ALCATEL
SPACE

HERSCHEL / PLANCK

Planck satellite CQM acoustic test specification
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Product Code:220000

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ENREGISTREMENT DES EVOLUTIONS / *CHANGE RECORDS*

ISSUE	DATE	§ : DESCRIPTION DES EVOLUTIONS *§ : CHANGE RECORD*	REDACTEUR *AUTHOR*
2	04/06/2004	Taking into account PPLM CDR remarks (see minutes H-P-ASP-MN-4966, 25/05/04)	
3	01/09/04	Additional strain gauges on the LFI (page 15, 16 and annex 2 page 54 and 55)	P Lodereau
3	01/09/04	Clarification of the objectives §1	P. Armand
3	01/09/04	Additional very low level §6.1 §6.2 §6.4.2	P. Armand
3	01/09/04	Typo Error	P. Armand
3	01/09/04	Correction of section number ref.	P. Armand
3	04/10/04	Added instrumentation for PR, SR and HFI 18K stage	D. Rébuffat

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1. INTRODUCTION

The Planck CQM early acoustic test main objectives are:

- Validate the Planck PLM instruments random specifications [RD 01], especially at the FPU interface
- Verify subsystems random and acoustic environment in flight configuration

The qualification level run will be confirmed during the test depending of the hardware behaviours especially FPU's (LFI dummy & HFI STM).

2. APPLICABLE AND REFERENCES DOCUMENT

2.1 Applicable documents

Ref.	*No.*	*Issue/date*	*Title*
AD 1		Iss. 3 Rev. 0	ARIANE 5 User's Manual
AD 2	H-P-1-ASPI-SP-0030	Iss. 4.2	Herschel / Planck environment and tests requirements
AD 3	H-P-1-ASPI-PL-0055	Iss. 2 R. 2	PA Plan

2.2 Reference documents

Ref.	*No.*	*Issue/date*	*Title*
RD 1	SCI-PT-IIDA-04624	Iss. 3 Rev. 2	Instrument Interface Document
RD 2	H-P-3-ASP-TN-0671	Iss. 1.0	Planck CQM technical description
RD 3	TN-PH293-400440-IAS	Iss.01 Rev. 01	HFI FPU Structural model Test instrumentation ICD

3. ORGANISATION AND RESPONSABILITIES

3.1 General

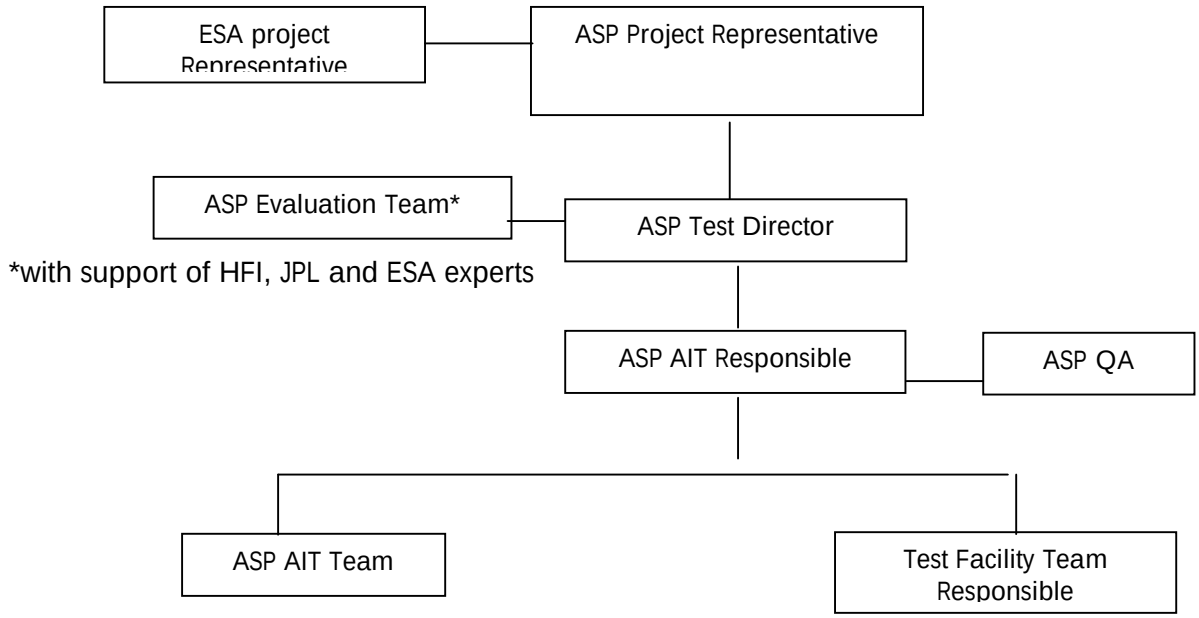
ESA
+ Project representative
+ Go ahead for instrument for each run

ASP is in charge of :
+ Engineering activities :
  - Preparation (test definition, except for instrument) and test execution
  - Spacecraft data analysis and go ahead for each run
+ AIT activities :
  - Spacecraft mechanical assembly, checkouts
  - Test management (reviews, leading procedure, daily meeting, key points)
  - Dedicated GSE installation / validations and use
  - Responsible for the test management and for interface between the Planck satellite and the test facility
+ Test facility activities
  - Preparation and execution on the test facility
  - Test instrumentation installation

HFI, JPL and ESA are in charge of:
+ Preparation, test instrumentation for HFI FPU STM and PACE
+ Interpretation of instrument results after each run

3.2 Organisation

The overall organization during the test is as follows:



3.3 Detail of Alcatel Responsibilities

The overall Alcatel responsibility during test is as follows :

Organization	Responsibility
ASP Project Representative	➢ Alcatel projects interface ➢ Represents ASP during the test and he is also the I/F point with the ESA representative
ASP Test Director	➢ Issue the test specification of the relevant test to be performed ➢ Go ahead for the test reviews (TRR, key point, PTR) ➢ Single point of contact with the ASP Evaluation team concerning the test result status.
ASP Evaluation Team	➢ Evaluate the test data in order to help the test director concerning the "Key point" status.
ASP AIT responsible	➢ Manage all activities done during the test including "key point" meeting. ➢ I/F point with the Test Facility Team Responsible ➢ Responsible of the ASP AIT Team ➢ Issue the leading procedure of all activities ➢ Organize the Daily meeting ➢ Initialize NCR…
ASP QA	➢ Organize the review (TRR/PTR…) ➢ Minute the running meeting (Key point)
Test Facility Team	➢ Issue the test facility leading procedure (in case of different activities) ➢ Issue the relevant test procedures ➢ I/F point with the ASP AIT responsible ➢ Operate the Test facilities ➢ Provide the test data ➢ Issue the test report.

3.4 Test Review Board

The people involved in TRR, PTR will be at least :

- ASP Project Representative
- ASP Test Director
- ASP AIT Responsible
- Test facility Responsible
- QA Manager
- ESA, co-ordinating HFI and JPL support

4. PLANCK CQM EARLY ACOUSTIC TESTS MODEL CONFIGURATION

4.1 Tested model description

See also [RD 2] for more details.

The Planck CQM Acoustic (CQMA) test model is composed of 2 main parts :

- The PPLM (cryo-structure + telescope) QM model, delivered by ALCATEL (sub-contracted to CSAG)
- The SVM dummy not "thermally" equipped, delivered by ALCATEL (sub-contracted to APCO). The VIS lower ring is closed by a dedicated tool plate. The sub-platform central hole is closed by an SLI.

The PPLM QM model will be equipped with the following equipment :
- CQM PACE on +Y side delivered by JPL
- Primary reflector dummy delivered by ALCATEL (sub-contracted to CSAG)
- Secondary reflector dummy delivered by ALCATEL (sub-contracted to CSAG)
- LFI FPU MTD delivered by ALCATEL (sub-contracted to LABEN), which is structurally flight representative (STM)
- HFI FPU mechanical model delivered by HFI/ESA

Simple mass dummies will be manufactured by ALCATEL for the following parts :

- PACE for -Y side : MD on V-grooves and FPU
- Upper WG support structure : MD on PR panel
- Pipes 0.1K and 4K : MD on V-grooves and lower beam
- Bellow : MD on PR panel
- JFET : MD on PR panel (with I/F blades)
- BEU and PAU boxes : MD on sub-platform

4.2 Tested model instrumentation

The tested model instrumentation is performed via accelerometers and strain gauges and have to fulfil the layout described in appendix 1 and 2.

The instrumentation is a compromise between the following constraints :
➤ measurement of the main subsystems vibration levels
➤ comparison with sub-systems tests results
➤ accelerometers mounting and dismounting accessibility

4.2.1 Accelerometers attachment

The accelerometers and associated cables have to fulfil to the following requirements, according to [AD 02] :
➤ A good behaviour during tests
➤ No damage during accelerometers removing
➤ No pollution generated

4.2.2 Accelerometers / strain gauges dismounting

The accelerometers and strain gauges will be dismounted after control low level.

4.2.3 Accelerometers and strain gauges list

In order to verify that the PPLM primary structure has a similar behaviour as during CSAG cryo-structure and telescope QM test campaign, some accelerometers have been added on V-grooves and baffle on relevant locations identical to CSAG instrumentation.

There are 2 types of coordinate systems used for defining accelerometers directions :

- **Cylindrical** coordinate system : Z axis identical to X satellite axis, coordinates expressed in R (radial), T (tangential), Z (longitudinal).
  Note : for the accelerometers mounted on the V-grooves, the Z axis is actually the out of plane direction (slightly different form X satellite axis).

- **Local** coordinate system : ⊥ perpendicular to mounting plane, Y parallel to Y satellite axis, // third direction.
  Note : for the FPU, ⊥ corresponds to Z RDP (instrument coordinate frame) direction.

Satellite coordinate system is presented on figure 1.

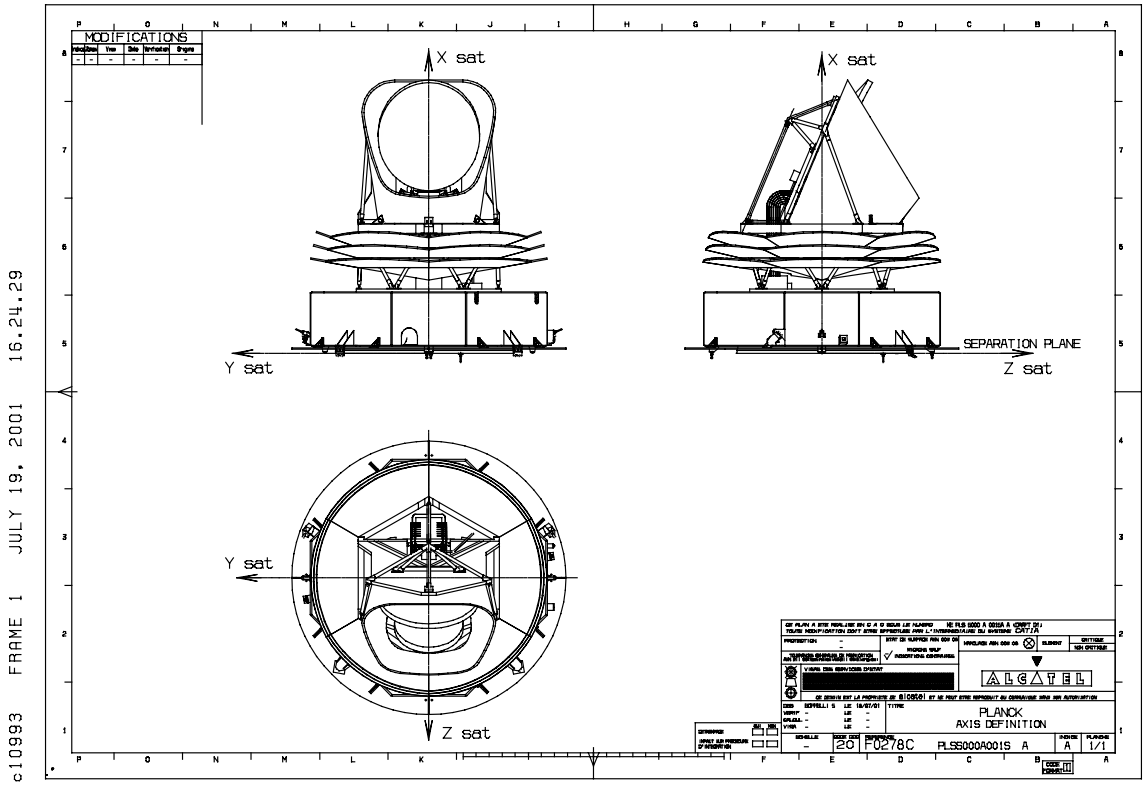


Figure 1: PLANCK Spacecraft Axes

List of accelerometers is given in table 2 and locations are described in appendix 1.

Ref. Accelerometer	Coordinate system
SUB1//	Local
SUB2Y	Local
SUB3⊥	Local
SUB4//	Local
SUB5Y	Local
SUB6⊥	Local
SUB7⊥	Local
SVM15R *	Cylindrical
SVM16T *	Cylindrical
SVM17Z *	Cylindrical
SVM18⊥	Local
SVM19⊥	Local
SVM20⊥	Local
SVM21⊥	Local
GVA30Z	Cylindrical
GVA31Z	Cylindrical
GVA32R *	Cylindrical
GVA33T *	Cylindrical
GVA34Z *	Cylindrical
GVA35Z *	Cylindrical
GVA36R *	Cylindrical
GVA37T *	Cylindrical
GVA38Z *	Cylindrical
GVA39Z *	Cylindrical
GVA40Z	Cylindrical
GVB50Z	Cylindrical
GVB51Z	Cylindrical
GVB52R *	Cylindrical
GVB53T *	Cylindrical
GVB54Z *	Cylindrical
GVB55Z *	Cylindrical
GVB56R *	Cylindrical
GVB57T *	Cylindrical
GVB58Z *	Cylindrical
GVB59Z *	Cylindrical
GVC70Z	Cylindrical
GVC71Z	Cylindrical
GVC72R *	Cylindrical
GVC73T *	Cylindrical
GVC74Z *	Cylindrical
GVC75Z *	Cylindrical
GVC76R *	Cylindrical
GVC77T *	Cylindrical
GVC78Z *	Cylindrical
GVC79R *	Cylindrical
GVC80T *	Cylindrical

GVC81Z *	Cylindrical
GVC82R *	Cylindrical
GVC83T *	Cylindrical
GVC84Z *	Cylindrical
GVC85Z *	Cylindrical
GVC86Z	Cylindrical
BF100⊥	Local
BF101⊥	Local
BF102⊥	Local
BF103⊥	Local
BF104⊥	Local
BF105⊥	Local
PRP120// *	Local
PRP121Y *	Local
PRP122⊥ *	Local
PRP123// *	Local
PRP124Y *	Local
PRP125⊥ *	Local
PRP126⊥ *	Local
PRP127⊥ *	Local
PRP128// *	Local
PRP129Y *	Local
PRP130⊥ *	Local
PRP131// *	Local
PRP132Y *	Local
PRP133⊥ *	Local
PRP134⊥	Local
PRP135//	Local
PRP136Y	Local
PRP137⊥	Local
PRP138//	Local
PRP139Y	Local
PRP140⊥	Local
PRP141⊥*	Local
SRP150//	Local
SRP151Y	Local
SRP152⊥	Local
SRP153//	Local
SRP154Y	Local
SRP155⊥	Local
FR165R *	Cylindrical
FR166T *	Cylindrical
FR167Z *	Cylindrical
FR168⊥	Local
LB180//	Local
LB181Y	Local
LB182⊥ *	Local

LB183⊥ *	Local
PR200//	Local
PR201Y	Local
PR202⊥	Local
PR203⊥	Local
PR204⊥	Local
PR205⊥	Local
SR206//	Local
SR207Y	Local
SR208⊥	Local
SR209⊥	Local
SR210⊥	Local
FPU220// *	Local
FPU221Y *	Local
FPU222⊥ *	Local
FPU223// *	Local
FPU224Y *	Local
FPU225⊥ *	Local
FPU226⊥	Local
FPU230//	Local
FPU231Y	Local
FPU232⊥	Local
FPU233//	Local
FPU234Y	Local
FPU235⊥	Local
FPU236//	Local
FPU237Y	Local
FPU238⊥	Local
FPU239//	Local
FPU240Y	Local
FPU241⊥	Local
FPU242//	Local
FPU243Y	Local
FPU244⊥	Local
FPU245//	Local
FPU246Y	Local
FPU247⊥	Local
FPU248//	Local
FPU249Y	Local
FPU250⊥	Local

Table 2: ACCELEROMETERS LIST

All accelerometers with a * are mandatory and must not show any failure during test. For the other accelerometers, failure rate shall not exceed 5%.

List of strain gauges is given in table 3 and locations are described in appendix 2 (see also RD 3 for HFI).

