facilities required:	OGSE: 1 Theodolite, 2 ATP, 2 Tripods MGSE: Inspection equipment: Consumables:	
Personnel required:	1 AIT eng, 2 alignment eng 1 QA	
Safety and Hazards:	No specific safety precautions or hazards identified.	
Constraints:	Class 100 clean room PLM mounted on Integration Dolly or Rotary Table	

No:	Activity	Proc/Drg/Result	Responsible & sign off
01	**See Annex**		
02			
03			
04			
05			
06			
07			
08			
09			
10			
11	.		
12			

Release AIT:	Release SE:	Release PA/Safety:	Sign off (PA/QC/Team Leader)
Th. Bayo	31.07.07 [signature]	[signature]	17.8.07 [signature]

APPENDIX

1. Monitoring of HIFI FPU Alignment Devices during final harness rail fixation

The following steps have to be performed

1. Remove cover plate (red tag) from FPU openings versus LOU
2. Set up theodolite in front of AD +Z.
3. Level theodolite and achieve auto-collimation with AD +Z, set HZ = 0.0000 deg.
4. Rotate theodolite to the left until Hz = 270.0000 is reached.
5. Install ATP such that theodolite is in auto-collimation with ATP.
6. Rotate theodolite back to AD +Z and achieve auto-collimation. Check that Hz = 0.0000 deg ± 10 arcsec. If this condition is not fulfilled, repeat steps 2 – 5 until condition is achieved.
7. Unscrew provisionally installed fixation screws of harness rail on FPU and observe AD through theodolite in auto-collimation.

1.1 AD orientation before harness rail fixation:

Rotary Table Level 1 A = 0°00'00"
Level 2 B = 0°00'01"

8. Record the following values:

HIFI FPU AD+Z before harness rail fixation				Mean
HZ =	0.0034°	0.0027°	0.0027°	0.0029°
V =	89.9957°	89.9952°	89.9953°	89.9954°
	Measurement Date: 2.08.07		Measurement Time: 10:30	

9. Set up theodolite in front of AD –Z such that ATP can be viewed from this position.
10. Level theodolite and achieve auto-collimation with ATP, set HZ = 270.0000 deg.
11. Rotate theodolite to the right and achieve auto-collimation with AD-Z.
12. Record the following values:

HIFI FPU AD-Z before harness rail fixation				Mean
HZ =	0.0218°	0.0211°	0.0206°	0.0212°
V =	89.9937°	89.9948°	89.9952°	89.9946°
	Measurement Date: 2.08.07		Measurement Time: 11:00	

13. Check and record ATP position: ... 270.0002° ...

1.2 AD stability monitoring during harness rail fixation

14. Tighten fixation screws with final torque (4.6Nm ± 10%) and observe the AD – Z side through theodolite in auto-collimation. Should any change occur, it will be quantified by the measurements from Sections 1.1 and 1.3.

1.3 AD orientation after final harness rail fixation:

15. Check theodolite levelling and achieve auto-collimation with ATP, set HZ = 270.0000 deg.

16. Rotate theodolite back to AD -Z and achieve auto-collimation.

17. Record the following values:

HIFI FPU AD-Z after harness rail fixation				Mean
HZ =	0.0176°	0.0179°	0.0200°	0.0185°
V =	89.9951°	89.9968°	89.9945°	89.9955°
	Measurement Date: 2.08.07		Measurement Time: 13:30	

18. Set up theodolite in front of AD +Z such that ATP can be viewed from this position.

19. Level theodolite and achieve auto-collimation with ATP, set HZ = 270.0000 deg.

20. Rotate theodolite to the right and achieve auto-collimation with AD+Z.

21. Record the following values:

HIFI FPU AD+Z after harness rail fixation				Mean
HZ =	359.9995°	0.0006°	0.0003°	0.0001°
V =	89.9953°	89.9961°	89.9958°	89.9957°
	Measurement Date: 2.0807		Measurement Time: 14:00	

22. Check and record ATP position: ... 270.0000° ...

23. Mount cover plate on FPU openings again

Rotary Table Level 1 A = 0° 00' 00"
Level 2 B = 0° 00' 01"

1.4 AD stability

24. Compare the values from steps 8 and 21 (AD+Z before rail fixation) and from steps 12 and 17 (AD-Z after rail fixation).
The deviations shall be smaller than ± 20 arcsec (±0.0056 deg.).

