PRATHAM
IIT BOMBAY STUDENT SATELLITE

Critical Design Review Report
Integration Sub-System

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Chapter 1

Introduction

1.0.1 Requirements

The Integration Sub-System is in charge of bringing all the other Sub-Systems together and finally integrating the complete satellite. The requirements for the Integration Sub-System are:

- To design and fabricate the satellite structure and all mounts for components
- To complete all connections between electrical packages and route wires between them
- To set up a facility and purchase necessary tools for satellite assembly at IIT Bombay
- To assemble the satellite (both qualification and flight models)
- To test the assembled models of the satellite

1.0.2 Scope of work

The tasks that have been already completed by this Sub-System are:

- Design of all mounts and structure
- Fabrication of all mounts and structure
- Determination of sequence of integration
- Design of fixtures for integration
- Fastener selection purchase
- Selection purchase of all tools and instruments
- Selection and purchase of all wires and connectors
- Determination of all wire routes, lengths and clamp positions between circuits
- Fabrication of actuators and determination of electrical characteristics
- Seperate integration sequences keeping in mind the requirements of **Q**ualification **M**odel (QM) and **F**light **M**odel (FM)

- Provision for handling the satellite during transportation and testing.
- Design of mock LVI and solar panels
- Practice using tools
- Fabrication of fixtures
- Fabrication of mock LVI and solar panels
- Integration of qualification model
- Vibration and thermovacuum testing

Further, the tasks that have not been completed are:

- Fabrication of flight model
- Integrate the LVI on flight model at VSSC

The detailed weight budget is given in Appendix Page ?? and ??. Moreover, the list of equipments procured for conducting the measurements is given in Appendix page ??

Chapter 2

Launch Vehicle Interface

IBL230 V2 is the Launch Vehicle Interface that will be given to Pratham from Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram. It caters to micro-satellites of mass 10kg to 50kg under lateral and axial accelerations of 6g and 11g respectively (Axial CoG offset of 420mm for 50kg satellite).

2.1 Mechanical Interface

As provided in the PSLV launch vehicle interface information document, the interface has a ball lock mechanism which is released by 2 pyro-thrusters. It is jettisoned by a set of 6 springs. It separates with a relative velocity of approximately 0.5-1 m/s. The interface with the S/C has 8 M 6x1, 16L screws equispaced on PCD 230. The mass of the LVI is 2.4 kg while that of the FE ring is 0.6 kg. The dimensions of the LVI are given in the table below.

Table 2.1: Dimensions of LVI

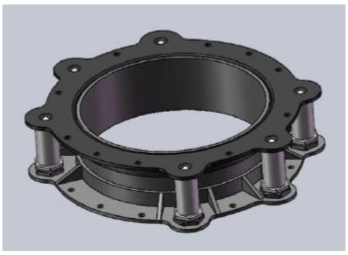


Figure 2.1: CAD model of Launch Vehicle Interface

2.2 Snap Circuit

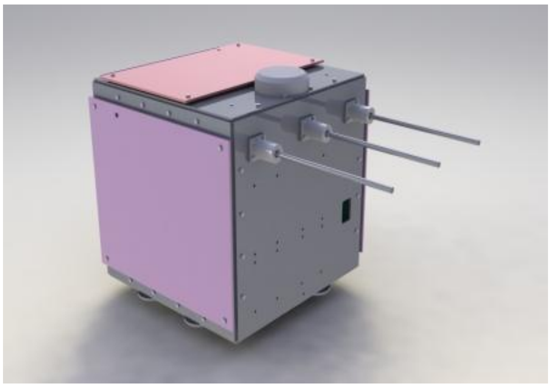
The Snap circuit will be used to detect the jettisoning of the space craft from the launch vehicle. During launch of the satellite, only the power circuit is on in low power mode and all the other circuits are off. After the Snap switch is detected by the power circuit, it switches on the other circuits in a predefined sequence.

The Snap circuit sits on the LVI (IBL230 V2). There are two snap circuits connected in series which will ensure that the satellite is jettisoned in a controlled way and any fault in the jettison process doesn't affect the main satellite on launch vehicle.The snap circuit consists of a DB15 connector with each having one half on the FE ring and the other half on the AE ring. 3 pairs of wires run from the DB15 connector to the power board. Each of the 3 pairs of wires is shorted on AE ring side. Hence in the non-jettisoning stage, the 3 pairs of wires become shorted. After jettisoning, the 3 pairs of wired become open. This transformation from short to open is detected by power circuit and it will know that the satellite is jettisoned from LVI. The 3 wires are used for triple redundancy. This Snap circuit is to be given to Pratham Team along with the LVI (IBL230 V2) by VSSC.

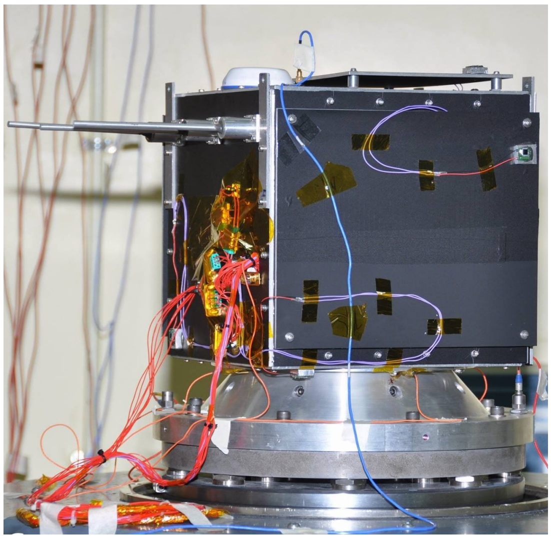
Chapter 3

Structure

The satellite structure is as shown in figure Fig. 3.1. The Engineering Drawings of each of the panels and the position of the components on the individual panels is shown in the appendix from page ?? to ??. All the components onboard the satellite were modelled in SolidWorks software.