Ref	Location
B1-1 (installed by HFI)	HFI FPU STM internal rod
B1-2 (installed by HFI)	HFI FPU STM internal rod
B2-1 (installed by HFI)	HFI FPU STM internal rod
B2-2 (installed by HFI)	HFI FPU STM internal rod
B3-1 (installed by HFI)	HFI FPU STM internal rod
B3-2 (installed by HFI)	HFI FPU STM internal rod
B5-1 (installed by HFI)	HFI FPU STM internal rod
B5-2 (installed by HFI)	HFI FPU STM internal rod
B6-1 (installed by HFI)	HFI FPU STM internal rod
B6-2 (installed by HFI)	HFI FPU STM internal rod
B7-1 (installed by HFI)	HFI FPU STM internal rod
B7-2 (installed by HFI)	HFI FPU STM internal rod
SG01 (installed by JPL)	PACE
SG02 (installed by JPL)	PACE
SG11 (installed by JPL)	PACE
SG12 (installed by JPL)	PACE
SG21 (installed by JPL)	PACE
SG22 (installed by JPL)	PACE
SG23 (installed by JPL)	PACE
SG24 (installed by JPL)	PACE
SG34 (installed by JPL)	PACE
SG41 (installed by JPL)	PACE
SG42 (installed by JPL)	PACE
SG43 (installed by JPL)	PACE
SG44 (installed by JPL)	PACE
SG35 (installed by Alcatel)	PACE
SG36 (installed by Alcatel)	PACE
SGVA1	V-groove 1 edge (top)
SGVA2	V-groove 1 edge (bottom)
SGVB3	V-groove 2 edge (top)
SGVB4	V-groove 2 edge (bottom)
SGLFI51	LFI Strut (–X sat)
SGLFI52	LFI Strut (–X sat)
SGLFI53	LFI Strut (–X sat)
SGLFI54	LFI Strut (–X sat)
SGLFI55	LFI Strut (–X sat)
SGLFI56	LFI Strut (–X sat)
SGLFI61	LFI Strut (–Y sat)
SGLFI62	LFI Strut (–Y sat)
SGLFI63	LFI Strut (–Y sat)
SGLFI64	LFI Strut (–Y sat)
SGLFI65	LFI Strut (–Y sat)
SGLFI66	LFI Strut (–Y sat)
SGLFI71	LFI Strut (Y sat)
SGLFI72	LFI Strut (Y sat)
SGLFI73	LFI Strut (Y sat)

SGLFI74	LFI Strut (Y sat)
SGLFI75	LFI Strut (Y sat)
SGLFI76	LFI Strut (Y sat)

Table 3: STRAIN GAUGES LIST

So, the requested number of channels is :

- 133 channels for accelerometers
- 31 channels for strain gauges (implemented by IAS and JPL for HFI and PACE, except for 2 strain gauges on PACE added by Alcatel)
- 18 additional channels for strain gauges (implemented by Alcatel for LFI)

5. GENERAL TEST CONFIGURATION

5.1 TEST CONFIGURATION

* The test and recording facilities are these of ALCATEL CANNES dynamics laboratory.
* The tested model defined on 4.1 is mounted on a dolly with bladders.
* A dedicated tool plate will close the VIS lower ring in order to avoid unrealistic cavity effects.

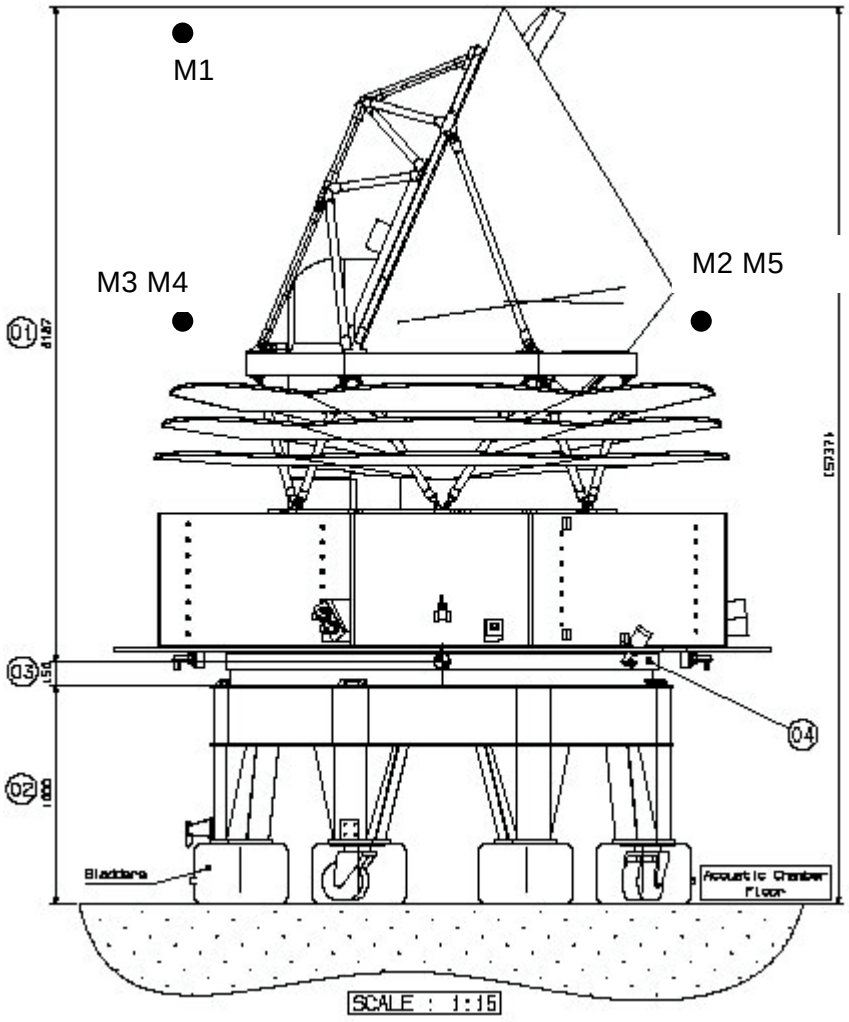


Figure 2 : acoustic test configuration – microphones position

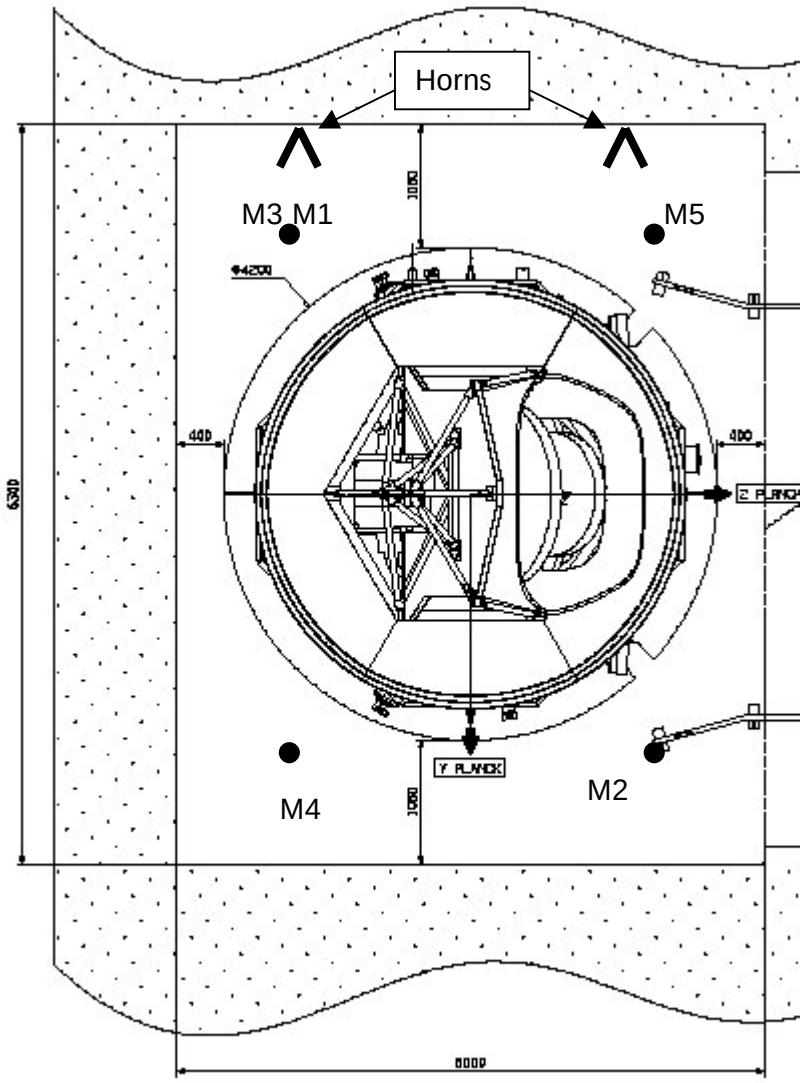


Figure 3 : acoustic test configuration – microphones position

Note : figures 2 and 3 correspond to the FM acoustic test configuration. Solar arrays are not mounted for the CQMA acoustic tests.

Microphones layout consist of 4 microphones (M2 to M5) located at mid-height of PPLM, plus a fifth one (M1) located 2 meters above the M3 (see figures 2 and 3).

A blank test will be performed in order to check the field homogeneity.

5.2 ENVIRONMENTAL CONDITIONS

The following environmental conditions have to be applied during tests (see [AD 02]) :

- Temperature : 22° ± 3°
- Humidity : 55 ± 10%

- Pressure : 970 to 1050 mbar
- Cleanliness : Class 100 000 or better

These environmental conditions shall be controlled and recorded.

5.3 TEST ACCURACY

The following accuracy shall be guarantied:

Microphone level : ± 0.5 dB
Acoustic test time : ± 1 s.
Power spectral density (accelerometers and strain gages) :
± 1.5 dB from 20 to 300 Hz
± 3 dB from 300 to 2000 Hz.

6. ACOUSTIC TESTS

6.1 LEVELS TO BE APPLIED AND ASSOCIATED TOLERANCES

The acoustic tests sequence include:

① One acoustic very low level for preliminary check.
② One acoustic low level for frequency search.
③ One intermediate acoustic level run.
④ One qualification acoustic level run.
⑤ One check out low level run.

6.2 ACOUSTIC TEST LEVELS

6.2.1 Very Low level acoustic test

This test will be performed with the acoustic low level (Qualification level - 12 dB / TBC at the TRR)

6.2.2 Low level acoustic test

This test will be performed with the acoustic low level (Qualification level - 8 dB)

6.2.3 Intermediate acoustic level run

This test will be performed with the acoustic qualification level - 4 dB

6.2.4 Qualification acoustic level run

These tests will be performed with the following qualification acoustic levels

Qualification level test		
OCTAVE BAND CENTRE FREQUENCY (Hz)	**QUALIFICATION LEVEL (dB) Ref.: 0 dB = 2.10^{-5} Pa**	**TEST TOLERANCE (dB)**
31.5	132	-2, +4
63	134	-1, +3
125	139	-1, +3
250	143	-1, +3
500	138	-1, +3
1000	132	-1, +3
2000	128	-1, +3
integrated level	146	-1, +3
Test duration :	2 min	

6.2.5 Check out low level acoustic test

This test will be performed with the acoustic low level (qualification level - 8 dB) and compared to the first low level test.

6.3 TEST PILOTING

5 omnidirectional microphones will be laid around the flight model in order to check and pilot the noise levels of the acoustic environment.
The average level of these 5 microphones is the basis for the tolerance check in each octave band.

6.4 ACOUSTIC SEQUENCE

6.4.1 Pre-test operations

- ❍ Functional Performance Test on PACE : leak under vacuum and electrical check
- ❍ Control and register of the accelerometers positions (pictures and positions in Satellite Coordinate System)
- ❍ Blank test
- ❍ Visual external control before tests
- ❍ Verification of accelerometers and strain gauges

6.4.2 Acoustic tests

① Very Low level acoustic test see § 6.2
This test enables to check the test item dynamic behaviour under acoustic loads

② Low level acoustic test see § 6.2
This test enables to check the test item dynamic behaviour under acoustic loads

③ Intermediate level run see § 6.2

④ Qualification level test. see § 6.2

⑤ Low level run see § 6.2
This test enables to check the good dynamic behaviour of test item after the qualification test by comparison with ①.

6.4.3 Post-test operations

- ❍ Functional Performance Test (same operations on PACE as those performed before test)
- ❍ Visual external control after tests
- ❍ Delivery to Test Director of the subsystems acceleration levels for each test

7. PRODUCT ASSURANCE

The applicable quality provisions for review of the test documents, following the mechanical tests, and the processing of non-conformance, are those provided by [AD 03].

8. FAILURE AND RETEST

If a failure, malfunction or out-of-tolerance performance occurs during or after a test, the test have to be discontinued. Failures shall be properly documented, reported and processed according to relevant PA requirements. The deficiency (including any design defect) will be corrected, and the pertinent environmental procedures repeated until successfully completed.

Nota : in case of failure, a MRB will be held.

9. SUCCESS CRITERIA

9.1 IMMEDIATE SUCCESS CRITERIA

The success criteria of Planck CQMA model acoustic testing which have to be checked after mechanical tests (for each axis) are the following ones :

- The test realisation have to be in accordance with the test specification and the test procedure.
- Initial and final low levels do not show significant discrepancies in frequency and amplitude (± 5 %) .
- All data have to be recorded, fulfilling the constraints of § 4.2.3.

9.2 DELAYED SUCCESS CRITERIA

- No damage detected after visual check following qualification test.
- The Functional Performance tests after acoustic tests have to be performed successfully.

10. TEST REPORTS

Main data and discussion during the test campaign will be reported in relevant "Running Meeting".
The test report (tests laboratory responsibility) following acoustic qualification test shall cover the following data :

- Description and views of the effective test sensors positions in satellite coordinate system.
- Test sequences (dates of actual sequences)
- As-run step by step procedure
- The Noise levels measured by each microphone
- The P.S.D. (Power Spectrum Density) of each accelerometer in narrow band with the overall level. The corresponding files will be delivered in universal format (.uff files, format Dataset58).
- Pre-test and Post-test verifications and measurements results
- Summary of discrepancies/deviations
- Summary and Conclusion

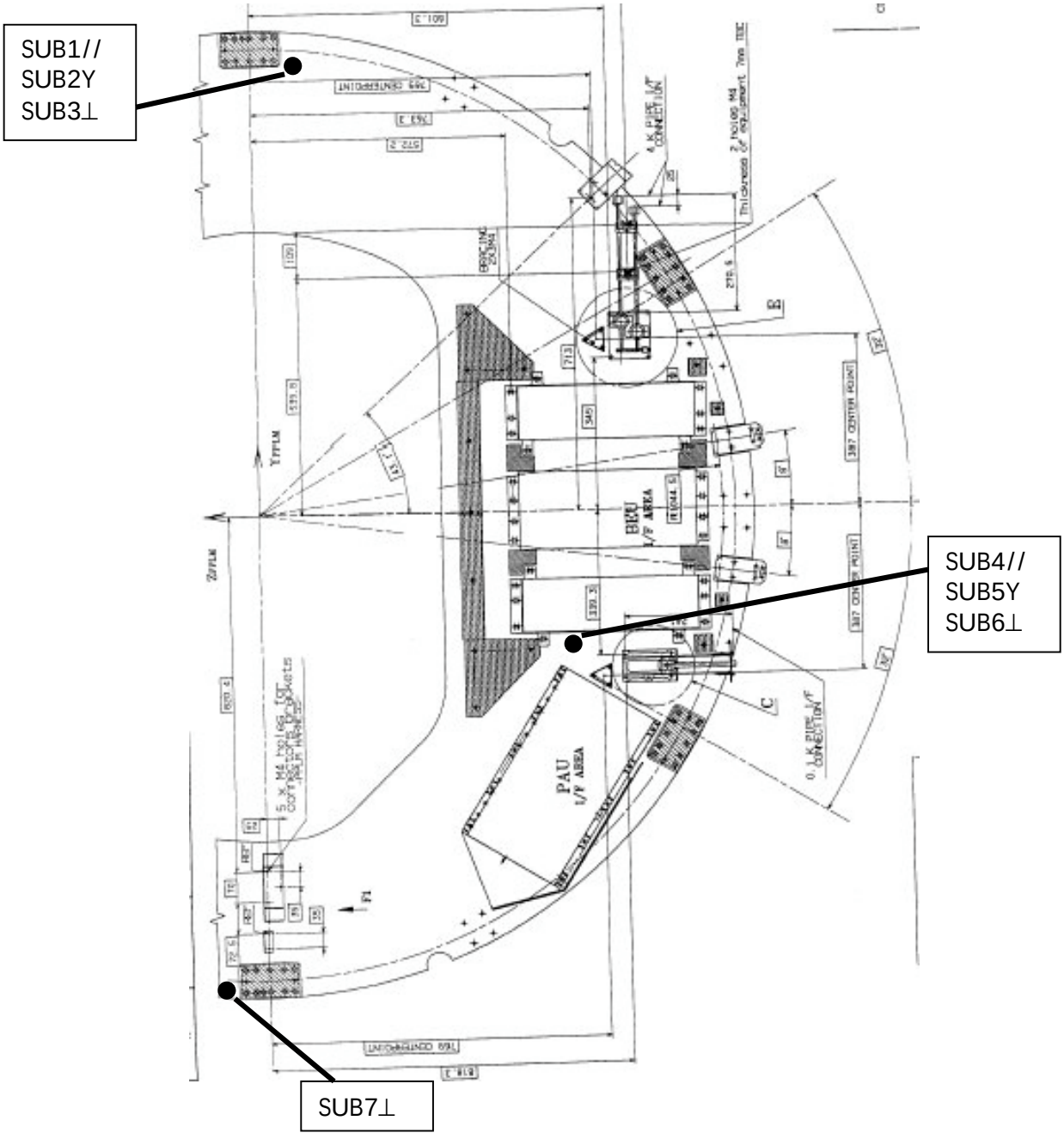
The whole mechanical test exploitation will be performed by ALCATEL CANNES Structural Analysis Team after test report delivery and will be followed by a test evaluation report.

