Interface Control Document

Telescope Assembly / Science Instrument Mounting Interface

TA_SI_02

SOF-DA-ICD-SE03-037

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Revision: 2

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Telescope Assembly / Science Instrument Mounting Interface

TA_SI_02

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ICD REVISIONS

Revisions to this document since the initial Rev. 0 baseline are summarized in this table. Please refer to the Document Change Record starting on page vii for changes to this ICD (SOF-ICD-KT-001) prior to this initial NASA SPO baseline release.

REV	DATE	DESCRIPTION	APPROVAL
0	01/11/02	Initial NASA SPO Release of KT Final ICD TA_SI_02, Issue 5, Dated 20 December 2001. (SOF-ICD-KT-001)	/s/ J. Logan
1	05/21/12	Per PRG-CCR-112: Assigned NASA document number SOF-DA-ICD-SE03-037 to ICD TA_SI_02 per SOF-AR-DEF-PM91-2023, *SOFIA Document File Numbering Schema (DFNS)*. Updated ICD format to match current SOFIA documentation standards (cover page, concurrence / approvals signature page). Updated Acronyms glossary. 2.2 Updated list of Reference Documents (RDs): Replace obsolete references w/ recently baselined docs SE01-2028, *SI System Spec.*, and OP03-2000, *SI Developers' Handbook*, update references to ICDs per SOF-AR-DEF-PM91-2023, *SOFIA Document File Numbering Schema (DFNS)*; Add RD25, SOF-PLA-MG-0000.0.13, *SOFIA Telescope Assembly Verification Plan* (already referenced in Section 5.3, *Verification*, for verification of TA-C side of the interface); Add RD5 (repurposing formerly deleted RD) SOF-DA-ICD-SE03-002 (GLOBAL_09), *SI Envelope*, now referenced in para. 4.4.3; Add RD26, SCI-AR-PLA-SV05-2014, *Science Instrument System Specification and ICD Requirements Verification Matrix Template* (newly referenced in Section 5.3, Verification, for verification of SI side of the interface, replacing earlier reference to PD96157000-000, PM12, *SOFIA Observatory Integration, Test and Verification Plan*, for the USRA (SI) side of the interface). 4.1 Add missing explicit requirement limiting SI assembly mass to 600 kg (1,320 lbm). Clarify that SIs w/ lower mass may opt to use fewer than 20 mounting bolts, w/ caveat that SI-provided structural analysis must reflect positive Margins of Safety (MS). Clarify intended and required usage of the TA IMF dowel pins and associated SI Flange requirements w/ respect to location and dimensions of holes and slot. Delete references to IMF and SI Flange zero-point orientation markers. Define commonly used nomenclature INF "tub". Replaced "shall" in definition of IMF to reflect this being intended as informational vs. a verifiable requirement. Fig. 4-1 Update graphic for Fig. 4-1 as errata correction for incorrectly defined locations of 4 x ½" inserts for jack screws; Add annotation under caption for Fig. 4-2 to clarify orientation depicted reflects TA Elevation at 90°, and that at SI installation, the TA Elevation angle will be 40° (i.e., rotated 50° clockwise) with dowel pins at top, bottom, left, and right of IMF.	PMB

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REV	DATE	DESCRIPTION	APPROVAL
1	05/21/12	Fig. 4-1b Update graphic for Fig. 4-1b to address legibility issues. 4.1.3.4 Clarify that fewer than 20 mounting bolts may be used, w/ reference to para. 4.1 for related flange and bolt loading and structural analysis considerations. 4.1.3.6, 4.1.3.7 Added more detailed bolt, nut and washer data and installation and torque specifications. 4.1.3.8 Clarifies / relaxes requirement w/ respect to size of SI Flange bolt clearance holes. Added verbiage re: the need for SI Flange bushings or inserts at bolt holes to be captive to avoid FOD concerns upon SI installation / removal. 4.1.3.9 Clarification re: source of IMF nut plates. 4.1.4 Clarify intended and required usage of the TA IMF dowel pins and associated SI Flange requirements w/ respect to location and dimensions of holes and slot. Fig. 4-2 Update graphic for Fig. 4-2 to correct errata w/ respect to dimensional tolerances on dowel pin diameter. 4.1.4.5 Clarifies / relaxes requirements w/ respect to number and size of SI Flange dowel pin clearance holes and slot, consistent with ANSI B4.1-1967, R1987 and ANSI B4.2-1978 (ISO 286:1988). Added verbiage re: the need for SI Flange bushings or inserts at dowel pin bore hole / slot to be captive to avoid FOD concerns, and adequately robust to preclude damage due to crushing. 4.1.5 Add missing explicit requirement prohibiting placement of SI Flange holes in 4 defined jack-screw locations. Fig. 4-3 Update graphic for Fig. 4-3 to correct errata w/ respect to dimensions of TA IMF o-ring gland width and depth. 4.1.6.4 Clarifies / relaxes requirements w/ respect to SI Flange planarity, surface finish and edge treatments. Addresses RDW process for SI use of non-standard sealing approaches. 4.1.8 Deletes requirements associated with IMF and SI Flange zero point orientation markers. 4.2 Changed "SI" to "SI Assembly" to clarify that the SI equipment in the PI Rack(s) and/or the CWR are not within the scope of these specifications (these are addressed in other ICDs); Update references to "SI electronic rack" and "SI-rack" to include "Counterweight Rack (CWR)". Clarified interpretation of two CG envelopes to avoid confusion re: definitions of "normal condition" and "heavy Science Instruments, that will not fit within the normal envelope". 4.3.5.2 Changed para. title from "Thread Size" to "Screw Thread and Clearance Hole Size" to reflect increased scope of paragraph; Added spec. for range of Pressure Coupler mounting screw clearance hole diameters.	PMB

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REV	DATE	DESCRIPTION	APPROVAL
1	05/21/12	4.3.6 Clarifies / relaxes requirements w/ respect to SI Pressure Coupler planarity and surface finish, as well as organization responsible for provision of pressure coupler. 4.4, 4.4.4 and 4.4.5 Changed language to reflect that the SI developer and not USRA is responsible for provision of the Optical Window Assembly (OWA) and the OWA O-ring seal; Added reference to Section 4.3 for definition of the OWA mounting screw clearance hole diameter range. 4.5.3 Corrected typo "On the INF tube…" to "On the INF tub…"; Corrected errata to match as-built TA INF: "… there are 1 inch [25.4 mm] NPT threads for connecting for example a pump-out line to the pressure coupler." to "… there are 3/4 inch [19.1 mm] NPT threads…" Fig. 4-7a Updated graphic for Fig. 4-7a to address legibility issues. 4.8 Updated requirements for SI envelope aft of SI Flange consistent w/ the need to ensure clearance with TA INF "tub" insulation. 4.15 Updated grounding requirements to correct suspected typo and to reference grounding specifications applicable to SIs. 5.3 Added boilerplate re: SI verification activity and process; Replaced reference to PD96157000-000, PM12, *SOFIA Observatory Integration, Test and Verification Plan*, with RD15, *SI Developers' Handbook*; Added RD26, *SI System Spec. and ICD Requirements Verification Matrix Template*, for the USRA (SI) side of the interface. Appendix Updated graphic for Fig. 4-1 (Enlarged) as errata correction for incorrectly defined locations of 4 x 1/2" inserts for jack screws.	PMB
1.1	05/08/13	Minor editorial change – DFNS document number shown on cover page typographical error SOF-DF-ICD-SE03-037 corrected to SOF-DA-ICD-SE03-037	PMB not required
2	07/27/16	4.1.6.4 Updated surface finish / roughness specification for SI mounting flange surfaces that contact the TA IMF O-ring seal to include the same relaxation already baselined since Rev. 1 in 4.3.6, i.e., from Ra ≤ 0.8 micron [32 micro-inch] to Ra ≤ 1.6 micron [64 micro-inch] for concentric surface lay. Additional administrative changes: Cover page: Update SOFIA logo graphic to match current template. Update references from DFRC / Dryden… to AFRC / Armstrong... Update running header to include Release date Signature page: Added 2nd "Prepared By" signature to represent TA side of interface. Updated Concurrence and Approvals signatures to reflect SOFIA Program organizational and staffing changes.	OCCB-CCR-801

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REV	DATE	DESCRIPTION	APPROVAL

Document Change Record

Iss./Rev.	Date	Description of Change	Pages Affected
Draft1	**23.06.97**	**First issue**	**All**
Draft2	**21.08.97**	**Update after ICWG meeting Waco 7/97:**	
		• RD4 from DCR 0025 to DCR 0025.R1 + preparation date	p. 2-1
		• added: "...avoid misorientation of SI....", "..Boltholes are through holes..", "...USRA provides .."	p. 4-1
		• Fig. 4-1 modified	p. 4-2
		• §4.1.3.6 "...Bolt torque...", §4.1.3.7 "...Bolt hole Diameter ..."	p.4-3
		• §4.1.4 completly reworked	p. 4-4
		• New Chapter 4.1.7 "Orientation Marker" + Fig. 4-3	p. 4-5
		• §4.2.3 120 kg / flight changed to 35 kg/flight	p.4-6
		• figure 4-3 correction of c.g. range diameter from 500mm to 1000mm	p. 4-7
		• § 4.3.3 ".. U=1870 mm ..."	p. 4-9:
		• §4.4 added: "..optical window assembly is provided by USRA...", §4.4.1 added: "... "..relevant for the interface..", "... thus on the side of ...", deleted:"..alternative pressure coupler interface." in fig. 4-5.	p. 4-11
		• deleted: §4.4.3, §4.4.4, §4.4.5, §4.4.6	p. 4-12
		• added: Fig. 4-6: "Principle of Airflow"	p. 4-14
		• §4.7 new text	p. 4-16
		• added: "..The here given volume..." "...The forward end...",	p. 4-17
Draft3	**10/10/97**	**UPDATE AFTER ICWG TELECON, 24.09.97:**	
		• TBDs and TBC have been assigned to a responsible	All
		• RD5 added (Flange Assembly Design Definition)	p. 2-1
		• §4.1: "..However for small instruments ..." replaced by "...However for some instruments...", added: "If the Optical Window Assembly is..."	p. 4-1
		• §4.1.5 Fig 4-1: "...example..." added	p. 4-5
		• deleted: "If the optical window is not installed", §4.3.6: "The O-Ring is provided by USRA"	p 4-12
		• Figure 4-5: "preliminary concept of .." added	p. 4-13
		• § 4.4 reworked according to USRA inputs	p. 4-13 /4-14

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Iss./Rev.	Date	Description of Change	Pages Affected
		• § 4.6 reworked according to USRA inputs	p 4-17
Draft 3A	**5.2.98**	**Changed Format of Document Approval Sheet**	**i**
01/-	**27.05.98**	**BASELINE** • Implementation of interface relevant data due to augmentations to FA design • Implementation of Comments J. Davidson, e-mail 10.3.98, J. Fitch letter received 26.3.98 • Implementation of inputs e-mail Erickson, Casey 19.1.98 • Implementation of inputs e-mail Erickson, Davidson 28.12.98 • Implementation of comments IWG Meeting Dec. 97 Gustavsburg	**Complete Revision**
1/A	**15.7.98**	**Implementation of comments J. Davidson recieved 20.5.98 and 18.6.98 and ICWG meeting Munich 29.01.98** • §1: Add "[worst case loading and] vibration spectrum" • Fig 3.1: coordinate system, origin and distance to IMF fwd surface included • § 4.1 Para 3 revised "The SI Flange and the IMF ...." • § 4,1 Para 4 revised "The SI will be fixed......nutplates..." • § 4,1 Para 5 revised "For standard operation the ..." • § 4,1 Para 6 revised "To provide ..4 dowel pins ...." • § 4.1 Para 8 changed • § 4,1 Para 11 new "The IMF is equipped with locations for jack screws...." • Figure 4-1: changes implemented • Figure 4-1b: new figure • § 4.1.3.2 revised • § 4.1.3.3, .6, .7 need date implemented • § 4.1.3.8 Changed hole diameter • New § 4.1.3.9 Nut Plates • Figure 4-2 revised • §4.1.2: complete revision	

Iss./Rev.	Date	Description of Change	Pages Affected
		• New Section §4.1.8 INF Material • §4.2.3 Revised according to DCR 0025 R2 • Figure 4-5 implemented • §4.3.5 ".. to be supplied by USRA" and need date • §4.3.6 Change O-Ring max. dia. from 260 to 240 • §4.4.6 New: Limit Loads for Pressure Coupler / Pressure Window Fixture • §4.5.3 NPT Threads instead of straight tubes inside Tub for exhaust / pumpout line connection to pressure coupler. • § 4.8 "Insulation removeable" • § 4.11 "Access port is ...pressure boundary...." • New §4.7.3 Airflow through Exhaust lines • New 4.7.4 Operation and Environment • §4.10.2 : clarification of limit and ultimate loads	
02/-	**12.05.99**	**Updates from:** - E-mail N. Kunz, NASA 26.3.99 - E-mail J. Davidson, USRA 22.3.99 - E-mail Davidson, USRA 12.3.99 - fax C. Wiltsee, NASA 24.2.99 - E-mail J. McCoury, USRA, 30.10.98 - E-mail J. Davidson, USRA 09.08.98 - Letter E. Ericson, NASA, 07.08.98 - E-mail J. Davidson, USRA 04.08.98	**All**
03/-	**March 2000**	**Updates from:** NASA comments / e-mail T. Brown 21.05.99 - e-mail J. Davidson 26.08.99 - e-mail J. Davidson 21.12.99 - e-mail J. Davidson 28.01.2000 - e-mail J. Davidson 02.02.2000 - e-mail R. Melugin 22.02.2000 <u>revised sections:</u>	**--**

Iss./Rev.	Date	Description of Change	Pages Affected
		1; 2.2; 4.1; 4.1.3; 4.1.3.3; 4.1.3.6; 4.1.4; 4.1.4.3; 4.1.9; 4.2.3; 4.3.2; 4.3.5; 4.3.6; 4.3.7; 4.3.8; 4.4.2; 4.4.6; 4.5.3; 4.5.4; 4.5.5; 4.6.5; 4.6.6; 4.7.1; 4.7.1.1; 4.7.1.2; 4.7.1.3; 4.7.2; 4.7.3; 4.7.4; 4.9.1; 4.9.2; 4.10; 4.10.1; 4.10.3; 4.11; 4.14; 4.15	
04/-	**December 2000**	**Updates from:** - NASA SPO comment Sheet dated 2/1/00 to ICD-KT-001, iss. 3, 3/22/00 - USRA Comments by J. Davidson dated 28.3.00 (e-mail 29.03.00) - Telecon USRA, MG, KT 18.05.00 - e-mail J. Davidson 09.09.00 - DCR 058.R2 - DCR 148 - Change of Pressure Coupler Bolthole Circle from 274mm to 275 mm - Seal-off fitting and Vacuum Locks as previously described in section 4.5.3 are no longer features of the FA/INF. <u>revised sections:</u> §2.2; §3 (figure 3-2); §4.1 (figure 4-1; 4-1b); §4.1.5; §4.2; §4.2.1; §4.2.2; §4.2.3; §4.3.2; §4.3.5.1; §4.3.5.2; §4.3.5.3; §4.3.5.4; §4.4.1 (figure 4-7a); §4.4.2; §4.5.3; §4.5.5; §4.7.1.1; §4.8; §4.9.1; §4.11	
05/-	**December 2001**	**- Final Version -** Updates from: - e-mail, J. Davidson dated 20.11.01 "...delete grade assignments from NAS Bolts..." - e-mail, P. DeLeon, dated 16.10.01 "... ICD required Documents List..." - e-mail, J. Davidson dated 01.10.01 "... add SRM and QA sections..." "...add actual measured accuracies of the dowel pins..." - e-mail J. Davidson / T. Kaluza, dated: 07.02.01: "...reference TA_SI_04 instead TA_SI_05..." - USRA Comments on TA_SI_02 Iss. 04 by J. Davidson, dated 06.02. 2001 - NASA Comments by A. Dinger and others, received 22.01.01	