(a) CAD model for Pratham



(b) Actual structure of Pratham

Figure 3.1: Structure of Pratham

Table 3.1 on next page shows the structural requirements and rationale behind those requirements

In Fig 3.2, the coordinate system marked in red-green-blue for X-Y-Z is the output coordinate system. The coordinate system marked in pink colour in the middle is the center of mass and the principal axes.
Some of the important parameters are :
Mass = 9690.0 grams
Volume = 5710919.39 mm^3
Surface area = 2552076.86 mm^2
Center of mass: X = 1.57, Y = 128.81, Z = -11.75
(in millimeters from output coordinate system)

Requirement	Rationale
To support all components required for functioning of the satellite	Subsystem requirement
To interface with the Launch Vehicle Interface according to the constraints imposed	Subsystem requirement
To shield the satellite from ESD	Requirement from Power & OBC subsystems for ESD sensitive components to be placed in a Faraday cage
To achieve inertia constraints Ixx <Izz <Iyy; Ixx + Izz <Iyy; $Ixy \sim Ixz \sim Iyz \sim 0$	Stability requirement from ADCS subsystem
To bring the centre of mass within 25mm of the LVI axis	Constraint from VSSC for ejecting without excessive spin
To maintain integrity of self and other components in launch and orbital phases	Subsystem requirement
To be easily assembled and disassembled	Student satellite requirement
To provide a ground plane for monopole antennae	Requirement from Communication subsystem
To provide a common ground for all electrical components	Requirement from all electrical subsystems

Table 3.1: Structural Requirements and Rationale

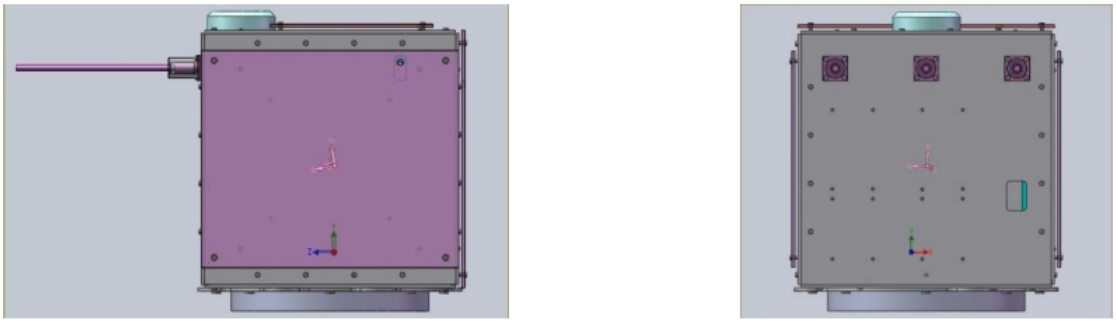


Figure 3.2: Output and Controls coordinate system

Principal axes of inertia and principal moments of inertia:
(grams * square millimeters)

- **Taken at the center of mass :**

I_x = (1.00, 0.06, -0.05) P_x = 195358915.06
I_y = (-0.03, 0.92, 0.40) P_y = 198634859.89
I_z = (0.07, -0.39, 0.92) P_z = 207879115.17

- **Taken at the center of mass and aligned with the output coordinate system**

$$L_{xx} = 195419771.65 \quad L_{xy} = 429817.08 \quad L_{xz} = -737006.60$$
$$L_{yx} = 429817.08 \quad L_{yy} = 200061557.96 \quad L_{yz} = 3331183.19$$
$$L_{zx} = -737006.60 \quad L_{zy} = 3331183.19 \quad L_{zz} = 206391560.52$$

- **Taken at the output coordinate system**

$$
\begin{array}{ccc}
I_{xx} = 378160685.82 & I_{xy} = 2677868.15 & I_{xz} = -937369.89 \\
I_{yx} = 2677868.15 & I_{yy} = 201529635.09 & I_{yz} = -12827705.86 \\
I_{zx} = -937369.89 & I_{zy} = -12827705.86 & I_{zz} = 387720147.29
\end{array}
$$

Care should be taken of the conversion from the output coordinate system of SolidWorks to the coordinate system followed by the Controls Sub-System. Taking into account the Controls Sub-System's coordinate system, and writing the Moment of Inertia matrix :

$$
\begin{array}{ccc}
I_{xx} = 0.167589486 & I_{xy} = -0.000971761 & I_{xz} = -0.000971761 \\
I_{yx} = -0.000971761 & I_{yy} = 0.172330002 & I_{yz} = -0.000971761 \\
I_{zx} = -0.000971761 & I_{zy} = -0.000971761 & I_{zz} = 0.172330002
\end{array}
$$

Since,I_{yy}>I_{xx}>I_{zz} and I_{yy}<I_{xx}+I_{zz} satellite is gravity gradient stabilized.

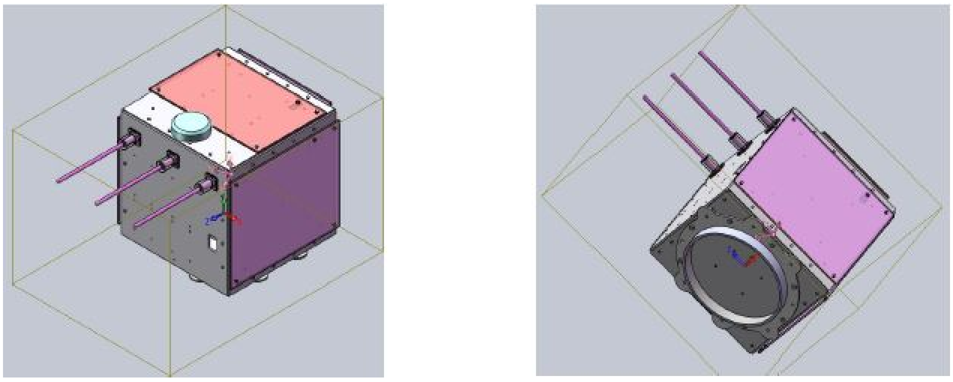


Figure 3.3: Other views of Pratham

Figure 3.4: Black tape coated Structure from ISAC

Figure 3.5: Structure with flight cards

Chapter 4

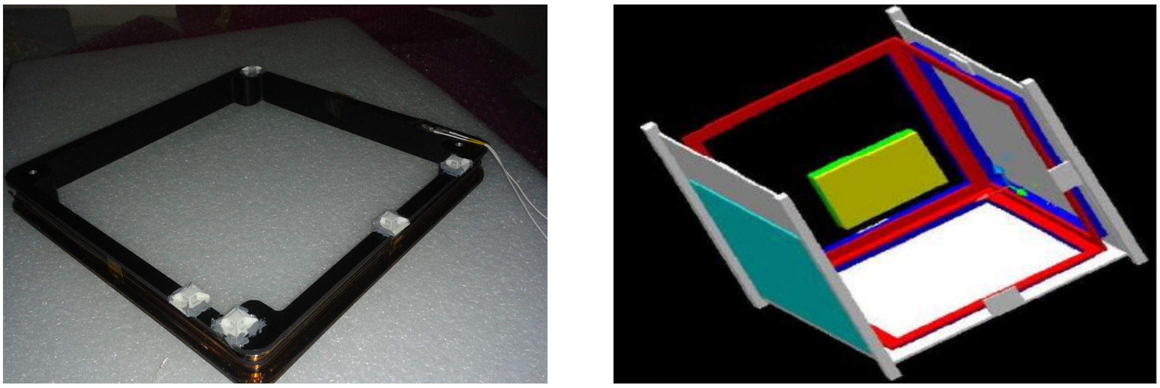
Mounts

4.1 Magnetorquers

Magnetorquer is the only actuator for our satellite. Three mutually perpendicular torquers are used for three axis attitude control of the satellite.