11. APPENDICES

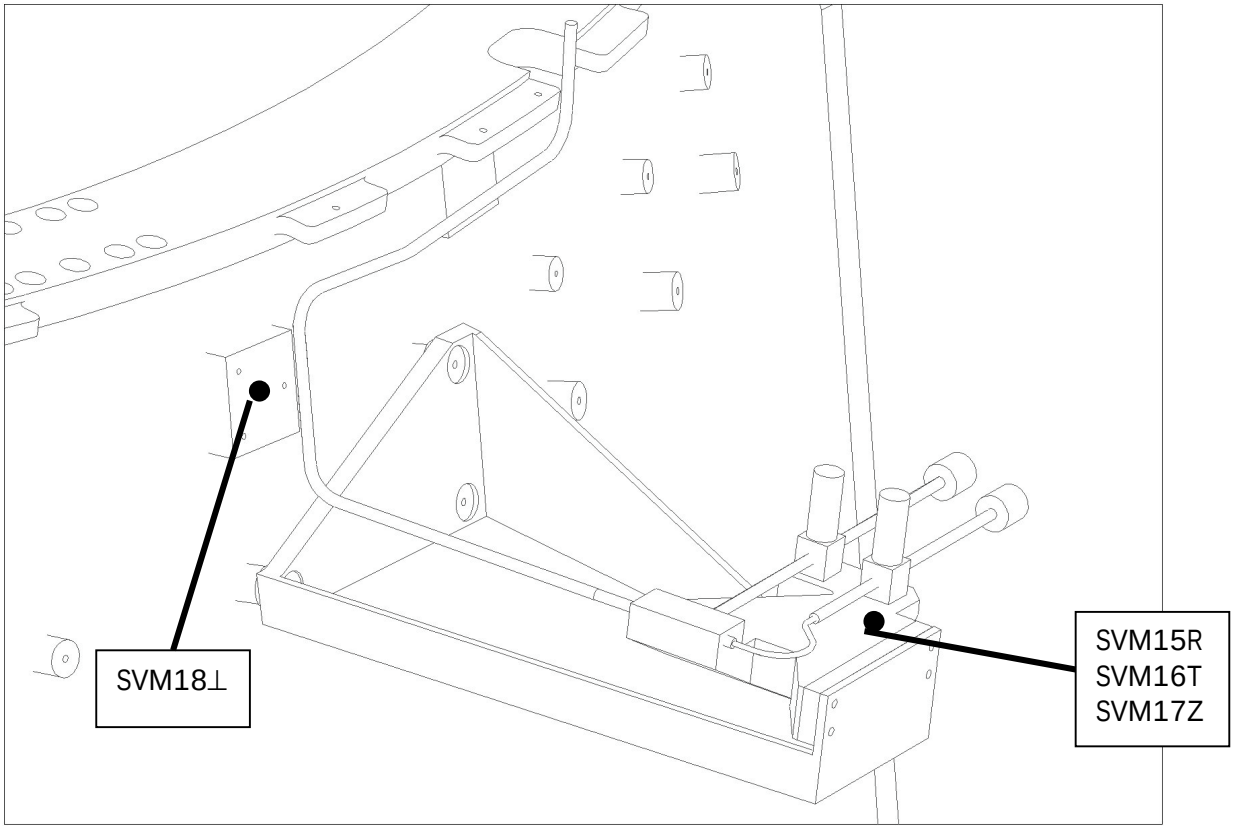
APPENDIX 1 : LOCATION OF ACCELEROMETERS ON PLANCK CQMA

APPENDIX 2 : LOCATION OF STRAIN GAUGES ON PLANCK CQMA

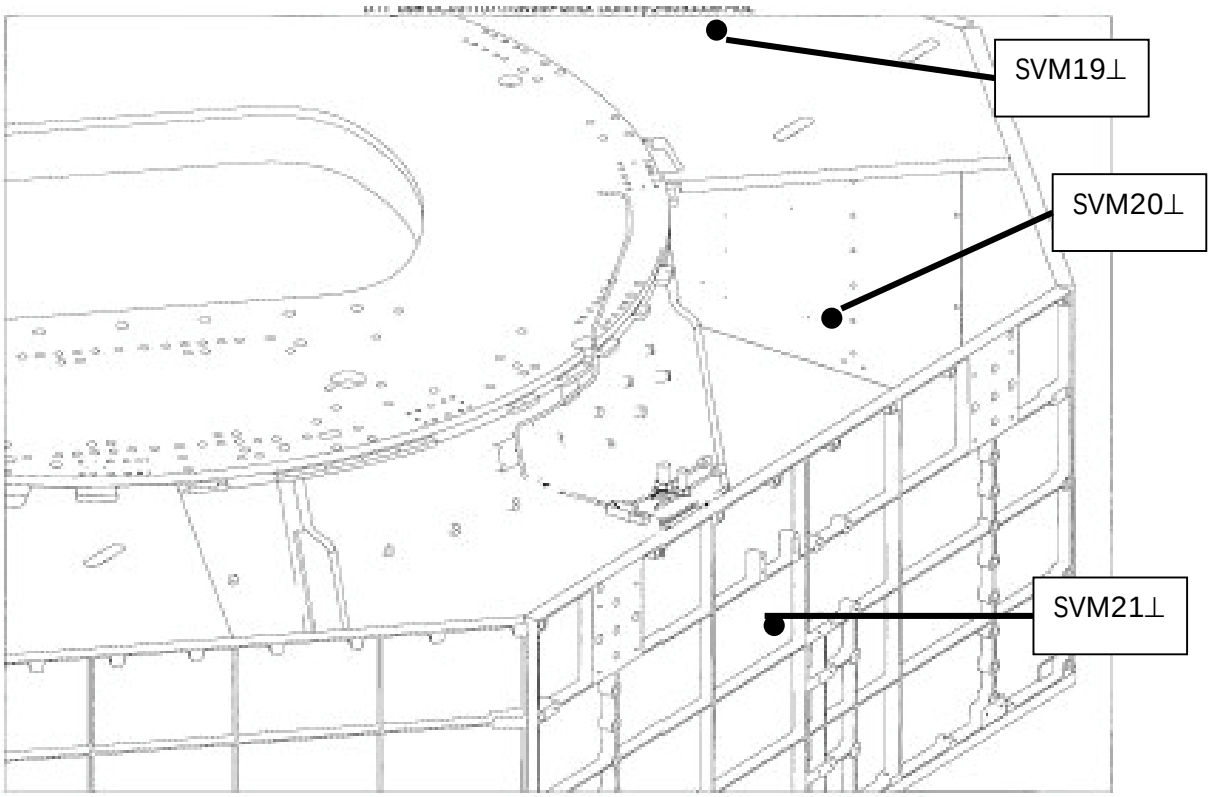
APPENDIX 1
LOCATION OF ACCELEROMETERS ON SUBPLATFORM



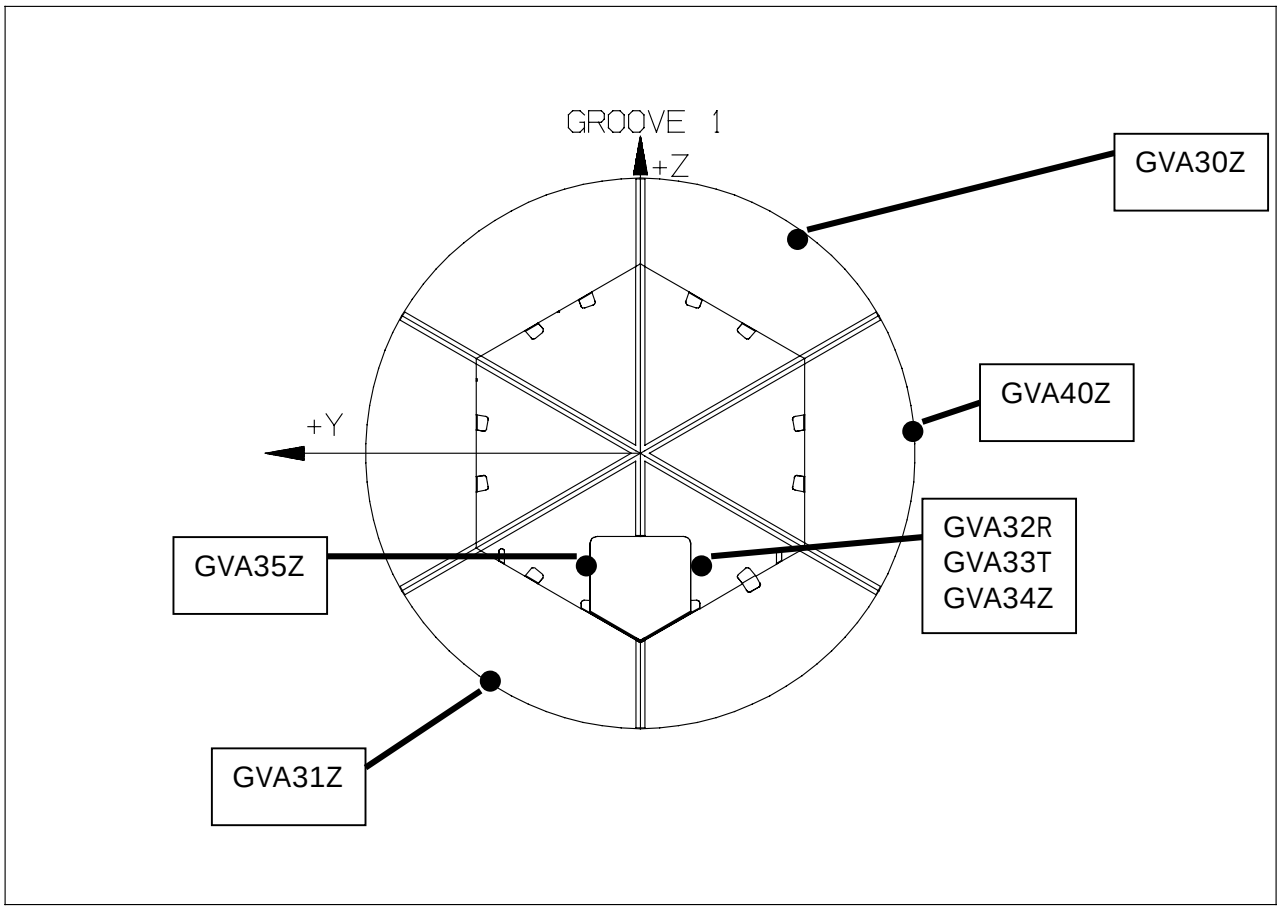
APPENDIX 1
LOCATION OF ACCELEROMETERS ON SVM DUMMY PACE I/F



APPENDIX 1
LOCATION OF ACCELEROMETERS ON SVM DUMMY PANELS

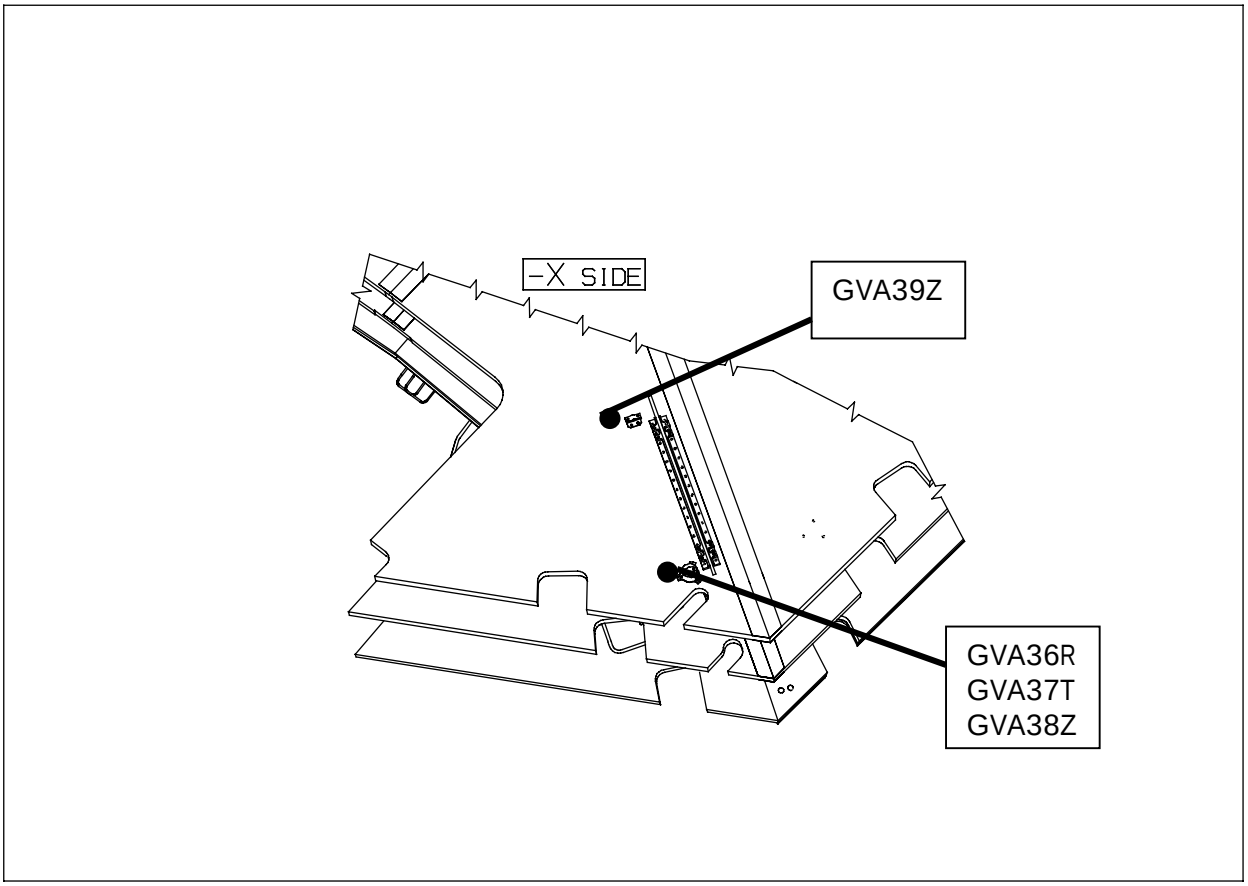


APPENDIX 1
LOCATION OF ACCELEROMETERS ON V-GROOVE 1 (LOWER SIDE)

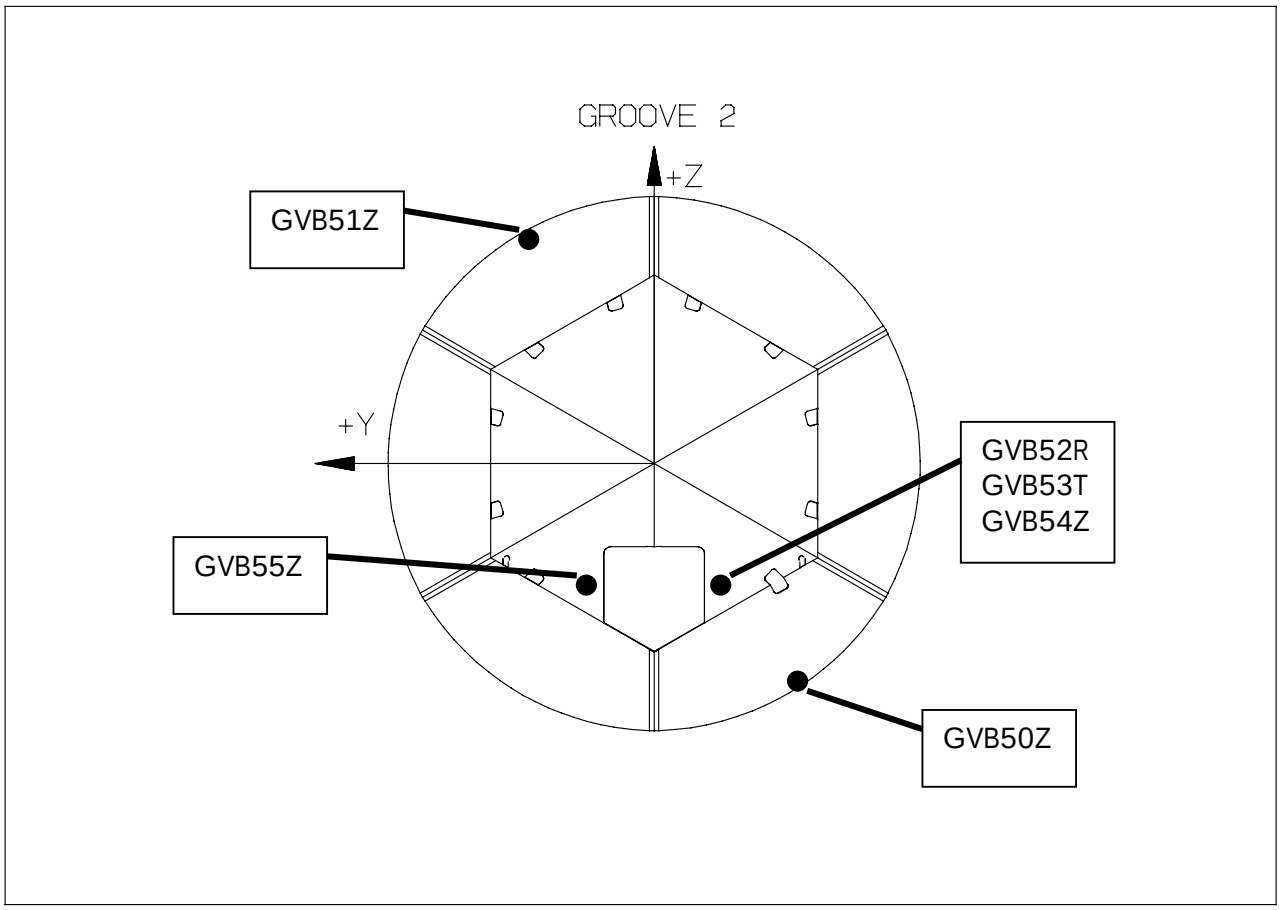


APPENDIX 1
LOCATION OF ACCELEROMETERS ON V-GROOVE 1 (LOWER SIDE – PIPE I/F)