Measured values **ΔHz(+Z) =** 0.0028°
ΔV(+Z) = -0.0003°

ΔHZ(-Z) = 0.0027°
ΔV(-Z) = -0.0009°

Result: With respect to harness rail fixation, the HIFI FPU-AD orientation

☒ **has remained stable**

☐ **has not remained stable**

Date/Time: 2.08.07

Personnel:
Name/Signature: D. Sch[illegible]
Name/Signature: E. [illegible]
Name/Signature: R. [illegible]

ϑ = 19.8 °C

H = 50.5 %

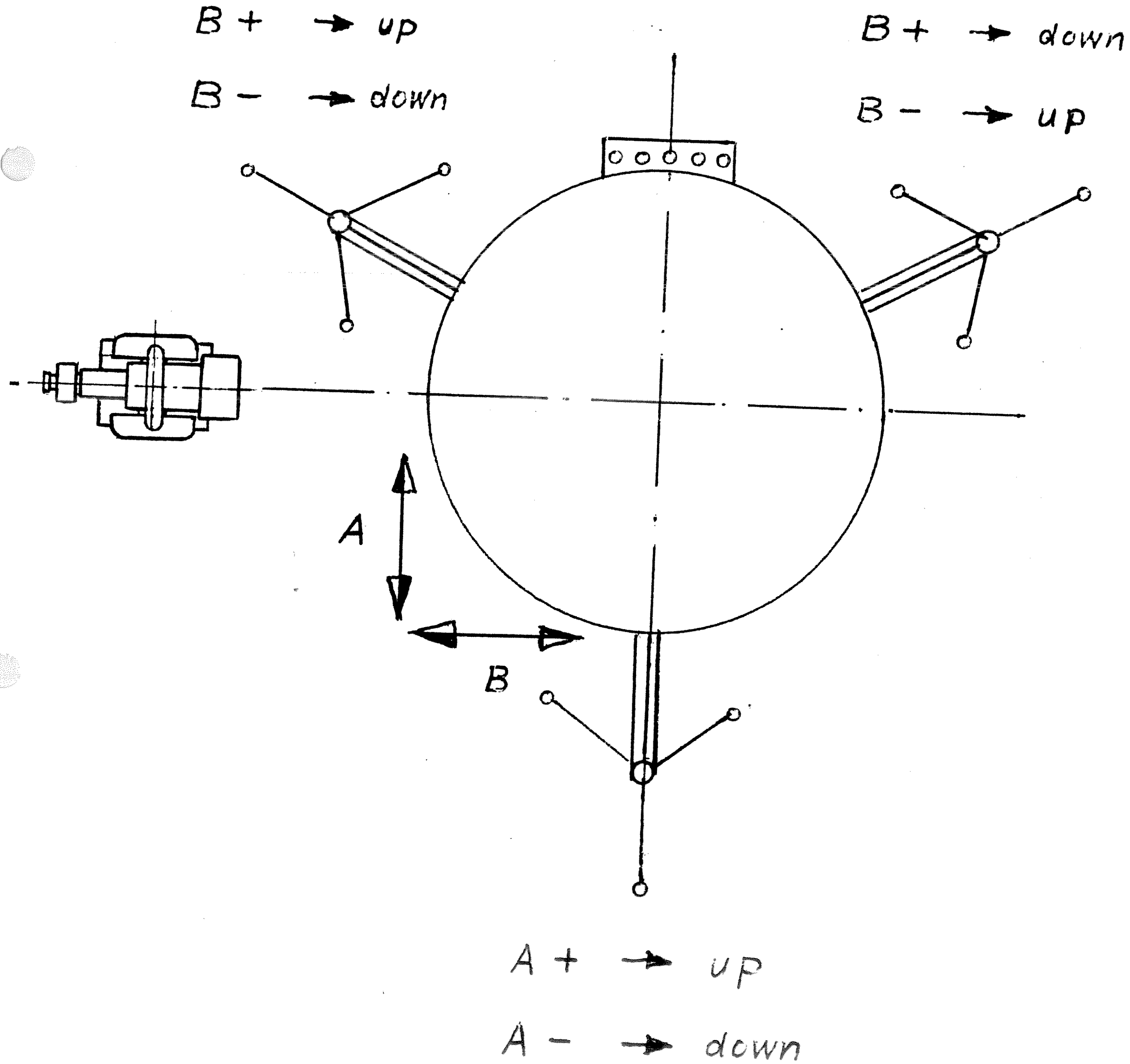
Test performed in cleanroom class 100

Test: TTAP loaded at +X with 1 Person

⇒ Rotary Table Level 2 B = 0° 00' 03"

STR leg correction in height

to adjust LEVELMETER reading to 0° 00' 00''



EADS Astrium HERSCHEL H-EPLM	ACTIVITY SHEET	HP-2-ASED-SD-0179 Iss: 1	Page 1 of 9

Location : FN	Title: Determination of CVV Flange Orientation		
Facility : Class 100	Model: PFM	Subsystem: CVV	Date: 6.08.07
	Test Conductor:		NCR Ref:
CI No 120000	Prepared By: E. Hölzle		CIL No:

Scope:
This Procedure covers the activities to perform: The determination of the CVV Flange orientation w.r.t. the CVVRC4 and the determination of the y axis using the rotary table centre pin and the TTAP y mark.
This ACS shall be used in conjunction with the following Procedures and reference documents:
Procedure for PFM Alignment of Herschel Instruments w.r.t. PLM, HP-2-ASED-TP-0111

EGSE S/W reference and issue	**On-Board S/W** reference and Issue

Facilities required:	OGSE: 1 Theodolite, 2 ATP, 2 Tripods MGSE: Inspection equipment: Consumables:	
Personnel required:	1 AIT eng, 2 alignment eng 1 QA	
Safety and Hazards:	No specific safety precautions or hazards identified.	
Constraints:	Class 100 clean room PLM mounted on Integration Dolly or Rotary Table	

No:	Activity	Proc/Drg/Result	Responsible & sign off
01	**See Annex**		
02			
03			
04			
05			
06			
07			
08			
09			
10			
11			
12			

