PRATHAM

IIT BOMBAY STUDENT SATELLITE

Conceptual Design Report

System Engineering

By

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Preface

The System Engineer has the job of seeing the mission of the project as a whole and diving it into requirements which for each of the Sub-System. One of the interesting paradoxes that the System Engineer often encounters during his work is the level of detail he is supposed to know and grasp about each Sub-System. A System Engineer cannot become a walking encyclopedia for the project who accurately keeps track of all the little details in each Sub-System. But at the same time, the best design solution will emerge only when the details are taken care of.

Since I am the System Engineer and the Project Coordinator for Pratham, it was decided that I must look at all the Sub-Systems in complete details. This includes attending all Sub-System reviews, checking all technical documentation and reports created by the Sub-Systems. Hence I have to keep myself updated with new literature as we progress in this project. This has helped me immensely in my System Engineering activities since I know all the Sub-Systems in detail. Obviously this method works only for small projects like ours and is not a solution for the above paradox.

Saptarshi Bandyopadhyay
System Engineer and Project Coordinator
Pratham, IITB Student Satellite

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Introduction

In this chapter, we will give a brief introduction to the concept of Student Satellite and about the work of the System Engineer.

Student Satellites

The concept of Cubesats was first proposed by Prof. Bob Twiggs, Space Systems Development Laboratory, Stanford University. These Satellite were small (100mm X 100mm X 100mm), standardized, low cost and specially built for commercial application. They had low fabrication costs since many onboard components were COTS and low launch costs. They were ideal for low cost, high risk space missions. Moreover, many companies like SSDL, Pumpkin started making COTS for Cubesats.

Many universities started exploring the concept of Cubesats. Mission with low cost yet exposure to space technology can be introduced into the curriculum and adequate funding is easily available from industry. Due to various methods of standardization and COTS, focus of later versions is more on Payload and the science objective. Students Satellite means students with no prior knowledge in this field, build their own Satellite.

International Standards for Nanosatellites are available. California Polytechnic's Specifications for CubeSATs are as follows

- No pyro-ordnance allowed onboard the Satellite
- CG must be within 20mm of Geometric Centre
- Rails must be smooth with edges rounded to 1 mm radius, with at least 75% (85.125 mm of a possible 113.5mm) in contact with the P-POD rails and hard anodized (To prevent cold-welding, reduce wear, and provide electrical isolation between the CubeSats and the P-POD)
- Separation springs must be included at designated contact points
- No electronics may be active during launch and CubeSats with rechargeable batteries must be fully deactivated during launch or launch with discharged batteries.
- One deployment switch is required (two are recommended) for each CubeSat

- Testing and battery charging after integration must be through GSE that connects to the CubeSat through designated access ports
- A RBF pin is required which will be removed once the CubeSats are placed inside the P-POD. RBF pins must fit within the designated data ports and not protrude more than 6.5 mm from the rails when fully inserted.
- Antennae may be deployed 15 minutes after ejection from the P-POD (as detected by CubeSat deployment switches). Larger deployables such as booms and solar panels may be deployed 30 minutes after ejection
- CubeSats may enter low power transmit mode (LPTM - short, periodic beacons) 15 minutes after ejection from the P-POD and enter high power transmit mode (HPTM) 30 minutes after ejection
- Operators must obtain and provide documentation of proper licenses for use of frequencies with proof of frequency coordination by the International Amateur Radio Union (IARU). Applications can be found at www.iaru.org.
- Qualification and acceptance testing for integrated S/C-SS system
- No external components other than rails may touch the sides of the PPOD
- Exposed surfaces must be alodyned to prevent corrosion in space environment (Alodyning – Treatment of Aluminum in a dichromate bath to create micron-thick film of chromate coating on surface – Similar to industrial CNC coating)
- Dimensional constraints must be strictly met
- Overall density of the CubeSAT cannot exceed 1 g/cc

The Poly Picosatellite Orbital Deployer (P-POD) is California Polytechnic's standardized CubeSat deployment system. It is capable of carrying three standard CubeSats and serves as the interface between the CubeSats and LV. The P-POD is a rectangular box with a door and a spring mechanism made of anodized aluminium. CubeSats slide along a series of rails during ejection into orbit. CubeSats must be compatible with the P-POD to ensure safety and success of the mission.

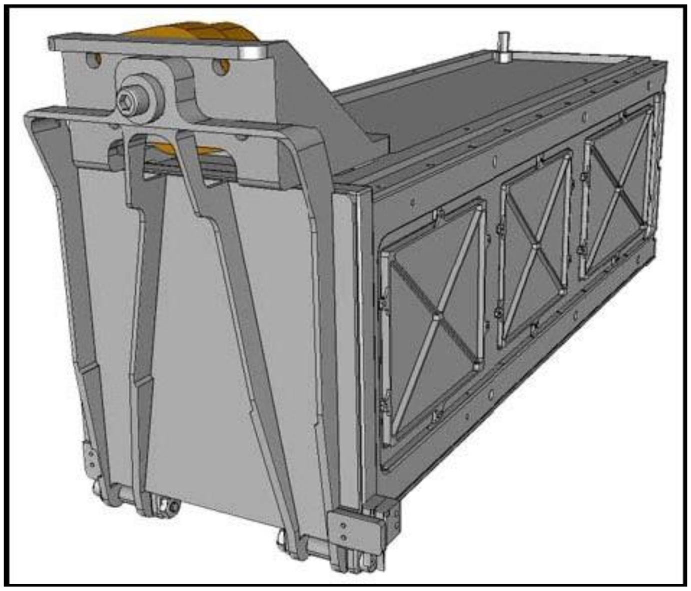

Figure 1: PPOD exterior

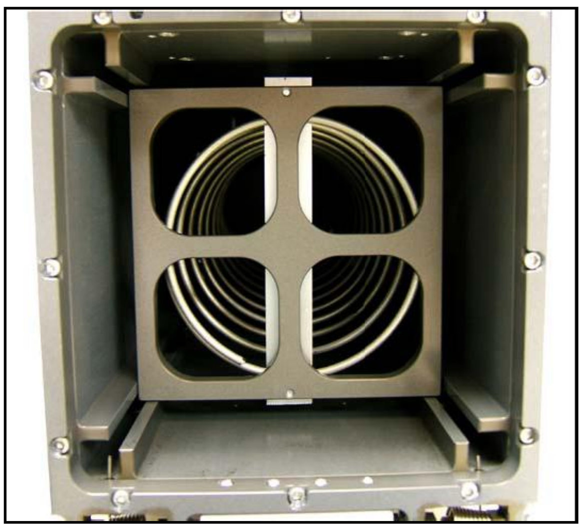

Figure 2: PPOD interior

Some of the Student Satellites that have been launched till date and we have extensively studied and used their documentation in our initial stages are

1. Mini-Sputnik
2. ASUSAT, Arizona State University
3. NCUBE, NTNU, HiN and NLH, Norway
4. SSETI, 11 universities in collaboration with ESA
5. AAU Cubesat, University of Aalborg, Denmark

6. SNOE, University of Colorado
7. ICARUS, University of Michigan
8. CATSAT, University of New Hampshire and the University of Leicester, England , supported by NASA
9. DTUSAT, Technical University of Denmark, DTU
10. MEROPE, Montana State University, USA
11. COMPASS, Aachen University of Applied Sciences, Germany
12. SEEDS, Nihon University, Japan

System Engineer's Tasks

The position of System Engineer is different from all other technical positions in the Satellite Team. All technical positions are meant to research and develop technical know-how towards the goal of the satellite. The System Engineer's job is NOT to involve in these technical research and development activities but to oversee that all of them fit together at the time of System Integration. This job is very similar to that of a designer who designs a system. Hence the focus of System Engineer's work will be majorly on Design and System Integration from a System level. The work of the System Engineer for Pratham is listed below and will be explained in detail in the succeeding chapters.