4.1.1 The concept of hardware design:

The design of the magnetorquers is based on the assumption that all three coils have same properties. This means that the mass of each coil is equal to one third of the total mass. The coils will be positioned inside the satellite body, connected via M4 steel screws to meet the requirements of orthogonality as shown below in Fig. 4.1:



(a) Fabricated Magnetorquer

(b) Modelled Magnetorquer

Figure 4.1: Magnetorquer for Pratham

Maximum Dimensions	230×230 mm
Maximum Weight	50g
Maximum Power per Torquer	1W
Maximum Mag. Moment	0.031 Am^2 *(See Calculations in appendix)
Voltage	3.3V

Minimum Temp	-100 °C
Max Temp	100 °C
Normal Temp	15 °C

4.1.2 Requirements from Torquer

Torque: As required by ADCS subsystem,torquer should be capable of producing 9.311 $\times 10^{-7}$ Nm torque

Design Constraints(per coil)

Physical constraints:

Environmental conditions:

4.1.3 Numerical Analysis

Formulae Used

m=$\mu_r niA$

$i = \frac{V}{R}$

$R = \frac{4\rho L}{\pi d^2}$

$A = ab$

$L = 2n(a + b)$

$V = 3.3V, constant$

$W = \frac{L \times \pi d^2 \times \sigma}{4}$

where,

$\Gamma =$ Torque

$P =$ Power

$R =$ Resistance

$n =$ Number of turns

$i =$ Current

$m =$ Magnetic moment

$B =$ Earth's Magnetic Field $= 3 \times 10^{-5} T$

$d =$ Diameter of Wire

$a =$ 230 mm $= b$

$\rho =$ Resistivity of wire

$\sigma =$ Density of wire

$\Theta =$ Angle between B & m

μ_r = 1 (Air core torquer)

W = Weight of the wire

4.1.4 Calculations

1. **Magnetic Moment**

   m=$\mu_r niA$

   m $= K_1 d^2$

   $K_1 = \frac{\pi \mu_r V ab}{8\rho(a+b)}$

2. **Weight**

   $W = \frac{L\pi d^2 \sigma}{4}$

   $W = K_2 n d^2$

   $K_2 = \frac{\pi(a+b)\sigma}{2}$

3. **Power**

   $P = \frac{V^2}{R}$

   $P = \frac{K_3 d^2}{n}$

   $K_3 = \frac{\pi V^2}{8\rho(a+b)}$

4.1.5 Selection of Coil Wire

Variables to be considered :

1. **Coil Material**

   For the design we will be choosing between Al and Cu wires. Advantage of Al wires is light weight where as that of Cu wires is low resistance

2. **Wire diameter**

   Wire diameter is extremely critical because : $m \propto d^2$.

   Therefore thicker the wire diameter more will be the magnetic moment produced

3. **No. of Turns**

   Even though Magnetic moment is independent of no. of turns it is an important factor when requirements of weight and power need to be satisfied

Calculations were performed for Aluminium and Copper wire. Table 4.1 below summarizes the comparison between Aluminium and copper wire.

	Al wire Torquer	Cu wire Torquer
Geometric		
Wire Diameter	0.35 mm	0.31 mm
No. of turns	60	60
A	23 cm	23 cm
B	23 cm	23 cm
Power		
Voltage	3.3 V	3.3 V
Current	0.211 A	0.265 A
Power (max)	0.695 W	0.876 W
Main Specifications		
Magnetic Moment	0.692 Am2	0.842 Am2
Power (max)	0.695 W	0.876 W
Weight	14.8g	37.1 g

Table 4.1: Comparison between Aluminum and Copper Wire

Since torque will be operating at less than maximum power point for most of the operation cycle therefore weight is the primary criterion for optimization.

Although the weight of Aluminium is lesser than that of Copper, Copper wire was choosed for magnetorquer due to the scanty availability of enamled Aluminium wire.

4.1.6 Torquer Winding Procedure

- The wire must not be glued to the aluminium frame. In case there is no provision for the wire to be winded without touching the frame, then 2 or 3 layers of cello tape must be winded around the frame, before applying the epoxy.
- A layer of epoxy must be applied uniformly on all 4 sides of the frame.
- Hold some part of one end of the wire aside (for connections) and start winding, such that adjacent layers just touch each other. There must not be any gap between adjacent layers.
- One pot of epoxy (as prepared above) will last only about 50 turns, which will approximately serve our purpose.
- Note that after the first row is complete; apply a coat of epoxy every 2 or 3 complete turns, before continuing.
- The wire must not have any kinks or breaks in it.
- After winding, leave the torquer at room temperature (25-30 C), to let it cure for 24 hours.

4.1.7 Torquer Testing

1. **Resistance(R)**
   Recommended method : Digital Multimeter
   Accepted method : LCR - Q instrument in well lab
2. **Inductance(L)**
   Recommended method : Impedance (Z) of the LR circuit is measured by Impedometer(an advance instrument available in a lab in Electrical department)
   $Z^2 = R^2 + X_L^2 = R^2 + (L\omega)^2$
   $L = \sqrt{(Z^2 - R^2)/\omega^2}$
   Here, ω =frequency of signal
   Accepted method : : LCR - Q instrument in well lab
3. **Magnetic Field**
   Recommended method : Calibration of the Coil:
   Magnetic field created by the torque coil at its centre can be measured by magnetometer. Magnetometer is placed at defined locations within the core of the coil and readings are taken for different values of current. The locations will be defined by using a graph paper on which the coil is placed
   Accepted method : Measuring torque using Helmholtz coil setup for a known uniform magnetic field. Using this torque, Magnetic moment of torquer was back calculated.

