

Title: **Interface Definition Document for the Quick External Science Tray**

**Appendix A**

**QUEST ON SPACEHAB MODULE ROOFTOP**

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### Abbreviations and Acronyms

IDD	Interface Definition Document
QUEST	Quick External Science Tray

## 1. SCOPE

This Appendix contains the specific interfaces when Quest is mounted on SH module rooftop.

Based on this IDD Appendix mission specific payload interface agreements will be defined in Interface Control Agreements (ICA) to cover all mission specific requirements.

## 2. DOCUMENTS

For applicable and reference documents see § 2 of main volume.

### 3. PHYSICAL INTERFACES

#### 3.1 Quest SHI Module Rooftop Configuration

The Quest panel is mounted on the SHI Module rooftop with 4 separate I/F adapter plates via 4 swivel bearings. Each of the adapter plates are carrying a standard 1 cell mounting pattern so that 2 Quest SHI Module Rooftop Configurations are possible:

- 9 cell Quest plate configuration
- 1 –4 cell configuration via I/F adapter plates

##### 3.1.1 Quest SHI Module Rooftop 9 Cell Configuration

The 9 Cell Configuration is defined as the standard configuration consisting of the Quest plate mounted on the 4 adapter plates as defined in Figure: 3-1 Quest SHI Module Rooftop 9 Cell Configuration (sheet 1) and Figure: 3-2 Quest SHI Module Rooftop 9 Cell Configuration (sheet 2)

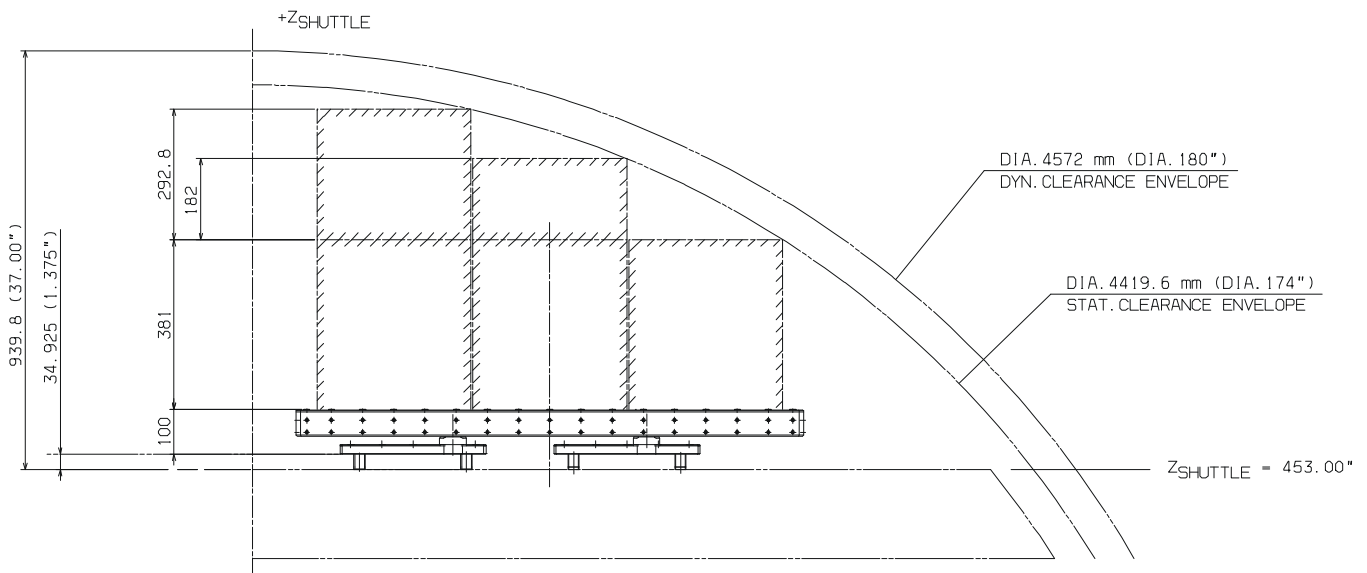


Figure: 3-1 Quest SHI Module Rooftop 9 Cell Configuration (sheet 1)



### 3.1.2 Quest SHI Module Rooftop 1 - 4 Cell Configuration

For the Quest SHI Module Rooftop 1 - 4 Cell Configuration only the I/F adapter plates will be mounted on the rooftop, the location is identical to the Q9 configuration, see Figure: 3-3 Quest SHI Module Rooftop 1 - 4 Cell Configuration.

The payload mounting pattern of the I/F adapter is defined in Figure: 3-4 Payload Mounting Hole Pattern of the I/F Adapter.