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		- DLR Comments by H. Witte dated: 10.01.01 Additional Changes due to comments by on the review version dated 29.11.01: - DLR, H. Witte, e-mail dated 5.12.01 - NASA, SPO, C. Wiltsee, e-mail dated 11.12.01 - USRA, J. Davidson, e-mail dated 14.12.01 revised sections: §2.1: AD01 changed to actual rev. 4, AD04 and AD05 added; §2.2:RD9 changed to TA EMC Control plan, RD21 to 24 added; responsible parties changed for RD2 and RD3; RD11 drawing number corrected §3 "BS" changed to "BSA"; §4.1: changed wording; "RD5" deleted; "nutplate design TBD by USRA" deleted; other minor changes in wording.; Figure 4-1: "Deep 30 mm" for hardpoints deleted; §4.1.3 "washers" added; §4.1.3.2: minor changes in wording, "grade 8" deleted; §4.1.3.3 TBD more precisely clarified; §4.1.3.6 "grade 8" deleted, torque limit defined; §4.1.3.7 changed title to "Bolt Data"; changed wording; "grade 8" deleted; §4.1.4: changed wording to reflect actual determined position accuracy of dowel pins after manufacturing; §4.1.5: "0.500" changed to "1/2"; §4.1.6.1/.4.1.6.3/4.1.7: English dimensions added; §4.1.8 "arrow shape" of marker deleted, clarified wording; §4.1.9 actual material is 1.4571, therefore 1.4546.9 deleted; §4.2.1 reference to wrong figure numbers deleted; §4.3 pressure coupler now to be provide by SI developer if required; §4.3.6.1/4.3.6.2: English dimensions added; §4.3.2: minor changes in wording; §4.3.5: inserts and tooling no longer required from USRA because manufacturing is accomplished; §4.4: reference to RD24 added; §4.4.6 note added that remaining info on TBD is not required by TA-C; §4.5: references to other ICDs added; §4.5.1/4.5.2: original wording replaced by references to other ICDs; §4.5.3: English dimension added; §4.5.4 changed wording and references to other ICDs added. §4.5.5/4.6 reference to other ICDs added; §4.6.1/4.6.2: original wording replaced by reference to other ICDs; 4.6.5 reference to other ICD added; 4.6.6 deleted; §4.8: English dimensions added; §4.10 English dimensions added; "0.500" changed to "1/2", depth added; inserts and tooling no longer required from USRA because manufacturing is accomplished; §4.10.1 "DCR0012.R2" changed to	

Iss./Rev.	Date	Description of Change	Pages Affected
		"DCR0012.R5 (AD5)"; §4.10.3: English dimensions added; §4.10.13: "TA_SI_05" changed to "TA_SI_04 (RD23)"; §4.11 bolt pattern and O-ring information added for the accessport; §4.14: "TBD" replaced by "to be measured during System AITV"; §4.15: English dimensions added; §4.16: "A USRA provided manufacturing tool ....." deleted; New SRM & QA Sections added (§5, §5.1, §5.2, and §5.3)	

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APPENDIX (Figure 4-1 Enlarged) A-1

ACRONYMS

AD	Applicable Document
aft	aft (direction opposite to Forward)
BSA	Balancing Subassembly
c.g.	Center of Gravity
CWR	Counterweight Rack (SI-rack)
XEL	Cross Elevation
cfm	Cubic feet per minute
DCR	Document Change Request
DIN	Deutsche Industrie Norm (German Industrial Standard)
EL	Elevation
FA	Flange Assembly
FAA	Federal Aviation Administration
FOD	Foreign Object Debris / Damage
FPI	Focal Plane Imager
fwd	Forward
GVPP	Gate Valve Pressure Plate
HW	Hardware
ID	Inner Diameter
I/F	Interface
ICD	Interface Control Document
IMF	Instrument Mounting Flange
INF	Instrument Flange
IR	Infra Red
kg	Kilograms
LOS	Line of Sight
N	Newtons (force)
NPT	National Pipe Taper (American Standard Pipe Thread)
NT	Nasmyth Tube
OD	Outer Diameter

lbm	Pound (mass)
PI	Principal Investigator
PWS	Pressure Window Subassembly
RD	Reference Document
SI	Science Instrument
TA	Telescope Assembly
TBC	To be Confirmed
TBD	To be Determined
U; V; W	Coordinates of the TA Coordinate System
UNF	Unified Fine (Thread)
VIS	Vibration Isolation System
Wt	Weight

1 Scope and Interface Contents

This document is to describe, define and control the SOFIA Telescope Assembly / Science Instrument Mounting Interface. This interface is led and documented by the TA Consortium member Kayser-Threde GmbH (KT).

The interface has the number TA_SI_02 and comprises:

- The mounting interface between SI and telescope instrument flange
- The mass and c.g. properties of the SI
- The pressure coupler interface
- The interface for the optical IR window
- The exhaust tube interface
- The vacuum lines interface
- Heat dissipation requirements and interface temperature limits
- The free volume aft of the SI flange
- Worst case loading and vibration spectrum imparted to the SI by the TA

2 Documents

2.1 Applicable Documents

AD1: SOFIA TA Development Statement of Work
SOW (DLR); REV. 4, 26.11.01

AD2: SOFIA TA Requirements
SOF-1011 (NASA); Rev. 8.1, 4/16/2012

AD3: SOFIA Interface Requirements
SOF-1030 (NASA); Rev. 3, March 1996

AD4: DCR 0015.R2 Pressure Window Assembly
(NASA)

AD5: DCR 0012.R5 Clarify Loads Environment
(NASA)

2.2 Reference Documents

RD1: SOFIA Interface Reference Document
PD-2003 (NASA);

RD2: GLOBAL_01 Master Interface Control Document List
SOF-DA-ICD-SE03-007 (NASA)

RD3: GLOBAL_05 SOFIA Coordinate Systems
SOF-DA-ICD-SE03-045 (USRA/RAIS)

RD4: DCR Max. Change of SI Wt During Flight
SOF-DCR-0025.R2 (NASA)

RD5: GLOBAL_09 SOFIA Science Instrument Envelope
SOF-DA-ICD-SE03-002

RD6: Flange Assembly Description
SOF-SPE-KT-4000.0.02

RD7: Flange Assembly Drawing (KT Part)

SOF-DWG-KT-4000.0.00

RD8: Flange Assembly (with FPI)

SOF-DWG-MG-4000.0.01

RD9: TA EMC Control Plan

SOF-PLA-KT-6000.0.01

RD10: Minutes of meeting MPE Garching 29.06.98

RD11: Flange ICD (KT part)

SOF-DWG-KT-4000.0.01

RD12: Design Loads (for Stress Analysis)

SOF-TAN-MG-0000.0.04

RD13: TA SI Flange Dowel Pin Analysis

30.10.98, J. McCoury

RD14: Military Standard MS 21209, Rev. E, 21.02.98

Insert, Screw Thread, Course and Fine, Screw Locking, Helical Coil, C RES

RD15: SOFIA Science Instrument Developers' Handbook

SCI-AR-HBK-OP03-2000

RD16: German Industrial Standard DIN ISO 2768

RD17: TA EMC Control Plan
SOF-PLA-KT-6000.0.01

RD18: SOFIA Science Instrument System Specification,
SCI-AR-SPE-SE01-2028

RD19: DCR148 SI cg & Mass Change Accommodation
(NASA)

RD20: DCR0058.R2 Telescope Balance
(NASA)

RD21: TA_SI_01 TA CLA to SI Cable Interface
SOF-DA-ICD-SE03-036

RD22: TA_AS_03 Aircraft System to TA CLA Interface
SOF-DF-ICD-SE03-013

RD23: TA_AS_04 Aircraft System / TA Optical and Non-Optical Installation and Removal Requirements SOF-DF-ICD-SE03-010

RD24: TA_AS_11 TA / Aircraft System Exhaust Tube and Vacuum Lines Interface SOF-DF-ICD-SE03-018

RD25: SOFIA Telescope Assembly Verification Plan SOF-PLA-MG-0000.0.13

RD26: Science Instrument System Specification and ICD Requirements Verification Matrix Template SCI-AR-PLA-SV05-2014

3 Interface Configuration

An overview of the TA with the mounted SI is given in figure 3-1. The Flange Assembly is shown in figure 3-2. A cross section of the FA (without BSA) is depicted in figure 3-3.

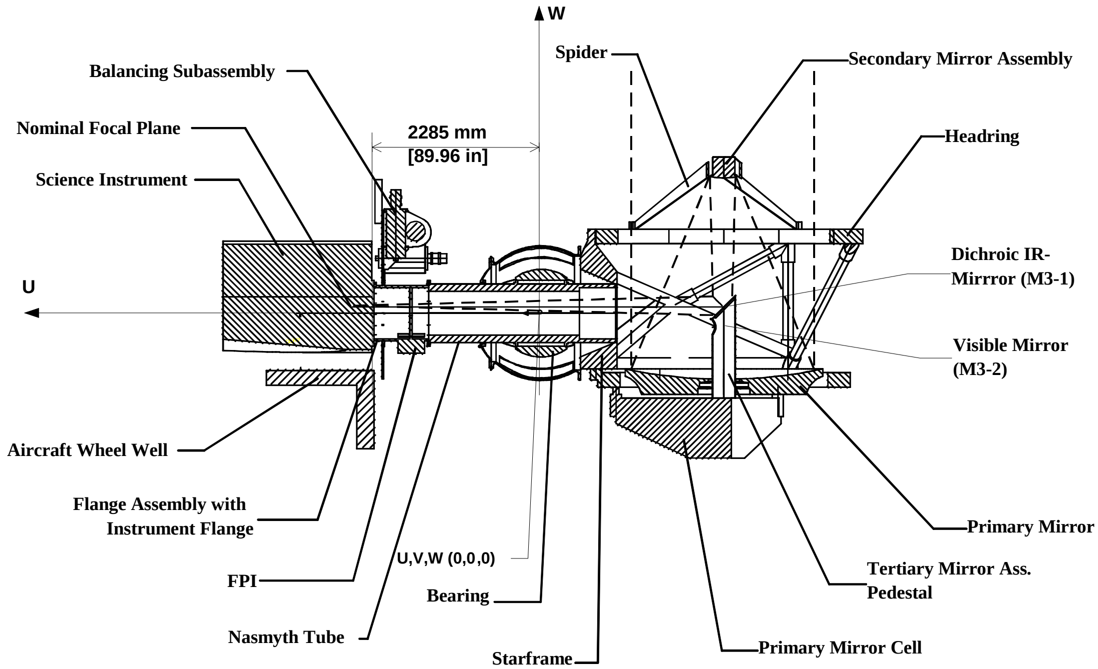
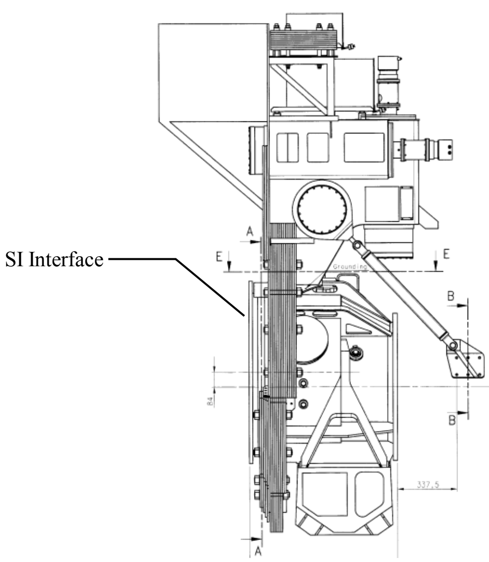


Figure 3-1: Mechanical TA System Configuration with Mounted SI



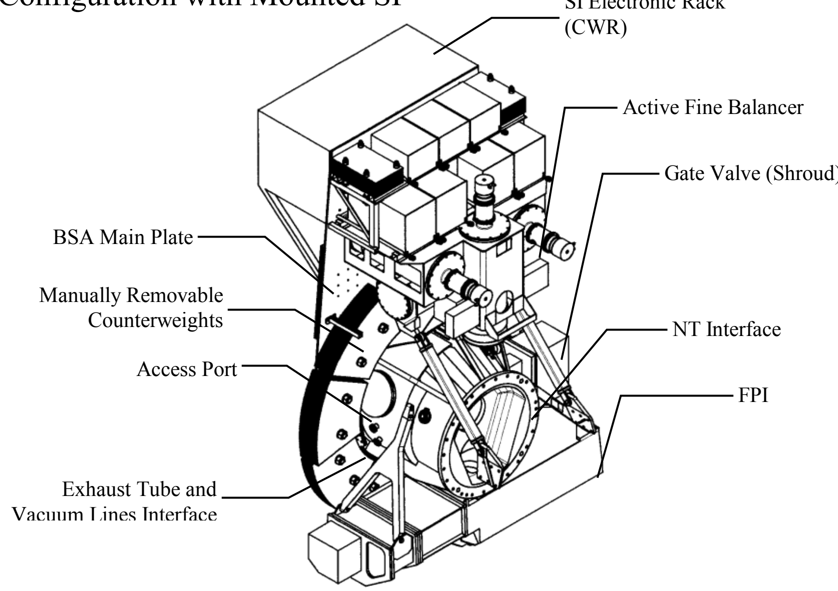
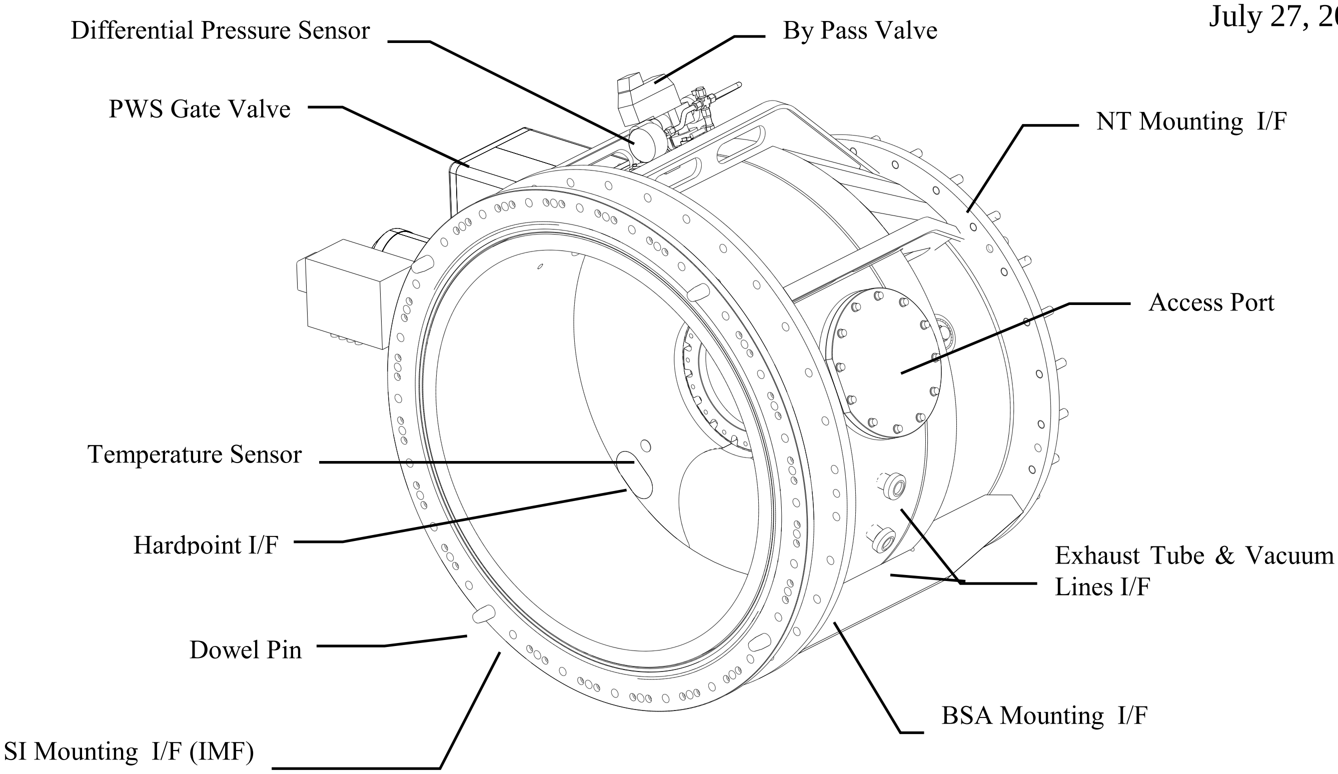