4.1.8 Parameters actually taken while fabrication

Wire material: Copper
Voltage: 3.3V
Current: 149.4 mA
Power: 0.49302 W

Side Length	200 mm
Diameter of coil wire	0.28 mm
Resistivity	0.000000017 ohm m
Density	8900 kg/m^3
Number of turns	60
Perimeter	800 mm
Total wire length required	48 m

Table 4.2: Magnetorquers' Design Parameter

4.1.9 Experimental results

Resistance , R = 15.6ohms
Inductance , L = 1.46mH

- Measured with the help of a LCR q-meter
- More accurate than plotting a curve i.e least square approximation method
- No idea regarding calculation of magnetic field

Requirement	Rationale
To provide a means of assembling the battery pack onto the structure	Integration requirement as battery pack has no fixturing provisions whatsoever
To prevent excessive vibrations of the batteries above limits specified by supplier	Structural requirement to protect battery
To provide a means of radiative thermal coupling for the battery pack	Thermal requirement to conduct heat away from battery and facilitate cooling
To create an enclosure giving temperature controlled environment for the batteries	Thermal requirement to simplify provision of temperature control for battery protection

Table 4.3: Caption

4.1.10 Theoretical results

R = 13.26 ohms

L = 1.88 mH

Hence theoretical and practical results match.

4.2 Battery Box

The Battery box is used to house the batteries inside the satellite. The requirements are :

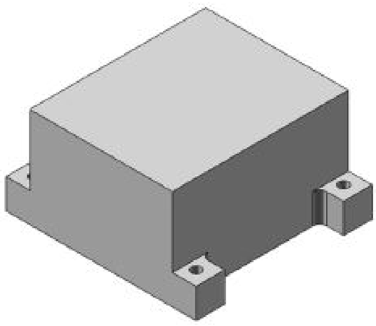


Figure 4.2: CAD model for Battery Box

Figure 4.3: Battery pack from ISAC

4.3 Monopole Holder

The monopole holder mechanism holds the monopoles in place in a pre-deployed positions. It is designed such that the monopoles are not harmed during launch. The major features of the holder are:

- to provide connectivity to the monopole
- to insulate it from the satellite body
- to provide it with mechanical rigidity

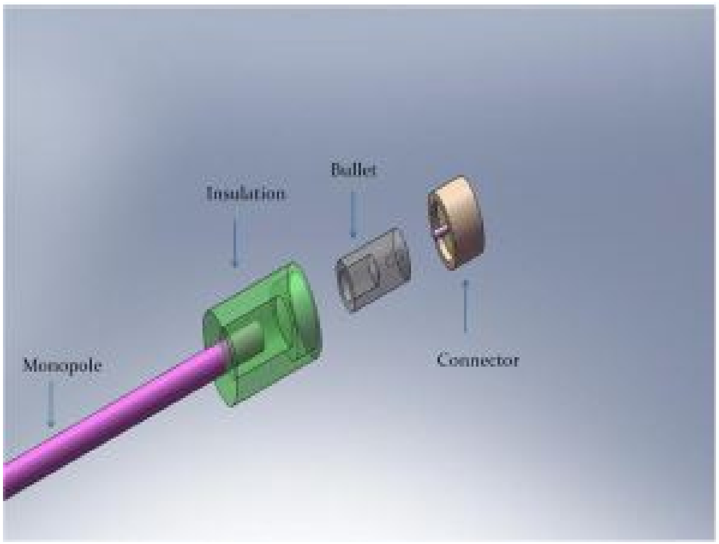


Figure 4.4: CAD representation for antenna holder assembly

The specifications for the monopole holder are:
Material : Al-6061
Dimensions
Outer diameter = 20mm
Inner diameter = 8mm
Length = 29 mm + 2mm (thickness of square base)
Length of square base = 25 mm
Finally, the monopole has been insulated from the satellite body while maintaining electrical connections with the feed point at all times, even during launch loads.

Chapter 5

Substitute Parts

In this section, we shall explain the two parts which have been replaced by substitutes in the Qualification Model of the Satellite.

5.1 Launch Vehicle Interface

The 'mock' LVI is an Al6061-T6 structure; fabricated by CNC machining. The Top flange is attached to nadir panel. The Bottom flange is attached to base plate with corresponding holes. Table 5.1 outlines the requirements and constraints kept in mind while designing mock LVI.

Requirement	**Rationale**
To mimic all necessary dimensions of the actual LVI needed for interfacing with the satellite	Integration requirement to check integration sequence and model correctness
To provide a handling interface for the satellite	Structural requirement to permit handling of the satellite
To approximate the mass of the actual LVI to within 5% of the actual value	Vibration testing requirement to achieve similar behaviour as with the actual LVI for QM
To provide a means of constraining all movement of the satellite during integration of panels	Integration requirement
To provide a means of attaching the satellite to the vibration table under similar conditions as the actual LVI	Vibration testing requirement