Release AIT:	Release SE:	Release PA/Safety:	Sign off (PA/QC/Team Leader)
[illegible]	6-8-2007 [illegible]	[illegible]	17.8.07 [illegible]

APPENDIX

Determination of CVV Interface Flange Orientation and CVV Reference Cube Rotational Offset wrt. Rx

The following activities have to be performed:

1. Determination of Mechanical Y-Axis using Rotary Table Pin and TTAP + Y Marking
2. Angular Offset about X of CVVRC4 wrt. Mechanical Y-Axis
3. CVV I/F Flange Orientation wrt. CVVRC4 (Ry, Rz)

1. Y-Axis Determination

1. Set up theodolite in front of Rotary Table (RT).

2. Direct levelled theodolite towards RT centre pin and centre on pin tip..

3. Set Hz = 0.0000 deg and rotate theodolite vertically towards rim of RT.

4. Rotate RT such that +Y mark coincides with theodolite reticle.

5. Rotate theodolite to the left until azimuth Hz = 270.0000 deg is reached.

6. Set up ATP in auto-collimation with theodolite.

7. Rotate theodolite back to RT +Y mark centre position. Check that Hz = 0.0000 deg ± 10 arcsec. If this condition is not fulfilled, repeat steps 2 – 7 until condition is achieved. If the condition is fulfilled, the + Y axis is determined, i. e., it is represented by the normal to the ATP direction.

2. Measurement of CVVRC4 Offset Rx

8. Set up theodolite such that CVVRC4 and the ATP can be viewed in auto-collimation.

9. Direct theodolite towards ATP such that auto-collimation is reached and set Hz = 2700.0000 deg.

10. Rotate theodolite back to CVVRC4, achieve auto-collimation and record the following values:

CVVRC4 versus mechanical Y-direction				Mean
HZ =	359.9685°	359.9653°	359.9664°	359.9667°
	Measurement Date: 6.08.07		Measurement Time: 15:50	

The difference ΔHz (CVVRC4) = 360 – Hz (CVVRC4) defines the relative azimuth offset of CVVRC4 wrt. the mechanical Y-axis.