1. Defining the Mission, Success Criterion for the Mission.
2. The System and Sub-System Requirements.
3. Defining the various stages of the satellite and the functions of the satellite in each stage.
4. Maintaining Budget for all inter-Sub-System quantities.
    a. Weight Budget (for Structures Sub-System)
    b. Power Budget (for Power Sub-System)
    c. Data Budget (for On-Board Computer and Communication Sub-System)
5. Interface, Connector, wires and Protocol requirements for each of the connections being used belonging to 3 basic Sub-Systems: Power, Data and Structures.
6. Configuration Layout of the various components on the Satellite.
7. Launch Vehicle Interface and its Design. Procurement (or purchase) of the LVI. Access ports definition and design conditions.

Since System Engineering is trying to bring all the Sub-Systems together towards the final Mission of the Satellite, the 6 Sub-Systems in Pratham will be introduced first.

1. Payload Sub-System deals with the Payload of the Satellite.
2. Communication Sub-System deals with the communication link between the satellite and ground station. They are in charge of the communication circuits onboard the Satellite and the Ground Station.
3. Attitude Determination and Controls Sub-System deals with determining the attitude and position of the satellite in space and controlling it within specified ranges.
4. On Board Computer Sub-System takes care of all the data processing and storage requirements on board the satellite and it will transmit all the necessary Data and Health Monitoring information to the ground station via the Communication channel.
5. Power Sub-System makes the necessary power available to all instruments on board the Satellite.
6. Structures Sub-System has the job of making a strong frame for the Satellite and mounting the various components in it and protecting them from the harsh environments of space.

Chapter 1: Mission

The Indian Institute of Technology Bombay, Student Satellite Project has an overall plan to launch atleast 5 satellites into orbit within the next 20 years. The Student Satellite named Pratham being currently made is the first of its kind. After months of literature survey, a Payload was chosen which was deemed fit for the first satellite.

1.1 Mission Statement for Pratham

The Mission for Pratham, IITB's First Student Satellite is

1. Educating Students and Professors within the institute in the field of Satellite and Space Technology.
2. Empowering the Satellite Team with the skills to develop the Satellite through various phases of Design, Analysis, Fabrication and Testing; till the Flight Model is made.
3. Launch the satellite into orbit and measure Total Electron Count of the Ionosphere and make its map above India.
4. Involve students from other universities in our Satellite mission by building ground stations in their universities and educate them about space technology.

When all the 4 mission statements are fully satisfied, we can call our satellite to a complete success (100%). The importance the IITB Student Satellite Team has attached to each of the mission statements is shown in Fig 1.

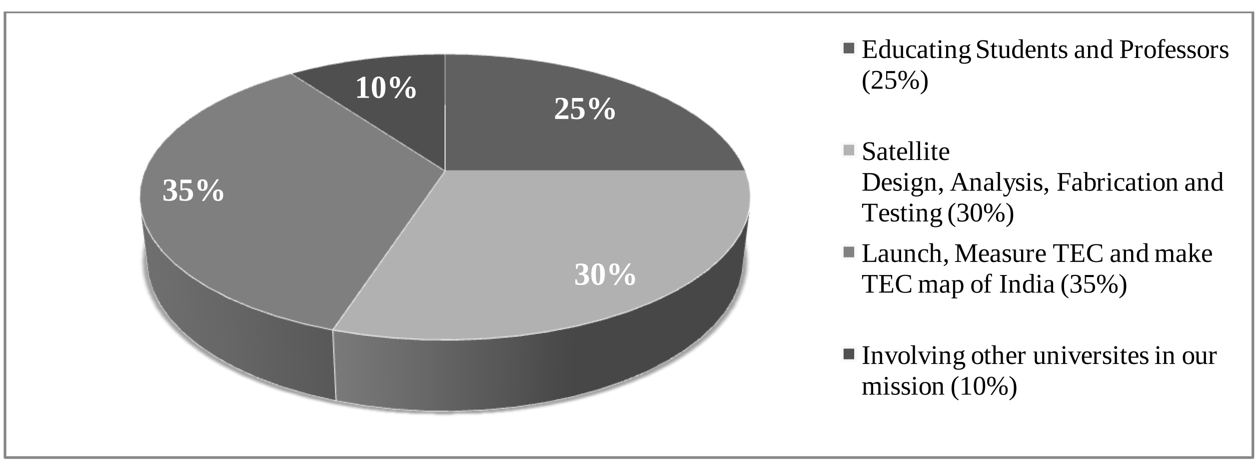

Figure 3: Mission Statement

1.2 Annotations of the Mission Statement

Indian Institute of Technology, Bombay is an Educational and Research Institute. It is obvious that a project of this magnitude will give rise to many research opportunities and advancements in technologies. The future Satellite projects of the institute could become a test-bed for new technological developments within the institute. Some of these technological innovations could also boast of space testing and qualification with the help of this Project. Hence, it is imperative that the institute gives a lot of importance to this project and learns as much as possible from each of it Missions. Here are some of the Educational goals that we have set for our satellite.

1. We have learnt about different Student Satellites being developed around the world. As of 2006, there were 50 universities throughout the world involved in such kind of projects and we can expect the number to increase. Some of the universities like California Poly-Technic have also established standards for Student Satellite called Cubesats.
2. Detailed literature survey has been done of different Sub-Systems and their practical utilization in space. Search for components, instruments, electronic chips and circuits, procedures and codes which have space heritage, i.e. have been use in space; have been carried out in great detail.
3. Since a lot of the Sub-System requirements actually come from other Sub-Systems, different methods for transfer of information and communication of information within Sub-Systems are being looked at. The role of the System Engineer is critical ion this field.
4. Some of the non-technical but equally important lessons learnt at the hassles of working in a large team, with members belonging to different disciplines. Again efficient methods of communication and directed transfer of information are being looked at.
5. We are getting a wonderful exposure to the process in which big projects are handled. We are learning to work professionally and at par with large government institutions like Indian Space Research Organization.

Finally, all the knowledge that is gained though these processes and literature surveys as very precisely documented for future Satellite missions. The new fields that we are exploring right now need not be explored again because all the details are accurately documented.

The various stages in the development of the Satellite are Design, Analysis, Fabrication and Testing which happen in a cyclic manner. During the Design phase for the Satellite, various System and Sub-System requirements are identified, defined and quantified. The different stages of Design in increasing order of maturity are Conceptual Design, Preliminary Design and Advanced Design.

Once a suitable model has evolved out of the Design requirements, the model is extensively analyzed using simulations. The various simulations are in the fields of Structures, Thermals, Power, Data and Attitude Control. In the phase of Fabrication, we get the various parts of the satellite fabricated. For example, the Main Body (frame of the Satellite) is fabricated by the Structures team, whereas the Power team fabricates it PCBs. In the Testing phase, most of the fabricated components are tested in ground using available test facilities. There are some parts which can never be tested on ground, and we have to wholly depend on Simulations for their validation. The importance the Team has attached to each of these individual phases is shown in Fig 2. The reason for such low weight for Fabrication and Testing are because there is very little effort from the Team to do it, compared to the amount of effort necessary for Design and Analysis.