Figure 3-2: Schematic Sketch of the Flange Assembly (shown w/o Cable Load Alleviator)



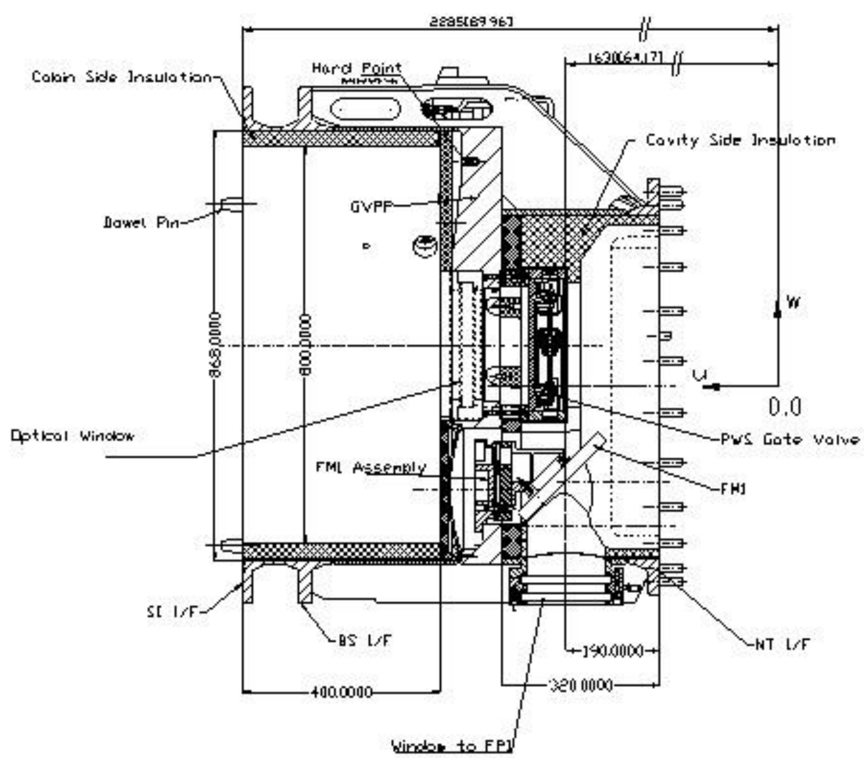


Figure 3-3: 3D View and Cross Section of INF and PWS without Balancing Subassembly

4 Interface Description

Note: All applicable dimensions within this document can be given either in metrical units or in Anglo-American units. The respective converted value is given in brackets for information only.

4.1 Mounting Interface between SI and Telescope Instrument Flange

The Instrument Flange (INF, HW No. 4100) is a Subassembly of the Flange Assembly (FA, HW No. 4000) which is part of the Telescope Assembly (TA).

The part of the INF to which the Science Instrument will be mounted is the IMF (Instrument Mounting Flange). The IMF is located at the fwd end of the INF. The interior portion of the INF forward of the Pressure Window Subassembly and aft of the IMF is commonly referred to as the INF “Tub”.

The part of the Science Instrument (SI) assembly which will be mounted to the IMF on the TA is called the SI Flange.

Refer also to RD6 about configuration, notations etc.

The SI Flange and the IMF are centered on the IR beam. The mass of the SI assembly shall not exceed 600 kg (1,320 lbm). The design and dimensions of the IMF and associated fasteners / pins was based on structural analysis of a worst-case 600 kg SI on a 41 inch diameter SI Flange, fastened with all 20 bolts (through holes and shear pin configuration).

SIs with a lower mass may opt to use a different flange configuration (e.g., an incomplete bolt circle) and/or fewer fasteners, however structural analyses shall be provided by the SI Developer reflecting positive Margin of Safety (MS) for all bolts in tension as well as shear tear-out and bearing failure modes at bolt locations, considering the emergency crash load factors in each direction. For more information, please refer to RD18, para. 3.5.2.1 and Table 3.5-1, and RD15, section 8.4.1.

Nuts can be optionally secured with nut plates. The bolts, located on a circle, are equally spaced in angular direction. Bolt holes in both flanges are through holes. Nut plates will be on the aft side of the IMF. USRA provides and installs bolts, nuts, and nut plates. The space available between the aft surface of the IMF plate and the fwd surface of the BSA Base Plate is shown in figure 4-1b. An additional hole pattern with 20 through holes is given for SI installations which do not use the nut plates (refer to figure 4-1).

For standard operation the FA provides the following vacuum sealing possibilities:

1. SI to IMF (and thus INF)
2. SI (via pressure coupler) to Gate Valve,
3. Window to Gate Valve. If the Optical Window Assembly is installed, it will form in some configurations the pressure seal to the cavity (refer to section 4.4).

The IMF is equipped with 4 dowel pins, each placed on the ∅990 mm diameter bolt circle, 90 degrees apart. Since the bolts are clearance through holes, to provide accurate positioning of the SI (or alignment tools) to the TA, 2 (opposite) dowel pins on the IMF must be used. One of these dowel pins will be used for SI positioning and for shear, the other only for angular positioning of the SI. The SI Flange is to position clearance holes at the locations of the other 2 (unused) dowel pins, such that these pins may be left in place on the IMF. Please refer to para. 4.1.4.5 for more detailed specifications re: the SI Flange dowel pin bore hole and slot dimensions. The front view of the INF (IMF) is shown in figure 4-1 (and large scale in the Appendix).

There are additional hard points for mounting of SI hardware inside of the INF Tub (refer to section 4-10 for details).

The IMF is equipped with 4 jack screws to facilitate SI removal from the IMF. The jack screw locations are evenly distributed on the IMF bolt circle.

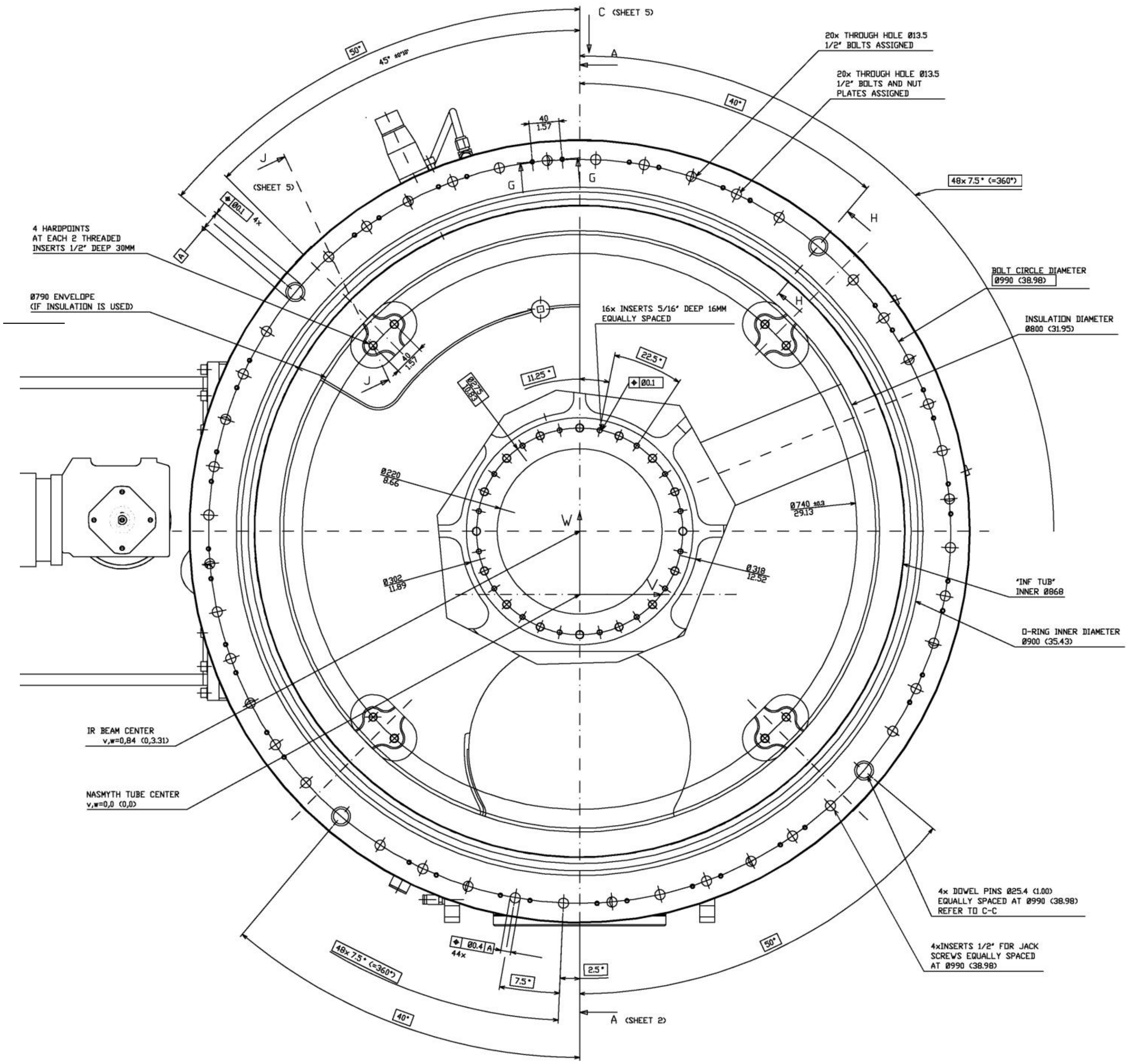


Figure 4-1: Front View of IMF (INF)
(refer to Appendix and RD11 for details)

Note: IMF depicted here with TA Elevation angle of 90°; During SI installation and removal, the TA Elevation angle is set to 40° (i.e., IMF rotated 50° clockwise from the orientation shown in Figure 4-1) such that Dowel Pins are at top, bottom, left and right positions.

general manufacturing tolerances in mm (according to RD 16)

Tolerance Class	nominal length of measure (mm)				
	0.5 to 6	6 to 30	30 to 120	120 to 400	400 to 1000
m (medium)	± 0.1	± 0.2	± 0.3	± 0.5	± 0.8

Note: as-built values will be given after manufacturing within a measurement protocol (refer to § 4.16)

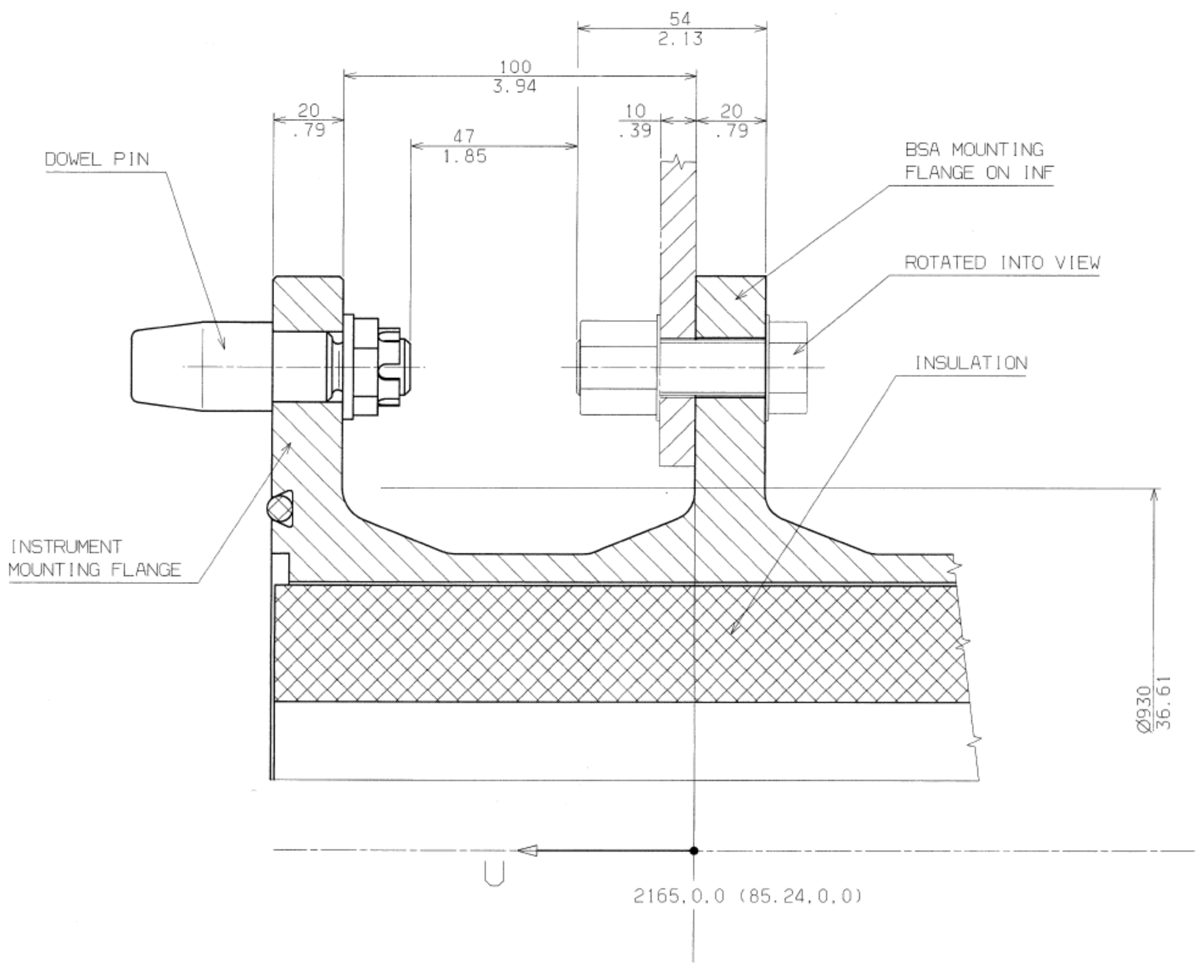


Figure 4-1b: Space between IMF back surface and BSA front Surface (from RD11) Dimension are given in mm (above) and inches (below)

4.1.1 Position of Interface Plane

The interface plane between the SI Flange and the IMF is located in the U-constant plane of the TA coordinate system at

U = 2285 mm [U = 89.96 inch], perpendicular to the actual IR Beam Centerline within ± 20 arc-min.

The coordinate system is defined in RD3.

4.1.2 IMF Outer Diameter

The IMF has an outer diameter (OD) of

D_O = 41 inch [1041.4 mm]

SI Flanges which use the TA IMF O-ring seal to effect the seal shall have an inner diameter (ID) of no greater than 884 mm [34.80 inch].

The annular region between this ID and the IMF OD shall meet the planarity specification defined in para. 4.1.6.4.

The center of D_O is the IR beam center, located at the TA Coordinates

W = 84 mm [3.31 inch]

V = 0 mm [0 inch]

4.1.3 Fixation Bolts

There are two bolt patterns for SI mounting purposes on the IMF. Each of them consists of 20 through holes. One pattern has fixation provisions for nut plates. When either bolt pattern is used washers will be installed under bolt heads.

4.1.3.1 Bolt Circle Diameter

The bolt circle is concentric with the IMF outer diameter ($D_{O'}$), as shown in Figure 4-1;

Accordingly, the SI Flange bolt circle diameter shall be D_B = 990 mm [38.976 inch] and centered on the IR beam.

4.1.3.2 Bolt Diameter and Thread

From strength calculations the bolt diameter has to be ≥ 12 mm [0.472 inch]

Bolts are sized to take axial accelerations during crash landings as specified in SOF-1030 for worst case SIs (600 kg) with all 20 bolts installed.