The dynamic and center of gravity envelope for Q1 is defined in Figure: 3-5 Q1 Single Cell Payload Mass and Center of Gravity

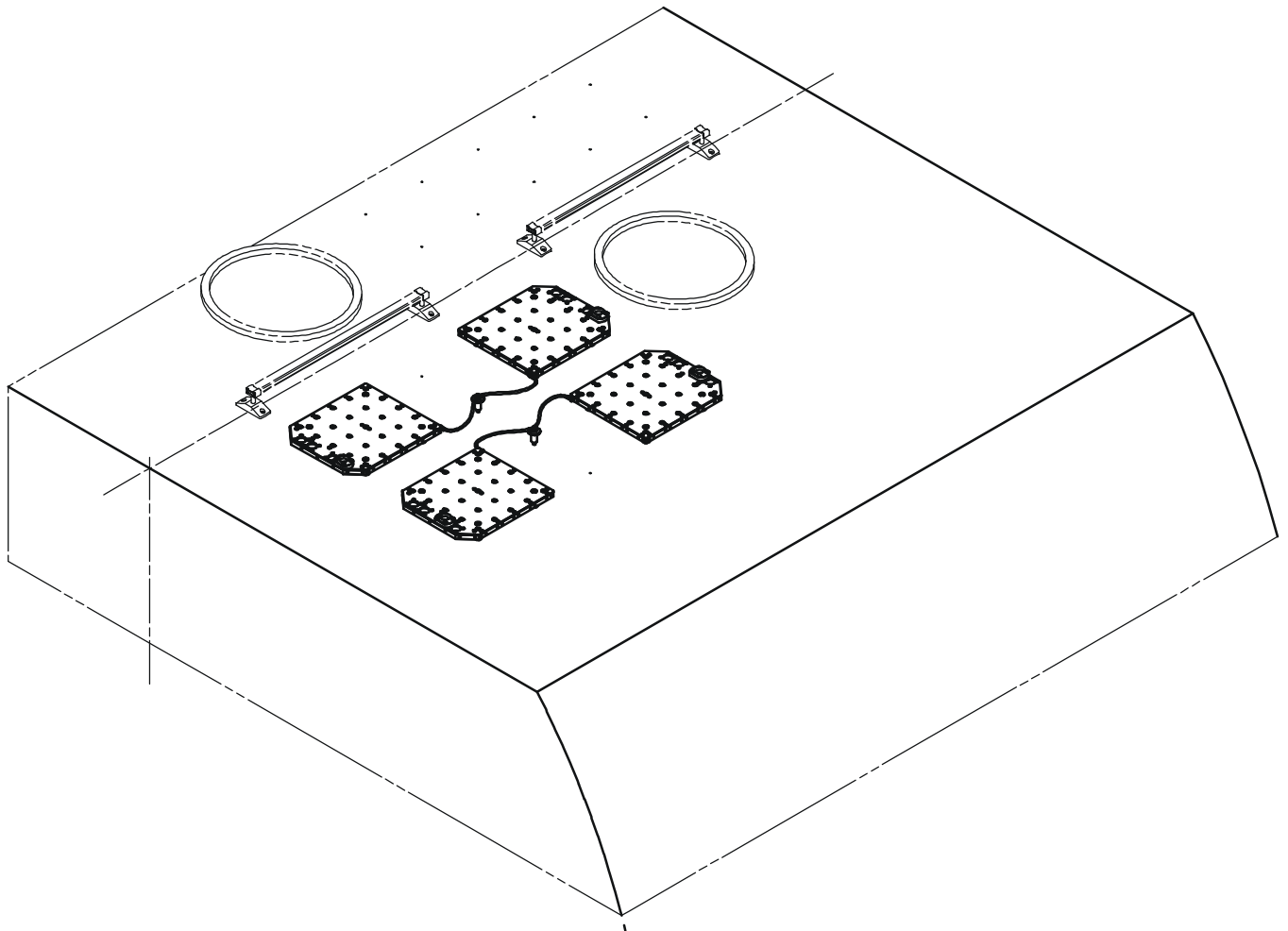


Figure: 3-3 Quest SHI Module Rooftop 1 - 4 Cell Configuration

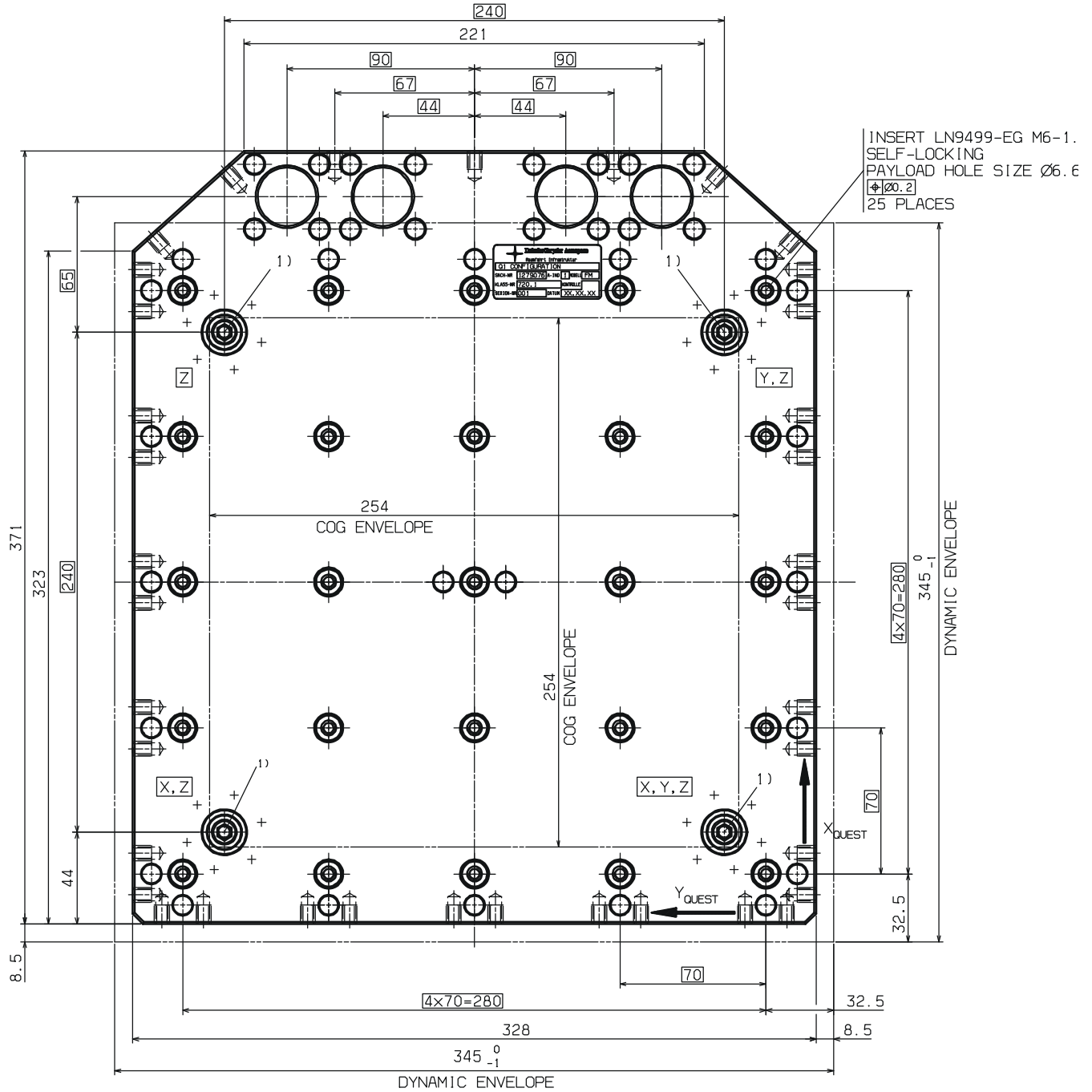


Figure: 3-4 Payload Mounting Hole Pattern of the I/F Adapter

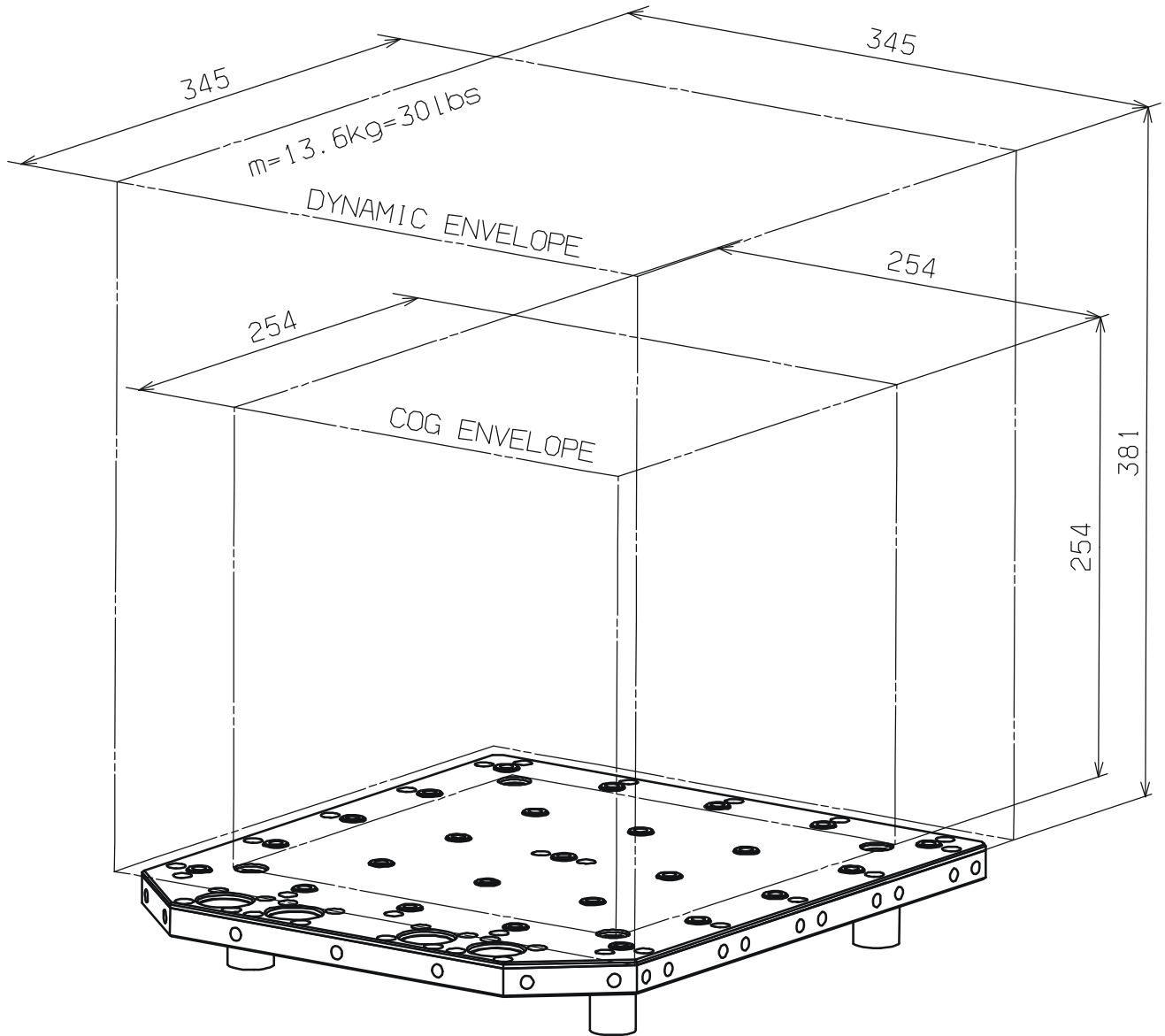