Table 5.1: Requirements and Rationale for Mock LVI

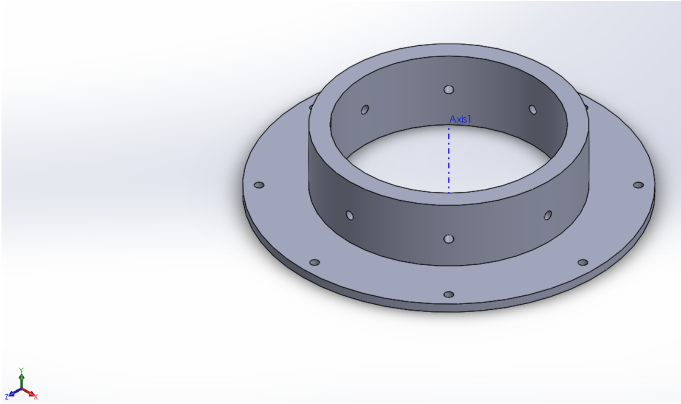


Figure 5.1: CAD model for mock LVI : FE Ring

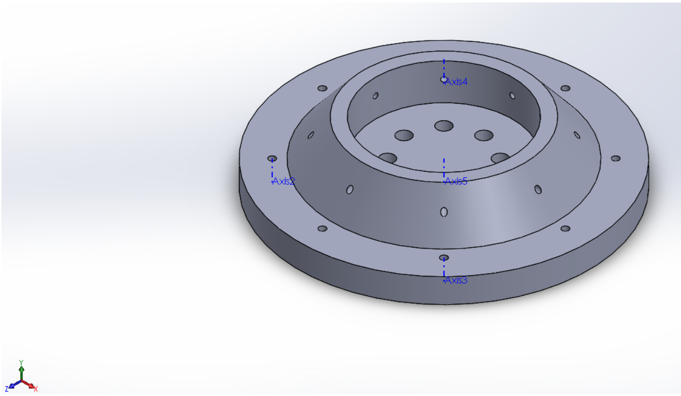


Figure 5.2: CAD model for mock LVI : AE Ring

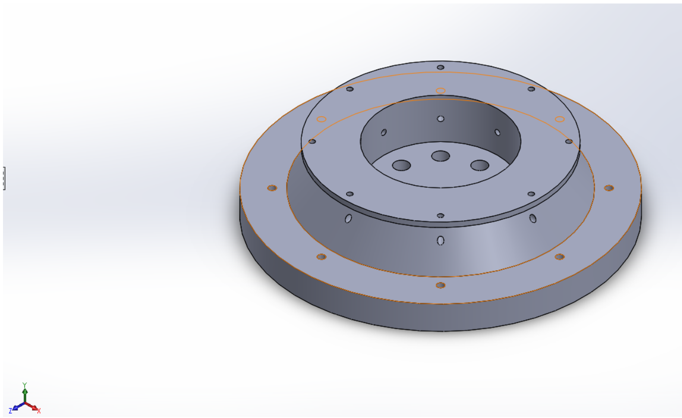


Figure 5.3: CAD model for mock LVI : FE and AE Ring Mated

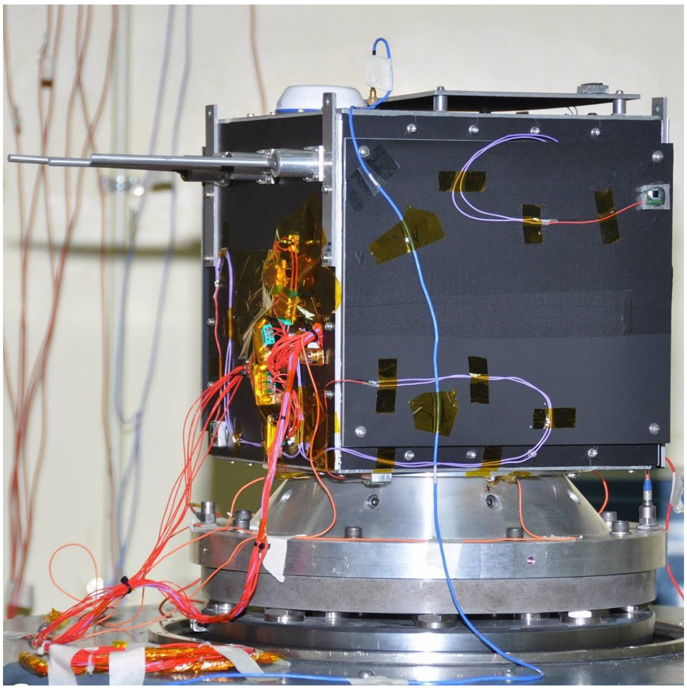


Figure 5.4: Mock LVI integrated with Satellite : Vibration testing of Qualification Model

5.2 Mock Solar Panels

Similar to mock LVI, mock solar panels were manufactured to mimic different subsystem requirements as shown in Table 5.2. These panels were made from Al 6061-t6. To duplicate thermal properties, black coating,as provided by ISAC was applied on both sides of the mock panel.

Requirement	**Rationale**
To mimic the linear dimensions of the actual solar panels	Integration requirement to check integration sequence and model correctness
To have approximately the same weight (within 1%) of the actual solar panels	Vibration testing requirement to give same mass properties and distribution
To have similar absorptivity and emissivity values (within 10%) of the actual solar panels	Thermovacuum testing requirement to create same temperature distribution as actual satellite

Table 5.2: Requirements and Rationale for Mock LVI

Chapter 6

Electrical Connections

6.1 Wire Routing Guidelines

- SOLAR PANEL WIRES should enter the satellite through the same side as the one on which the solar panel is mounted.
- There is a minimum diameter constraint required for the bunch of wires so that they are effectively set in the Beta-Clamps.
- The SUNSENSOR WIRES (2) of the sunsensor mounted on a given solar panel on a given side has to be routed along with the solar panel wires of the same solar panel.
- Should not route wires below the boards as far as possible. If we have to route wires below the boards we need to make sure that the current carrying wires do not influence the functioning of the board.
- Data and Power wires should not be routed together and they should not cross each other too.
- SUNSENSOR WIRES (6 wires) are ANALOG wires .Thus new signals are generated when they are crossed by Data or Power wires.
- The clamps should be placed at appropriate distances.
- If we are going to leave free ends of a bundle of wires then route them in such a manner that you leave the minimum length free.

It is preferred for soldering and functional purposes that we use multi-strand wires instead of single strand. Due to thermals subsystem's requirement, the wires used for environmental testing of Qualification Model were Teflon coated. However, as suggested by ISAC, Polyimide coated wire will be used in Flight Model.

Note: The solar panel wires are routed externally. The solar panel wires are connected in 2 pairs (2 + 2) to avoid catastrophic failure in case the connection gets loose. These are connected via DB-9 connectors on Antisunside, which relay the connection to Power board.

Chapter 7

Mechanical Fasteners

7.1 Helicoils

7.1.1 Selection of helicoils inserts

Helicoil are inserts made of coiled wire. The helicoil is inserted into a tapped hole that is larger than the desired hole. They are usually over-sized so that they anchor themselves. The basic aim of a helicoil is to hold a screw inside a tapped hole. They give a strong hold which prevents the screw from coming out the hole even under high magnitudes of vibration.
Helicoils come in 4 types :

1. Tanged helicoil
2. Tang-less helicoil
3. Self-locking helicoil
4. Free running helicoil

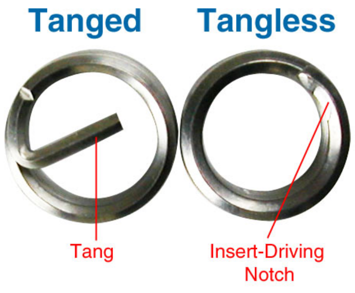


Figure 7.1: Tanged and Tangless Helicoil

Figure 7.2: Self Locking Helicoil

7.1.2 Principle of working for Helicoil

In Free State, the helicoils are greater in diameter than the tapped hole into which they are installed. In the assembly operation the torque applied to the tang reduces the diameter of the leading coil and permits it to enter the tapped thread. When the torque or rotation is stopped, the coils expand with a spring-like action anchoring the insert permanently in place against the tapped hole.