Note : instrumentation shall be made on +Y side (symmetrical to hereunder view)

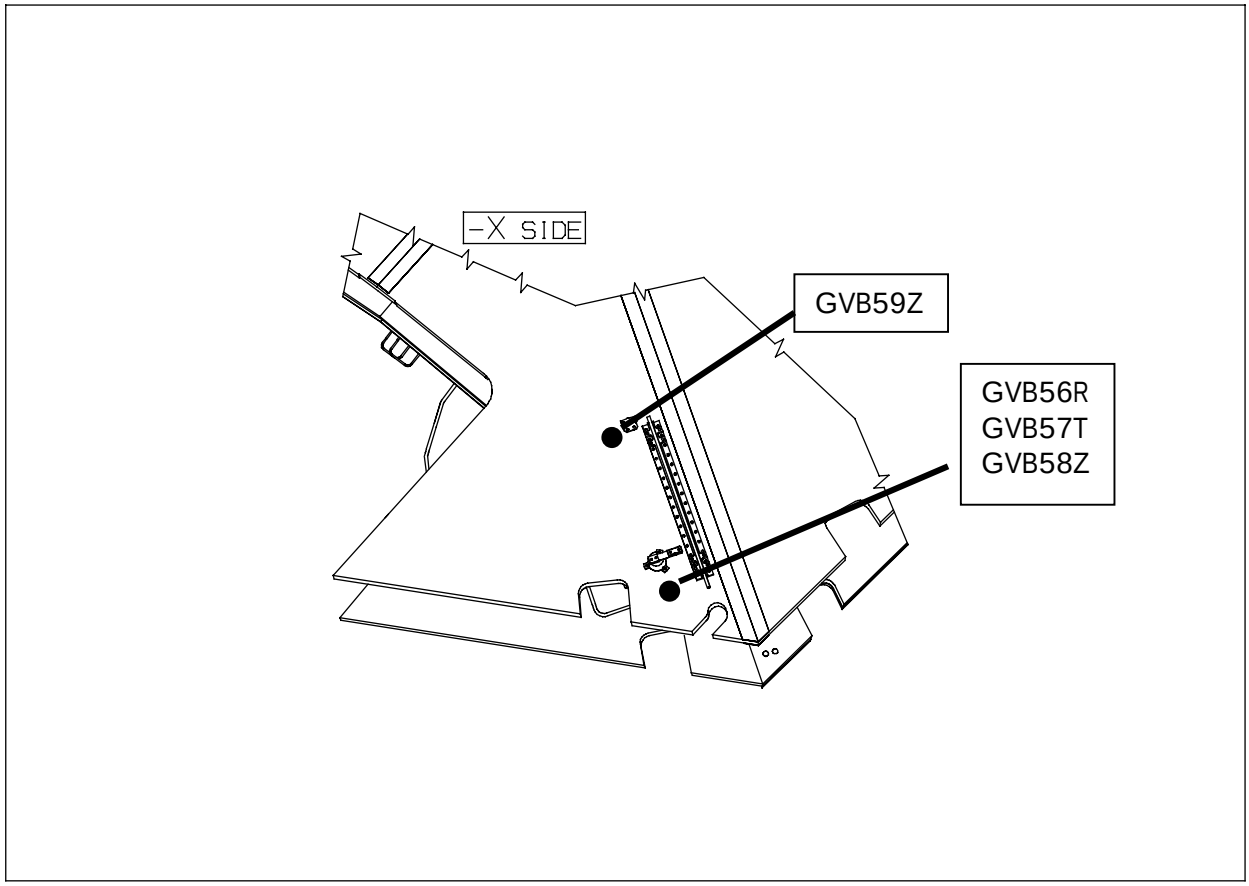


APPENDIX 1
LOCATION OF ACCELEROMETERS ON V-GROOVE 2 (LOWER SIDE)

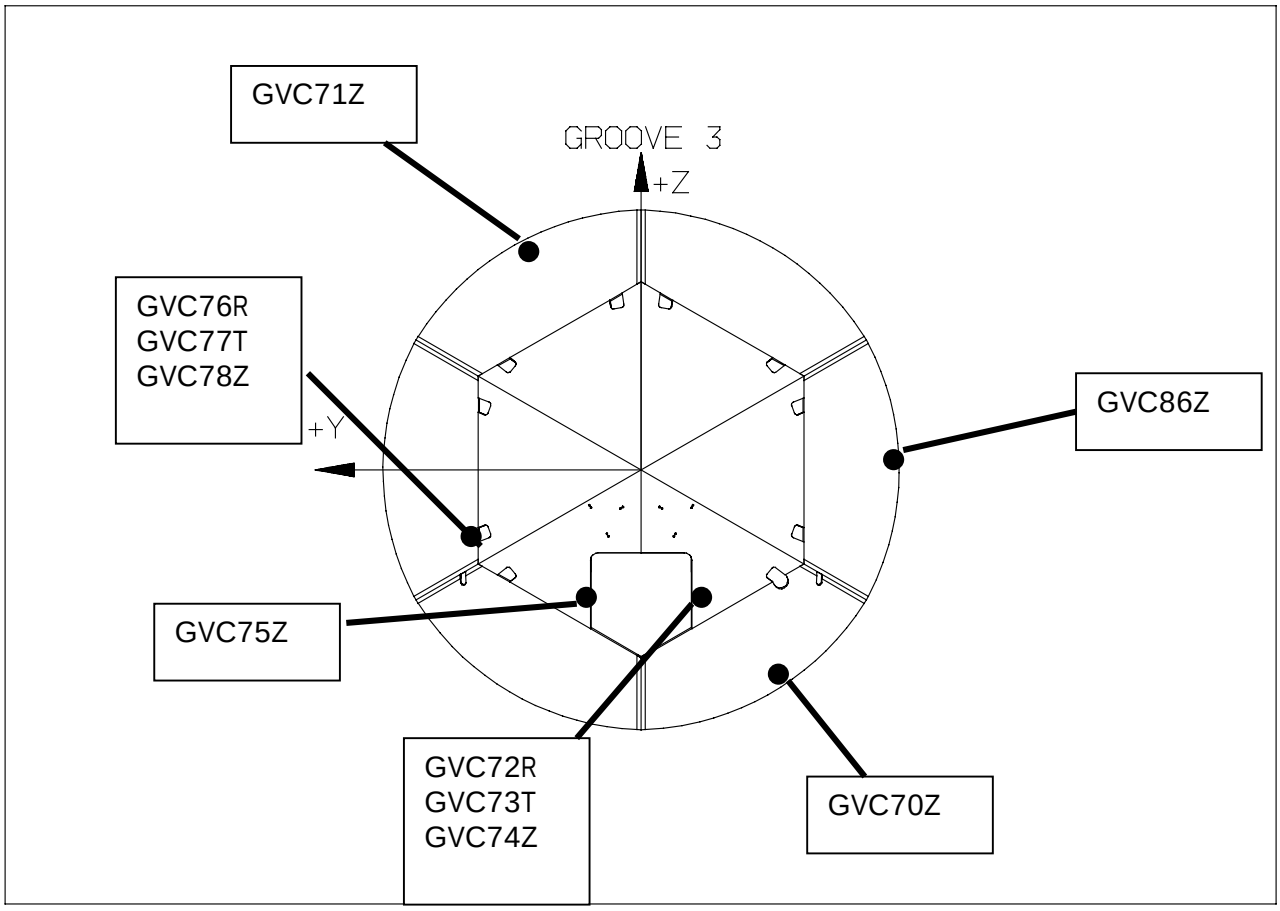


APPENDIX 1
LOCATION OF ACCELEROMETERS ON V-GROOVE 2 (LOWER SIDE – PIPE I/F)

Note : instrumentation shall be made on +Y side (symmetrical to hereunder view)

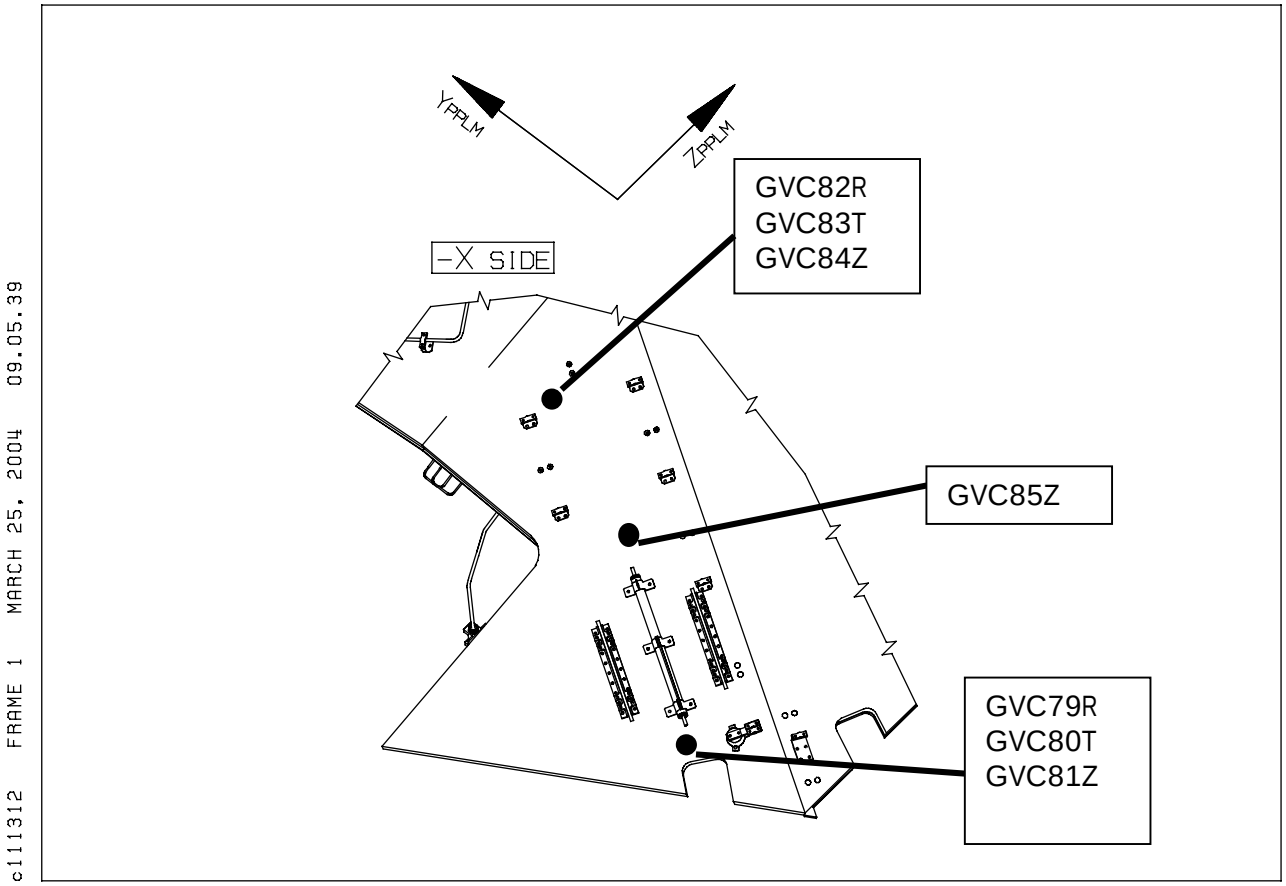


APPENDIX 1
LOCATION OF ACCELEROMETERS ON V-GROOVE 3 (LOWER SIDE)

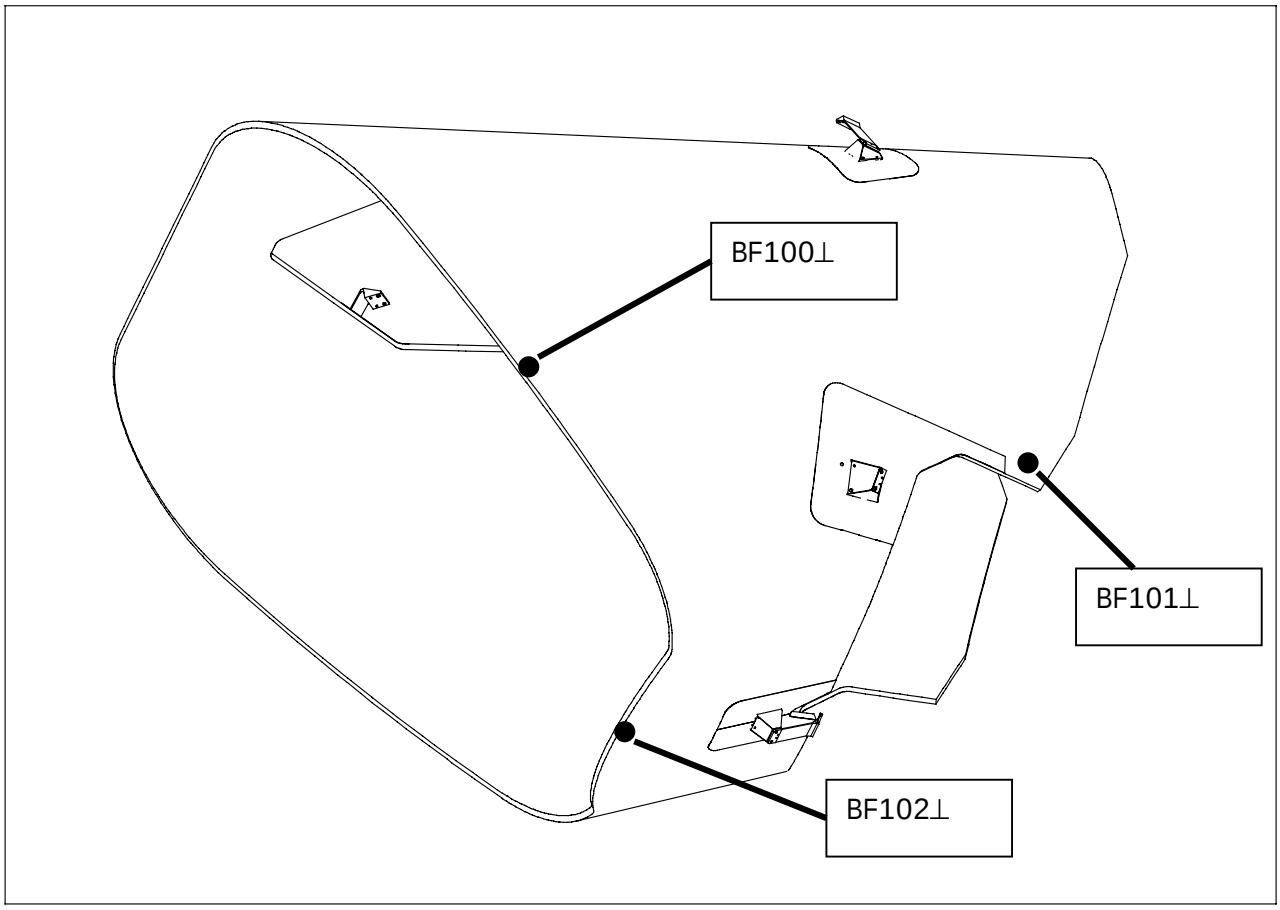


APPENDIX 1
LOCATION OF ACCELEROMETERS ON V-GROOVE 3 (LOWER SIDE – PIPE I/F)

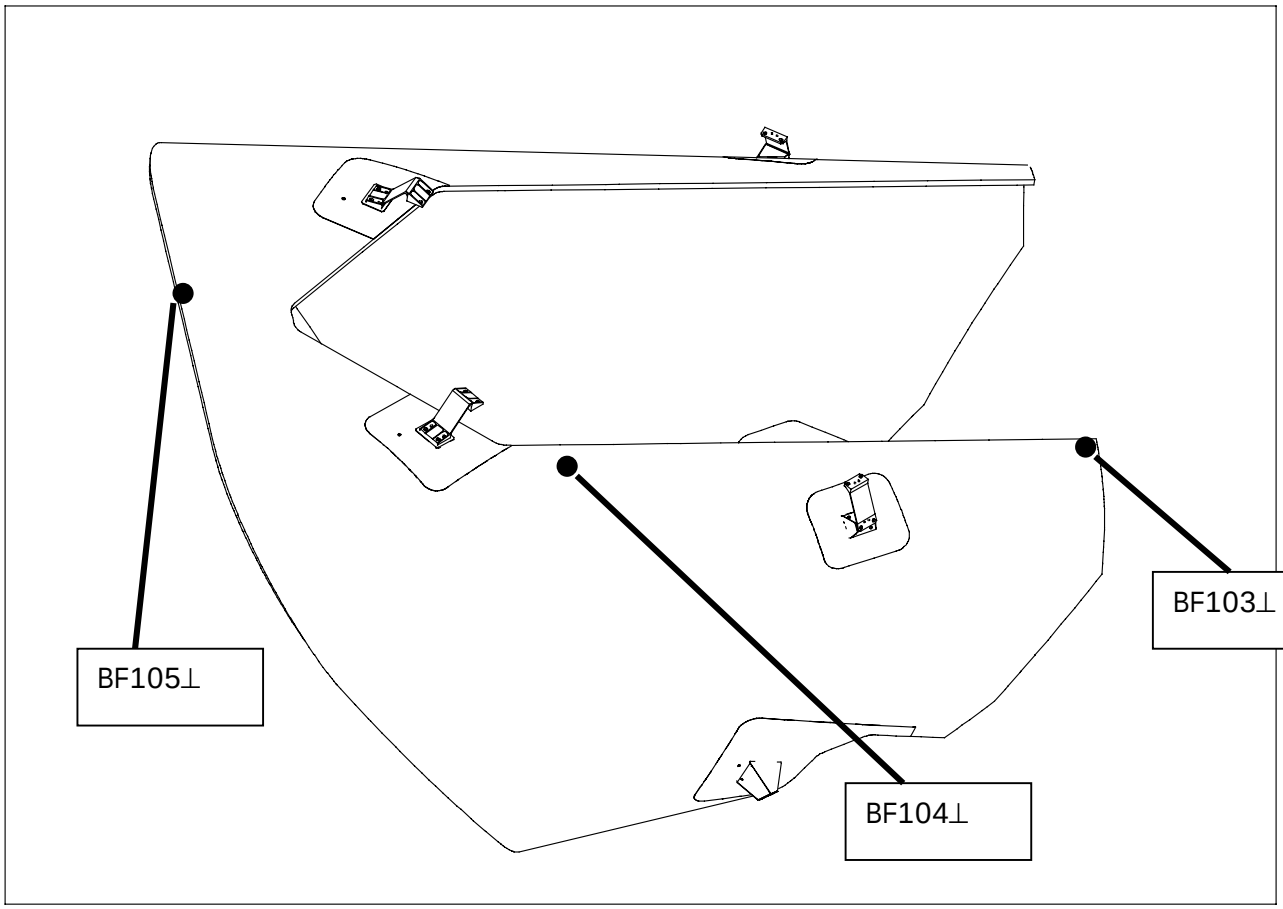
Note : instrumentation shall be made on +Y side (symmetrical to hereunder view)