Figure: 3-5 Q1 Single Cell Payload Mass and Center of Gravity

### 3.2 Bonding I/F

Each single I/F adapter plate is bonded to the SHI Module rooftop with a separate bonding strap as defined in Figure: 3-6 Bonding Interface. The bonding path to the Quest panel is a structural bond via the 4 swivel bearings. This configuration will satisfy potential payload RF bonding requirements.

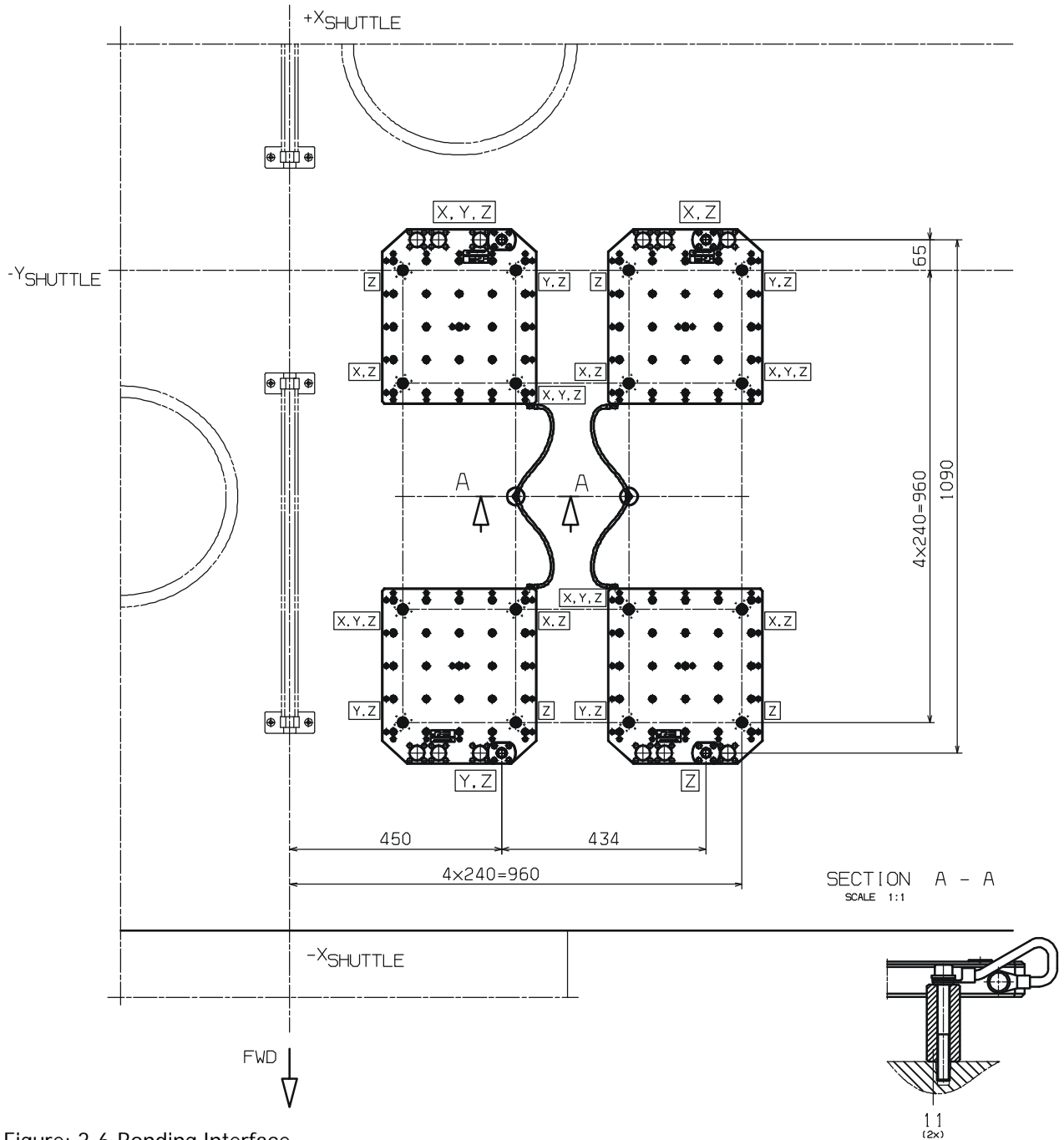


Figure: 3-6 Bonding Interface

## 4. STRUCTURAL INTERFACES

### 4.1 Structural Design Criteria

#### 4.1.1 Design Conditions/Environment and Loads

Basing on the generic environment and loads defined by NASA by the applicable documents [1,4], the relevant design criteria for the Rooftop Quest Payload are given. All of the environmental conditions are taken into account.