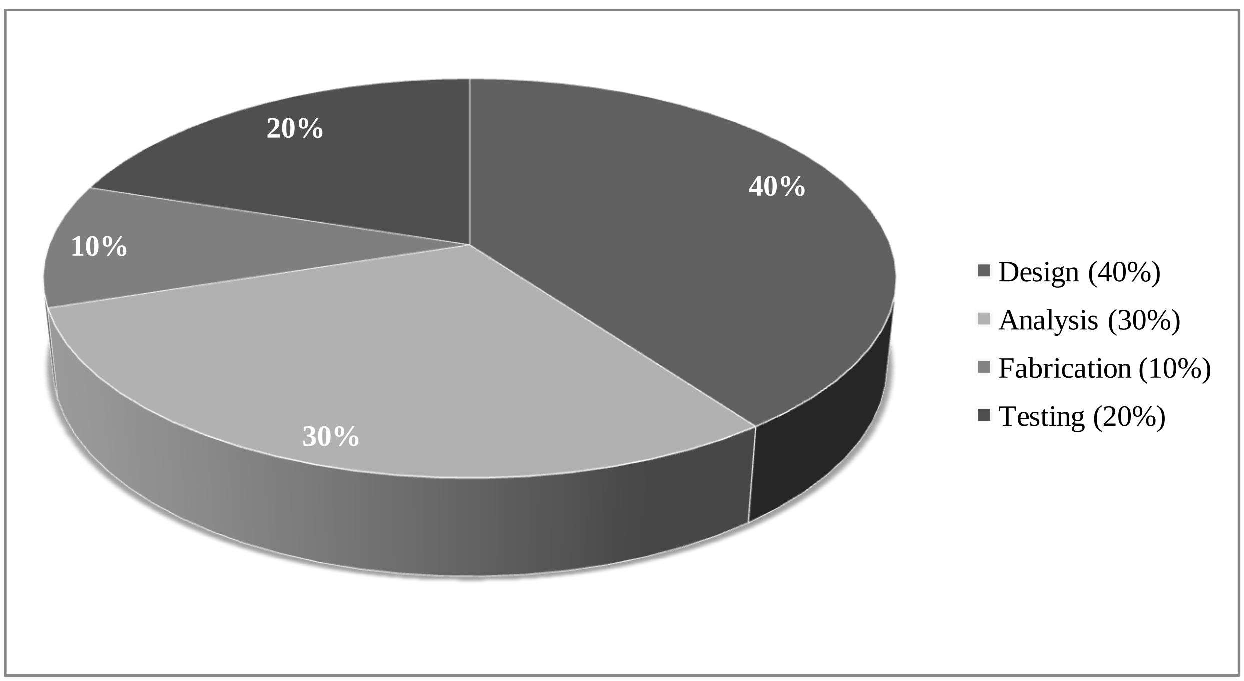

Figure 4: Design, Analysis, Fabrication and Testing

The objective of the Payload for Pratham is to measure the Total Electron Count in the Ionosphere. This is achieved by transmitting two linearly polarized beams of radio waves from the satellite and detecting the change in angle of polarization after they have crossed the ionosphere, using a ground station. Obviously, by this method, we will me able to measure the TEC of the region only directly above the ground station. Since more the number of ground stations, more TEC data can be produced; we wish to approach other universities to set up ground stations for us. We will educate the students from these universities about our Satellite project and hope to get them interested in similar endeavors. This is our small step in trying to give back to the society from which we have got so much.

The various models of the Satellite that will be made as the project matures are:

1. Lab Model
2. Engineering Model
3. Qualification Model
4. Flight Model
5. Spare Model

We wish to launch of Pratham in the launch scheduled in the 3^{rd} or 4^{th} quarter of 2009, which is a 10:30 polar sun-synchronous orbit. Since it is a small satellite, it will be carried as a piggy-back on this PSLV launch. For the launch vehicle interface, we wish to use XPOD GNB that was recently used in the PSLV C9 launch to launch the CanX-6 Satellite.

1.3 Success Criterion

For a mission of this magnitude, the success criterion which can numerically give the success of the mission, incase the mission stops/gets terminated in any stage, has to be defined. Taking into account the Mission statement described above and some inter-related factors, the Team has decided on the following Success Criterion for Pratham.

Description	**Importance**	**Success of Mission**
Successfully make the Flight Model	55%	55%
Satellite is Launched and Beacon Signal is received	10%	65%

Students from Ground Stations in other universities are able to receive our signal	10%	75%
Communication link with the Satellite is established when there is an overhead pass	5%	80%
TEC measurements are successfully carried out in IITB ground station	5%	85%
TEC map of India is made using measurements done at ground stations all over the country	5%	90%
Satellite is alive and all Sub-Systems are functional for the lifetime of 4 months	10%	100%

Table 1: Success Criterion

The first stage of success is when the Flight Model is made. We can say that the educational goals and the Design, Analysis, etc. goals for the satellite have been met at this point. Hence the importance attached to this phase is 55%, which is a summation of the importance attached to these two aspects in the Mission Statement. Hence even if there is a failure during launch, mostly because of factors which are not in our control, your mission will be a partial success.

Each of the Stages of the Satellites Success Criterion has been given importance as deemed fit by the Team. In the end, if the Satellite live for its specified lifetime of 4 months, the Mission will be a complete success (100%). The lifetime of four months is the design lifetime of the Satellite. We have reached this value because we will need 2 months of data to validate it against known standards, and then we wish to acquire 2 months of additional data that we can claim is our own and correct.

Chapter 2: System and Sub-System Requirements

The System requirements arise from the Mission statement. The Sub-System requirements arise as we try to meet the System requirements. It is these Sub-System requirements that the individual Sub-Systems are trying to meet. The basic System Requirements are:

- Successfully build a Satellite and Ground Station.
- Measure TEC of Ionosphere.
- Make TEC map across India.
- Satellite must be fully functional and autonomous for a lifetime of 4 months after launch.

These give rise to Sub-System Requirements. The Sub-System requirements are captured in the figure below and explained in detail.