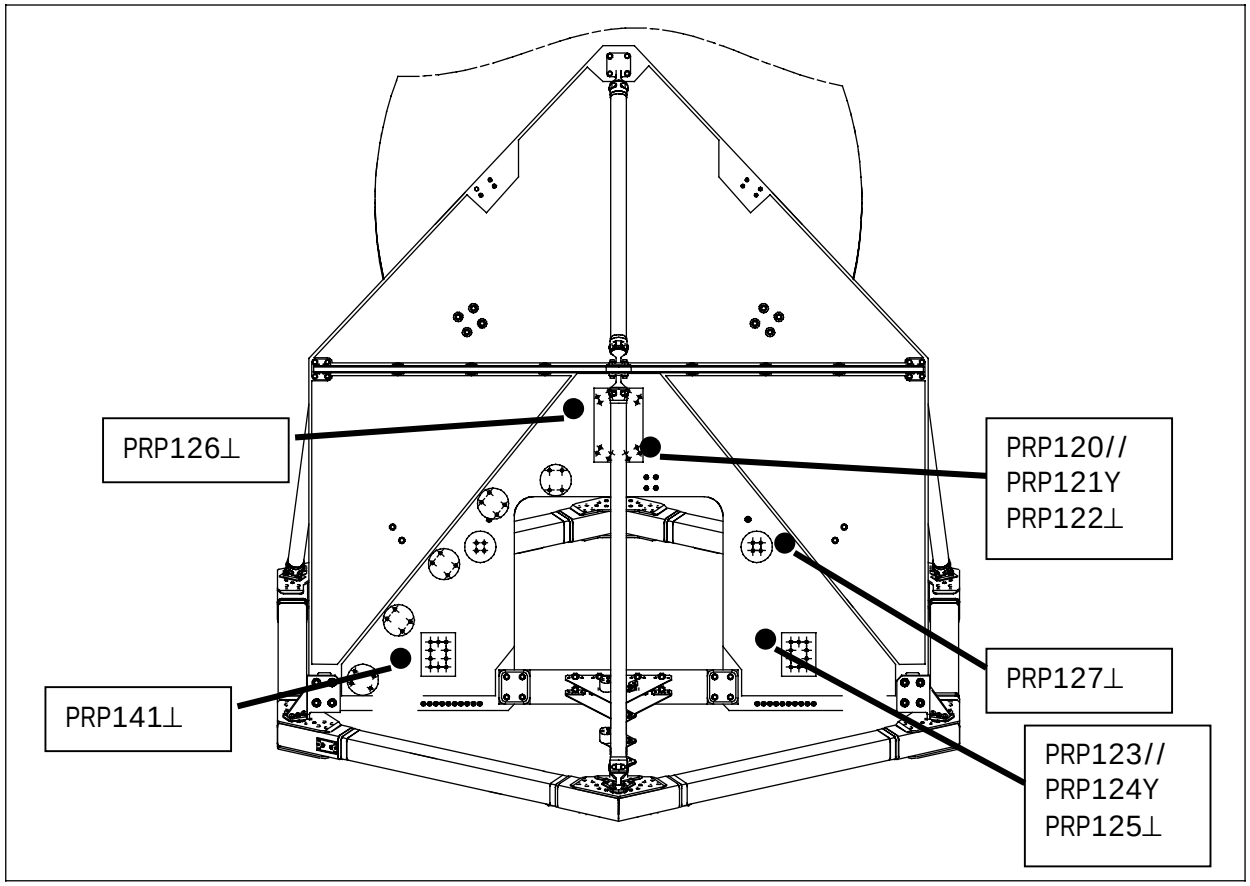
APPENDIX 1
LOCATION OF ACCELEROMETERS ON BAFFLE



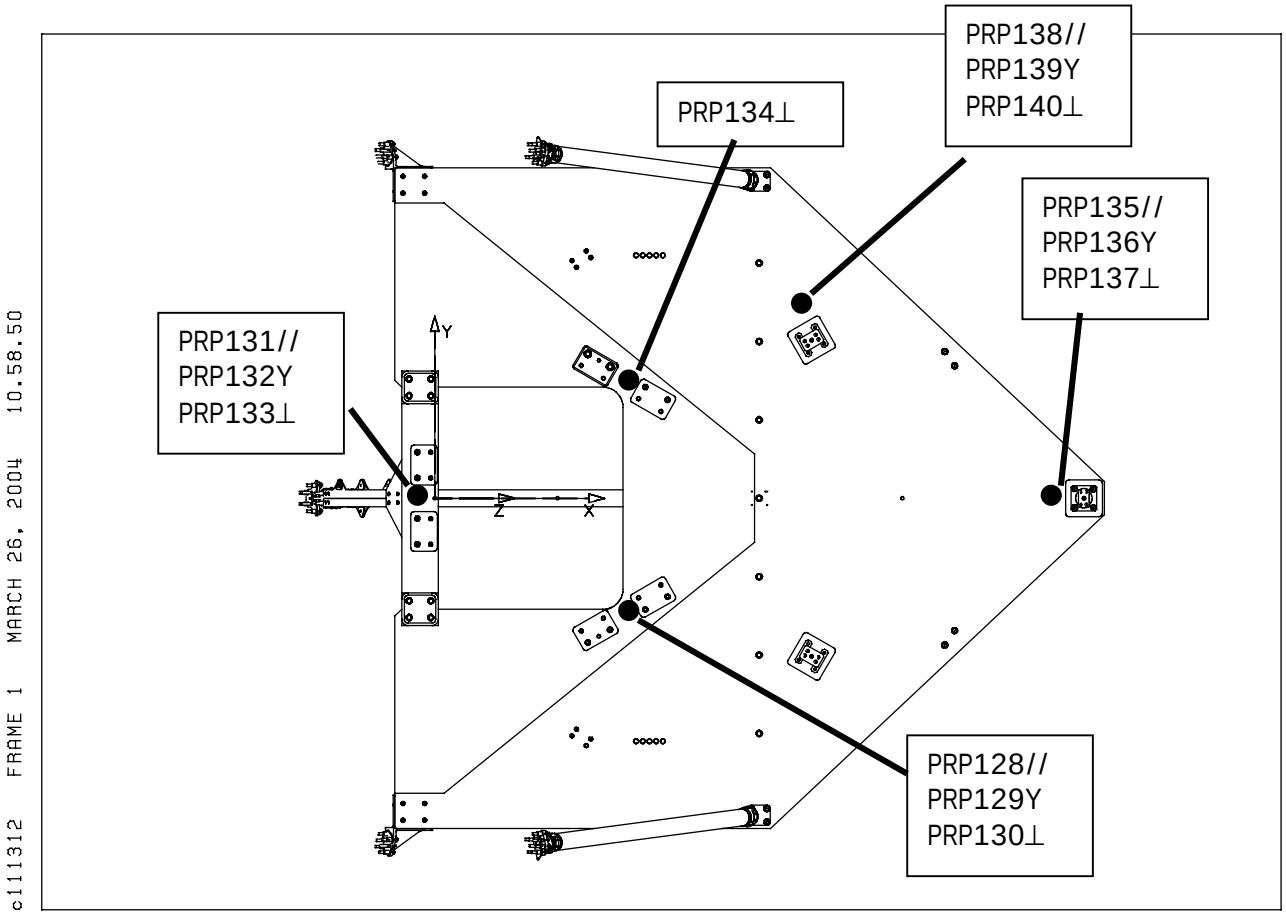
APPENDIX 1
LOCATION OF ACCELEROMETERS ON BAFFLE



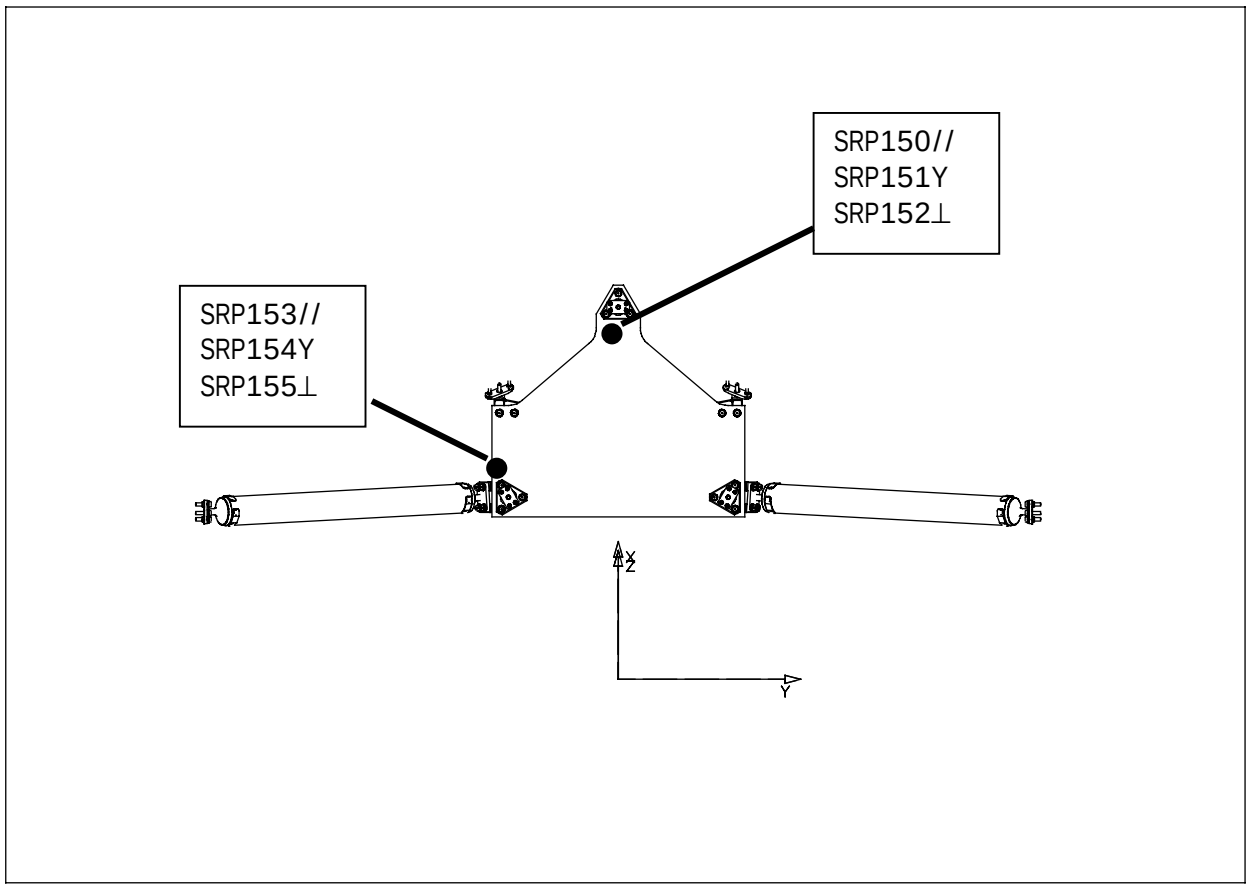
APPENDIX 1
LOCATION OF ACCELEROMETERS ON TELESCOPE PR PANEL (-Z SIDE)



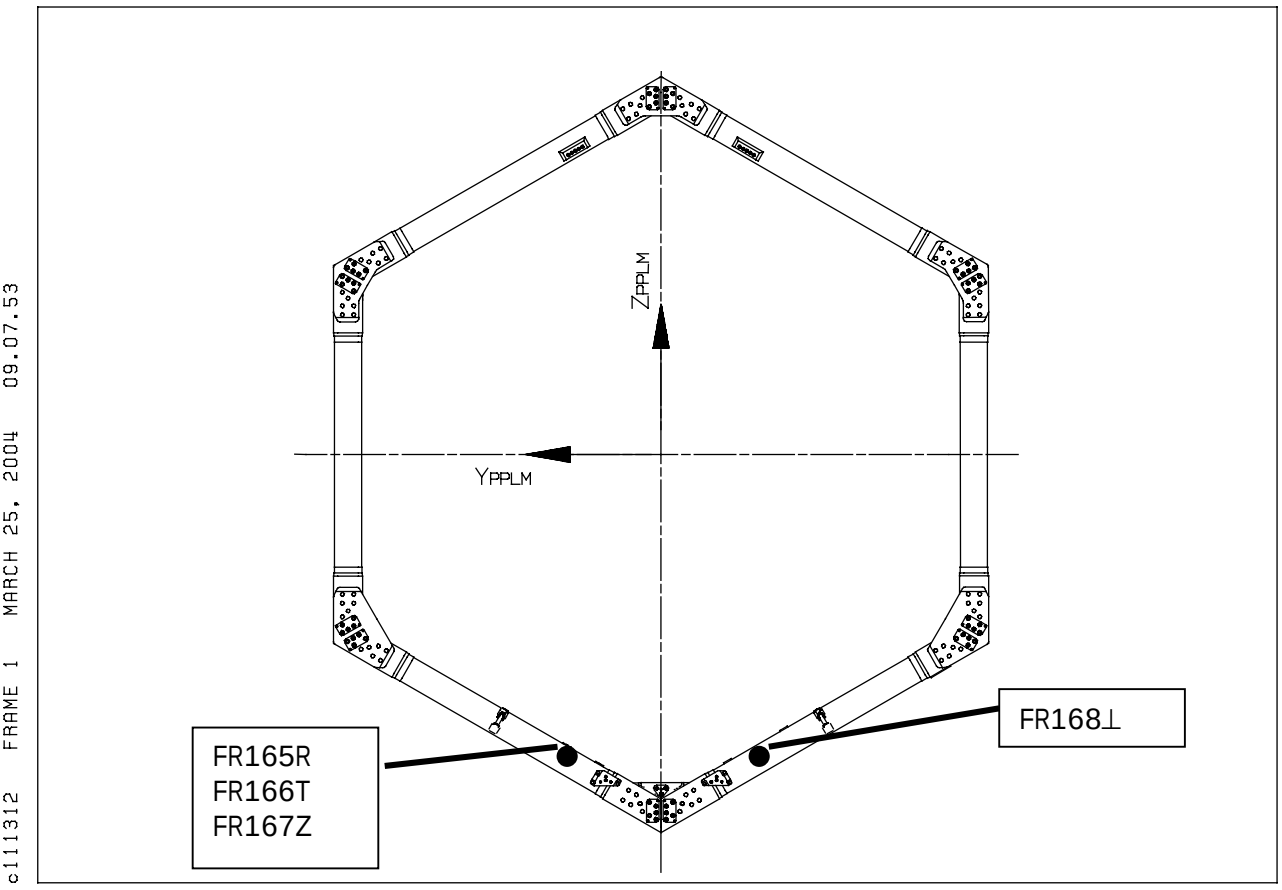
APPENDIX 1
LOCATION OF ACCELEROMETERS ON TELESCOPE PR PANEL (+Z SIDE)