##### 4.1.1.1 Inertial Load Cases

For the purpose of designing and verifying the hardware, design load factors are given for the different events during the mission [3]. The load factors relevant for the Rooftop Quest are defined in Table: 4-1Quest Rooftop Load Factors.

Environment	Event	N <sub>x</sub>	N <sub>y</sub>	N <sub>z</sub>
Transient *	Liftoff	5.9	1.8	7.3
	Landing	9.9	2.5	8.6
Quasi-Static	Ascent	3.11	0.28	0.78
	On Orbit	0.02	0.12	0.19
	Descent	1.00	0.48	2.50

Table: 4-1Quest Rooftop Load Factors

Remark: For undefined Payload orientation the worst in plane design load factors shall be considered.

\*Note: Low frequency transient load factor includes steady-state acceleration of 1.5 g's for x-direction during lift-off and 1.0 g's in z-direction during landing.

##### 4.1.1.2 Random Vibration Environment and Design Load Cases

The random vibration environment is defined in section 4.4.3

The limit load contribution from random vibration depends on the Rooftop Quest's own dynamic behavior and cargo mass loading. These loads may be obtained using the above mentioned environment and a 3-sigma factor in Miles Equation expressed as:

$$R = 3 * (\pi/2 * Q * f_n * PSD)^{0.5}$$

Where Q is the magnification factor for initial design Q=10 shall be used), f<sub>n</sub> is the fundamental frequency and PSD is the Power Spectral Density at f<sub>n</sub>.

The random environments are present during liftoff and landing and are to be combined with the other respective load factors to the load sets as defined in Table: 4-2 Load Combination

LOAD IN EACH AXIS ACTING SIMULTANEOUSLY			
LOAD SET	ORIBER X <sub>0</sub> AXIS	ORIBER Y <sub>0</sub> AXIS	ORIBER Z <sub>0</sub> AXIS
<b>Lift-off</b>			
1	$1.5 \pm [(T_1 - 1.5)^2 + R_1^2]^{0.5}$	$\pm T_2$	$\pm T_3$
2	$\pm T_1$	$\pm [(T_2^2 + R_2^2)^{0.5}]$	$\pm T_3$
3	$\pm T_1$	$\pm T_2$	$\pm [(T_3^2 + R_3^2)^{0.5}]$
<b>Landing</b>			
4	$\pm T_1$	$\pm T_2$	$\pm T_3$

Table: 4-2 Load Combination

Where:

T<sub>i</sub> = Low frequency transient load factor in the ith direction (g's) includes steady-state acceleration of 1.5 g's for x-direction during lift-off and 1.0 g's in z-direction during landing. The magnitude of T<sub>i</sub> may be different, depending on the direction (+ or -) of the low frequency transient load.

Remark : Add 15 % to the low frequency transients to cover rotational acceleration.

R<sub>i</sub> = Random load factor in the ith direction (g's)

#### **4.1.1.3 Vibroacoustics**

For Quest Payload dimensioning, the impact of acoustic noise excitation is considered to be included in loads as described under sec.4.1.1.2 above. If the payload is sensitive to direct acoustic impingement the loads shall be considered as defined by the environment in section 4.4.4

#### **4.1.1.4 Pressures**

Verifying necessary in order to avoid overpressure within the shuttle bay. The venting rate shall not undercut 0,3 psi/s [2].

#### **4.1.1.5 Crew Induced Loads**

Inadvertent kick loads shall be considered to withstand a limit load of 125 lbs. (556 N) in any one direction distributed over a 4-inch by 4-inch area.

#### **4.1.1.6 Non-Flight Conditions**

It shall be assured by appropriate means, that loads/environment due to ground events (transport, handling, maintenance) do not become design driver to the flight H/W. Load cycles during ground events shall be considered for generation of however.

## 4.2 Design Criteria

### 4.2.1 Stiffness

The Quest mounted payload shall have a first natural frequency > 50 Hz in each direction.

### 4.2.2 Structural Integrity

#### 4.2.2.1 Failure Modes and Factors of Safety

All Quest items shall have positive margins of safety (MS) for all load combinations using the applicable factors of safety (SF) as defined in Table: 4-3 Factors of Safety

	Yield	Ultimate
Flight Loads	1.25	2.0
Emergency landing Loads	-	1.0

Table: 4-3 Factors of Safety

$$MS = \text{allowable} / SF \text{ calculated} - 1 > 0$$

For static strength and stability analysis minimum wall thickness and worst case dimensions shall be used.

Structural failures shall only be allowed for the different failure modes under the load conditions as described in Table: 4-4 Failure Mode Load Condition

Failure Mode	Allowed above		
	Limit Load	Yield Load	Ultimate Load
Rupture			X
Instabilities <sup>1)</sup>			X
Yielding		X	
Excessive deformations (exceeding of allowable clearances)	X		
Gapping of bolted Connections <sup>2)</sup>		X	

Table: 4-4 Failure Mode Load Condition

- 1) Resulting in loss of minimum structural performance (load carrying capability, stiffness) of the structure itself or unacceptable impact on interfacing hardware.
- 2) For verification of no-gapping max. friction coefficient shall be used; for integrity analyses of fasteners min. friction coefficient shall be used.