The bolts thread type is NAS (Anglo American), hence the bolt hole diameter allows also the use of metrical M12 bolts.

bolt thread diameter = 1/2 inch (1/2 – 20 UNF, NAS, 1/2 inch diameter bolts)

4.1.3.3 Bolt Length

Bolt length = (TBD at the Critical Airworthiness Design Review CADR for each SI by the SI developer or USRA respectively)

Note: Information on bolt length not required by TA-C

4.1.3.4 Number of Bolts

Number of bolts ≤ 20 (see para. 4.1 for flange and bolt loading and structural analysis considerations)

4.1.3.5 Angular Spacing

Angular spacing of bolt holes on the SI Flange shall follow the bolt hole angular spacing pattern defined in figure 4-1. SIs may use holes from either of the two defined bolt hole patterns, or a combination of the two, for mounting of the SI Assembly to the TA. Note that the TA IMF is rotated to the 40° elevation angle for SI installation and removal, and the TA IMF dowel pins are positioned at the top, bottom, left, and right positions at this elevation angle.

4.1.3.6 Torque

The nut will be torqued per L3 TPS 2-404 [14] to 630 – 1070 in-lbs (dry bolt), or 440 – 650 in-lbs (lubed bolt). If nut plates are used and bolt heads are wrenched, the installation torque will be the maximum torque indicated (i.e.,1,070 inch pounds [121 Nm] dry bolt).

4.1.3.7 Fastener Data

Bolt: MS21250, tension, steel, external wrenching, flanged, 12-point, 180 ksi alloy steel, 450°F

Modulus of elasticity E= 28 x 10^6 PSI

Yield tensile strength of bolts 1/2 - 20 = 22,400 pounds

Ultimate tensile strength of bolts 1/2 - 20 = 28,800 pounds

Nut: NAS1804, self-locking, extended washer, 12-point, 180 ksi alloy steel, 450°F

Washers: NASM20002C8, countersink washer under bolt head, plated steel

NASM20002-8, plain washer under nut, plated steel

Washers will be used under bolt heads and nuts when using nuts for installation, or just under bolt heads when using nut plates for installation.

4.1.3.8 Bolt Hole Diameter

The bolt hole diameter for the IMF is 13.5 mm [0.5314 inch]

The bolt hole diameter for the SI Flange shall be between 17/32 inch [13.5 mm] and 9/16 inch [14.3 mm]

If bushings or other inserts are to be used at the bolt hole locations (e.g., dielectric material to effect electrical isolation between the TA IMF and the SI Flange), such bushings shall be captive to avoid FOD concerns associated with small, loose components (e.g., interference fit).

4.1.3.9 Nut Plates

One of the two bolt patterns has provisions for the attachment and removal of nut plates on the aft side of the IMF. For design details refer to Fig. 4-1 and RD11: SOF-DWG-KT-4000.0.01 sheet 5/5.

Note: Off-the-shelf nut plates that fit the IMF are not available. A custom plate that retains the NAS1804 nut will be fabricated and provided by the SOFIA Program.

4.1.4 Dowel Pins

The dowel pins provide the accuracy and repeatability of the SI mounting on the IMF, and react all shear loading at the interface. For SI mounting and positioning, 2 of the 4 Pins must be used. One of the dowel pins will interface with a tight clearance through hole on the SI Flange for positioning in both the W and V axes, and reacts all shear forces during crash landings and during extreme maneuvers (Telescope slamming into hard stops). The opposing dowel pin will interface with a slotted hole in the SI Flange, and is used for angular positioning only. The dowel pins are part of the IMF. The dowel pin design is depicted in figure 4-2. The two dowel pins not in use are removable, but will be accommodated by oversized clearance through holes on the SI Flange such that they may remain in place on the TA IMF.

Refer to RD15 for SI airworthiness certification procedures. RD15 section 8 provides an overview of the airworthiness certification process, and section 8.4.1 provides additional details re: calculation of loads and structural analysis for SI flanges and IMF dowel pins.

The actual locations of the dowel pins after manufacturing were determined to be better than ±0.05 mm [± 0.002 inch] to their nominal locations as shown in Fig. 4-1 and Appendix.

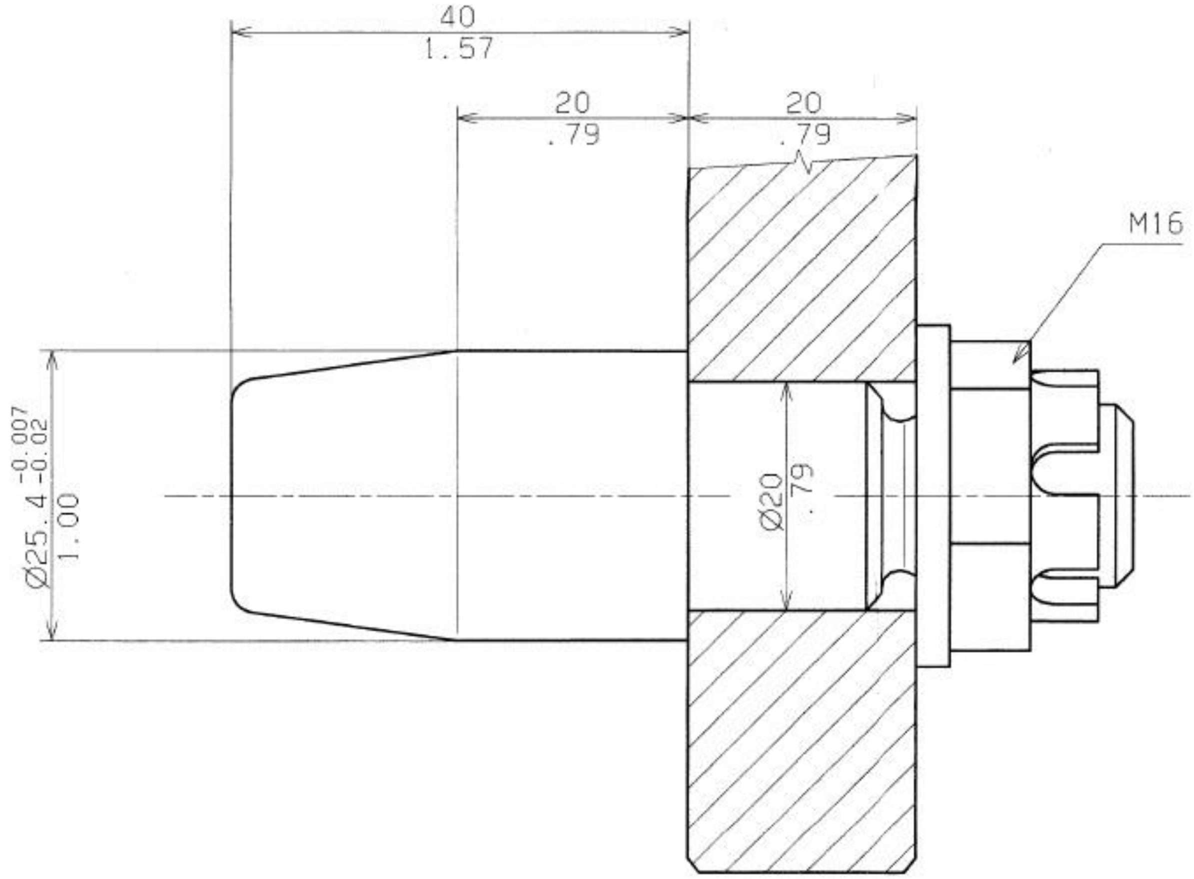


Fig 4-2: Dowel Pin Design (dimensions shown in mm with inches shown underneath witness lines)

4.1.4.1 Number of Dowel Pins

Total number of TA IMF dowel pins = 4 (2 each pattern)

4.1.4.2 Size

The dowel pin dimensions are given in figure 4-2.

4.1.4.3 Material

The dowel pins are made from Stainless Steel DIN 1.4545 (hardened steel) with the following allowables:

Tension 253 KN

Shear Bearing 235 KN

Shear 186 KN

The allowables are ultimate values since there is no yielding for hardened steel material.

4.1.4.4 Shape

The TA IMF dowel pin shape is given in figure 4-2.

4.1.4.5 Dowel Pin Bore Hole Diameter

Bore hole diameter on the TA Side is = 20 mm $^{+0.021}_{+0}$ [0.787 inch $^{+8E-04}_{+0}$]

Bore hole diameter on the SI Side is = 1 inch $^{+0.003}_{+0}$ [25.4 mm $^{+0.08}_{+0}$]

The SI Flange shall position a hole with a diameter as defined above, centered at the Dowel Pin location used for location and shear loads.

The SI Flange shall position a slotted hole centered at the Dowel Pin location opposite the one defined above for location and shear loads. The minor dimension (width) and tolerance of this slot shall match the Dowel Pin Bore hole diameter on the SI Flange. The major dimension (length) of this slot shall be between 1.12 inch [28.5 mm] and 1.25 inch [31.8 mm] and shall be oriented such that it points to the center of the flange (i.e., is aligned with the IR beam center).

If bushings or other inserts are to be used at any of the Dowel Pin Bore Hole locations (e.g., dielectric material to effect electrical isolation between the TA IMF and the SI Flange, or to achieve the correct diameter), such bushings shall be captive to avoid FOD concerns associated with small, loose components (e.g., interference fit), and should be adequately robust to preclude damage due to crushing upon SI installation.

The SI Flange shall position oversized clearance holes with diameter of at least 1.12 inch [28.5 mm] centered at the remaining two (2) Dowel Pin locations.

4.1.4.6 Angular Spacing

The TA IMF dowel pin pattern is given in figure 4-1.

The SI Flange shall have a pattern of 4 dowel pin clearance holes and slot with 90-degree angular spacing on a 990 mm [38.976 inch] bolt circle centered on the IR beam, as shown in Figure 4-1, and as described in paragraph 4.1.4.5, above.

4.1.5 Jack Screws for Lift Off

The INF is equipped with 4 jack screws to lift off the SI from the INF. Locations of the jack screws are given in Fig. 4-1 or RD11. The SI Flange shall position no holes in any of the four IMF jack screw locations.

Thread/Insert Specification: F8-15 (1/2-20) acc. to MS21209; Helicoil Fine Thread ∅ 1/2 inch x 1.5D

4.1.6 Seal

The vacuum seal between the INF (IMF) and the SI is formed by an O-ring.

The O-ring is part of the INF. TA Consortium provides 1 O-Ring and 1 Spare.

The O-ring is held in a captive groove to avoid accidental removal.

The captive groove with the O-ring is shown in figure 4-3.

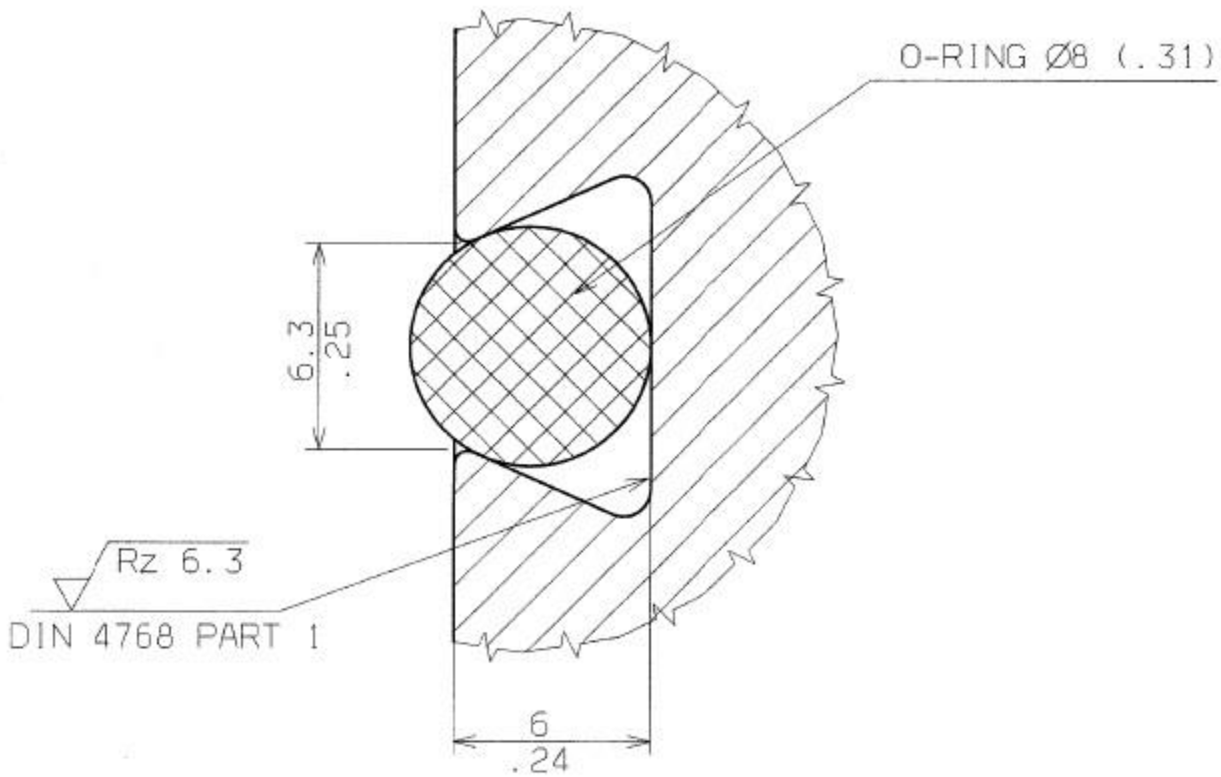


Figure 4-3: O-ring in captive groove (mm [inch])

4.1.6.1 O-Ring Diameter

O-ring diameter (inner dia.) = 900 mm [35.433 inch], centered on the IR beam (refer to figure 4-1).

4.1.6.2 O-Ring Material

The O-ring is made out of VITON or similar material

4.1.6.3 O-Ring Thickness

O-ring thickness = 8 mm [0.315 inch]

4.1.6.4 Surface Roughness and Planarity

For SI Flanges which use the TA IMF O-ring seal to effect the vacuum seal (i.e., the pressure boundary between the pressurized aircraft cabin and the unpressurized TA cavity), an annular portion of the SI Flange surface from ∅884 mm (34.80 inch) ID to ∅928.6 mm (36.56 inch) OD shall meet the following requirements, to provide a smooth, flat faying surface for the O-ring seal:

planarity ≤ 0.4 mm [0.016 inch]

surface finish / roughness Ra ≤ 0.8 micron [32 micro-inch]; Alternately, the surface finish / roughness may be relaxed to Ra ≤ 1.6 micron [64 micro-inch] with the additional specification of a concentric surface texture lay.

SI Flange edges that contact the TA IMF O-ring seal shall be chamfered or otherwise deburred / broken with a minimum edge radius of 0.2 mm [0.008 inch] to prevent damage to the seal material.

SIs which position the SI Flange such that it does not make direct metal-to-metal contact with the TA IMF (e.g., those which are electrically isolated using a dielectric material at the mechanical interface between the TA IMF and the SI Flange) shall ensure that the O-ring seal is compressed no less than 15% of the O-ring cross-sectional thickness upon SI installation, considering the thickness and placement of the dielectric material, stack-up of all dimensional tolerances, and the TA IMF O-ring and gland dimensions defined in Figure 4-3.

If a non-standard interface is deemed necessary to effect a suitable seal for whatever reason, the SI developer will need to pursue a Request for Deviation or Waiver (RDW) against this ICD requirement, defining the alternate sealing interface provisions. A vacuum decay test (or similar) may be required in order to verify that the non-standard seal interface complies with acceptable leakage rates.

4.1.7 Inner Diameter of INF / IMF

The inner diameter of the INF "Tub" is centered on the IR beam optical axis (V = 0 mm [0 inch], W = 84 mm [3.307 inch]).

The INF inner diameter is D_I = 800 mm [D_I = 31.496 inch] with insulation and 868 mm [34.17 inch] without insulation.