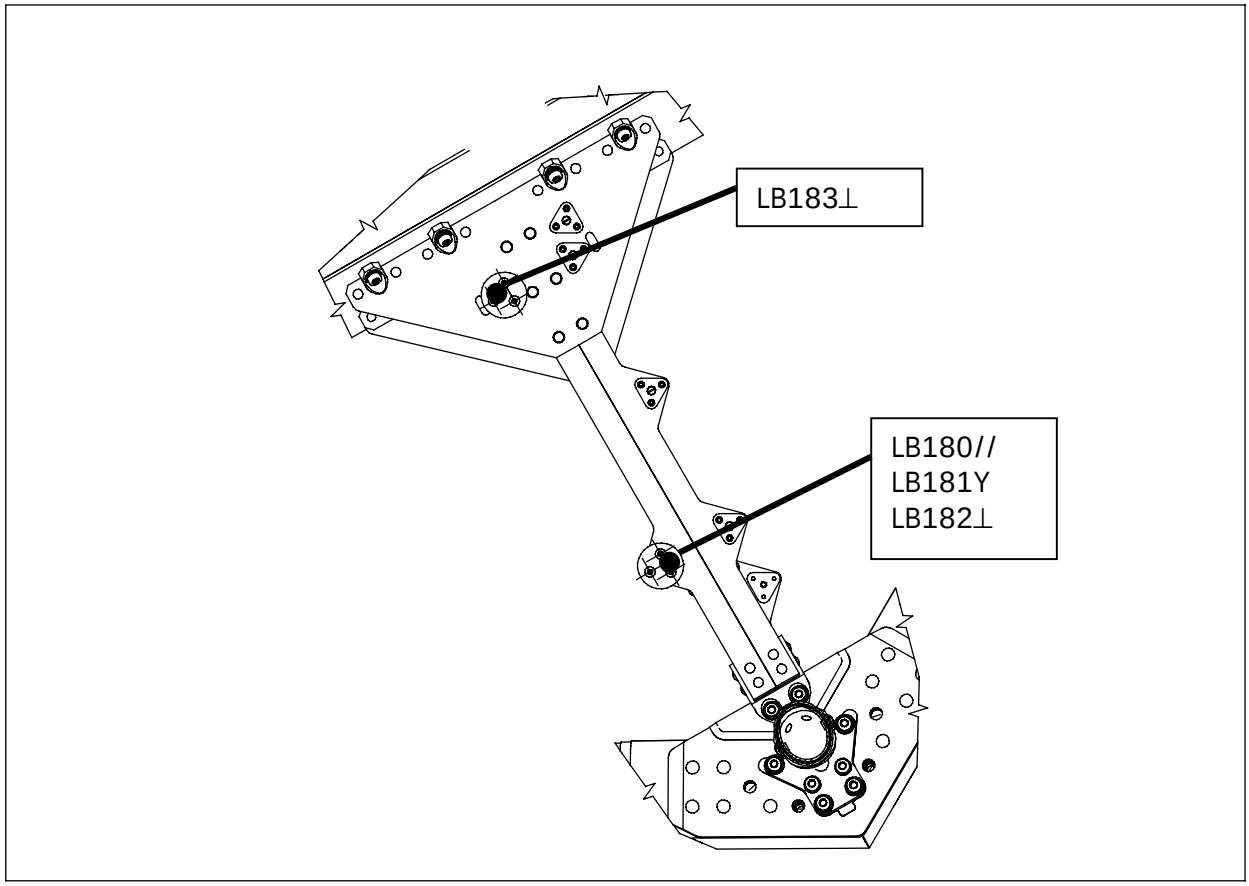
APPENDIX 1
LOCATION OF ACCELEROMETERS ON TELESCOPE SR PANEL



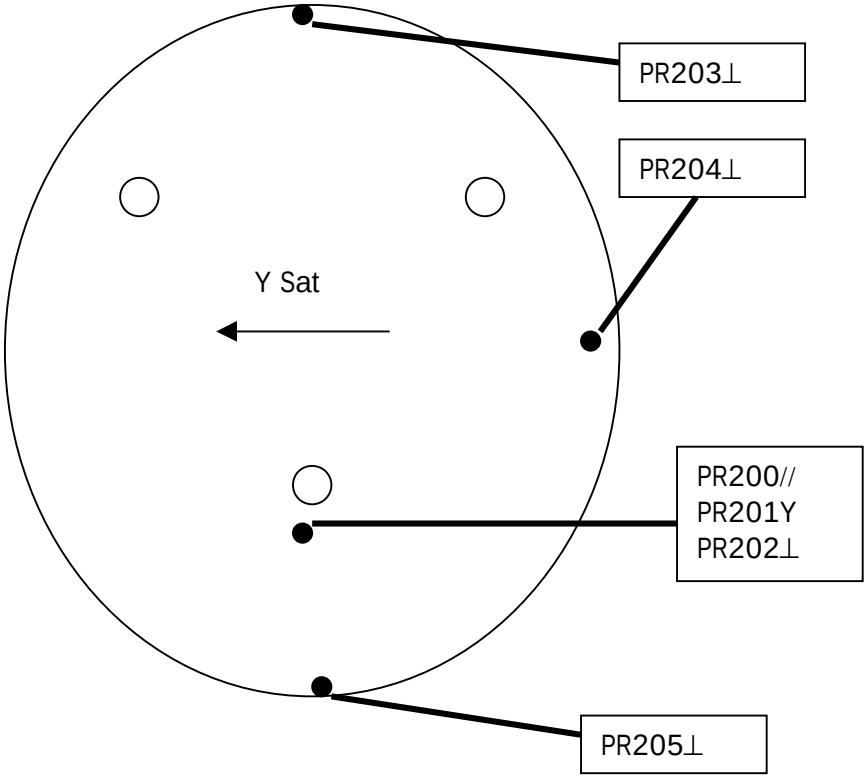
APPENDIX 1
LOCATION OF ACCELEROMETERS ON TELESCOPE FRAME



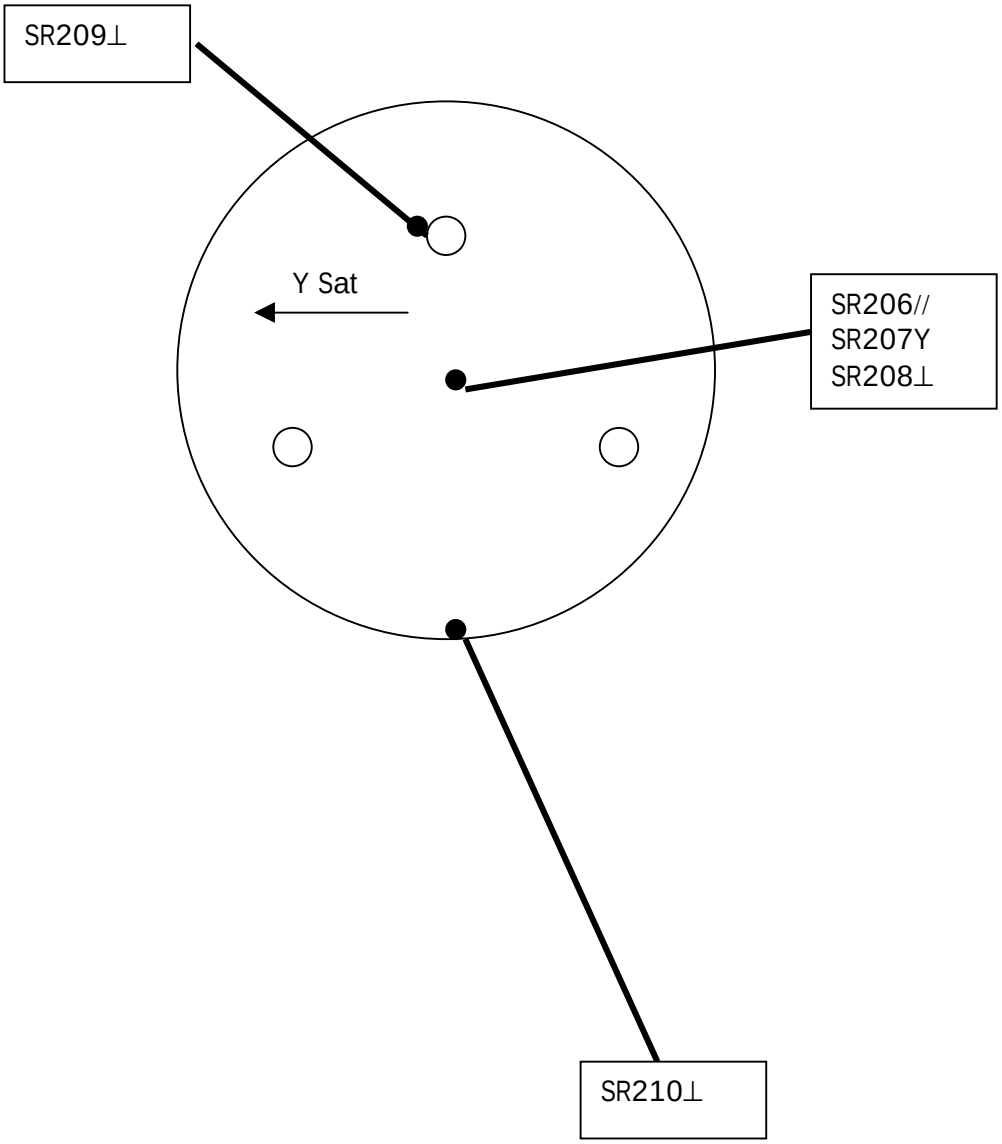
APPENDIX 1
LOCATION OF ACCELEROMETERS ON TELESCOPE LOWER BEAM



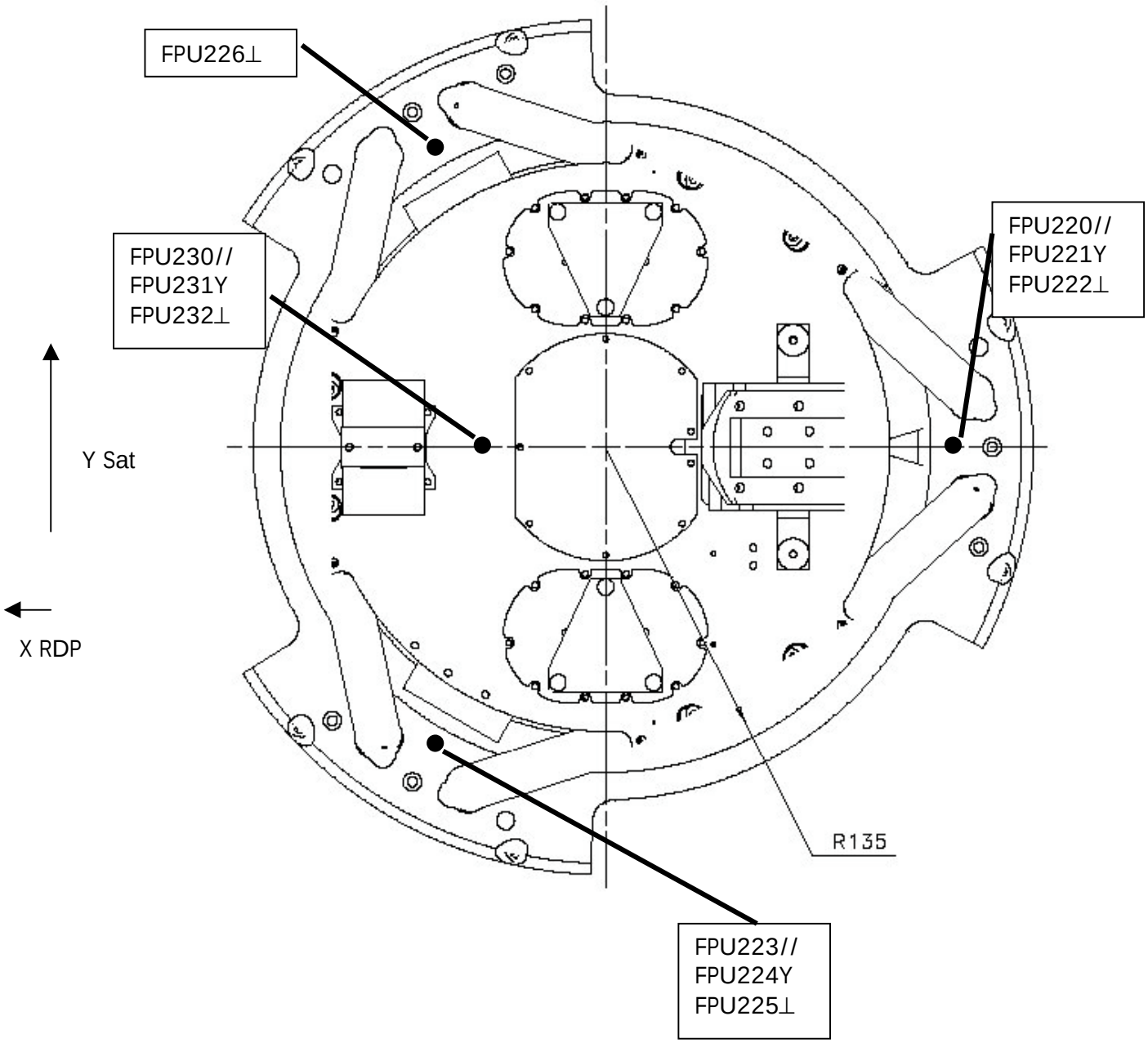
APPENDIX 1
LOCATION OF ACCELEROMETERS ON PR (back side)



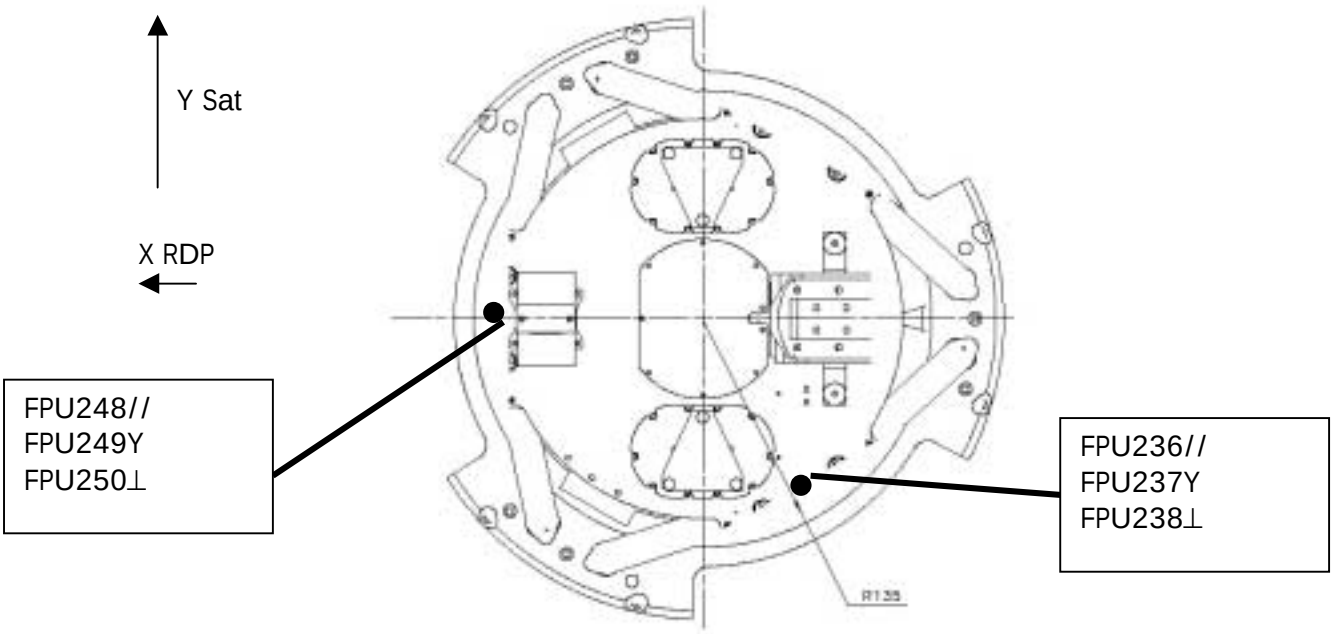
APPENDIX 1
LOCATION OF ACCELEROMETERS ON SR (back side)



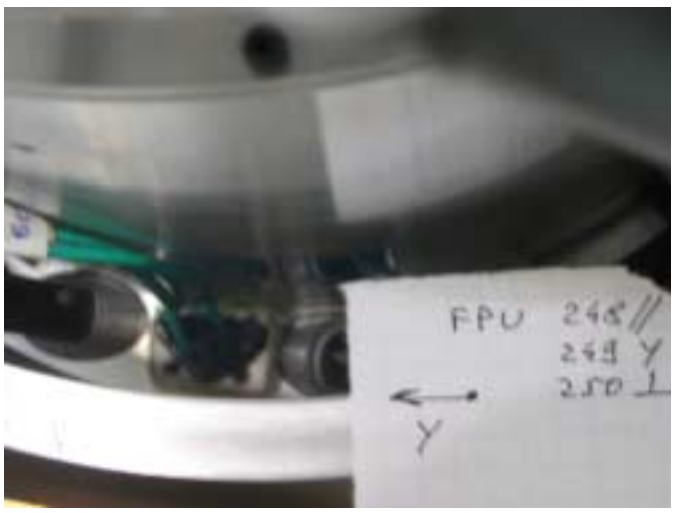
APPENDIX 1
LOCATION OF ACCELEROMETERS ON HFI FPU STM (HFI/LFI I/F and 18K stage)