Helicoils come in 5 sizes, i.e., d, 1.5d, 2d, 2.5d and 3d where d is the diameter of the helicoil. They are inserted in the thicker portion of the two surfaces in contact. Hence, as long as size permits, the longer the helicoil, the better the grip.

Our satellite is under huge amounts of vibrations during launch. Therefore we have to ensure that the screws will not come out during launch. Hence we need self-locking helicoils. Also tanged helicoils are easier to insert using the insertion tool. Taking into consideration the dimensions of the holes in the satellite the size of the helicoils was decided to be 2d. Therefore 'Tanged helicoils' have been finalized.

Tanged helicoil

Tanged helicoils have a tang at one end of the helicoil as shown in Fig.7.1. The insertion tool applies torque on the tang reducing the diameter of the leading edge hence making the helicoil enter the tapped hole. This tang has to be removed before the insertion of the screw with the help of a tang removal tool. This is done so that it will not hinder the screw in a through hole.

7.1.3 Assembly of helicoil inserts

Before the insertion of the helicoils the holes have to be tapped. This is done using a tap wrench, a roughing and a finishing tap. The helicoil is then inserted into the hole using the helicoil insertion tool (see Fig. 7.3). The size of the helicoil is larger than that of the hole. Hence a compressing torque has to be applied on the helicoil to insert it. This is done by the insertion tool. This applies a compressing torque on the tang of the helicoil and inserts it as the leading edge. There is also a helicoil extraction tool(see Fig. 7.4) which is used to extract the helicoil after it has been inserted into the hole. Inserts may be removed manually with little effort. This is done by inserting the blade of the extracting tool into the helicoil insert so that a flat side of the blade is toward the top end of the insert. Strike the head of the tool with a light blow. Maintaining a steady pressure of blade against insert, turn the extracting tool counter-clockwise until the insert is removed.

Figure 7.3: Helicoil Insertion Tool

Figure 7.4: Helicoil Removal Tool

7.1.4 Selection of screws

We are using screws to attach any two surfaces in contact on our satellite. The size of the screw will be decided by the maximum depth of penetration of the hole. The screws are made of the material SS304 (stainless steel) as we wanted stainless steel and this was the commonly used type (as suggested to us by TIFR)

Selection Criteria

Single slotted and Phillip screws tend to slip off while using a screw-driver to screw them.These fasteners are easily damaged at the slot. In addition, these are hard to use with a torque wrench.

Allen/hex head fasteners are very common in most equipment. These are more durable and less likely to slip. This also allows use of torque wrenches. Hence, Allen headed screws have been chosen for Pratham.

Figure 7.5: Allen head screw

7.1.5 Assembly of screws

The assembly of screws was done using a torque screw driver. This will ensure that all the screws all screwed to an equal level of torque. The appropriate helicoils have to be inserted in the holes before the assembly of the screws. All the screws on the same level in the integration sequence have to be integrated at the same time. This is done so that no warping takes place in the structure. The screws have a particular value of torque at which they have to be screwed. These values were provided by ISAC and are shown below in Table 7.1.

Screw Size	Torque value
M3	k Nm
M4	kj Nm
M6	j Nm

Table 7.1: Torque values for Screws

In addition to these, predefined torques must be applied at GPS antenna's nut, screwlocks (at all the board connectors). The following values have been finalised :

Location	Torque value
GPS puck antenna	34 Nm
Screwlocks	0.34 Nm

Table 7.2: Torque values for other fasteners

7.2 Adhesives

7.2.1 Use of adhesives in Assembly

1. In comparison with other fabrication methods, adhesive assembly is essentially fast.
2. In contrast to welding, adhesives allow a wide freedom of choice during material specification. It is possible to mix and match material combinations to suit product function and save production costs in ways which have been impossible in the past.
3. Adhesives form an integral part of a wide variety of fabricated products, offering the potential to create new and challenging designs.
4. Structural and specialty adhesives account for about 30 % of total adhesive
5. Good adhesion and cohesion are required to achieve high performance joints.
6. This means that forces in a structure may be transmitted from one member to another through the joint.
7. This force would be taken up by the adhesive and spread or transmitted to the next member.
8. Adhesive assembly offers significant cost savings if material costs can be reduced and production operations can be simplified.
9. New approaches can be taken to the manufacture of sub components, and castings may be combined with extrusions, sheet components and parts produced in a variety of other way , better production sequences.

7.2.2 Advantages of using adhesives

- dissimilar materials can be joined
- the bond is continuous
- stronger and stiffer structures can be designed;

- on loading there is a more uniform stress distribution
- local stress concentrations are avoided
- porous materials can be bonded
- adhesives prevent catalytic corrosion
- adhesives seal and join in one process
- no finishing costs
- improved fatigue resistance
- vibration damping
- reduced weight and part count
- large areas can be bonded
- small areas can be bonded accurately
- fast or slow curing systems available
- easy to combine with other fastening methods
- easily automated/mechanised

7.2.3 Adhesives selected

: || || ?? TBD

7.2.4 Methods of using Adhesives

Pretreatment

- The strength and durability of a bonded joint is dependent on proper treatment of the surfaces to be bonded.
- At the very least, joint surfaces should be cleaned with a good degreasing agent such as acetone or other proprietary
- Degreasing agents in order to remove all traces of oil, grease and dirt.
- Low grade alcohol, gasoline, or paint thinners should never be used.
- The strongest and most durable joints are obtained by either mechanically abrading or chemically etching ("pickling")
- the degreased surfaces. Abrading should be followed by a second degreasing treatment.

Application of adhesive

- The resin/hardener mix may be applied manually or robotically to the pretreated and dry joint surfaces
- A layer of adhesive 0.002 to 0.004 in (0.05 to 0.10 mm) thick will normally impart the greatest lap shear strength to the joint. Huntsman stresses that proper adhesive joint design is also critical for a durable bond. The joint components should be assembled and secured in a fixed position as soon as the adhesive has been applied.

7.2.5 Epoxy Specifications

TBD

7.2.6 Handling

- Advice on safe handling : provide sufficient air exchange and / or exhaust in work rooms .
- Handle and open container with care .