Measured offset value: **ΔHz (CVVRC4) =** 0.0333 **deg.**

				Time
Rotary Table levelling	Level 1	A =	- 00° 00' 01"	
	Level 2	B =	00° 00' 01"	15:30
	Level 1	A =	- 00° 00' 01"	
	Level 2	B =	00° 00' 00"	16:00

ATP Position Hz = 270.0011° 16:00

3. Measurements of CVV Flange Orientation

The orientation of the CVV I/F flange, i. e. its tilt about Y and Z axes shall be measured. To do so, a reference cube is put onto the flange at various positions and the respective elevation of a selected the cube face is measured. The principle is shown in Fig. 1.

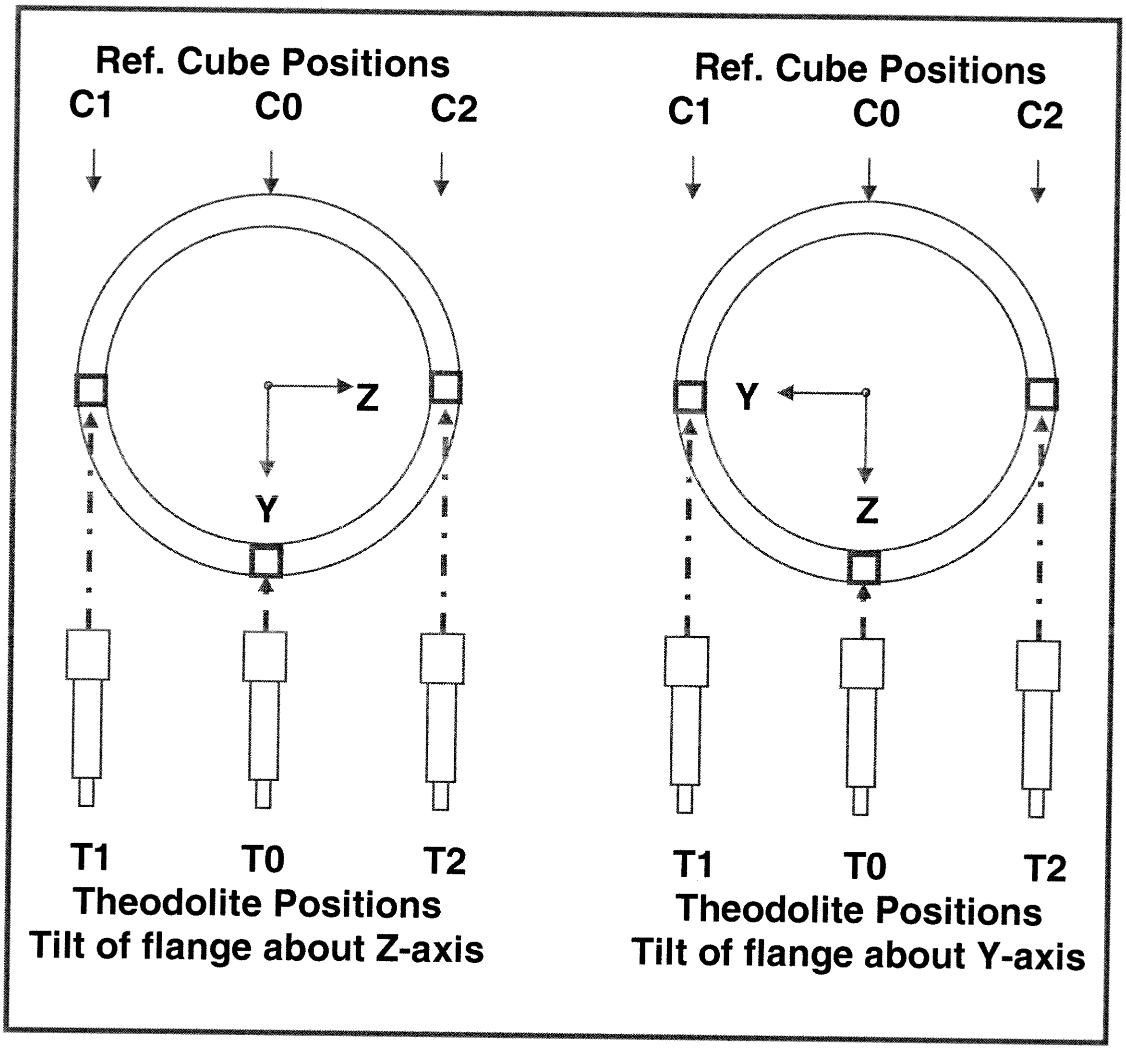


Fig. 1: Principle set-up for measurement of CVV I/F flange orientation.

Left figure: Measurement of tilt about Z-axis (from +Y side)

Right figure: Measurement of tilt about Y-axis (from +Z side)

The reference cube is set onto the flange at the indicated three points: Flange at intersection with Y-axis and both intersections with Z-axis, and after rotation through 90 deg at intersection of flange and Z-axis and at both intersections with Y-axis. From the respective three measurements per side a mean inclination (elevation) of the flange plane can be determined.

The movable reference cube is put directly onto the flange surface with top face 8 opposite to cube mounting flange). For the measurements always the same face is directed towards the theodolite.

The orthogonality of two adjacent cube faces is better than 10 arcseconds.

3.1 Measurements from +Y side: Tilt about Z-Axis

11. Set up theodolite in at position T0 such that ATP can be viewed from this position.

12. Direct theodolite towards ATP, achieve auto-collimation and set HZ = 270.0000 deg.

13. Rotate theodolite back to Hz = 0.0000 deg.

14. Put reference cube onto CVV I/F flange at position C0, orient it such that theodolite achieves auto-collimation and record the following values:

CVV I/F flange tilt from +Y Position 0				Mean
V =	90.00780°	90.00750°	90.00810°	90.00780°
	Measurement Date:	6.08.07	Measurement Time:	16:00

Rotary Table Levelling! Level 1 A = −0° 00' 014
Level 2 B = 0° 00' 004

15. Set up theodolite in at position T1 such that ATP can be viewed from this position.

16. Direct theodolite towards ATP, achieve auto-collimation and set HZ = 270.0000 deg.

17. Rotate theodolite back to Hz = 0.0000 deg.

18. Put reference cube onto CVV I/F flange at position C1, orient it such that theodolite achieves auto-collimation and record the following values:

CVV I/F flange tilt from +Y Position 1				Mean
V =	90.00680°	90.00680°	90.00710°	90.00690°
	Measurement Date:	6.08.07	Measurement Time:	17:40

19. Set up theodolite in at position T2 such that ATP can be viewed from this position.

20. Direct theodolite towards ATP, achieve auto-collimation and set HZ = 270.0000 deg.

21. Rotate theodolite back to Hz = 0.0000 deg.

22. Put reference cube onto CVV I/F flange at position C2, orient it such that theodolite achieves auto-collimation and record the following values:

CVV I/F flange tilt from +Y Position 2				Mean
V =	89.9980°	89.9986°	89.9985°	89.9984°
	Measurement Date: 6.08.07		Measurement Time: 17:20	

3.2 Measurements from +Z side: Tilt about Y-Axis

23. Rotate PLM such that mechanical +Z-axis is directed towards theodolite

24. Set up theodolite in at position T0 such that ATP can be viewed from this position.

25. Direct theodolite towards ATP, achieve auto-collimation and set HZ = 270.0000 deg.

26. Rotate theodolite back to Hz = 0.0000 deg.

27. Put reference cube onto CVV I/F flange at position C0, orient it such that theodolite achieves auto-collimation and record the following values:

CVV I/F flange tilt from +Z Position 0				Mean
V =	90.0073°	90.0082°	90.0083°	90.0079°
	Measurement Date: 6.08.07		Measurement Time: 16:25	