The free volume between the SI Flange and the Pressure Window Subassembly is defined in section 4.8.

There is a step on the front side of the INF Tub with 5 mm depths and an outer diameter of

884 mm $^{+0.1\ \text{mm}}_{-0.5\ \text{mm}}$ [34.803 inch $^{+0.004\ \text{inch}}_{-0.02\ \text{inch}}$]

which can be used for centering purposes.

4.1.8 Orientation Marker [Requirement deleted]

4.1.9 INF Material

The INF is made out of stainless steel (DIN 1.4571, stainless chromium-nickel-steel with 0.05% C, 18% Cr, 10% Ni, 0.6% Nb, comparable to AISI 347, resp. ASTMA 240 316 TI)

4.2 Mass and C.G. of the SI Assembly

Due to the numerous different possible configurations of science instruments, mass and center of gravity are variable. C.G. and mass range of the SI Assembly are specified in RD19 and 20.

4.2.1 SI Assembly Mass and C.G. Range (static)

SI Assembly c.g. location (refer to RD19 for details):

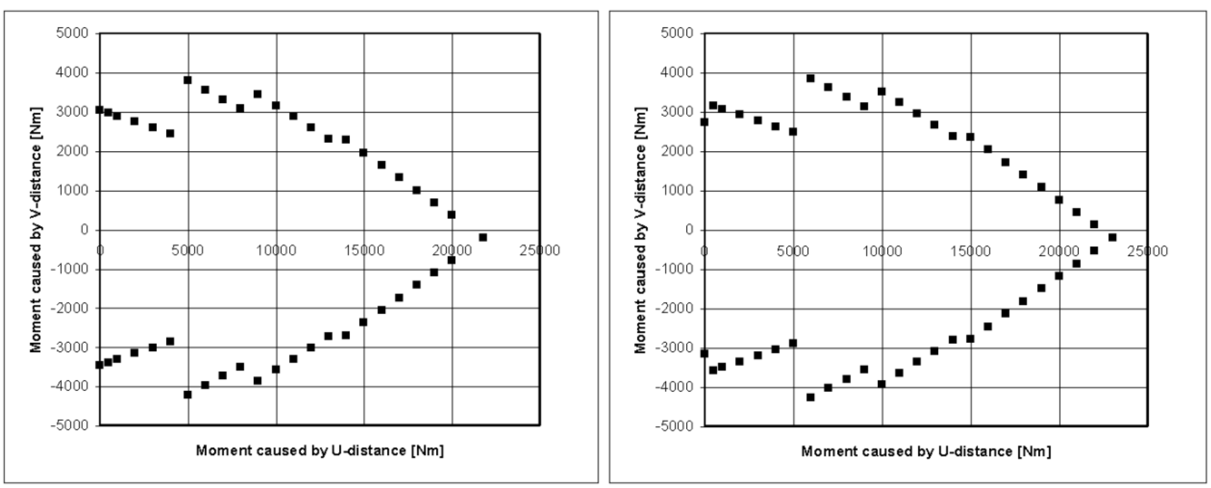
The SI Assembly c.g. in the longitudinal direction (U coordinate axis) shall be between U = 3285 mm [129.33 inch] and U = 1785 mm [70.28 inch]

The SI Assembly c.g. in the radial direction shall be within a cone shaped moment envelope defined by connecting adjacent points with straight lines in Figures 4.2.1-1 and 4.2.1-2. Applicability of a moment envelope is dependent on the mass of the SI electronics and Counterweight Rack (CWR) located on the balancing subassembly of the TA. All SI installations will include a CWR installation. For SIs that do not use a CWR for SI equipment, SOFIA Mission Operations will install a CWR loaded with ballast weights to achieve the minimum CWR mass of 100 kg (220 lbm).

Two envelopes are given:

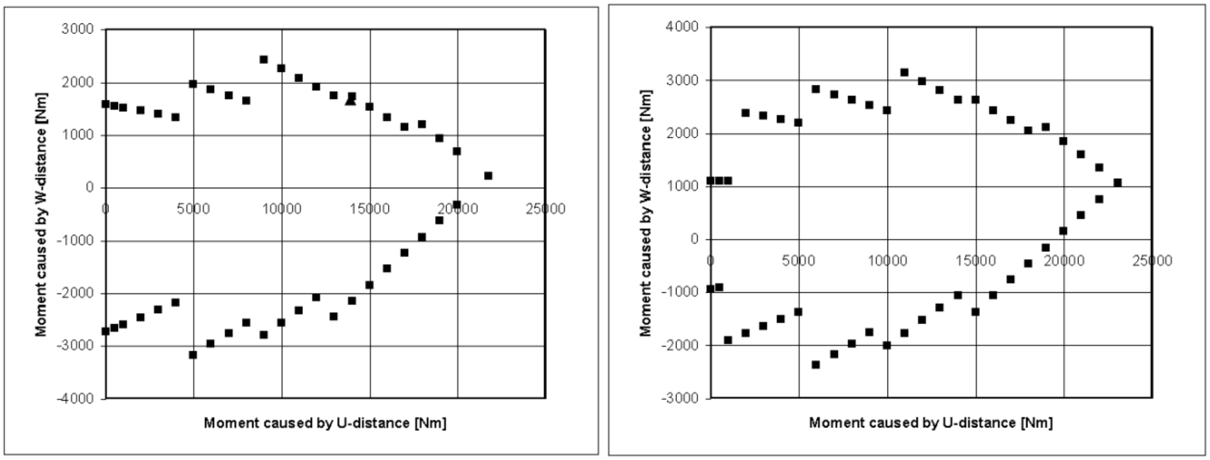
- considering a mass of the CWR of 150 kg (330 lbm)
- considering a mass of the CWR of 100 kg (220 lbm)

Figure 4.2.1-1 shows the maximum moments caused by c.g.-variation in V-direction
Figure 4.2.1-2 shows the maximum moments caused by c.g.-variation in W-direction.
The SI assembly c.g. envelope is defined by a cone shaped by these axes.



mass of CWR = 150 kg mass of CWR = 100 kg

Fig. 4.2.1-1



mass of CWR = 150 kg mass of CWR = 100 kg

Fig. 4.2.1-2

4.2.2 Mass Change of SI During Flight

The TA provides its pointing accuracy and stability, without rebalance, under moment changes up to 150 Nm around XEL and LOS and 30 Nm around EL, caused by changes in SI mass and SI c.g. during flight.

The active balance subsystem is designed to accommodate SI mass and SI c.g. changes totaling an equivalent 800 Nm moment change around XEL and LOS and 400 Nm around EL calculated for a 10-hour flight.

SIs which use expendable liquid cryogens to cool their instrument shall exhibit a moment change of not more than 800 Nm around the XEL and LOS axes, and not more than 400 Nm around the EL axis, over a 10-hour flight, resulting from SI mass and c.g. change during flight due to the depletion of the cryogens in the SI dewar.

4.3 Pressure Coupler Interface

The pressure coupler connects the open (optical) port of the Pressure Window Subassembly with Science Instruments which use only or additionally a small vacuum sealing interface diameter at the GVPP. The pressure coupler is provided by the SI developer if required. Within this document the interface of the coupler to the TA is described.

The pressure coupler shares the same interface to the TA as the Optical Window Assembly (refer to section 4.4). The pressure coupler / optical window interface is depicted in figure 4-7a

4.3.1 Configurations

There are various pressure coupler configurations. Some of them have additional connections to the vacuum and/or the exhaust fittings / feedthroughs of the tub (located as described in section 4.5 and 4-6) The configurations of the pressure coupler interface are shown in figure 4-5.

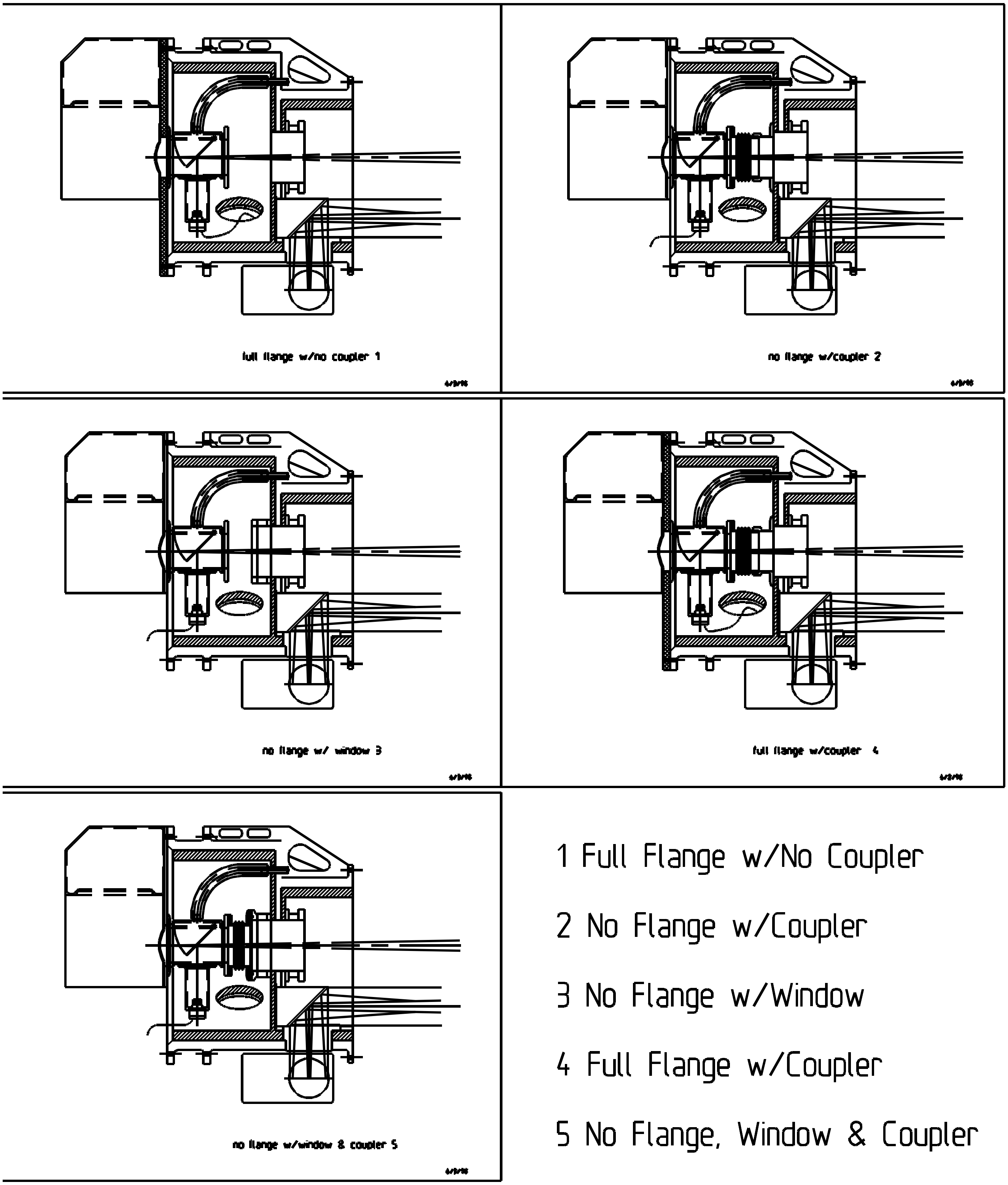


Figure 4-5: Pressure Coupler Interface Configurations (Not to scale, access port drawn into view)

4.3.2 Free Diameter

The free optical diameter of the pressure coupler interface is centered on the IR beam

(V= 0 mm; W = 84 mm [3.31 inch])

Free Diameter = 220 mm [8.66 inch] at U = 1800 mm [70.87 inch]

The vignetting is limited at U=1795 mm [70.67 inch] with a diameter of 220 mm [8.66 inch]

4.3.3 Position of Interface Plane

The interface plane of the pressure coupler to the TA is at

U = 1800 mm [70.87 inch]

4.3.4 Mechanical Interface Flange Diameter

The maximum mechanical interface flange (outer) diameter of the pressure coupler on the aft end = 300 mm [11.81 inch]

4.3.5 Fixation Threads

The GVPP pressure coupler / optical window interface has 16 available threaded inserts at the interface for the purpose of mouting the pressure coupler / optical window assembly on the GVPP.

4.3.5.1 Insert Type

- 5/16 helical coil inserts,
- screw- locking 5/16-24 according to MS 21209
- Material CRES (corrosion resistant stainless steel)
- Dash No. F5 – 20
- Fine thread

4.3.5.2 Screw Thread and Clearance Hole Size

Thread diameter x depth = ∅ 5/16 inch x 0.63 inch [7.9 mm x 16 mm] (refer to fig. 4-7a)

The pressure coupler flange shall have clearance holes with a diameter between ∅ 0.323 inch (P drill size) [8.2 mm] to ∅ 0.332 inch (Q drill size) [8.4 mm]

4.3.5.3 Number of Bolts

Number of bolts ≤ 16**,** equally spaced in angular direction (refer to fig. 4-7a). The number of bolts, clearance holes and threaded inserts used by the SI Developer shall be substantiated by a structural analysis provided by the SI Developer reflecting positive Margin of Safety (MS) considering the emergency crash load factors in each direction. For more information, please refer to RD18, para. 3.5.2.1 and Table 3.5-1, and RD15, section 8.4.1.

4.3.5.4 Bolt Circle Diameter

The bolt circle diameter of the pressure coupler / optical window assembly flange that interfaces with the GVPP pressure coupler / optical window interface shall be 275 mm [10.83 inch] centered on IR beam, as shown in fig. 4-7a.

4.3.5.5 Angular Spacing

The angular spacing of clearance holes on the pressure coupler / optical window assembly flange shall use the threaded insert angular spacing pattern shown in Figure 4-7a.

4.3.6 Pressure Seal

The pressure seal between the pressure coupler and the TA is given by an O-ring

The O-ring is part of the pressure coupler provided by the SI developer (if required).

4.3.6.1 O-Ring Diameter

The O-ring inner diameter is centered on the IR beam. Various O-ring diameters are possible. The inner diameter of the O-Ring gland at the pressure coupler / optical window assembly mating surface shall be between 230 mm [9.06 inch] and 240 mm [9.449 inch].

4.3.6.2 O-Ring Thickness

The O-ring thickness shall be ≤ 6 mm [0.236 inch]

4.3.6.3 Surface Properties

Pressure Coupler surfaces which interface with the TA Pressure Window Subassembly and O-Ring seal (including the bottom surface of the Pressure Coupler O-Ring seal gland) shall meet the following requirements:

planarity ≤ 0.3 mm [0.012 inch]
surface finish / roughness Ra ≤ 0.8 micron [32 micro-inch]; Alternatively, the surface finish / roughness may be relaxed to Ra ≤ 1.6 micron [64 micro-inch] with the additional specification of a concentric surface texture lay.

The O-ring seal and corresponding seal gland shall be dimensioned so as to ensure that the O-ring seal is compressed no less than 15% of the O-ring cross-sectional thickness upon assembly, considering a worst-case stack-up of all applicable dimensional tolerances.

4.3.7 Free Volume (Envelope)

The pressure coupler / optical window interface is countersunk in the GVPP. Thus, the pressure coupler diameter shall be limited to ∅300 mm [11.81 inch] between U = 1800 mm [70.87 inch] and U = 1885 mm [74.21 inch].

Pressure coupler assembly length shall be limited to 485 mm [19.09 inch], the distance between the GVPP mounting interface (U = 1800 mm [70.87 inch]) and the IMF interface (U = 2285 mm [89.96 inch]).

4.3.8 GVPP Motion under Pressure

The differential pressure between the fwd GVPP volume and aft GVPP volume causes the interface plane on the GVPP to move in the U-Direction. The pressure coupler shall be able to accommodate a 0.1 mm [0.004 inch] range of motion in the U-direction, resulting in an additional tilt of approximately 0.03 degrees.

4.4 Optical Window Interface (Optical Window Assembly)

This interface equals the pressure coupler interface (section 4.3).