The strength of fasteners used in preloaded joints shall be assessed at zero and maximum preload. For the zero preload case, the factor of safety shall be applied to the induced fastener load. For the maximum preload case, the factor of safety need only be applied to the additional fastener load induced beyond the preload. In both cases, the preload plus induced fastener loads times the factor of safety shall be less than the fastener ultimate strength. Unless specifically designed to separate, all joints shall maintain a factor of safety against separation. Minimum preload shall be used in the separation assessment for transfer of shear loads by friction in the clamped joint [5],

Protoflight Approach: Ultimate Strength    j = 1,4  
                                  Joint Separation        j = 1,2

#### **4.2.2.2 Design Life Safety/Damage Tolerance**

For Fracture Control activities the NASA-STD-5003 shall be applicable [11]. A scatter factor of 4 on life cycles shall be considered. In general different aspects shall be addressed as there are:

- Design life
- Fatigue life
- Fracture control (safe crack growth life / fail safe)
- Fasteners
- Lines, fittings
- Non-destructive inspection (NDI)

The fatigue spectra are defined in Qu-RIBRE-TN-0003 Fatigue Spectra for QuEST Payloads on Q9 and Q1 Plates.

#### **4.2.3 Material Properties**

The selection shall be in accordance with the relating NASA or equivalent ESA documents. The thermal environment shall be taken into account.

#### **4.2.4 Load Carrying Capability**

Enveloping Cargo configurations as per section 3.2.2 QuEST IDD main volume

## **4.3 Structural Verification**

### **4.3.1 Verification Philosophy**

A NASTRAN model shall be established and the modal parameters shall be analyzed for a hardmounted boundary condition as realized during a modal survey test. The resulting fundamental frequencies for each axis shall be taken for calculating of the revised random vibration load factor and subsequent updating of the design loads.

### **4.3.2 Verification Approach**

The static verification shall be performed by analysis only. Due to the protoflight approach this is to be agreed by the SWG.

The dynamic verification shall be performed by analysis and equivalent dynamic testing.

A random test shall be performed according to section 4.4.

## 4.4 Quest Payload Mechanical Environment and Test Level Definitions

### 4.4.1 Quest Payload Mechanical Environment

### 4.4.2 Sine Vibration Environment

-not considered

### 4.4.3 Random Vibration Environment

The random vibration load factors result from the random vibration environment as caused by the acoustic noise levels inside the cargo bay. The random vibration environment is defined at the Quest Panel to Quest Payload Interfaces. The random vibration environment relevant for Quest Q1 and Q9 to Payload interfaces is defined in Table: 4-5 Random Vibration Environment for Quest Q1/Q9 Envelope and in Table: 4-6 Random Vibration Environment for Quest Q1/Q9 Envelope

Frequency in Hz	PSD Level in g <sup>2</sup> /Hz	Slope in dB/oct
20	0,0013	
20-300		4,0
300-700	0,05	
700-2000		-12,2
2000	0,0007	
Composite: 6,11 grms		
Exposure Duration per Axis: 30 sec + 30sec per Mission (1 Mission Abort and Scatter Factor 4 included)		

Table: 4-5 Random Vibration Environment for Quest Q1/Q9 Envelope

- In Plane (X-Orbiter and Y-Orbiter Axis) at Payload Interfaces

Frequency in Hz	PSD Level in g <sup>2</sup> /Hz	Slope in dB/oct
20	0,0295	
20-130		3,3
130	0,225	
130-170		2,3
170	0,275	
170-180		2,8
180	0,29	
180-200		29
200-240	0,8	
240-300		0,9
300-350	0,858	
350-550		-14,8
550	0,0935	
550-950		-7
950	0,0262	
950-2000		-11,5
2000	0,00152	
Composite: 15,92 grms		
Exposure Duration per Axis: 30 sec + 30sec per Mission (1 Mission Abort and Scatter Factor 4 included)		

Table: 4-6 Random Vibration Environment for Quest Q1/Q9 Envelope  
- Out-of-Plane (Z-Orbiter Axis) at Payload Interfaces

#### 4.4.4 Acoustic Environment

Orbiter Payload Bay Combined Liftoff/Ascent Acoustic Environment [3] is defined in Table: 4-7 Orbiter Payload Bay Combined Liftoff/Ascent Acoustic Environment

1/3 Oct Band Center Freq. in Hz	Sound Pressure Level in dB re 2*10E-5 N/m <sup>2</sup>
20	97,8
25	111,7
31,5	123,1
40	125,5
50	126,1
63	128,2
80	128,5
100	129,6
125	130,8
160	130,1
200	130,6
250	129,9
315	130,2
400	129,4
500	126,6
630	125,2
800	123,3
1000	120,8
1250	119,6
1600	118,0
2000	115,6
2500	114,4
3150	112,7
4000	110,7
5000	109,2
6300	107,9
8000	106,6
10000	106,2
Overall	140,4
Duration in sec	30 sec + 30sec per Mission (1 Mission Abort and Scatter Factor 4 included)

Table: 4-7 Orbiter Payload Bay Combined Liftoff/Ascent Acoustic Environment

#### 4.4.5 Shock Environment

-not considered

## 4.5 Quest Payload Mechanical Test

### 4.5.1 Sine Vibration Test

#### 4.5.1.1 Low Level Sine Sweep

Pre and Post Low Level Sine Vibration Test level for Resonance Search, Structural Integrity and Instrumentation Check-out are defined in Table: 4-8 Pre and Post Low Level Sine Vibration Test level