28. Set up theodolite in at position T1 such that ATP can be viewed from this position.

29. Direct theodolite towards ATP, achieve auto-collimation and set HZ = 270.0000 deg.

30. Rotate theodolite back to Hz = 0.0000 deg.

31. Put reference cube onto CVV I/F flange at position C1, orient it such that theodolite achieves auto-collimation and record the following values:

CVV I/F flange tilt from +Z Position 1				Mean
V =	90.0059°	90.0060°	90.0061°	90.0079
	Measurement Date: 6.08.07		Measurement Time: 16:45	

32. Set up theodolite in at position T2 such that ATP can be viewed from this position.

33. Direct theodolite towards ATP, achieve auto-collimation and set HZ = 270.0000 deg.

34. Rotate theodolite back to Hz = 0.0000 deg.

35. Put reference cube onto CVV I/F flange at position C2, orient it such that theodolite achieves auto-collimation and record the following values:

CVV I/F flange tilt from +Y Position 2				Mean
V =	90.0039°	90.0042°	90.0043°	90.0041°
	Measurement Date: 6.08.07		Measurement Time: 17:15	

Rotary Table levelling: Level 1 A = −0° 00' 01"
Level 2 B = 0° 00' 00"

The measurements performed according to Sect. 3.1 and 3.2 provide the tilt of the interface flange about Y- and Z-axis.

See data evaluation.

Date/Time: 6.08.07

Personnel:

Name/Signature: D. Schi[illegible]

Name/Signature: E. [illegible]

Name/Signature: ? [illegible]