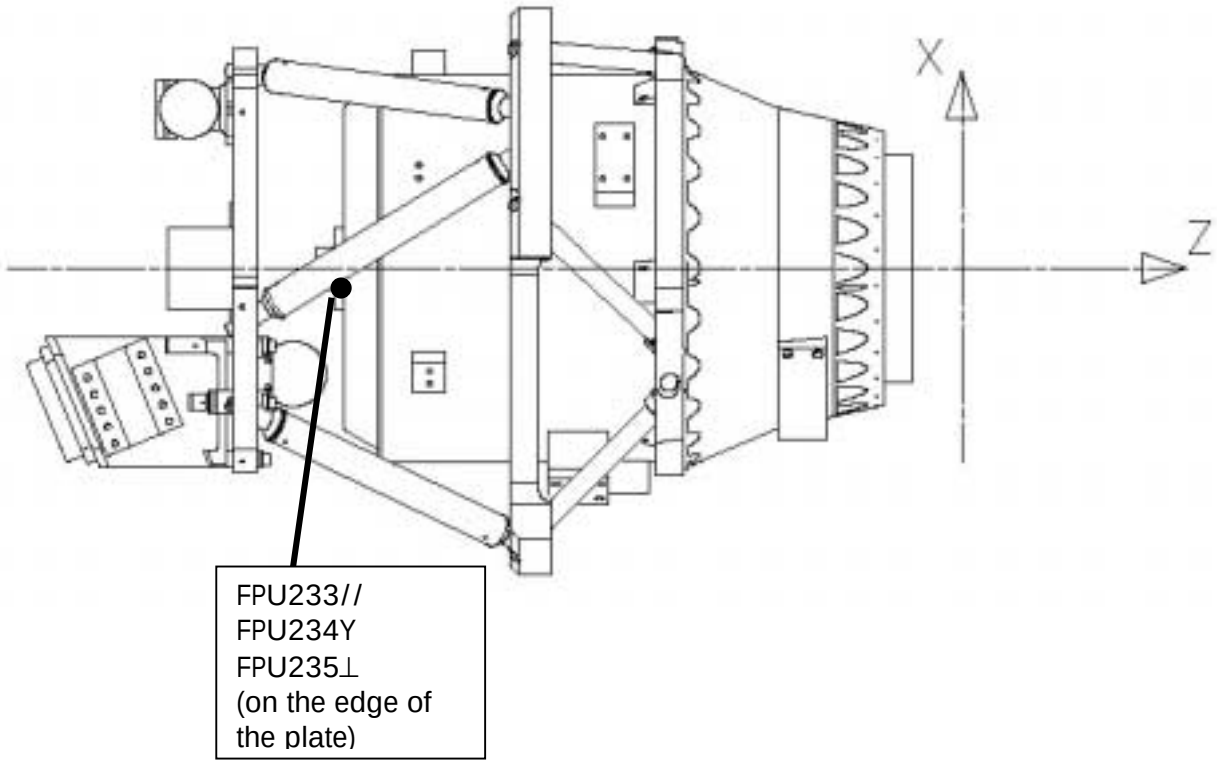
APPENDIX 1
LOCATION OF ACCELEROMETERS ON HFI FPU STM (18K stage)



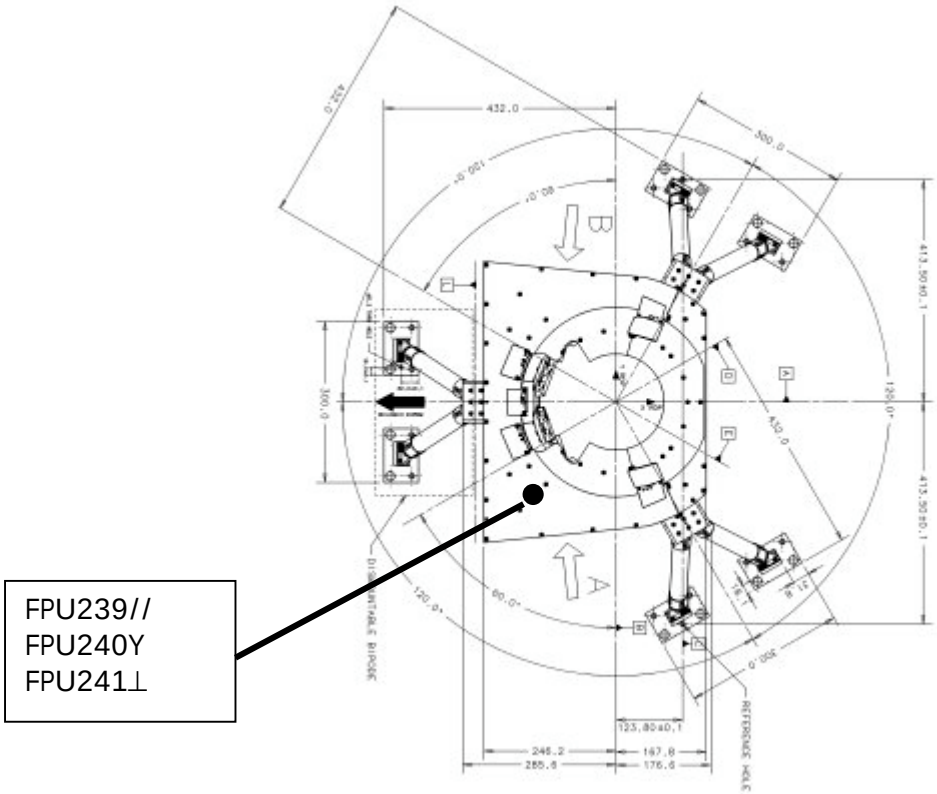
Note : Accelerometers are placed on the other side of the 18K plate (+Z RDP)



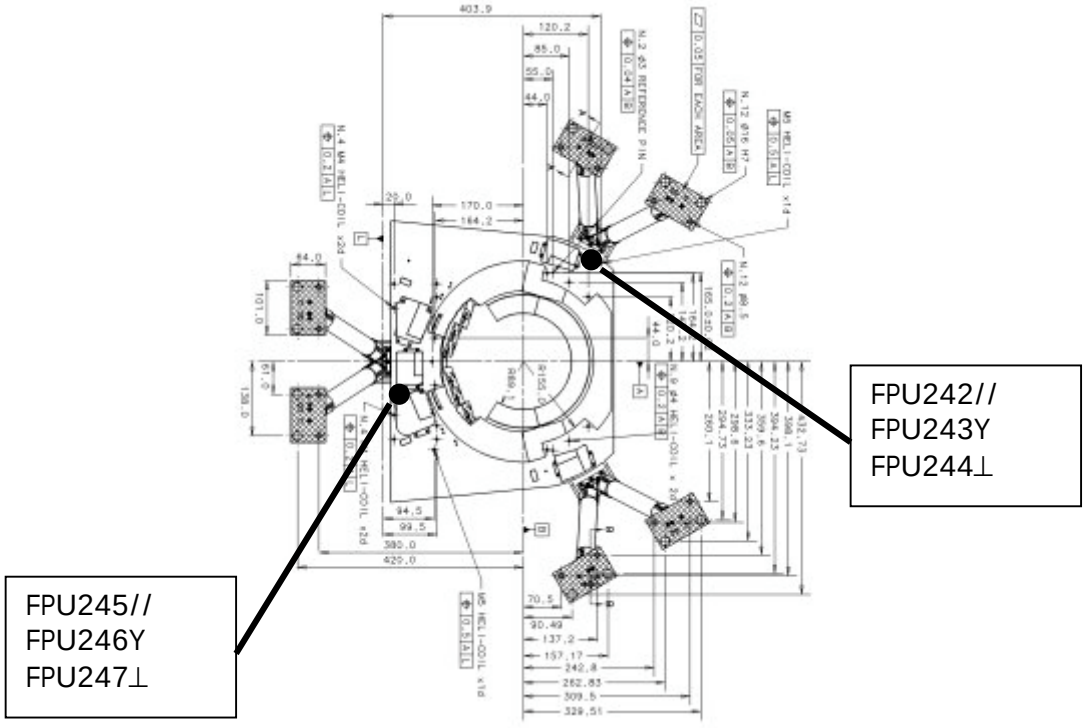
APPENDIX 1
LOCATION OF ACCELEROMETERS ON HFI FPU STM (4K stage)



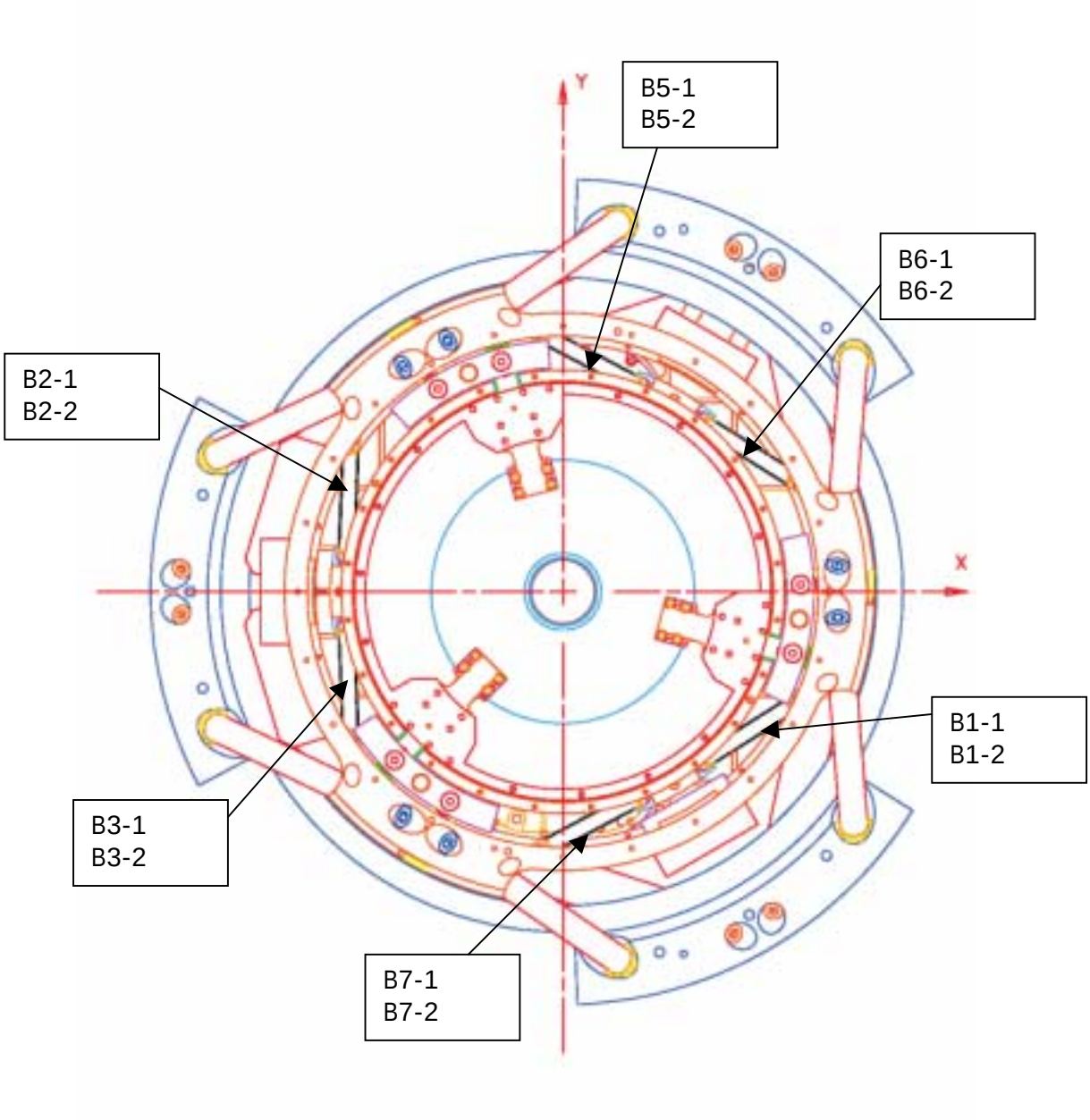
APPENDIX 1
LOCATION OF ACCELEROMETERS ON FPU MAIN FRAME



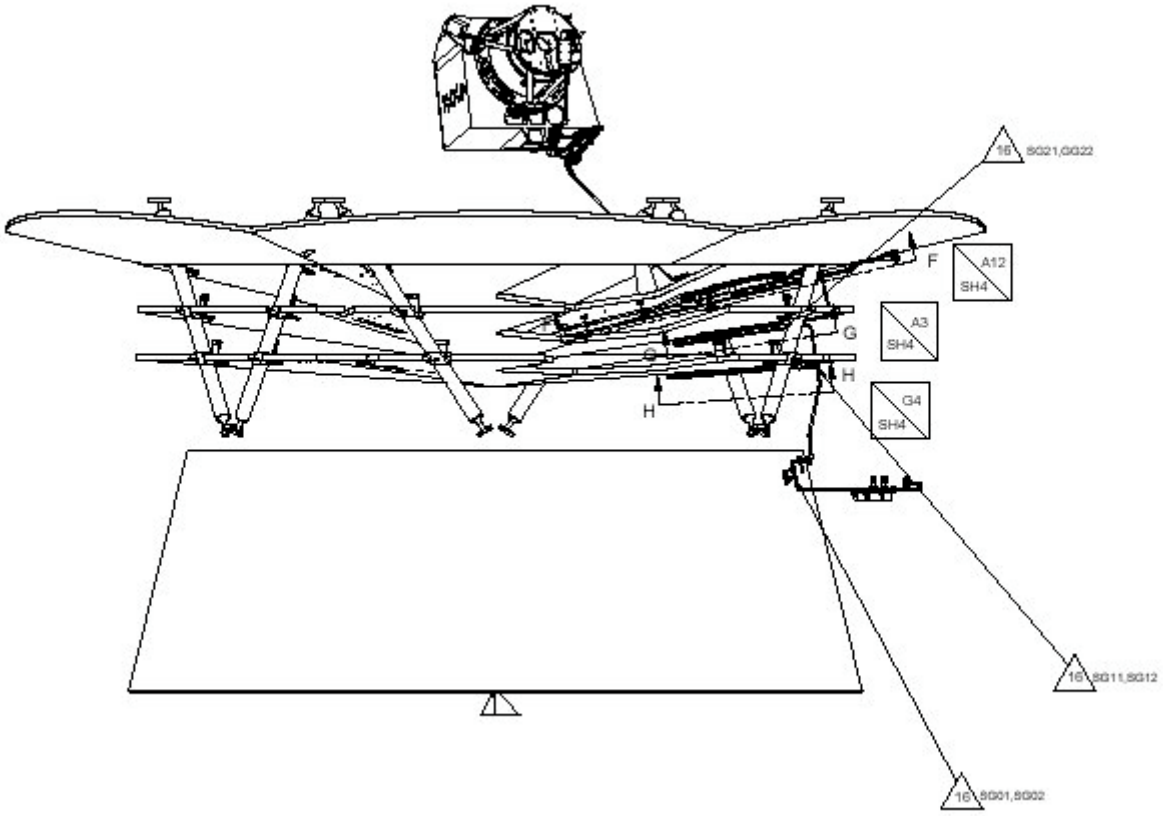
APPENDIX 1
LOCATION OF ACCELEROMETERS ON FPU MAIN FRAME



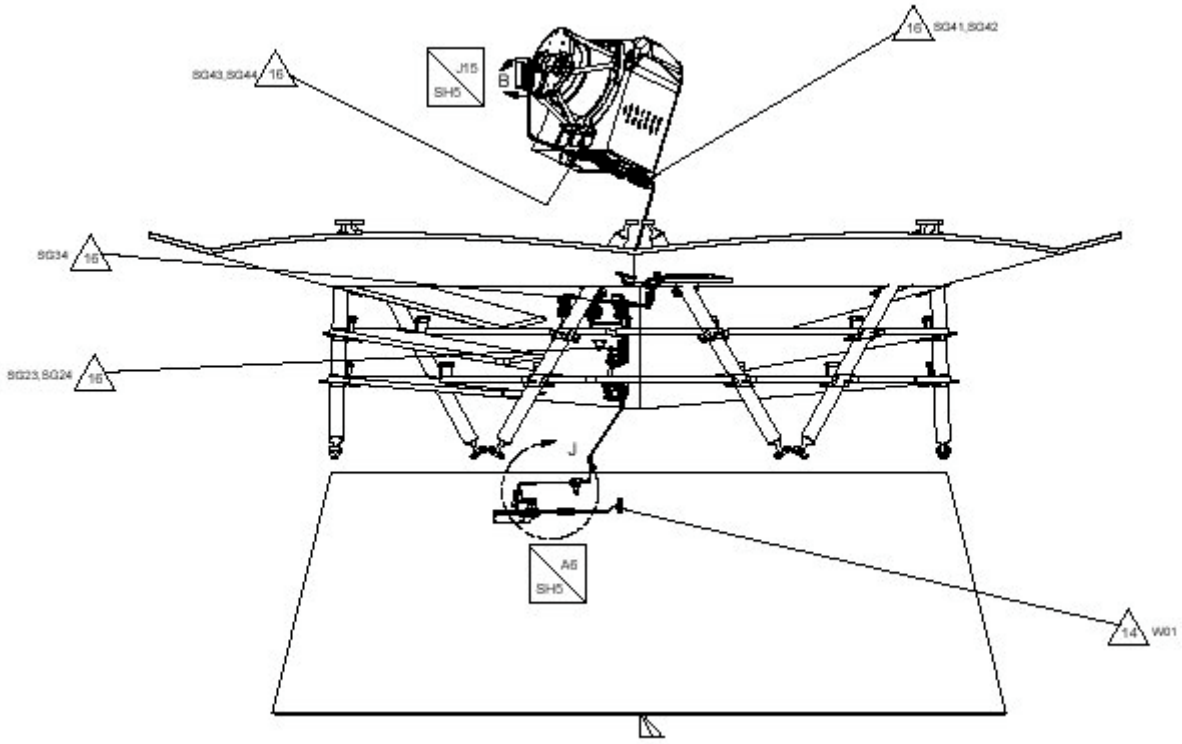
APPENDIX 2
LOCATION OF STRAIN GAUGES ON HFI FPU STM