7.2.7 Storage

- Keep away from food, drink and animal feeding stuffs.
- Keep container tightly closed.

7.2.8 Few Guidelines

- All tools should be cleaned with hot water and soap before adhesives residues have had time to cure. The removal of cured residues is a difficult and time-consuming operation.
- If solvents such as acetone are used for cleaning, operatives should take the appropriate precautions.
- Avoid contact with skin , eyes and clothing
- Avoid breathing vapour , mist and spray .
- Repeated skin contact with resins and hardeners may cause chronic contact dermatitis, which is usually milder but longer lasting. If left untreated for long periods it can progress to eczema, a form of dermatitis that can include swelling, blisters and itching. Inhaling concentrated epoxy vapors, if done frequently or for long periods, can irritate your respiratory tract. Exposing sensitive skin areas, like the eyelids, to highly concentrated epoxy vapors may cause itching and swelling.
- When resin and hardener are mixed, the hardener is diluted and therefore less corrosive. Although mixed epoxy is less corrosive, never leave it on your skin. It cures rapidly and is difficult to remove.
- The burn may discolor and slightly scar the skin
- Never breathe the sanding dust of partially cured epoxy. Epoxy chemicals remain reactive until they have cured. Serious health problems can result from sanding epoxy before it is fully cured. When you inhale these dust particles, they become trapped in the mucus lining of your respiratory system. The reactive material can cause severe respiratory irritation and/or respiratory allergies.
- Breathing highly concentrated epoxy vapor can irritate the respiratory system and cause sensitization. At room temperature, epoxy vapors are unlikely to be highly concentrated. However, if you are already sensitized to epoxy, exposure to low concentrations of epoxy

vapors can trigger an allergic reaction. At warmer temperatures and in unventilated spaces, the epoxy vapor levels increases.

The following safety precautions should be taken care of :

- Use of impervious (rubber or plastic) hand gloves is recommended.
- For eye protection tightly fitting safety goggles .
- Wash hands before breaks and immediately after handling the product .
- Keep away from the sources of ignition – No smoking
- For skin and body protection wear long sleeved clothing

7.2.9 First aid measures

- If swallowed drink 3-4 glasses of water but never induce vomiting
- Inhalation : Move to fresh air
- Eye contact : Rinse immediately with a plenty of water for at least 15 min. . If eye irritation persists , consult a specialist
- Skin contact : Wash off immediately with soap and plenty of water

Chapter 8

Integration Sequence

Guidelines followed during defining the integration sequence:

1. The sequence has been decided in such a manner that the person performing the integration has adequate space for comfortably handling the tools.
2. Fixtures have been designed keeping in mind the integration sequence such that the person performing the integration needs to support minimal number of components giving him better freedom in handling the tools
3. Integration of sensitive components like the sunsensor and the solar panles is delayed as far as possible as they are very susceptible to handling damage arising from tools hitting their surfaces.
4. Each integration step involving screws has a predefined fastening sequence of the screws to minimise warping of the plate as even the slightest warp might affect the hole alignment in the assembly.
5. Each screw must be tightened to a predefined torque value to avoid any imbalance in torques resulting in warping of plates.

The detailed Integration sequence is given in the Appendix Page ?? to ??.

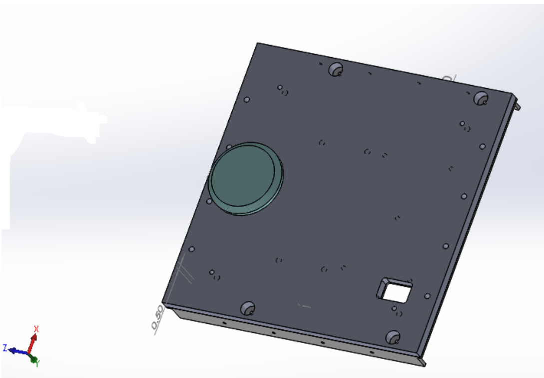
Chapter 9

Panel Assembly Fixture

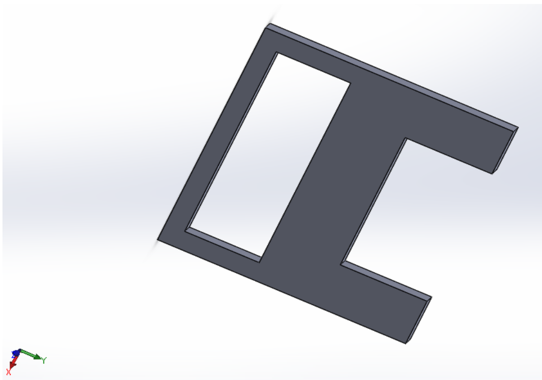
We require a fixture on which the satellite body will rest during assembly as well as after finishing the complete model. This model will be used during the integration of the satellite body as a whole as well as for individual sides.

Individual side assembly fixture

1. Fixture for assembling components onto each panel
2. Slots given for fitting magnetometer, magnetorquers for inserting screws from outer side of panel
3. Grooves to fit flanges provide constraint for panels



(a) Zenith Side Assembly



(b) Fixture for Zenith

Figure 9.1: Fixure design for Zenith*

*Sunsensor has not been shown in Figure

Chapter 10

Transportation and Handling

Transportation box is used as safe enclosure for carrying satellite between various stations on ground during various occasions for different tests before it is launched. The first concern before designing transportation box is to decide the mode of travel (Air, Train or Road). After considering the loads acted and handling procedures, the road transportation was finalised as the mode of transportation for QM. The air transportation is eliminated because it involves severe loads acted on box during various stages of flight and also it has to hand over to the cargo crew which is strictly not permitted from satellite safety and handling considerations. Above all if any accident happens to flight hardly there will be any part of satellite that could be traced. The main objective of transportation box is to provide vibration isolation, humidity level control, air tight, ESD prevention and clean environment for satellite.

10.1 Transportation box design

Transportation box is a rectangular wood box as shown in the picture (below) with foam filled inside. The inner dimensions of the box are 650 mm*550 mm*600 mm. And the foam shape at the base is female projection of the satellite nadir face along with LVI system. This will ensure snug fit and corner blocks of foam are placed at the bottom all the other four corners of the top.

(a) Internal View*

(b) External View

Figure 10.1: Transportation Box design**

*The foam cushioning is not shown
*As suggested by ISAC, this box is too big for handling and storage by ISAC/VSSC. Thus this will be redesigned to a smaller size before Flight model is submitted.