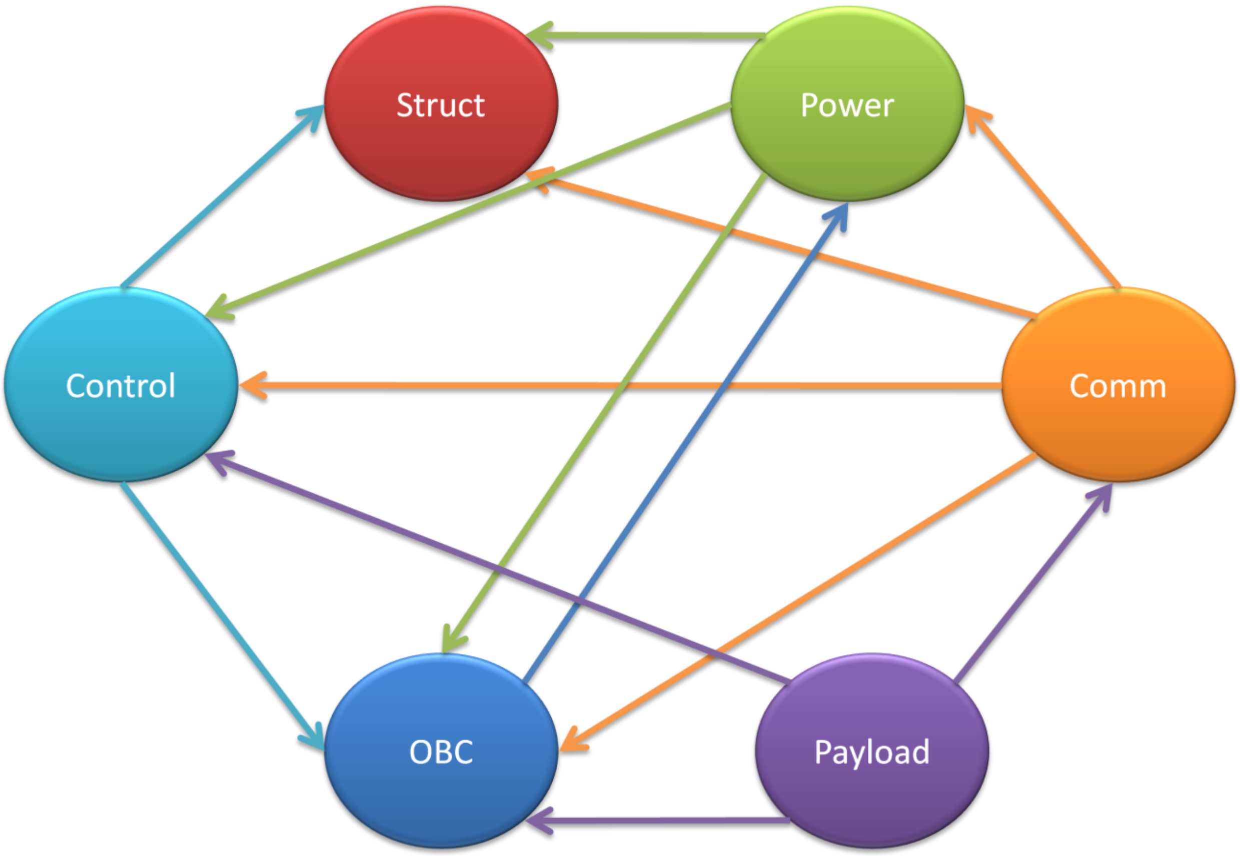

Figure 5: Sub-System Requirements

1. Payload to Communication

- 2 linearly polarized parallel monopoles on board the Satellite. (Polarization error less than 1%)
- Detecting the difference is the angle of polarization at Ground Station. (Error in angle less than 0.1 deg)
- Radio frequencies close to each other but larger than the bandwidth. (currently 400MHz and 437MHz)
- Low cost ground station to measure TEC, for other universities. Aim for cost less than Rs10,000. (Achieved till now, GS cost Rs20,000)

2. Payload to OBC

- Store Position and Attitude Data every 2min. (Average or Instantaneous ?)
- Detect Satellite is above India and switch on Mon2.
  - When over India but not over IITB, Mon2 will transmit the current position (GPS) data.
  - When Satellite over IITB, Mon2 will transmit Data stored in memory for the last 24 hrs.

3. Communication to Power

- Each monopole on board needs to tranmit at 0.4W. Therefore, the input power to the communication circuit for each monopole is 2W. Hence both the monopoles together need 4W of power on board when they are both on.
- The Beacon is always on, hence it always needs 2W.
- Since Monopole 2 is on only for 12-15min in a day (1% duty cycle), hence the Mon2 requires much less average power.

4. Communication to Structures

- The 2 monopoles must be deployed such that it has about 15-17 degrees angle with the nadir plane. (length of each antenna ~ 18cm)
- The distance between the 2 monopoles should be about 16-18cm. (lambda/2)
- There should be less than 0.05deg angular error in parallelism. (150microns error)

5. Communication to Controls

- The Satellite should be controlled within 3degress error in attitude on pitch and roll axis, for proper communication.

6. Controls to OBC

- Run the Control Law
  - Detumbling Control Law in Stage 1
  - Nominal Control Law in Stage 2, 3
- OBC needs to talk to all the sensors and actuators of Controls and do the required processing.
- After every boot-up, the OBC will enter Detumbling phase
- Error correction and redundancy algorithms for the sensors are being implemented by OBC

7. Controls to Structures

- The geometric axis must coincide with the principal axis.
- Conditions for Static stability of the Satellite are to be met. $Ix>Iy,Iz$; $Ix<Iy+Iz$;
- The magnetorquers are placed on 3 sides along 3 axis with maximum possible internal surface area.
- The GPS must be placed on zenith and the antenna must be exposed to space.
- The magnetometer must be placed away from all circuits generating magnetic field.
- The Sun-Sensors must be placed on all 6 sides and exposed to space.

8. Communication to OBC

- Switch on Beacon right after launch. From this time, Beacon is independent of OBC.
- Switch on Monopole 2 when over India. OBC will send AX25 packeta of information to Monopole 2
  - When over India but not over IITB, Mon2 will transmit the current position (GPS) data.

    - When Satellite over IITB, Mon2 will transmit Data stored in memory for the last 24 hrs.

- Transmit the last 24hrs collected data within 7.5mins, i.e. 1 set of good passes. Total communication time is 13-15mins per day.

9. OBC to Power

- Avg Power consumption of 1W.
- Power muC must send HM data of its sensors when the OBC polls it for data after every 2mins.
- Communication between OBC and Power muC exsits.
- OBC can explicitly ask Power muC to shut down certain components.

10. Power to OBC

- Power low is the only hard interrupt for OBC. OBC is supposed to get ready to be shut down within the next 1-5secs. (exact time TBD)
- Power muC will inform OBC is some component is misbehaving and had to be shutdown. The decesion to shut it down is taken locally at Power muC, OBC is just informed.

11. Power to Structures

- Solar Panels must be placed on the 5 sides facing the sun.
- The Panels must be protected from overheating.
- No shadow due to other deployed structures must fall on the Solar Panels.
- Battery must be maintained within its temp range of 20 – 60 degC.
- Heat from Power Ckt must be properly removed. The temp range of these circuits (industrial grade) is -40 to +85 degC.

12. Payload to Controls

- The Satellite must be controlled within 10deg to the desired position in yaw axis to minimize errors due to misalignment of monopoles onboard.
- We donot know the magnitude of jitter (high freq disturbance) and its effects on our Payload.

13. Power to Controls

- When the Satellite is in Stage 2, the yaw control should be such that Power generated onboard, is maximized. Hence maximum surface area of the solar panels must be visible to sun.

Chapter 3: Stages of Satellite

We have divided the entire life of the Satellite into Stages. In each stage, the Satellite does a specific set of function. Overall, the life of the Satellite can be safely assumed to be within one of these stages. This process of division into stages is easy to explain, code and debug and test or simulate. We have denoted the start of Stage 0 as the time of liftoff T=0.

3.1 Stage -1: Preflight checks

During this stage, the Flight Model of the Satellite is at the launch site. We are unsure whether there will also be a spare model. The basic System checks are done within the Clean Room at the launch site, in our case Shriharikota. These checks include

1. Testing the communication circuits
2. Getting Health Monitoring status of the OBC and memory units
3. Getting Health Monitoring status of the sensors, actuators, Power microcontroller, Battery
4. Charging the Battery

All these testing are done using the access ports on the 2 opposite sides of the Satellite. We also have to charge the batteries through these access ports. The access ports have to placed at a specified location with respect to the rails, for easy access. It will be described in detail in Configuration layout. There is an RBF pin (Remove Before Flight pin) that separates the Power lines mechanically and has to be removed while final integration of the Satellite with the Launch Vehicle.

3.2 Stage 0: Launch of Satellite

The Satellite will be launched into a 10:30 polar sun-synchronous orbit by PSLV. During the 17mins from liftoff (T=0) to deployment of the Satellite from the Launch Vehicle (T=17mins), the Satellite will be experiencing severe structural and vibrational loading. It is usually suggested to keep the Power off during launch. The OBC and all components will be switched off. Till the time the Satellite is deployed and away from the Satellite, nothing is switched on.