The design described here is compliant with DCR 0015.R2 (AD 04)

This interface does not include optical parameters like transmission, surface quality, index of refraction etc.

The change of focus position and a degradation of the image quality due to refractive, chromatical or other influences of the window is not reflected in this ICD.

The window element together with the window mount and the fixation ring forms an assembly, the Optical Window Assembly. The Optical Window Assembly, where needed, is provided by the SI developer.

Relevant for the interface between SI and TA is only the mechanical interface between the Optical Window Assembly (i.e. the window mount) and the Flange Assembly (i.e. the GVPP).

The Optical Window Assembly design has to be capable to take loads, caused by motions of the GVPP under changing pressures (refer to section 4.3.8.for details).

4.4.1 Configuration

The Optical Window Assembly is depicted as concept in figure 4-7 b. It shows a possible mounting of the IR window element. This assembly will be mounted to the FA GVPP on the same interface as the pressure coupler, thus on the FA side there is only one interface.

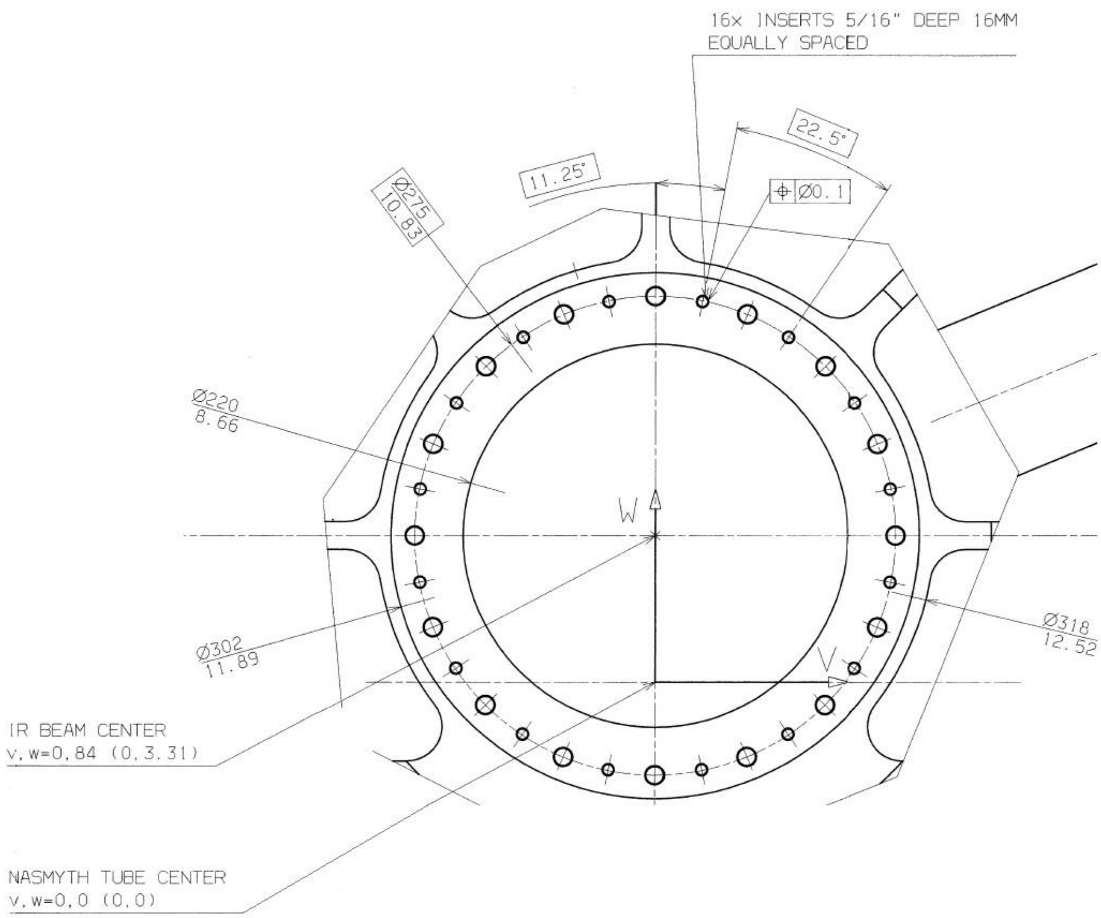


Figure 4-7 a: Pressure Coupler / Optical Window Assembly interface dimensions. Dimensions are given in mm (above) and inches (below)

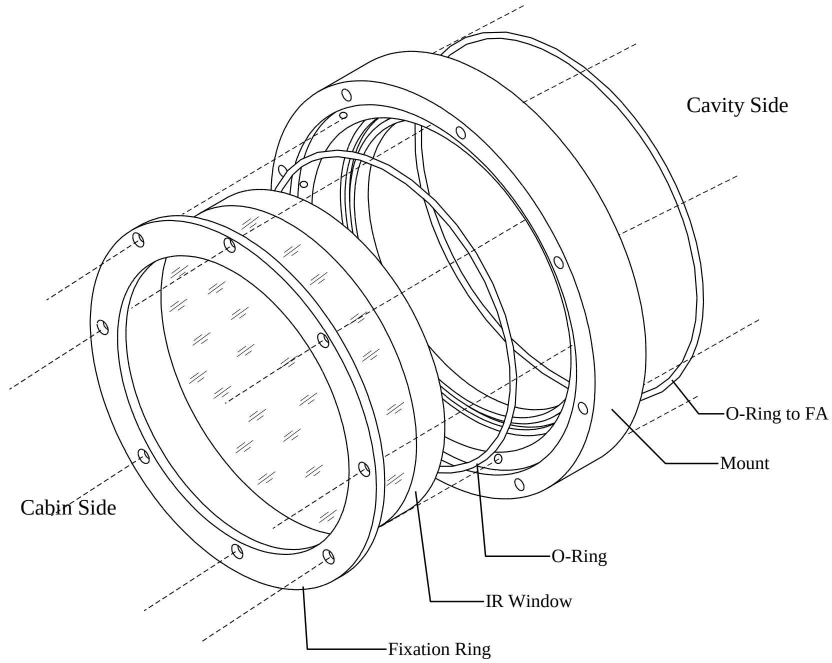


Figure 4-7 b: Example for a possible concept of Optical Window Mounting Assembly

4.4.2 Optical Free Diameter

The optical free diameter of the window mount

free diameter = 220 mm [8.66 inch] at U=1800 mm [70.87 inch]

4.4.3 Mechanical Diameter of the Mount

The mechanical (outer) diameter of the Optical Window Assembly and flange shall be limited to the same diameter as the pressure coupler (refer to section 4.3.7).

The stay-in envelope for the Optical Window Assembly in the U-direction is dependent on the dynamic envelope of the SI assembly aft of the IMF. If an SI Assembly uses the maximum SI depth in the INF as defined in RD5, the Optical Window Assembly depth in the U-direction shall be limited to 85 mm [3.34 inch].

4.4.4 Bolt Circle Diameter and Bolt Size

Bolt circle diameter, bolt size, bolt pattern, and mounting screw clearance hole diameter shall be identical to the dimensions defined for the pressure coupler interface (section 4.3, figure 4-7 a).

4.4.5 Seal Between Optical Window Assembly and TA/FA

The seal between the Optical Window Assembly and the Flange Assembly shall match the specifications defined for the pressure coupler (section 4.3.6).

The O-ring is part of the Optical Window Assembly and is provided by the SI developer (if required).

4.4.6 Limit Loads for Pressure Coupler / Pressure Window Fixture

The pressure coupler/pressure window fixture is certified to take the loads given in section 4.9.1 for masses of 10 kg or less. Pressure Coupler Assemblies and Optical Window Assemblies mounted to the GVPP Pressure Coupler / Optical Window interface shall not exceed 10 kg. Larger masses may have to be supported by other means as well as by the window fixture. Fixation configuration of larger masses than 10 kg is TBD by each SI critical airworthiness design review (Note: This information is not required by the TA-C).

4.5 Exhaust Tube Interface

The exhaust tube is routed from the fuselage via the Cable Load Alleviator and on the outside of the Flange Assembly to the SI or the INF Tub (refer also to ICDs TA_AS_11 and TA_SI_01).

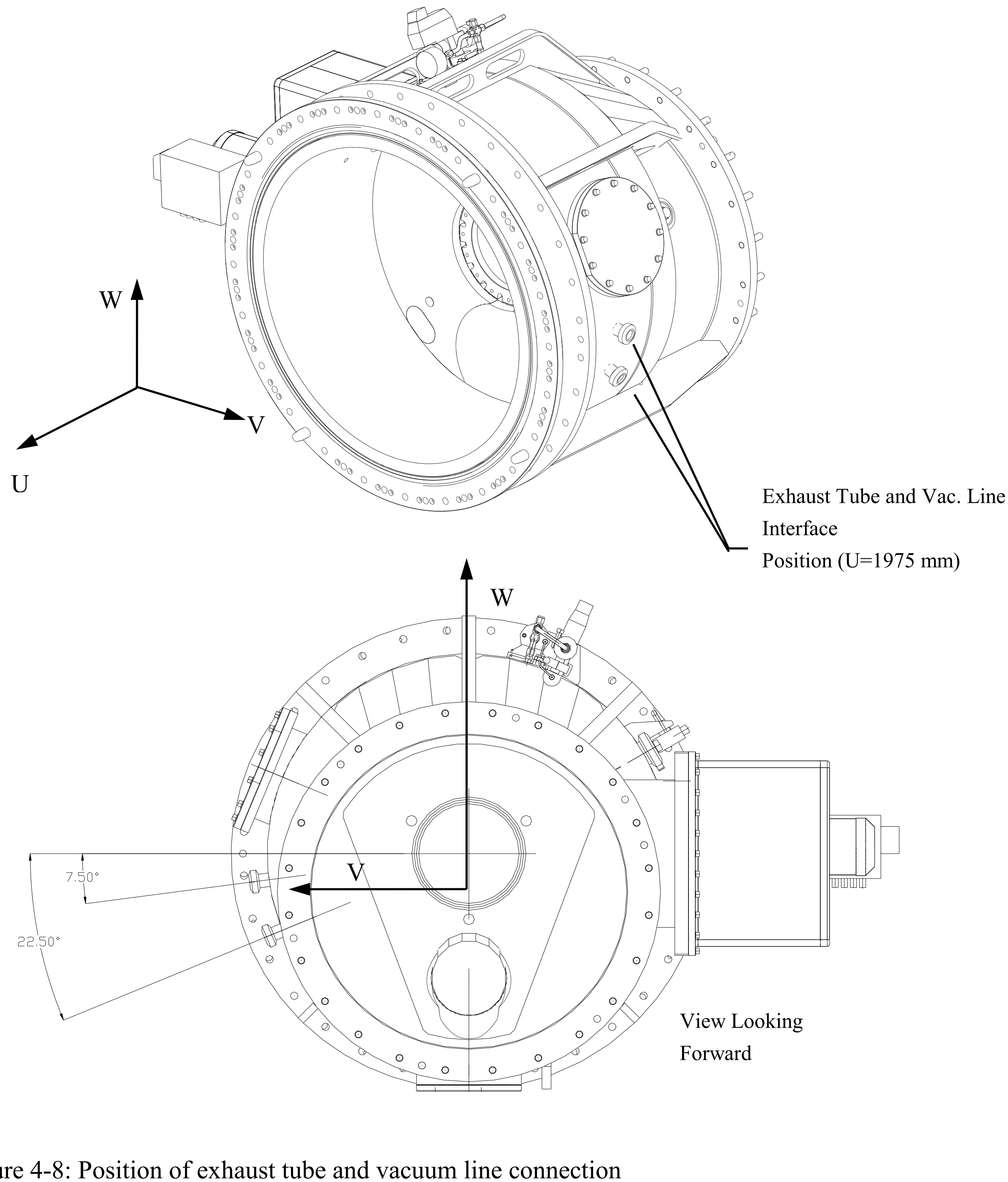


Figure 4-8: Position of exhaust tube and vacuum line connection

4.5.1 Tube Diameter

Refer to TA_SI_01 (RD21) and TA_AS_03 (RD22)

4.5.2 Tube Material

Refer to TA_SI_01 (RD21) and TA_AS_03 (RD22)

4.5.3 Type of Connection

On the cabin side of the INF there are two KF-25 Quick Flanges. The connection on the FA side can be used either for exhaust tube or vacuum line connection (refer to section 4-6).

Hoses that connect to the cabin side KF-25 Quick Flanges on the INF shall be KF-25 Quick Flanges. Standard hinged clamps and centering rings shall be used for fixation and sealing.

On the INF tub inner side there are 3/4 inch [19.1 mm] NPT threads for connecting for example a pump-out line to the pressure coupler. The NPT threads are closed by a piece of insulation when not in use. Thermal bridging should be avoided.

An additional interface can be used to connect to the volume between the Gate valve and the optical window. There is a T-Coupler in the tubing of the bypass valve, which connects this volume via the by-pass valve to the cavity. Type of Coupler is a 6 ECR 6 A-Lock fitting from Parker Hannifin Corporation, suitable for 6 mm [0.236 inch] diameter tubes (nut size is 7/16 – 20 UNF).

4.5.4 Position of Connection

The exhaust tube / vacuum line connections on the cabin side of the INF are located radially on the INF tub (refer to figure 4-8).

Science Instrument or INF Tub will connect to the CLA via hoses (refer to RD 21).

The hoses do not require attachment points on the TA Flange Assembly structure.

Routing of the hoses is not part of this document.

4.5.5 Exhaust Blower Rate

Refer to section 4.7.3

4.6 Vacuum Lines Interface

The vacuum lines are routed from the fuselage via the Cable Load Alleviator and along the outside wall of the Flange Assembly to the SI or the INF Tub. This is described in various ICDs (RD 22: TA_AS_03, RD25: TA_AS_11; RD21: TA_SI_01). This ICD includes only the connection between the vacuum lines and the INF Tub. On the INF Tub there are two KF 25 connections which can be used either for vacuum lines or for exhaust tubes (refer to chapter 4.5).

4.6.1 Diameter

refer to TA_SI_01 (RD21) and TA_AS_03 (RD22)

4.6.2 Material

refer to TA_SI_01 (RD21) and TA_AS_03 (RD22)

4.6.3 Type of Connection

Refer to section 4.5.3

4.6.4 Position of Connection

Refer to section 4.5.4

4.6.5 Number of Lines

Refer to RD21

4.7 Thermal Interface

The volume fwd of the PWS (i.e. the INF Tub) is thermally insulated, but not thermally controlled. The surface temperature limits of the walls surrounding this volume are not specified. For PI purposes this volume shall be as large as possible. Due to the above given constraints the thickness of the thermal insulation will be kept at a minimum (i.e. will be dimensioned according to the heat transfer requirement given in SOF-1011 §3.3.2.5 only).

4.7.1 Heat Dissipation Requirements

To limit seeing effects and heating of the NT, the heat dissipation from the SI to the TA inner volume shall be kept as small as possible.

4.7.1.1 Electronics Heating

- Maximum heat by SI electronics mounted on the FA conducted to the FA ≤ **8 W**.
- Minimum heat input to the FA from SI electronics is **0 W**.

4.7.1.2 Convective Heating

Heating of the SIs will occur due to convective contact between the SI and the cabin air. Cooling of SIs will be primarily through conduction to the FA. The heat input to the FA can only be calculated with the thermal model of the FA, because it depends on the equilibrium temperature of the FA. The following are inputs for the FA/TA thermal model:

- Maximum heat input:

  This would correspond to an SI with maximum surface area mounted with negligible thermal impedance to the FA. This maximum surface area is roughly that of a cylinder with 1 m [39.37 inch] diameter and 2 m [78.74 inch] length with only one end not exposed to cabin air, or 7.5 m^2 [11.62 $inch^2$] exposed to the cabin. The SI seals at the SI flange, and an insulation of the same quality as on the interior of the FA tub is used on the aft side of the SI mounting plate. For this case the gate valve is assumed to be open, and no window is used. The thermal conductance between the SI and the FA is about 300 mW/K.