10.2 Loads considered in design are given below:

Approximate Horizontal and Vertical loads (harmonic load): 1g at 3-10 Hz. Impulse loads are acted on the box whenever vehicle hits the bumps or sudden fall of box from a height.

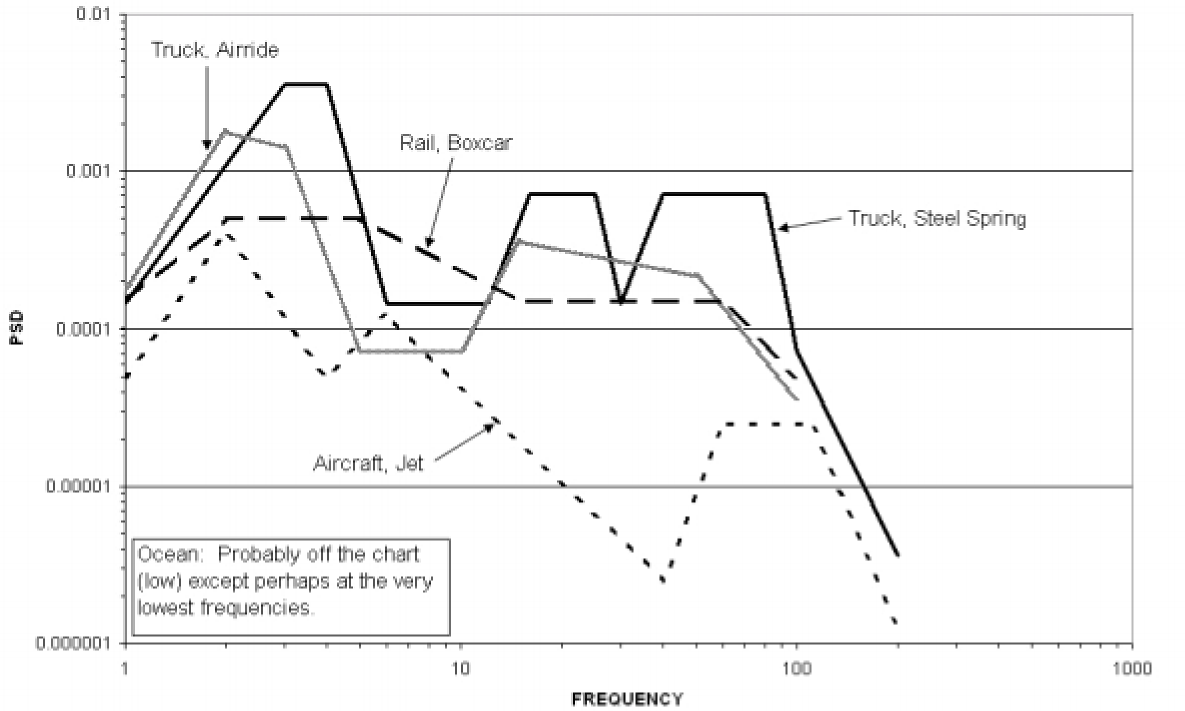


Figure 10.2: Random vibration load data during transportation

10.3 Analysis of Design

Design to account for vibration: Here we have two options to provide vibration isolation. One is to arrest the vibrations before they are transmitted to transportation box itself by keeping it on an isolation system (like foam sheets) so that no strict conditions are required on inside (between satellite and inside faces of transportation box). And the other is to keep the transportation box directly on the vehicle base surface and provide the proper insulation between satellite and inside faces of transportation box. When vibration analysis is performed by modelling it as a single DOF damped spring mass system the stiffness of the spring required came out to be 120 N/m which is too soft to sustain the static weight of transportation box and satellite (above 90kg). And also as we planned to provide isolation by using foam rather than any other dampers, no proper foam is available. Hence we planned to implement the second idea in spite of the simplicity in implementation of the first one. This is done by selecting proper foam (flexible polyurethane) as packaging material and ensuring snug fit of satellite with it. The thickness, density of the foam is selected based on the information available on site http://www.qualityfoam.com/custom-foam-selection.asp.

Humidity control: Typically the humidity levels in India are 40-70%. The satellite structure will be safe below 50%. Excessive humidity can lead to corrosion of Al 6000 series metals. Hence humidity level control is an important factor. Typical desiccant silica gel in calculated amount is used to achieve this. Typically 2 kg/m3 of silica gel is used. As per this our transportation box (0. $25m^3$) requires 500 grams of silica gel (Rhapid gel). It has to be replaced every 90 days.

ESD protection: Aluminium foils are placed on all the inner faces of the transportation box and electrical connection with satellite is always maintained through copper strip connection. This is in turn connected to another strip outside the box which is always grounded in some way.

Thermal Considerations: Typical temperature range in INDIA is 20. 5- 41. All the satellite components are designed to temperature range of -40C-80C. In India It is very unlikely for the transportation box and inside satellite to go out of this range hence no extra protection/accessories is needed in this concern.

10.4 Materials used

Marine ply wood: The outside box is made with 12mm Marine plywood because of its enough strength and good water proof quality.
Sun mica sheets: Sun mica sheets: Sun mica sheets are pasted on outside surface of wooden box so that no dust produces from the ply wood when rubbed against rough floor surfaces.
Polyurethane foam: The inside foam is selected based on the guide lines quoted in the site http://www. qualityfoam. com/custom-foam-selection. asp. The foam material is selected based on static loading (load/area of contact on which object is laid). After the foammaterial is selected foam thickness is selected based on the foam material chart for drop height and fragility index. Fragility index is selected as per application. 130 mm thick polyurethane (4 lb/ft^3)foam is selected.

Aluminium Foil: For avoiding ESD of satellite aluminium foil is placed on all the inner surfaces of the transportation box and electrical connectivity is maintained between satellite structure and this foil.

Silica gel: Silica gel is used to absorb the extra humidity inside the transportation box.

10.5 Fabrication

The wooden box was fabricated in IDC carpentry workshop. Sun mica and inside aluminium sheets work was done by a hired carpenter. Foam work was done by another artisan.

10.6 Challenges

- In no case any of the satellite face should stuck to the transportation box walls.
- Maintaining it airtight.
- Maintaining Cleanliness inside the box.
- Making (cutting) female projection of Nadir face of satellite along LVI system in foam material. (perfect machine cut)