Frequency in Hz	Level
5-2000	0,5g
Sweep Rate: 2oct/min	
Number of Sweeps: 1 Sweep up	
In each of three axes	
Pre and Post of each nominal Vibration Test Run	

Table: 4-8 Pre and Post Low Level Sine Vibration Test level

#### 4.5.1.2 Sine Vibration Qualification Test

- not considered

### 4.5.2 Random Vibration Test

#### 4.5.2.1 Prototype/Qualification Model QM Random Vibration Test

The Prototype/Qualification Model QM Random Vibration Test level for Quest Q9 Payloads are defined in Table: 4-9 Prototype/Qualification Model (QM) Random Vibration Test Quest Q1/Q9 Envelope and in Table: 4-10 Prototype/Qualification Model (QM) Random Vibration Test for Q1/Q9 Envelope

Frequency in Hz	PSD Level in g <sup>2</sup> /Hz	Slope in dB/oct
20	0,017	
20-80		+3
80-350	0,067	
350-460		-3,2
460-700	0,05	
700-800		-11,5
800	0,03	
800-2000		-3
2000	0,012	
Composite: 8,05 grms		
Test Duration per Test Axis: 90 sec + 30sec per Mission (1 Mission Abort and Scatter Factor 4 included)		

Table: 4-9 Prototype/Qualification Model (QM) Random Vibration Test Quest Q1/Q9 Envelope

- In Plane Test Axes (X-Orbiter and Y-Orbiter Axis)

Frequency in Hz	PSD Level in g <sup>2</sup> /Hz	Slope in dB/oct
20	0,0295	
20-130		3,3
130	0,225	
130-170		2,3
170	0,275	
170-180		2,8
180	0,29	
180-200		29
200-240	0,8	
240-300		0,9
300-350	0,858	
350-550		-14,8
550	0,0935	
550-950		-7
950	0,0935	
950-2000		-3,2
2000	0,012	
Composite: 16,25 grms		
Test Duration per Test Axis: 90 sec + 30sec per Mission (1 Mission Abort and Scatter Factor 4 included)		

Table: 4-10 Prototype/Qualification Model (QM) Random Vibration Test for Q1/Q9 Envelope  
- Out-of-Plane Test Axis (Z-Orbiter)

#### 4.5.2.2 Protoflight Model PFM Random Vibration Test

The Protoflight Model PFM Random Vibration Test for Quest Q1 and Q9 are defined in Table: 4-11 Protoflight Model (PFM) Random Vibration Test- for Quest Q1/Q9 Envelope and in Table: 4-12 Protoflight Model (PFM) Random Vibration Test for Q1/Q9 Envelope

Frequency in Hz	PSD Level in g <sup>2</sup> /Hz	Slope in dB/oct
20	0,01	
20-80		3
80-240	0,04	
240-300		3
300-700	0,05	
700-930		-13,5
930	0,014	
800-2000		-2,7
2000	0,007	
Composite: 6,87 grms		
Test Duration per Test Axis: 30 sec + 30sec per Mission (1 Mission Abort and Scatter Factor 4 included)		

Table: 4-11 Protoflight Model (PFM) Random Vibration Test- for Quest Q1/Q9 Envelope  
- In Plane Test Axes (X-Orbiter and Y-Orbiter Axis)

Frequency in Hz	PSD Level in g <sup>2</sup> /Hz	Slope in dB/oct
20	0,0295	
20-130		3,3
130	0,225	
130-170		2,3
170	0,275	
170-180		2,8
180	0,29	
180-200		2,9
200-240	0,8	
240-300		0,9
300-350	0,858	
350-550		-14,8
550	0,0935	
550-950		-7
950	0,0935	
950-1150		-12,3
1150	0,012	
1150-2000		-2,9
2000	0,007	
Composite: 16,03 grms		
Test Duration per Test Axis: 90 sec + 30sec per Mission (1 Mission Abort and Scatter Factor 4 included)		

Table: 4-12 Protoflight Model (PFM) Random Vibration Test for Q1/Q9 Envelope  
- Out-of-Plane Test Axis (Z-Orbiter Axis)

#### 4.5.2.3 Flight Model FM Random Vibration Acceptance Test

The Flight Model FM Random Vibration Acceptance Test level (Detection of Workmanship/Material Defects ) for Quest Q1 and Q9 are defined in Table: 4-13 Flight Model (FM) Random Vibration Acceptance Test for Quest Q1/Q9 Envelope and in Table: 4-14 Flight Model (FM) Random Vibration Acceptance Test for Case Q1/Q9 Envelope

FM - In Plane (X-Orbiter and Y-Orbiter Axis) - At Quest Q1 to Payload Interface		
Frequency in Hz	PSD Level in g <sup>2</sup> /Hz	Slope in dB/oct
20	0,01	
20-80		+3
80-350	0,04	
350-2000		-3
2000	0,007	
Composite: 6,06 grms		
Test Duration per Test Axis: 60 sec		

Table: 4-13 Flight Model (FM) Random Vibration Acceptance Test for Quest Q1/Q9 Envelope  
- In Plane Test Axes (X-Orbiter and Y-Orbiter Axis)