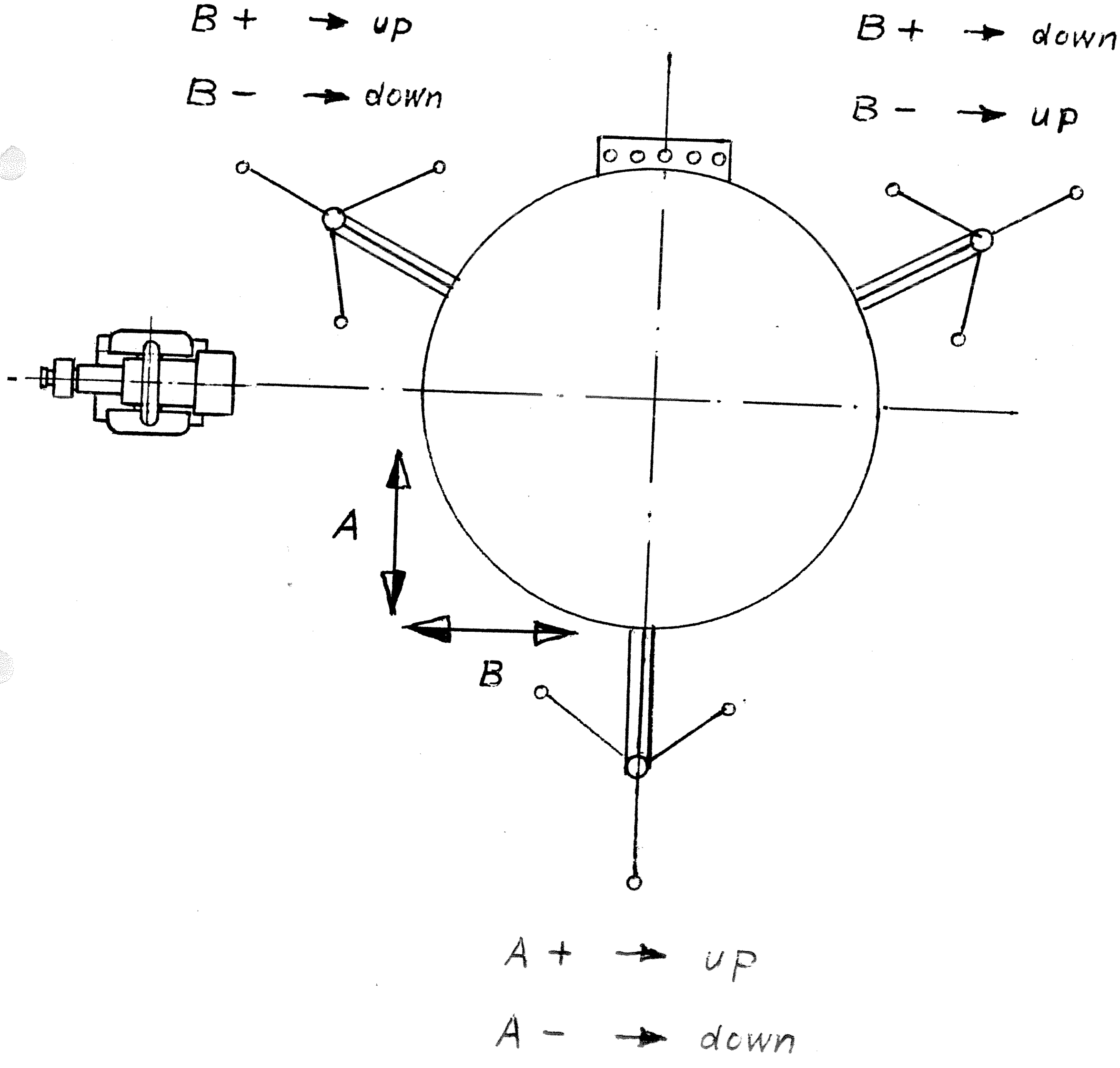
T = 19.9 °C

RH = 51 %

Test performed in cleanroom class 100

STR leg correction in height

to adjust LEVELMETER reading to 0° 00' 00''



END OF DOCUMENT

	Name	Dep./Comp.		Name	Dep./Comp.
	Alberti von Mathias Dr.	ASG23		Schmidt Thomas	AED15
	Baldock Richard	FAE12		Schweickert Gunn	ASG23
	Barlage Bernhard	AED13	X	Sonn Nico	ASG51
X	Bayer Thomas	ASA42		Steininger Eric	AED32
	Brune Holger	ASA45	X	Stritter Rene	AED11
	Edelhoff Dirk	AED2		Suess Rudi	OTN/ASA44
	Fehringer Alexander	ASG13		Theunissen Martijn	DSSA
X	Fricke Wolfgang Dr.	AED 65		Vascotto Riccardo	HE Space
	Geiger Hermann	ASA42		Wagner Klaus	ASG23
	Grasl Andreas	OTN/ASA44		Wietbrock Walter	AET12
	Grasshoff Brigitte	AET12		Wöhler Hans	ASG23
	Hamer Simon	Terma		Wössner Ulrich	ASE252
	Hanka, Erhard	FI552		Zumstein Armin	ASQ42
	Hendrikse Jeffrey	HE Space			
	Hendry David	Terma			
	Hengstler Reinhold	ASA42			
	Hinger Jürgen	ASG23			
X	Hohn Rüdiger	AED65			
X	Hölzle Edgar Dr.	AED32			
	Hopfgarten Michael	AED32			
	Huber Johann	ASA42			
	Hund Walter	ASE252			
X	Idler Siegmund	AED312			
	Ivády von András	FAE12			
X	Jahn Gerd Dr.	ASG23			
	Kalde Clemens	ASM2	X	ESA/ESTEC	ESA
X	Kettner Bernhard	AET42	X	Thales Alenia Space Cannes	TAS-F
	Klenke Uwe	ASG72		Thales Alenia Space Torino	TAS-I
	Knoblauch August	AET32			
	Koelle Markus	ASA43		**Instruments:**	
X	Koppe Axel	AED312	X	MPE (PACS)	MPE
X	Kroeker Jürgen	AED65	X	RAL (SPIRE)	RAL
	La Gioia Valentina	Terma	X	SRON (HIFI)	SRON
	Lang Jürgen	ASE252			
X	Langenstein Rolf	AED15			
X	Langfermann Michael	ASA41		**Subcontractors:**	
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	Platzer Wilhelm	AED2		EADS CASA Espacio	ECAS
	Reichle Konrad	ASA42		European Test Services	ETS
	Runge Axel	OTN/ASA44		Patria New Technologies Oy	PANT
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