3.3 Stage 1: Detumbling

The Satellite is deployed into orbit by the Launch Vehicle. This is detected by the Satellite since the mechanical deployment switches as well as the timer to measure the launch time have been tripped. There is some minor wait (exact time is not known, but around 1min) after which the OBC is switched on. The OBC boots and initializes the memory. The Power microcontroller switches on the sensors, actuators, etc and the OBC checks their health. After 15mins from deployment from the launch vehicle, the monopoles are deployed and the Beacon Circuit is switched on. There is a rule that prevents high data rate communications within 30 mins after deployment. We plan to do communication in a high data rate (1.2kbps) on over our ground station at Mumbai and that too after complete detumbling.

When the Satellite is ejected, it is tumbling at 1deg/sec on all 3 axes. We have to reduce this tumble and bring it to a desired orientation. This is called detumbling. This is done by the Control Law being processed in the On Board Computer. After the detumbling stage, the Satellite will be brought to nominal mode of operation where the rates along the 3 axis are of the order of 0.001rad/sec (0.05deg/sec). This entire detumbling phase is supposed to take about 2-3 orbits, i.e. about 5hrs. But from literature, we know the maximum detumbling time is about 1 day. The Stage 1 ends when the Satellite has completed detumbling.

The Fig 3 shows the approximate time taken by the Satellite in each of these stages. The time taken during Stage -1, i.e. Preflight checks is 6days. The duration of Stage 0, i.e. liftoff to deployment of Satellite is 17mins. The duration for Stage 1 is 1day. The X-axis is in minutes.

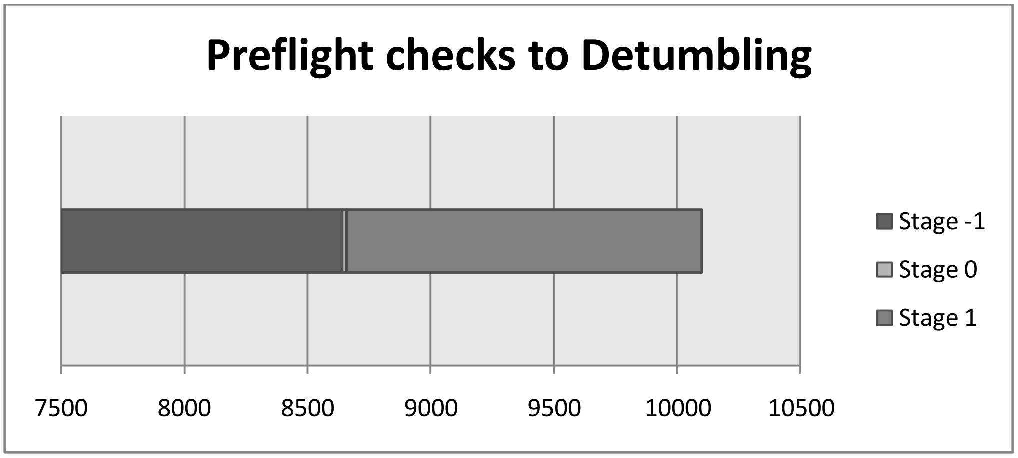

Figure 6: Preflight checks to Detumbling

3.4 Stage 2: Nominal Mode without Downlink

This is the Stage in which the Satellite is supposed to remain for the most part of its life. In this stage the Satellite is fully functional but not over India. The Satellite is being controlled within its attitude ranges by the nominal control law. The Satellite is under 3 axis attitude control and the yaw stabilization is at an angle to maximize power. The beacon is switched on and transmits a predetermined signal all over the world. The Monopole 2 is switched off. The Satellite keeps searching whether it has entered the zone over India. Health Monitoring, Attitude and Position measurements are stored at a fixed interval of 1 min (or 2 mins). Power Health Monitoring data is regularly updated at the OBC every 1 min.

3.5 Stage 3: Nominal Mode with Downlink

This is the Stage in which the Satellite fully functional and over India. The Satellite is being controlled within its attitude ranges by the same nominal control law used in Stage 2. The Satellite is under 3 axis attitude control and the yaw stabilization is at an angle to keep the 2 monopoles perpendicular to the direction of motion of the Satellite. The beacon is on and transmits the same predetermined signal. The Monopole 2 is also switched on. When over India but not over IITB, Monopole 2 will transmit the current position (GPS) data. When Satellite is over IITB, Monopole 2 will transmit Data stored in memory for the last 24 hrs. The Satellite keeps searching for its current location so that it can transmit the correct signals described above. Health Monitoring, Attitude and Position measurements are also stored at a fixed interval of 1 min (or 2 mins). Power Health Monitoring data is also regularly updated at the OBC every 1 min. TEC can be measured in ground only in Stage 3.

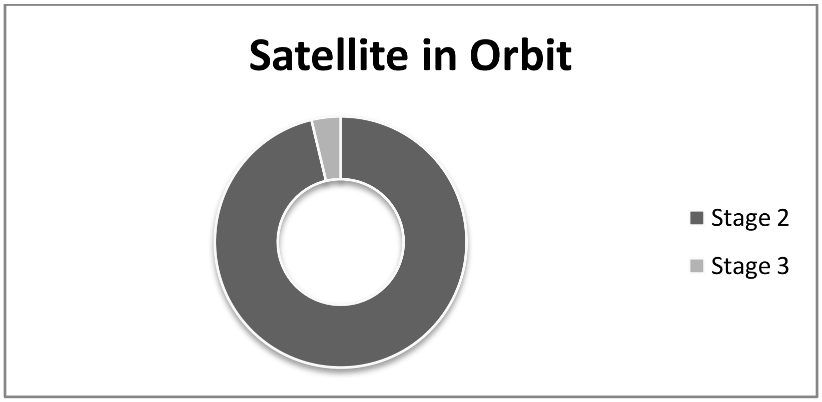

Figure 7: Satellite in Orbit; Stages 2,3

If the Satellite orbit is assumed to be at a height of 670kms, then the total time for each orbit is 107 mins. The average contact time with IITB ground station is 15 min per day. The average time per orbit the Satellite will be in Stage 3 is around 1 hour per day. Hence the average time in Stage 3 in 1 orbit, for 15 orbits in a day is around 4 minutes. The rest time the Satellite spends in Stage 2.

3.6 Stage 4: Emergency Mode

The Satellite will enter this mode when some error is encountered in any component, sensor or application, during its operation. Some of the error correction algorithms have been identified. But a detailed analysis of all the possible errors that can be dealt with and those that can't, hasn't been done yet.

3.7 Stage 5: Safe Mode

This mode is entered when the power drops below a lower threshold. We know that the OBC, Beacon and Power microcontroller respectively are the last things to be switched off in case of this failure. But detailed analysis hasn't been done yet.

All these stages have evolved not only to divide the functions of the Satellite in different stages but also to facilitate design and testing of the Sub-Systems involved.

Chapter 4: Budgets for Weight, Power and Data

It is very essential to maintain detailed and accurate budgets of weight, power and data and keep a tight leash on them. Hence this job is done by the System Engineer. Here we will describe the Weight, Power and Data budget in detail.

4.1 Weight Budget

The weight Budget is maintained along with the Structures and Thermals Sub-System. First, we will present the overall weight budget. Then we will present the detailed weight budget.

Name	**Weight (grams)**
Monopoles and Deployment Mechanism	798
Solar Panels	1691
Power Circuit	486
Battery	825
OBC circuit	286
GPS	111
Magnetorquer	259
Sun-Sensor	536
Launch Vehicle Interface and Access Ports	365
Main Body	1750
Total Weight	7105

Table 2: Weight Budget (Brief)

The total weight of the Satellite is about 7kgs. All the major components are tabulated above. Below, we will give the detailed breakup of all the components, and the source of the data. As of now, we are maintaining the Version 1B of this Weight Budget.