- Minimum heat input:

  This would correspond to an SI with minimum surface area mounted with insulation between it and the FA. The minimum area might correspond to a cylinder 25 cm [9.84 inch] in diameter and 25 cm [9.84 inch] high. The insulation can be modeled as a 6 mm [0.236 inch] thick, 25 mm [0.984 inch] wide, and 100 mm [3.937 inch] diameter G10 fiberglass ring. Such a small SI can be assumed to be mounted on the gate valve with a short, 10 cm [3.937 inch] diameter pressure coupler, and to have most of its surface insulated with insulation of the same quality as the interior of the FA tub. The SI area is about 0.3 m^2 [465 $inch^2$] and thermal conductance between the SI and the FA is about 30 mW/K.

4.7.1.3 Radiative Heating

Radiative effects are estimated with the following simple assumptions:

- The power radiated from the SI mounted on the IMF flange into a 25 cm [9.84 inch] diameter hole located at the gate valve is between **2W and 13 W**
- A power of **2 W** is radiated from the 10 cm [3.937 inch] diameter mounting flange into the Nasmyth Tube through the hole in the gate valve.

4.7.2 Interface Temperature Limits

The temperature limits for the TA to SI shall be kept as low as possible in order to keep the N2 consumption, the dimensioning of the cooling fans and blowers as small as possible.

In the moment the SI interface temperatures are considered to be 300 K.

Interface temperature limit ≤ 300 K

4.7.3 Airflow through exhaust line(s)

Airflow rate in the tub (through exhaust line(s)) is large enough (i.e. ≥ 20 cfm) to avoid backflow into the Nasmyth Tube when the Gate Valve is open without a window installed. This is required for proper operation of the Nasmyth tube cooling system and to meet the SOF-1011 surface temperature requirement.

4.7.4 Operation and Environment

To avoid ice forming on optical elements, sensors and mechanisms which would reduce performance, functionality and lifetime of above items, all operations must guarantee, that no moist air is in the tub when pressure will be equalized before opening of the Gate Valve. This can be assured by pumping out the tub or a pressure coupler, using the vacuum pump connection before the Gate Valve is opened.

4.8 Free Volume Aft of the SI Flange

There is a free volume available inside of the FA between the Pressure Window Subassembly and the Instrument Mounting Flange. This volume might be used by the PI or the operator for different purposes such as a boresight box, foreoptics, a calibrator, or a small SI.

The free volume is given by a cylinder centered on the IR Beam optical axis (V, W) = (0 mm, 84 mm) [(0 inch, 3.307 inch)].

The inside walls of the INF tub are covered by an insulation layer, for the purpose of thermal insulation. The insulation is designed to be removable. The inner diameter of the insulation layer inside the INF is 800 mm [31.5 inch]. The inner diameter of the INF tub is 868 mm [34.17 inch]. A radial margin of 5 mm [0.2 inch] between stay-in and stay-out envelope should be used. The insulation layer inside the INF tub should remain in place, except when removal is required for TA maintenance activities. Removal of the insulation for non-standard SI installations will require technical justification for a waiver request, and will require formal review by the Program.

The free volume inside the INF available for SI use is included in the total SI Dynamic Envelope defined in SOF-DA-ICD-SE03-002 (ICD GLOBAL_09) Section 3.1. Science Instruments must meet the SI Dynamic Envelope interface requirement in GLOBAL_09. The SI stay-in envelope inside the INF (aft of the Instrument Mounting Flange) is the following:

SI stay-in envelope = ∅ 790 mm [31.1 inch] x 390 mm [15.4 inch]

Fwd end of envelope cylinder is at the SI interface plane (U= 2285 mm [89.961 inch] refer to section 4.1.1)

Aft end of envelope cylinder is at U = 1895 mm [74.606 inch].

4.9 Worst Case Loading Imparted to the SI by the TA

The worst case loading imparted to the SI by the TA under operational flight conditions are defined in this chapter. During flight operation, the aircraft vibrations are attenuated by the VIS. The vibration levels at the SI Interface will be measured during vibration testing. This document gives only expected vibration level from mathematical simulation.

4.9.1 Acceleration at SI Interface

Total linear accelerations at the Science Instrument c.g., located at (c.g._U, c.g._V, c.g._W), can be calculated from numbers in Table 4-1 using the following matrix transformation:

$$\begin{vmatrix} AU \\ AV \\ AW \end{vmatrix} = \begin{vmatrix} US \\ VS \\ WS \end{vmatrix} + \begin{vmatrix} 0 & a\_rot\_w & a\_rot\_v \\ a\_rot\_w & 0 & a\_rot\_u \\ a\_rot\_v & a\_rot\_u & 0 \end{vmatrix} \begin{vmatrix} c.g.\_U \\ c.g.\_V \\ c.g.\_W \end{vmatrix}$$

Notes:

- TA-Coord. System and Aircraft-Coord. System are according to SOFIA Coordinate Systems ICD Global_05
- Resulting Loads at the SI Flange are dependent on the respective SI mass, SI c.g. and SI moments of inertia
- All tables are basically compiled from Design Loads SOF-TAN-MG-0000.0.04 Issue 04 Date 17.11.99 (RD12)
- The reduced number of load cases presented in this notice does not release each SI stress analyst from the verification of all applicable loads on his own responsibility.
- For details refer to the design load document RD12, Section 6.9.
- The temperature load cases are only applicable for parts which are not influenced by the cabin-cavity gradient or other thermal sources. For inhomogeneous temperature distributions additional load cases must be defined by each stress analyst.

Load cases are only listed for verification of structural strength, not for function of mechanical components.

Aircraft flight, TA operating, uncaged								
Flight Cases	Linear Acceleration at (U,V,W)=(0,0,0) (g (= 9.8 m/ s^2))				Rotational Acceleration about (U,V,W) = (0,0,0) (rad/s^2)			Pressure Diff. (bar)
	US	VS	WS		a_rot_u	a_rot_v	a_rot_w	PRUC
RRBPT2b	0	-1,0	0		16,69	0	3,32	0,65
RLCPT2b		-1,0			-16,69		-3,32	0,65
PVCPT2b		-2,9			-2,12		-2,83	0,65
PVBPT2b		-2,9			-0,16		-0,21	0,65
PWBPT2b			2,9			-2,30		0,65
PWCPT2b			2,9			-0,17		0,65
YRVCPT2b			1,0		-2,45		-3,28	0,65
YLVBPT2b			1,0		2,45		3,28	0,65
YRWCPT2b		-1,0				2,66		0,65
YLWBPT2b		-1,0				-2,66		0,65
SVBPT2b		-1,0			-0.60		-0,80	0,65
SWCPT2b			1,0			0,65		0,65

Table 4-1 : TA Flight Operation Cases resulting in extreme accelerations. Cases are defined in RD 12 and included TA in varying elevation positions and under varying disturbances. The pressure difference is between cabin and cavity.

Scaled case	Basic case linear acceleration			press.
	US	VS	WS	PRUC
Aircraft flight, TA caged				
LUVAPT3b	+1,0	-1,0		0,65
LUWAPT3b	+1,0		+1,0	0,65
LVPT3b		-3,29		0,65
LWPT3b			+3,29	0,65
UVCPPT3b	-0,81	-2,37		0,65
UWCPPT3b	-0,81		+2,37	0,65
LUVFMT3b	-1,07	-1,0		-0,017
LUWFMT3b	-1,07		+1,0	-0,017
LWXT3b			+1,0	0,86

Table 4-2 Structure relevant flight cases (ref. to RD12)

Scaled case	Basic case linear accel.		
	US	VS	WS
Aircraft on ground incl. taxiing and towing			
LUVFT3a	-1,07	-1	
LUWFT3a	-1,07		+1
LVT3a		-3,29	
LWT3a			3,29
SVTxa		-1	
SWTxa			+1
SVTxab		-1	
SWTxab			+1

Table 4-3 Structure relevant ground cases (ref. to RD12)

Scaled case	Basic case linear acceleration		
	US	VS	WS
Aircraft flight, TA caged, Emergancy Landing			
UEM	-9		
VEM		-6	
WEM			+6
Aircraft flight, TA uncaged / caged			
UOC	1		
VOC		1	
WOC			1
Handling loads			
UHA VHA WHA	Analyse separately due to different boundary condition		

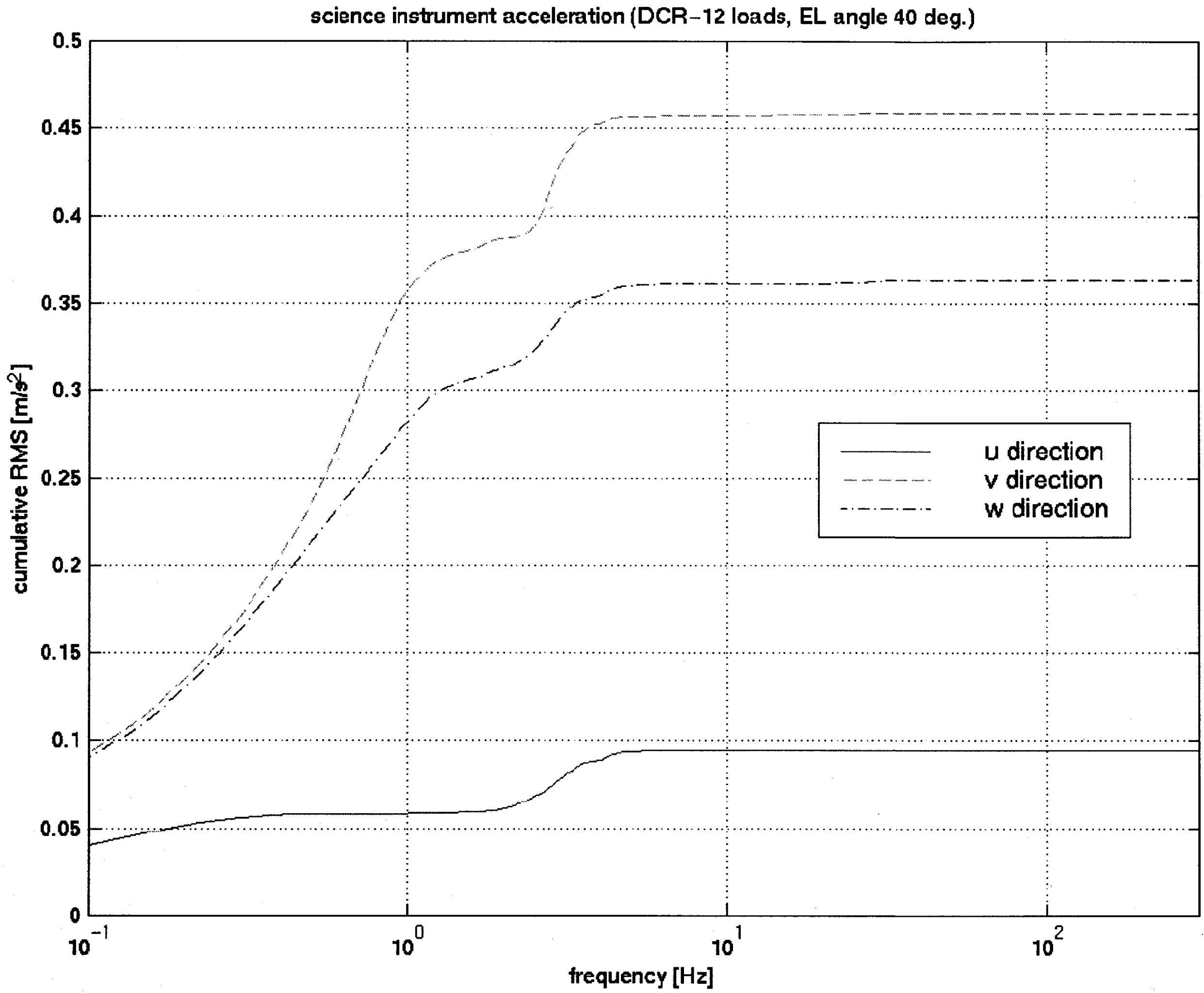
Table 4-4 Single cases (ref. to RD12)

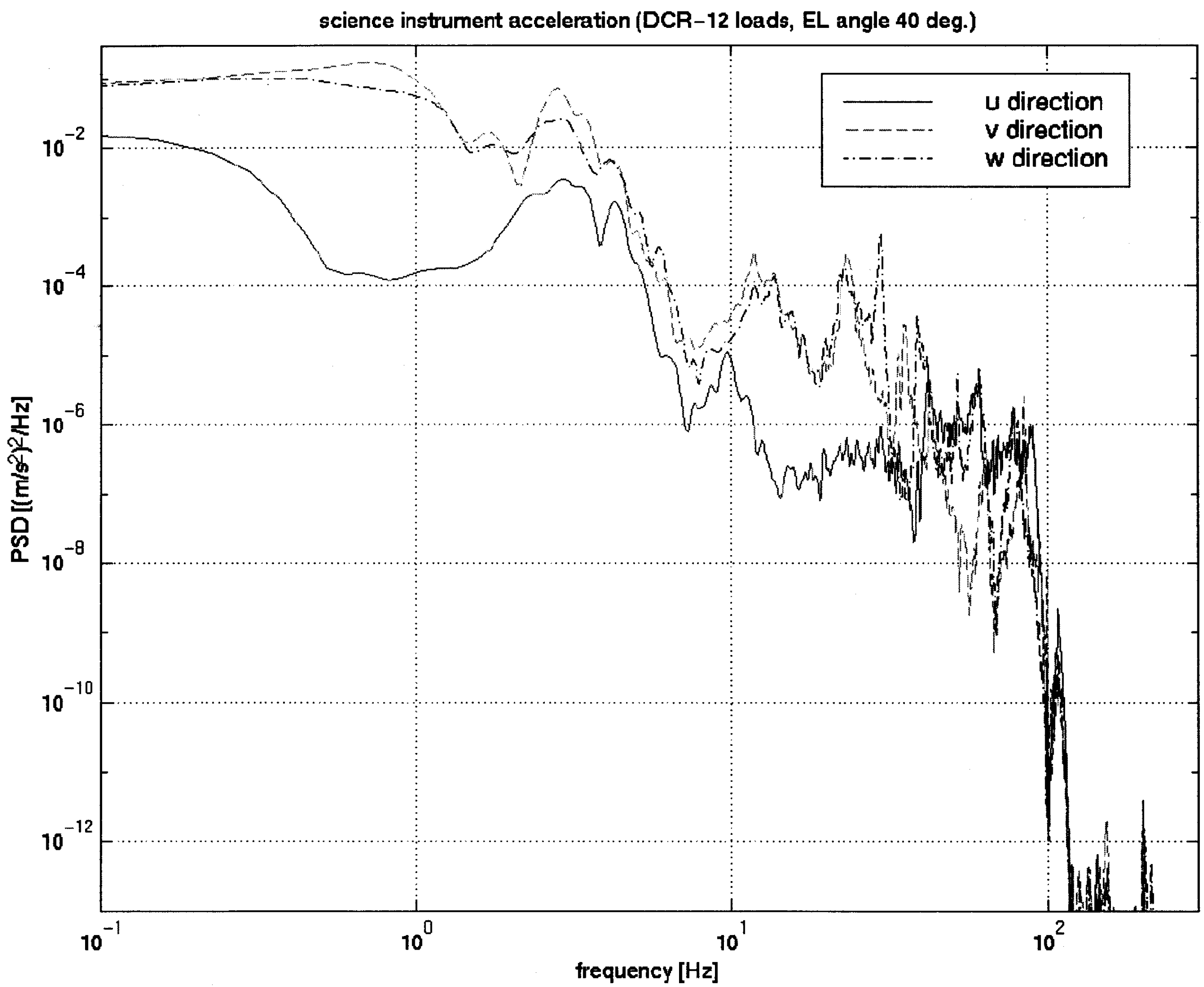
Case	Cabin Temperature [°C] Absolute	Cabin Temperature [°C] Difference to 22,5°C
2b. TA flight		
T2b2	28	5,5
T2b4	12	-10,5
3a. towing and taxiing		
T3a2	55	32,5
T3a5	-10	-32,5
3b. aircraft flight		
T3b1	35	12,5
T3b5	5	-17,5
Exposure a. (Safety)		
TEXa2	85	62,5
TEXab5	-40	-62,5

Table 4-5 Temperature Cases for structural components in cabin (ref. to RD12)

4.9.2 Vibration

PSD curves from a preliminary analysis are given below. Final vibration levels will be available after TA Vibration Tests.




science instrument acceleration (DCR−12 loads, EL angle 40 deg.)
u direction
v direction
w direction
PSD [(m/s^2)^2/Hz]
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
10^{-1}
10^{0}
10^{1}
10^{2}
frequency [Hz]

4.10 Hardpoints in the INF Tub

There are 4 hardpoints on the GVPP each with two ½ inch fixation threads (Helicoil inserts ∅1/2” x L 1”), located on a diameter of 740 mm [29.13 inch] which is centered on the IR beam optical axis (refer to figure 4-1).