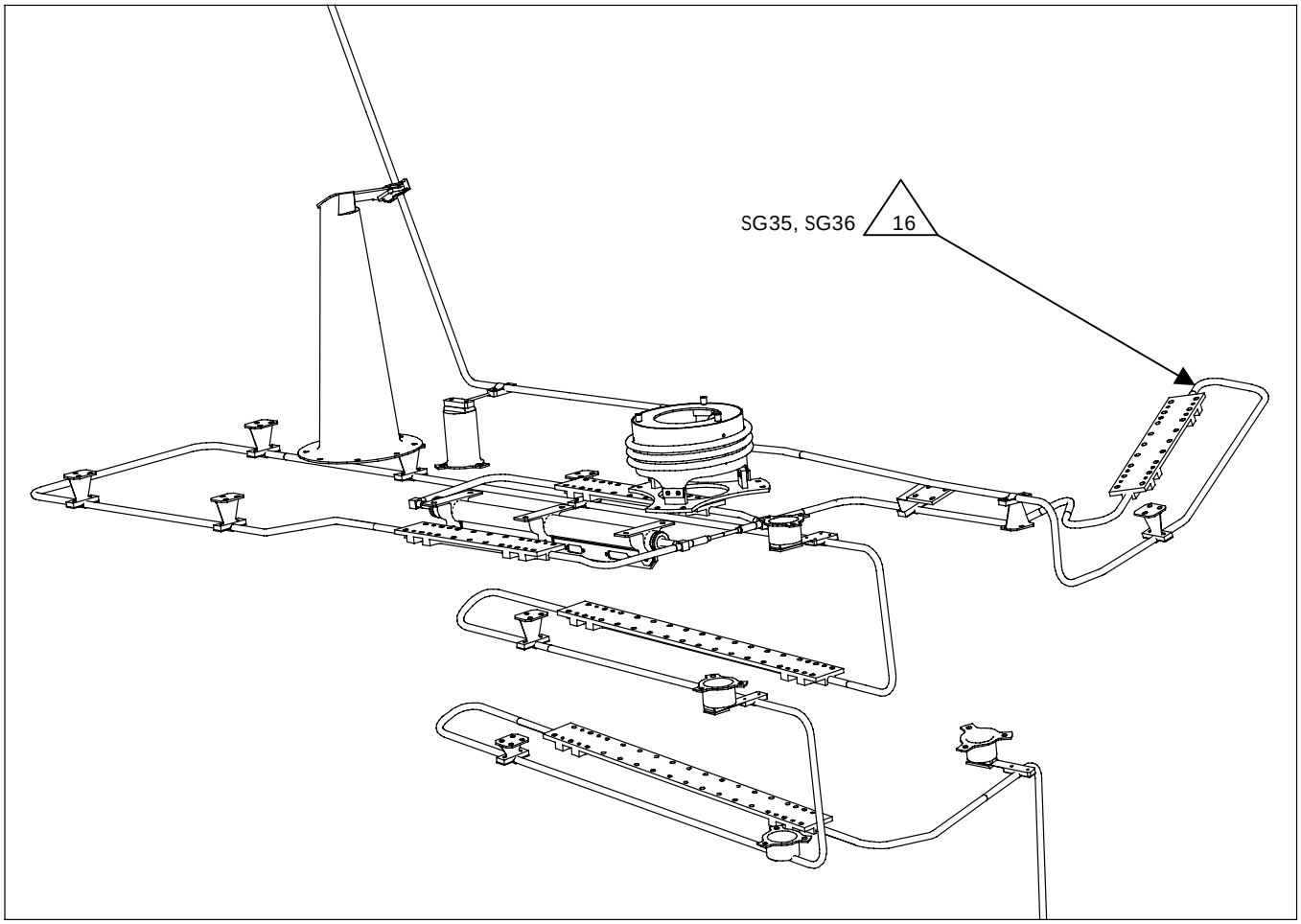
APPENDIX 2
LOCATION OF STRAIN GAUGES ON PACE (indicated by mark “16”)



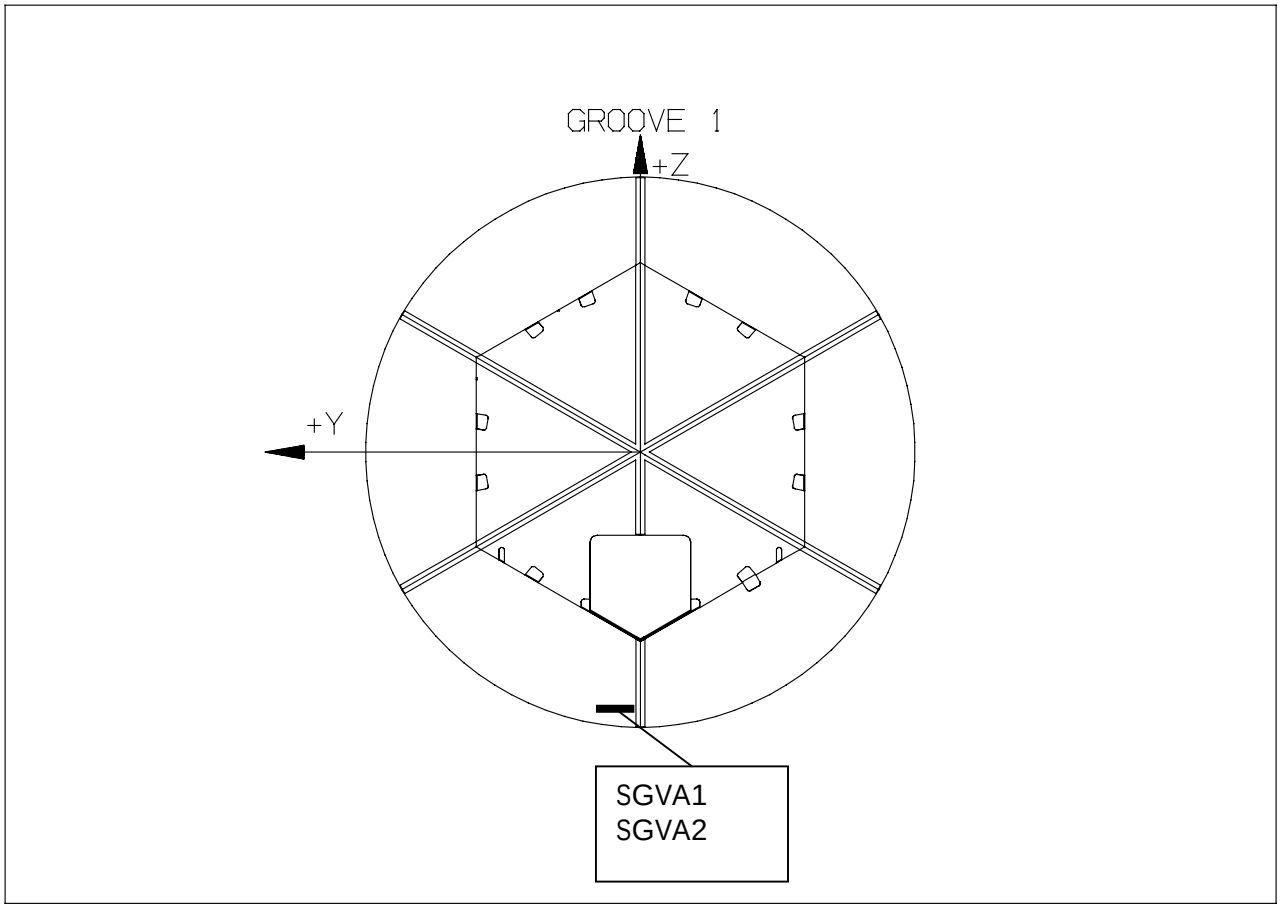
APPENDIX 2
LOCATION OF STRAIN GAUGES ON PACE (indicated by mark “16”)



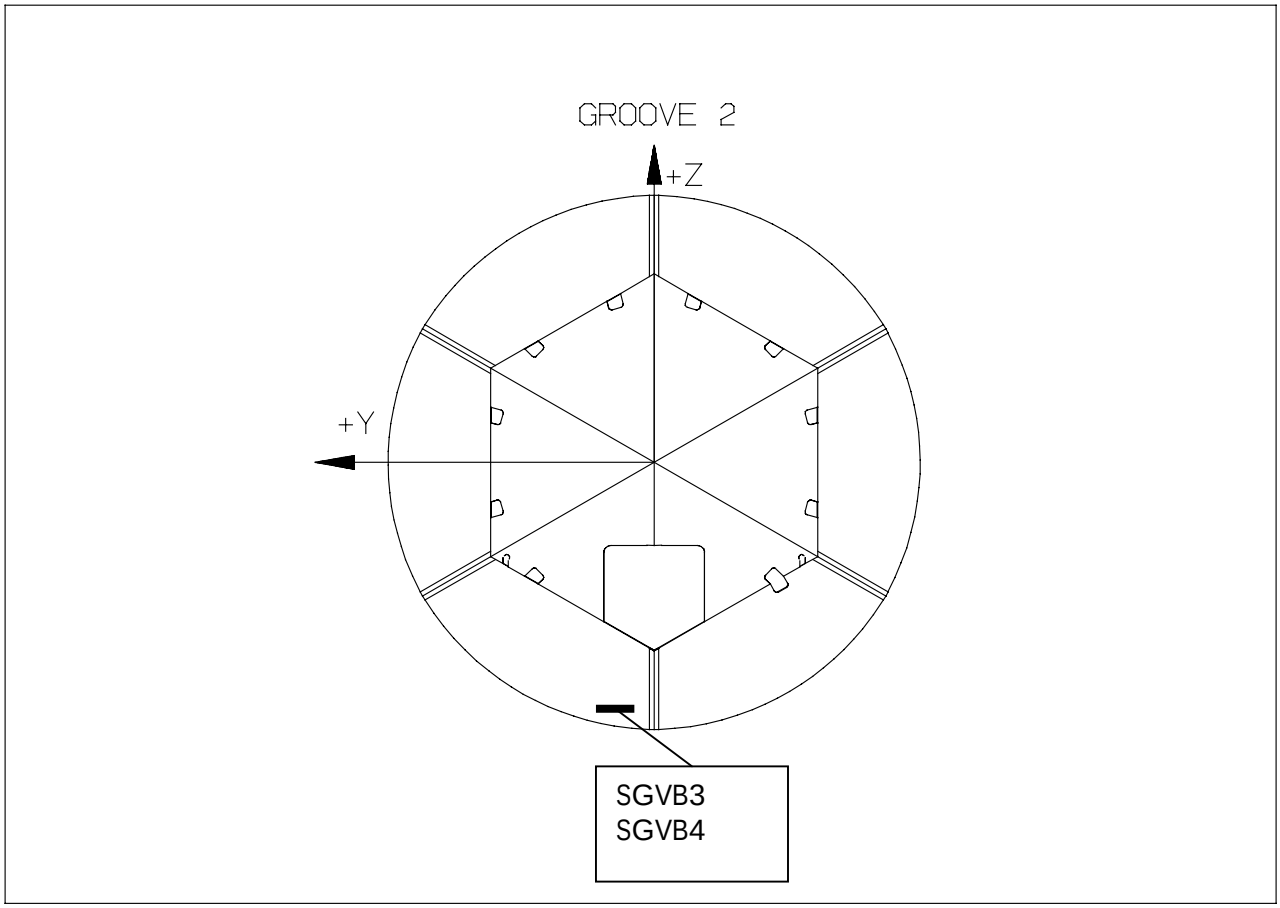
APPENDIX 2
LOCATION OF STRAIN GAUGES ON PACE (indicated by mark “16”)
Gauges added by Alcatel



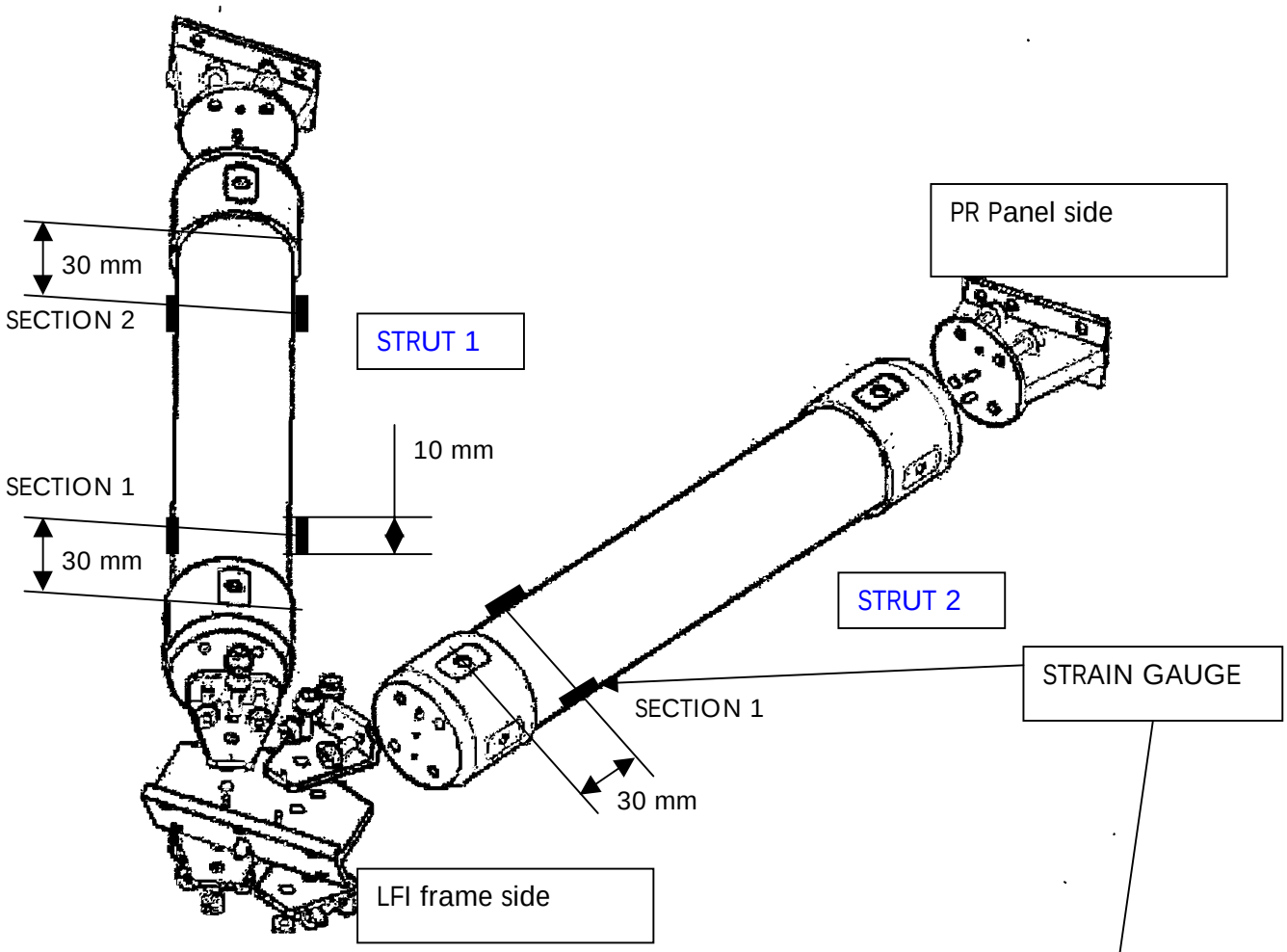
APPENDIX 2
LOCATION OF STRAIN GAUGES ON V-GROOVE 1



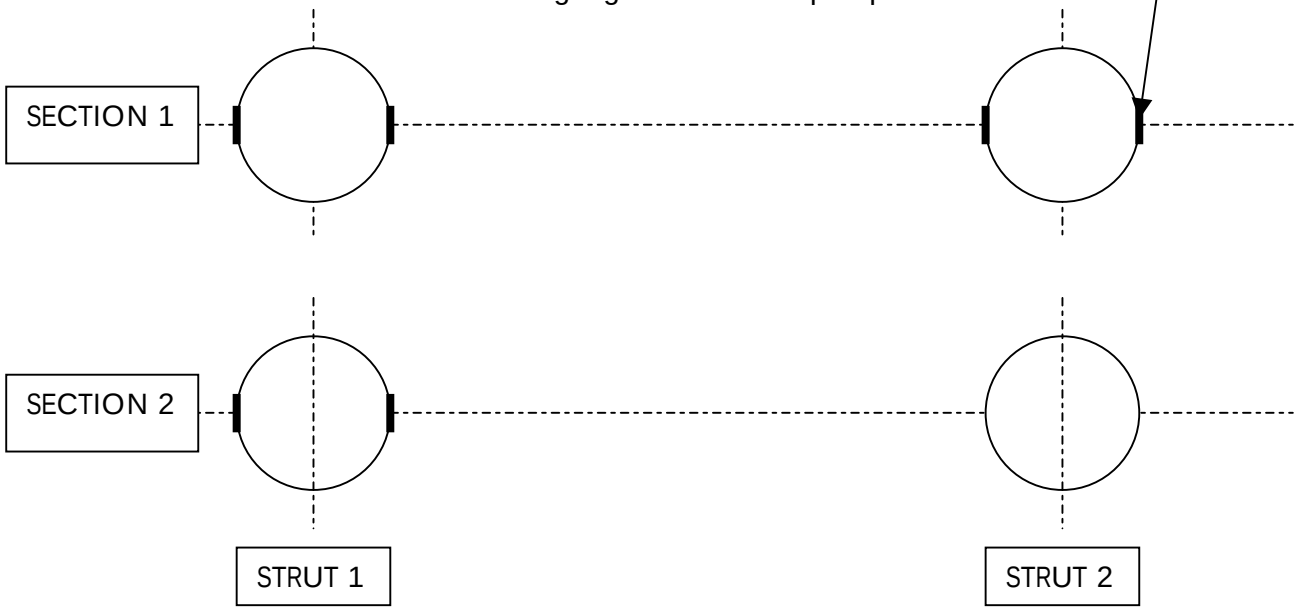
APPENDIX 2
LOCATION OF STRAIN GAUGES ON V-GROOVE 2



APPENDIX 2
LOCATION OF STRAIN GAUGES ON LFI STRUT (FPU)



The strain gauges are in the bipod plane.



APPENDIX 2
LOCATION OF STRAIN GAUGES ON LFI STRUT (FPU) cont.'