Name	**Weight (gms)**	**Size (mm)**	**Specification**
Beacon			
Beacon (Monopole 1)	5.033511638	cylinder of l=164.9mm, radius(a) = 1.1mm	433 MHz, l = 164.9mm,

			radius(a) = 1.1mm, vol = 626.838mm^3
Monopole harness on satellite	10		
Connectors from monopole circuit to antenna	10		
Monopole Circuit	75	10 X 7 X 2	CC1000 IC (9.7 X 4.4 X 0.9 mm, 0.112g)
Monopole circuit holders and thermals	33.48		Structural harness of Al: height 1cm, width inwards 2cm. L shaped with 2mm. and 4 screws at corners
Power connectors coming out of monopole ckt	10		
Power cable going to the Power ckt	27.31296	length = 59cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Connector for Beacon switching on cable	10		
Data cable going to the OBC ckt or Umbilical cord	18.20864	length = 41cm	Teflon wire of 5mm outer dia and 2mm inner

			dia. Linear density is 0.39584g/cm
Monopole 2			
Monopole 2	6.495237828	cylinder of l=178.8mm, radius(a) = 1.2mm	400 MHz, l = 178.8mm, radius(a) = 1.2mm, vol = 626.838mm^3
Monopole harness on satellite	10		
Connectors from monopole circuit to antenna	10		
Monopole Circuit	75	10 X 7 X 2	CC1000 IC (9.7 X 4.4 X 0.9 mm, 0.112g)
Monopole circuit holders and thermals	33.48		Structural harness of Al: height 1cm, width inwards 2cm and 4 screws at corners
Power connectors coming out of monopole ckt	10		
Power cable going to the Power ckt	18.20864	length = 41cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is

			0.39584g/cm
Data connectors coming out of monopole ckt	10		
Data cable connecting Monopole 2 to OBC ckt	27.31296	length = 59cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Monopole Deployment Mechanism			
Surface	189	200 X 180, thickness = 3mm	carbon fiber
Mechanism	50		hinge: 20gm, 2 X spring: 15gm each
Magnetometer	94	75 X 33 X 5	
Power connectors	10		
Power cables to Power ckt	18.20864	length = 41cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Data Connectors	10		
Data cables to OBC	27.31296	length = 59cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm

798.0535495			
Solar Panels			
Individual Solar Panels (Side 1) opposite nadir surface, i.e. top surface. size 18cm X 18cm	45.056	160 X 160 X 5	Triple junction solar panels from Spectrolab. Clearance of 1cm from all sides.
Side1: Solar Panel harness on the satellite	142.236		Structural harness of Al: height 1cm, width inwards 2cm. L shaped. + shaped view with 4 hollows in between. 9 screws at all corners
Side1: Power connectors coming out of this solar panel	10		
Side1: Power cable going to Power ckt	9.10432	length = 20.5cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Side1: Thermals below panel	76.8		
Individual Solar Panels (Side 2) side with the power ckt. size 23cm X 18cm	59.136	210 X 160 X 5	Triple junction solar panels from

			Spectrolab. Clearance of 1cm from all sides.
Side2: Solar Panel harness on the satellite	164.916		Structural harness of Al: height 1cm, width inwards 2cm. L shaped. + shaped view with 4 hollows in between. 9 screws at all corners
Side2: Power connectors coming out of this solar panel	10		
Side2: Power cable going to Power ckt	4.55216	length = 11.5cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Side2: Thermals below panel	100.8		
Individual Solar Panels (Side 3) side with the OBC ckt. size 23cm X 18cm	59.136	210 X 160 X 5	Triple junction solar panels from Spectrolab. Clearance of 1cm from all sides.
Side3: Solar Panel harness on	164.916		Structural

the satellite			harness of Al: height 1cm, width inwards 2cm. L shaped. + shaped view with 4 hollows in between. 9 screws at all corners
Side3: Power connectors coming out of this solar panel	10		
Side3: Power cable going to Power ckt	18.20864	length = 41cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Side3: Thermals below panel	100.8		
Individual Solar Panels (Side 4) side with the GPS module and one Monopole (assume Monopole 2 as it is smaller) size 23cm X 18cm	59.136	210 X 160 X 5	Triple junction solar panels from Spectrolab. Clearance of 1cm from all sides.
Side4: Solar Panel harness on the satellite	164.916		Structural harness of Al: height 1cm, width inwards 2cm. L shaped. + shaped view

			with 4 hollows in between. 9 screws at all corners
Side4: Power connectors coming out of this solar panel	10		
Side4: Power cable going to Power ckt	18.20864	length = 41cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Side4: Thermals below panel	100.8		
Individual Solar Panels (Side 5) side with the big monopole (beacon, assumed!) size: 23cm X 18cm	59.136	210 X 160 X 5	Triple junction solar panels from Spectrolab. Clearance of 1cm from all sides.
Side5: Solar Panel harness on the satellite	164.916		Structural harness of Al: height 1cm, width inwards 2cm. L shaped. + shaped view with 4 hollows in between. 9 screws at all corners
Side5: Power connectors	10		

coming out of this solar panel			
Side5: Power cable going to Power ckt	27.31296	length = 20.5cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Side5: Thermals below panel	100.8		
1690.88672			
Power Circuit			
Circuit Board	150	100 X 70 X 20	2 PCBs
Power connectors coming out	220		22 power cables come out from this baord
Data connector coming out	10		
Data cable connecting Power ckt to OBC ckt	18.20864	length = 41cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Harness of the Power Ckt onto the satellite	66.96		Structural harness of Al: height 1cm, width inwards 2cm and 4 screws at corners. 2 independent PCB harness

Thermals around the power ckt	21		
486.16864			
Battery			
4 Batteries	600	18.5 X 60 X 65 per battery, 72ml	Saft company, MPS176065
Battery cage	73.1808	2mm thick box: inner 60 X 65 X 74, outer 62 X 67 X 76	2mm thick box around the 4 batteries stacked vertically
Power cables to the Power ckt	10		
Harness of the Battery cage to the satellite	33.48		Structural harness of Al: height 1cm, width inwards 2cm and 4 screws at corners.
Passive Thermals around the battery cage	78.9		
Active Heaters around the cage			
Power connectors to supply power to the heaters	10		
Power cable connecting to power ckt	9.10432	length = 20.5cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Thermal Sensors on the cage	10		LM19

824.66512			
OBC ckt			
Circuit Board	75	100 X 70 X 20	PCB board 15 gm, Micro-controller 0.8 gm, RAMs(3) 3 gm, PROM 1 gm, Solder 1 gm, Resistors(10) 0.5 gm, Capacitors(20) 1 gm, Total 22.3 gm
Rate gyro	10	7 X 7 X 3	
Power connector coming out	10		
Power cables going to Power ckt	16.22944	length = 41cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Data cables coming out	120		12 data cables coming out from this board
Harness of the OBC Ckt onto the satellite	33.48		Structural harness of Al: height 1cm, width inwards 2cm and 4 screws at

			corners. 2 independent PCB harness
Thermals around the OBC ckt	21		
285.70944			
GPS			
GPS module	20	70 X 70 X 30	
harness for the module and thermals	25.164		Structural harness of Al: height 1cm, width inwards 2cm and 4 screws at corners. 2 independent PCB harness
Power connectors	10		
Power cables to Power ckt	18.20864	length = 41cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Data Connectors	10		
Data cables to OBC	27.31296	length = 59cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
antenna (if any)			

harness for antenna (if any)			
110.6856			
Magnetorquer			
Side1: Mechanical harness, size 18cm X 18cm	34.02	4 sides with 2mm width, 21cm length and 5mm thickness	
Side1: Coil weight	31.7780625	Cu coil of 0.3mm dia and 100 turns	
Side1: Power connectors	10		
Side1: Power cables to Power ckt	9.10432	length = 20.5cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Side2: Mechanical harness, size 23cm X 18cm	34.02	4 sides with 2mm width, 21cm length and 5mm thickness	
Side2: Coil weight	31.7780625	Cu coil of 0.3mm dia and 100 turns	
Side2: Power connectors	10		
Side2: Power cables to Power ckt	4.55216	length = 11.5cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Side3: Mechanical harness, size 23cm X 18cm	34.02	4 sides with 2mm width, 21cm length and 5mm thickness	