Frequency in Hz	PSD Level in g <sup>2</sup> /Hz	Slope in dB/oct
20	0,01	
20-80		3
80-93	0,04	
93-170		2,7
170	0,0688	
170-180		2,8
180	0,0725	
180-200		29
200-240	0,2	
240-300		1,0
300-350	0,215	
350-550		-14,1
550	0,026	
550-2000		-3,1
2000	0,007	
Composite: 8,71 grms		
Test Duration per Test Axis: 60 sec		

Table: 4-14 Flight Model (FM) Random Vibration Acceptance Test for Case Q1/Q9 Envelope  
- Out-of-Plane Test Axis (Z-Orbiter Axis)

### 4.5.3 Acoustic Test

Acoustic Tests shall be performed only if sensitive to direct acoustic impingement. The test level for Quest Q9 and Quest Q1 Payload Prototype Model/Qualification Model (QM) and Protoflight Model (PFM) are defined in Table: 4-15 Quest Q1 and Quest Q 9 Payloads Prototype Model/Qualification Model (QM) and Protoflight Model (PFM) Acoustic Noise Test

1/3 Oct Band Center Freq, in Hz	Sound Pressure Level in dB re 2*10E-5 N/m <sup>2</sup>
20	97,8
25	111,7
31,5	123,1
40	125,5
50	126,1
63	128,2
80	128,5
100	129,6
125	130,8
160	130,1
200	130,6
250	129,9
315	130,2
400	129,4
500	126,6
630	125,2
800	123,3
1000	120,8
1250	119,6
1600	118,0
2000	115,6
2500	114,4
3150	112,7
4000	110,7
5000	109,2
6300	107,9
8000	106,6
10000	106,2
Overall	140,4
Prototype/Qual Model QM Test Duration in sec	90 sec + 30sec per Mission (1 Mission Abort and Scatter Factor 4 included)
Protoflight Model PFM Test Duration in sec	30 sec + 30sec per Mission (1 Mission Abort and Scatter Factor 4 included)

Table: 4-15 Quest Q1 and Quest Q 9 Payloads Prototype Model/Qualification Model (QM) and Protoflight Model (PFM) Acoustic Noise Test

The Quest Q9 and Quest Q1 Payload Flight Model (FM) Flight Acceptance Test level (Environment -6 dB), only is sensitive for Detection of Workmanship/Material Defects, are defined in Table: 4-16 Quest Q1 and Quest Q 9 Payloads Flight Model (FM) Acoustic Noise Acceptance Test (Environment -6 dB)

1/3 Oct Band Center Freq, in Hz	Sound Pressure Level in dB re 2*10E-5 N/m <sup>2</sup>
20	91,8
25	105,7
31,5	118,1
40	119,5
50	120,1
63	122,2
80	122,5
100	123,6
125	124,8
160	124,1
200	124,6
250	123,9
315	124,2
400	123,4
500	120,6
630	119,2
800	117,3
1000	116,8
1250	113,6
1600	112,0
2000	109,6
2500	108,4
3150	106,7
4000	104,7
5000	103,2
6300	101,9
8000	100,6
10000	100,2
Overall	134,4
Flight Model FM Test Duration in sec	60 sec

Table: 4-16 Quest Q1 and Quest Q 9 Payloads Flight Model (FM) Acoustic Noise Acceptance Test (Environment -6 dB)

- Acoustic Test, only if sensitive to direct acoustic impingement
- for Detection of Workmanship/Material Defects

#### **4.5.4 Shock Test**

- for Prototype Model/Qualification Model (QM) and Protoflight Model (PFM)  
Bench Handling Shock Test in accordance with MIL-STD-810E, Method 516.4, Procedure VI

### **5. THERMAL INTERFACES**

The Quest payload shall be compatible with the thermal environment as defined in para 3.4 main volume. If mounted on the SHI module rooftop the following specific requirements shall apply:

The maximum temperature of any Quest component shall not exceed 350 K (77 C, 171 F) under all mission scenarios to ensure the structural load capacity. The minimum temperature of any Quest component shall not drop below 180 K (-93 C -135 F) to ensure compliance with the heat extraction requirements of the SHI module IDD. Both boundaries have to be verified by a mission specific thermal analysis.

- **Quest Q9 configuration**

The max Heat Load that may be rejected into the Quest panel shall be calculated according to the following formula

$$\text{Head load [W]} = 50 \text{ [W/m}^2\text{]} * \text{Payload area projected onto the Q9 panel [m}^2\text{]}$$

- **Quest Q1 configuration**

The max Heat Load that may be rejected into the Quest Adapter panel shall be calculated according to the following formula

$$\text{Head load [W]} = 300 \text{ [W/m}^2\text{]} * \text{Payload area projected onto the Q1 panel [m}^2\text{]}$$

### **6. ELECTRICAL POWER INTERFACES**

The characteristics and requirements for electrical power interfaces are defined in the SPACEHAB Experiment IDD [3]

### **7. COMMAND AND DATA INTERFACES**

The definition of characteristics and requirements for the command and data interfaces are defined in the SPACEHAB Experiment IDD [3]

## **8. ELECTRICAL WIRING INTERFACES**

The definition of characteristics and requirements for electrical wiring interfaces are defined by the SPACEHAB Experiment IDD [3]

## **9. SOFTWARE INTERFACES**

The QuEST payload S/W interfaces are defined in the SPACEHAB Experiment IDD [3].