The hardpoints are located in U-Direction at U= 1840 mm [72.44 inch]

Note that the hardpoint interface plane lies behind the GVPP insulation (U= 1885 mm [74.213 inch]) and that the stiffener webs on the GVPP increase their height from GVPP edge (U= 1840 mm [72.441 inch]) to GVPP Center (U=1860 mm [73.228 inch]) refer to figure 4-9.

Insert specification (according to MS 21209):

- Insert: 1/2-20 F helical coil insert
- Depth: 1 inch [25.4 mm]
- Material: CRES
- Dash No.: F8-20

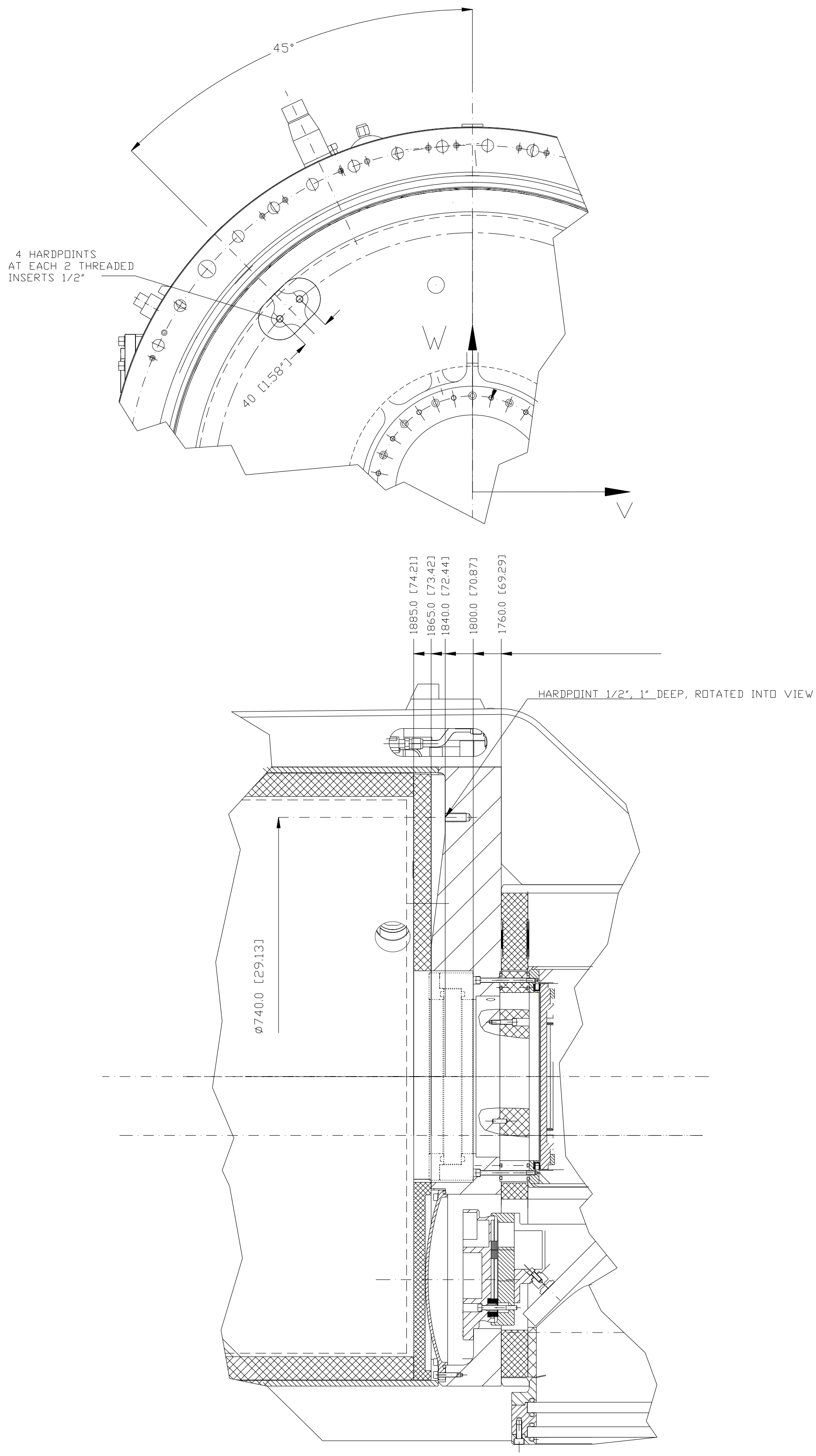


Figure 4-9: Hardpoint Interface

4.10.1 Loads

The single loads / moments on one hardpoint are given below and in figure 4-10. The loads were determined under the assumption, that always both screws on the hardpoints are used.

Ultimate Loads:

- The maximum allowed moments on each hardpoint are 60 Nm
- The maximum allowed axial forces are Fu = 1500 N on each hardpoint
- The maximum allowed radial forces are Fv,w = 1500 N on each hardpoint

Limit Loads:

- The maximum allowed moments on each hardpoint are 40 Nm
- The maximum allowed axial forces are Fu = 1000 N on each hardpoint
- The maximum allowed radial forces are Fv,w = 1000 N on each hardpoint

According DCR0012.R5 (AD5), there is a factor of 1.5 between limit and ultimate loads.

SI equipment mounted to the GVPP hardpoints shall engage both threaded inserts for each hardpoint, using 1/2-20 screws (see 4.10).

SI equipment loading on individual GVPP hardpoints shall not exceed the limit loads (forces and moments) specified in this section and Figure 4-10.

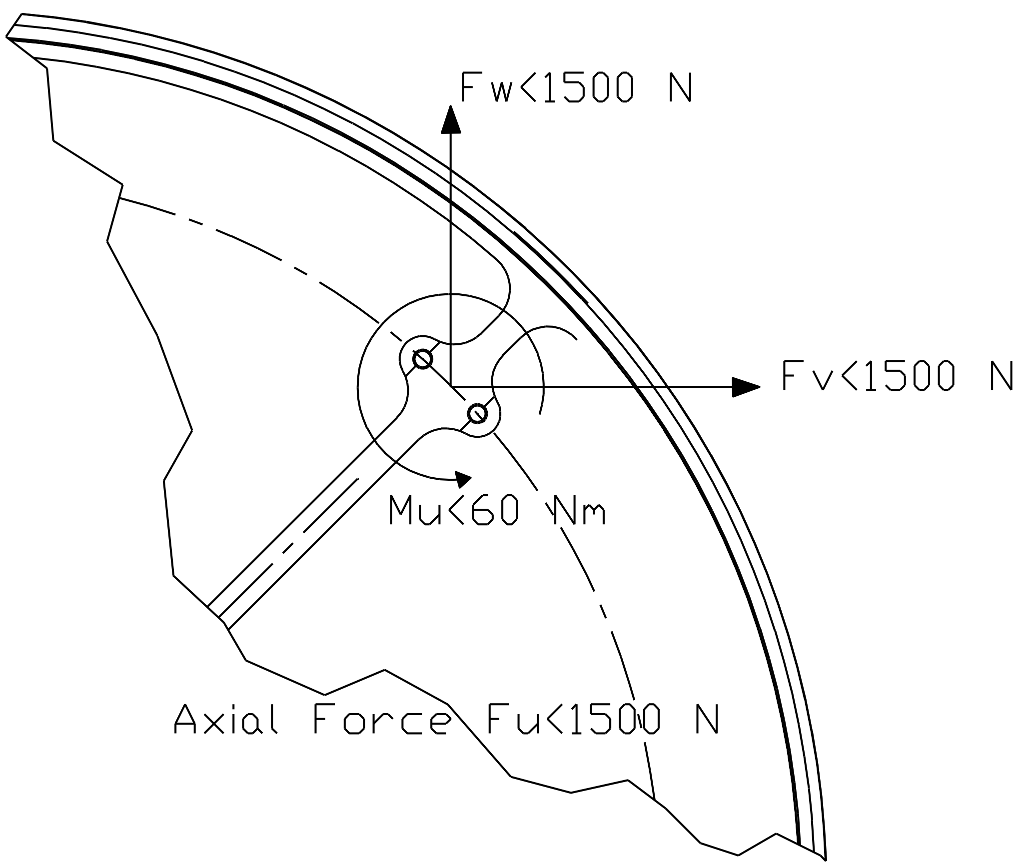


Figure 4-10: Maximum loads and moments on a hardpoints (ultimate)

4.10.2 Thermal Constraints

To avoid thermal bridging during standard operation (hard points not used), the hardpoints will be covered by a piece of thermal insulation.

Any heat load from SI hardware attached to the hardpoints will not be considered for the TA thermal design.

4.10.3 Stiffness and Tolerances

There is no possibility to provide a number for the stiffness of each hardpoint, since it is depending too much on the respective Item which is mounted to it (e.g. how many hardpoints are used, mass of item, c.g. and moment of inertia of item, stiffness of item)

Hard points are located to each other on a circle of ∅ 740 ± 0.3 mm [∅29.134 ± 0.012 inch]

4.11 Access Port

There is an access port located at U = 1975 mm [77.76 inch] on the INF Tub outer surface with an inner diameter of 8 inch. It is oriented in radial direction at angle VW= 22.5 °. The access port is not designed for attachment of additional hardware. The access port is the primary cabin to cavity pressure boundary under some SI configurations. The Access Port Cover Plate has insulation attached to avoid thermal leakage, and an O-ring pressure sealing. Size of O-ring: ∅ 216 mm x 5 mm.[8.504 inch x 0.197 inch].

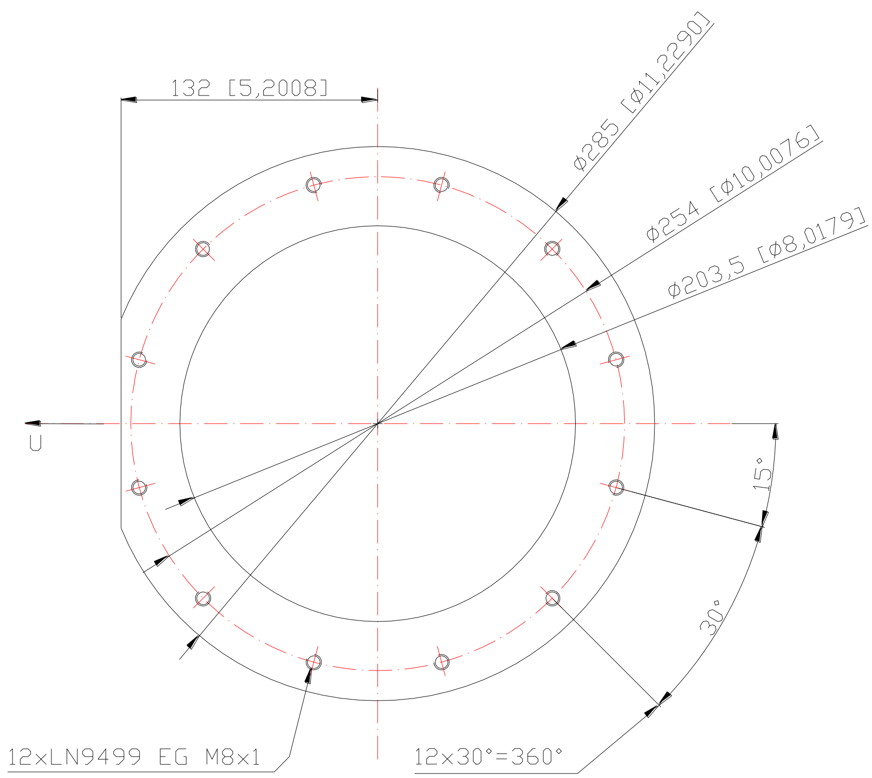


Figure 4-11: Accessport Bolt Pattern (12 threaded inserts with thread M8x1, 2D deep)

VERIFY THAT THIS IS THE CORRECT REVISION BEFORE USE

4.12 Mass Limit for Integration / Deintegration

NASA / USRA plan to remove the FA from the TA for different purposes. Due to aircraft floor loading restrictions the mass limit for one integration unit is 600 kg

4.13 Size Limit for Integration / Deintegration

NASA / USRA plan to remove the FA from the TA for different purposes. Due to aircraft restrictions the size limits for one integration unit are the 1 L Door dimensions as given in TA_AS_04 (RD23)

4.14 Nominal Electromagnetic Field at IMF

The electromagnetic field at IMF during operation is **to be measured during system AITV.** Refer to TA EMC Control Plan for details on TA EMC design (RD17).

4.15 Grounding of FA and TA

The grounding concept of the FA and the TA is described in RD9.

Per RD21 para. 4.1.3.6, the TA and the SI Assembly must be electrically grounded with a resistance $\leq$ 10 mΩ (milli-ohms). This is generally achieved via the metal-to-metal contact between the mating TA IMF and SI Flange, but in cases where the SI is electrically isolated at this mechanical interface intentionally (e.g., in cases where the CWR or U402 GND terminal strip lug is to be used as a single-point ground), a grounding strap / cable to be provided by the SI developer must be used.

Further information about the use of TA U402 GND terminal strip lug and ground conductor sizing for any SI Assembly grounding provisions may be found in RD21 section 4.1.3.

For SI grounding purposes there is an additional grounding stud on the FA, with a diameter of $\varnothing$ 6mm [0.236 inch] with M6 thread (metric) and 25 mm [0.984 inch] length.

4.16 Flange Mockup Input Data and Policies

Inputs for the design and manufacturing of the USRA Flange Mockup will be provided by KT in the form of design drawings and as-built data. Drawings will be the actual specifications.

5 SRM & QA

5.1 Safety

Interface design information in this ICD is referenced in PD96165004-000 (PA10-002, The Observatory Hazard Analysis) for hazard mitigation design control for specific design features crossing the interface boundary as described in the scope of this document.

5.2 Quality Assurance Provisions

Quality Assurance will verify each hardware interface to the drawing, and participate in testing by reviewing and verifying plans and procedures; witnessing tests; and approving reports in accordance with PD96100021-000 (PM21), for the USRA side of the ICD, and SOF-PLA-MG-0000.0.03 Safety, Reliability, Maintainability and Quality Assurance (SRM & QA) Plan, for the TA-C side of the ICD, respectively.

5.3 Verification

The verification plan for this interface is documented in RD25, SOF-PLA-MG-0000.0.13 (SOFIA Telescope Assembly Verification Plan), for the TA-C side of the ICD.

The process for verifying SI compliance with the specified requirements of Section 4 is described in RD15, Science Instrument Developers' Handbook (SCI-AR-HBK-OP03-2000). RD26, Science Instrument System Specification and ICD Requirements Verification Matrix Template (SCI-AR-PLA-SV05-2014) contains a complete list of requirements from the Science Instrument System Specification and the electrical and mechanical SI ICDs, and includes all SI interface requirements within this ICD. The template specifies verification method listed by development phase, expected verification activity, and the SI compliance authority for each SI interface requirement.

APPENDIX

FIGURE 4-1 ENLARGED