Side3: Coil weight	31.7780625	Cu coil of 0.3mm dia and 100 turns	
Side3: Power connectors	10		
Side3: Power cables to Power ckt	18.20864	length = 41.5cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
259.2593075			
Sun Sensor			
Sun Sensor	60	6 X 6.4	6 SS on all sides.
Temp Sensor	60		6 Temp sensors on all sides
Harness for Sun Sensors	159.1488		6 harnesses, Structural harness of Al: height 1cm, width inwards 2cm and 4 screws at corners. 2 independent PCB harness
Power connector	60		6 connectors
Power cable to Power ckt	68.2824		Teflon wire of 5mm outer dia and 2mm inner dia. Linear

			density is 0.39584g/cm
Data Connector	60		6 connectors
Data Cable to OBC ckt	68.2824		Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
535.7136			
Launch Vehicle Interface			
Mechanical Harness on Side6: Nadir surface, size 18cm X 18cm	248.4	10 X 10 X 230	4 rails of 1cm square cross-secton, along 4 edges
Umbilical Cord: Power Connector	10		
Power cable to power ckt	9.10432	length = 20.5cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Umbilical Cord: Data Connector	10		
Data cable to OBC ckt	9.10432	length = 20.5cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Mechanical Switches	40		

Access Ports			
Connector	10		
Data cable to OBC ckt	9.10432	length = 20.5cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
Battery charger port (connector)	10		
Power cable to battery	9.10432	length = 20.5cm	Teflon wire of 5mm outer dia and 2mm inner dia. Linear density is 0.39584g/cm
364.81728			
Main Body			
Weight of 6 sides	1700	230 X 230 X 230	
Fastners	50		
Heat Pipes			
Thermals			
Stiffners			
Transportation & Handling Appendages			
1750			
Total	**7105.959257**	**gms**	

Table 3: Weight Budget (Detailed)

4.2 Power Budget

The Power Budget is maintained along with the Power Sub-System. The power budget is tabulated below. Details about the Power Budget will follow.

Loads	Average power	Peak power	Voltage
On-board computer	1W	1W	3.3V
ADCS	2.25W	2.25W	6V (magnetometer) & 5V (gyro)
Beacon	2W	2W	3.3V
Monopole 2	0.06W	2W	3.3V
Thermals	0.3W	2W	Unregulated battery

Table 4: Power Budget

Losses in the power storage and distribution are estimated at 1.5W. The OBC will need maximum 1W of power. ADCS means the Attitude Determination and Controls Sub-System will need the above powers. They will have the following sensors:

1. Magnetometer (1)
2. Sun-Sensor (6)
3. Rate-gyros (3)

They also have 3 actuators in the form of magnetorquers. The Beacon is on for all the time hence it needs lot of power, whereas Monopole 2 is on for a very short fraction of the time (about 4%). The thermals consists of a heated used to keep the battery warm and within its acceptable temperature ranges. Almost all the components work t 3.3V. Only the sensors of ADCS have ratings of 5V and 6V which have to be specially dealt with by the Power circuit.

4.3 Data Budget

The data budget is made along with OBC Sub-System. Here all the data being collected over the orbit is tabulated such that the data can be sent to IITB ground station when we are over it.

Sr. No	Description	Data Size	Frequency
1	Voltage + Current	8 bits * 26	1 / min

2	Temperature	(4 + 6) * 8bits	1 / min
3	Attitude	3 * 16 bits	1 / min
4	Position	25 * 8 bits	1 / min
5	Time	32 bits	1 / min

Table 5: Data Budget

The main data stored is the Attitude, Position and Health Monitoring at a frequency of once per min. Also additional data from the Power microcontroller also get added to the stored data every minute. The above table gives the idea of all the bits being stored. We have 26 voltage/current sensors, 10 temperature sensors and 25 position sensors. Total amount of data generated in one day 284 KB in 24 hours. Memory needed for temporary storage for averaging, since data taken at 1/sec to be averaged over one minute, hence total extra memory needed is 5.8 KB. Since the data rate is 1.2kBps, so that gives us a downlink capability of 504 kB assuming a 7 min transmission suitable pass. For the Program Memory, the restriction from the micro-controller is that we need to store the code on a non-volatile memory that can be accessed used the EBI peripheral. The Code variables would naturally have to be on a RAM memory. This will probably be the internal SRAM (8 kB should be more than enough for code variables).

Chapter 5: Configuration Layout

This chapter deals with the placement of the different components on the Satellite. It can be divided into External and Internal Configuration layout depending on the position of the component outside or inside the Satellite respectively. The Size of the Satellite after this Configuration Layout is cube of 230mm X 230mm X 230mm.

5.1 External Configuration Layout

The components that need to be placed on the external surface of the Satellite are:

1. Solar Panels of dimensions 230mm X 160mm, on the 5 sun-facing sides of the Satellite.
2. Monopole deployment Mechanism of dimensions 180mm X 180mm on the side that does not ever face the sun.
3. Sun sensors of dimensions 6mm X 6mm on all the 6 sides.
4. GPS receiver antenna of dimensions about 20mm X 20mm on the zenith surface.
5. Rails for the Launch Vehicle Interface. They are on the 4 edges touching the side that never faces the sun and the sun that always faces the sun.
6. Access Ports on the 2 sides namely, the side that never faces the sun and the sun that always faces the sun.

The schematic of the External Configuration Layout is shown below in Fig 6. Some of the constraints on the above components are as follows:

1. No shadow must fall on the solar panels during it operation. Since the only deployed structure is the Monopole Deployment Mechanism, it is kept on the side that never faces the sun. This way we have prevented any shadows from falling on the solar panels.
2. For proper power pattern of the Monopoles, they must be perpendicular to the side on which they are mounted and close to the zenith surface. They should also be perpendicular to the direction of motion to reduce errors due to misalignment.
3. The sun-sensors are small and place no hard constraints. But they must be placed on all sides.
4. The GPS receiver needs to see the GPS Satellites in MEO, hence it needs to be in open view of the space above. Hence it is placed on the zenith surface.

5. We want to use the launch vehicle interface called XPOD. Hence there are rails on 4 sides to supports the Satellite in the XPOD. There are also 2 access ports on 2 opposite sides to test/reach the Satellite once it is inside the LVI.

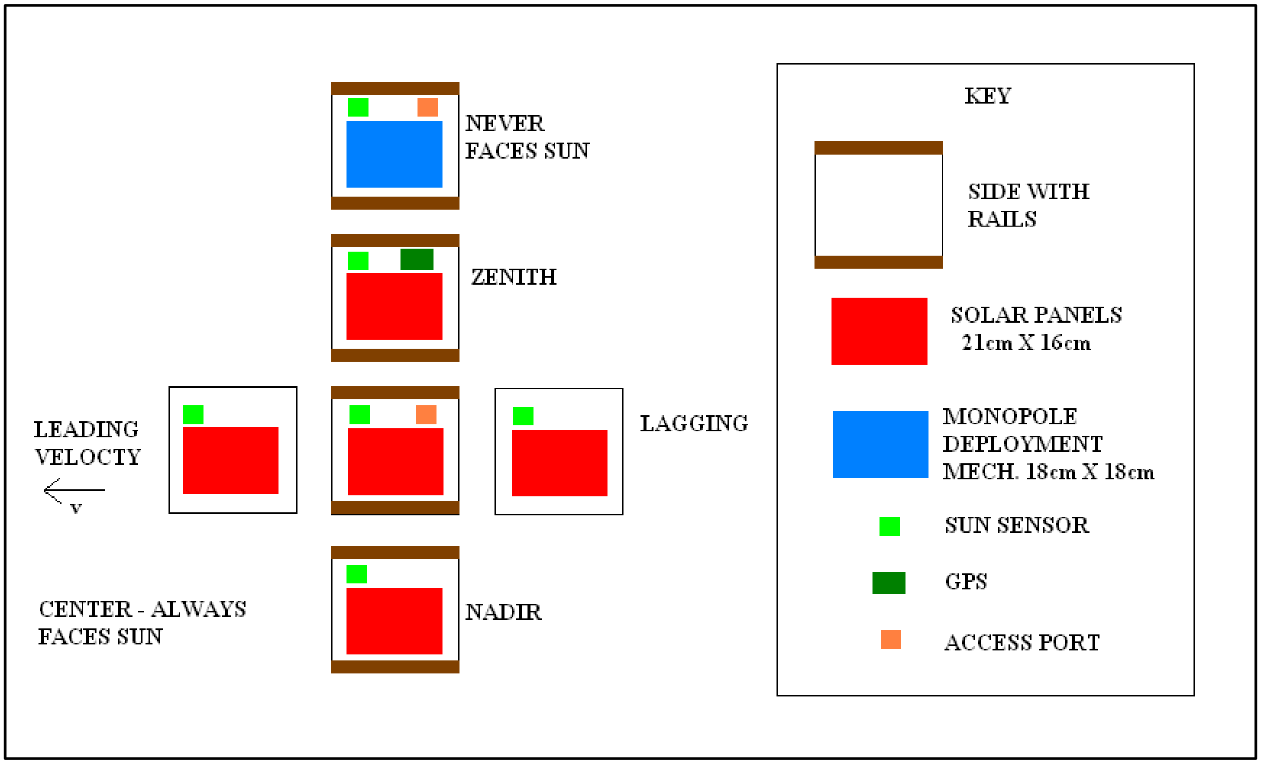

Figure 8: External Configuration Layout

5.2 Internal Configuration Layout

The components that are placed on the internal surface of the Satellite are as follows:

1. Beacon Transmitter circuit
2. Monopole 2 Transmitter circuit
3. Battery
4. On Board Computer circuit
5. Power Distribution circuit
6. GPS Receiver circuit
7. Magnetometer
8. Magnetorquers (3)

Although the internal Configuration Layout hasn't been worked out yet, some of the factors affecting it are described here.

5.2.1 Internal Architecture

There are 2 possible methods of arranging the circuits inside the Satellite and both have been widely used in space. They are Rack mounting and Panel mounting architecture. Hence both the designers involved in configuration layout drew up an House of Quality chart and these are its results.

Property	Description
Accommodation of all components	All components must be able to be fitted in in proper shape within the structure
MI requirements satisfaction	How easily this structure lends itself to satisfying the requirements of MI
Probability of slippage from position	How well this structure will withhold itself from having a PCB slip out of position
Variation of orientation for components	Whether different boards can be mounted in different orientations
Length of data and power buses	How short the lengths of buses can be made without having RMA structure
Ease of assembly and disassembly	How easily it can be taken apart and refitted together
Area optimization	How intensively it depends on the utilization of surface area on the interior
Stiffness of PCBs	How well (from litt survey) it is reported PCB will respond to vibrations
Passive heat removal	How easily a mechanism for removing heat from a board/component can be provided
Volume optimization	How optimally the volume is utilized with highest possible density
Ease of analysis	How easily the structure in its entirety can be analysed for loading data given
Thermal control requirements and analysis	Whether the boards can be simply analysed independently or they influence each other highly thus making it complex
Ease of fabrication	How easily the structure can be fabricated
Transferral of loads	To what extent loads on metal panels are transferred to the PCBs
Grounding	How easily PCBs can be connected to the common ground
Ease of fastening	Whether boards can be easily fastened onto their support

Table 6: Properties for Internal Architecture

Design by System Engineer

Property	Weightage	Rack Mounting		Panel Mounting	
		Rank	Weightage	Rank	Weightage
Accommodation of all components	0.11627907	8	0.00665114	10	0.0065036
MI requirements satisfaction	0.11627907	4	0.00332557	9	0.0058532
Probability of slippage from position	0.104651163	3	0.00224476	8	0.0046826
Variation of orientation for components	0.104651163	1	0.00083139	10	0.0065036
Length of data and power buses	0.104651163	10	0.00415696	3	0.0009755
Ease of assembly and disassembly	0.093023256	9	0.00673428	8	0.0046826
Area optimization	0.069767442	10	0.00581975	5	0.0022762
Stiffness of PCBs	0.058139535	6	0.00399068	9	0.0046826
Passive heat removal	0.058139535	5	0.003325573	10	0.0052029
Volume optimization	0.034883721	9	0.00374127	4	0.0013007
Ease of analysis	0.034883721	4	0.0016627	9	0.0029266
Thermal control requirements and analysis	0.034883721	4	0.00166278	9	0.0029266
Ease of fabrication	0.023255814	8	0.00532091	7	0.0036420
Transferral of loads	0.023255814	9	0.00598603	3	0.0015608
Grounding	0.011627907	2	0.0013302	10	0.0052029
Ease of fastening	0.011627907	5	0.0037412	10	0.0058532
Total		97	**0.0605254**	124	**0.0647762**

Design by Structures and Thermals Sub-System Head

Property	Weightage	Rack Mounting		Panel Mounting	
		Rank	Weightage	Rank	Weightage
Accommodation of all components	0.11627907	8	0.009031384	10	0.009377344
MI requirements satisfaction	0.11627907	4	0.004515692	9	0.00843961
Probability of slippage from position	0.104651163	3	0.003048092	8	0.006751688
Variation of orientation for components	0.104651163	1	0.001016031	10	0.00843961
Length of data and power buses	0.104651163	10	0.010160307	3	0.002531883
Ease of assembly and disassembly	0.093023256	9	0.008128246	8	0.0060015
Area optimization	0.069767442	10	0.006773538	5	0.002813203
Stiffness of PCBs	0.058139535	6	0.003386769	9	0.004219805
Passive heat removal	0.058139535	5	0.002822308	10	0.004688672
Volume optimization	0.034883721	9	0.003048092	4	0.001125281
Ease of analysis	0.034883721	4	0.001354708	9	0.002531883

Thermal control requirements and analysis	0.034883721	4	0.001354708	9	0.002531883
Ease of fabrication	0.023255814	8	0.001806277	7	0.001312828
Transferral of loads	0.023255814	9	0.002032061	3	0.000562641
Grounding	0.011627907	8	0.000903138	10	0.000937734
Ease of fastening	0.011627907	5	0.000564462	10	0.000937734
Total		103	**0.059945812**	124	**0.063203301**

Hence in both the above designs it was seen that the Panel method was better than the Rack method. Hence we will go ahead with the panel method in our Satellite. Panel method means placing the circuits on the 6 side panels. Rack method means making racks for placing the circuits and just attaching the racks on to the Satellite frame.

5.2.2 Arrangement Criteria

We have come across conditions placed on the method on which the components are laid on the circuit board. We have seen that most components are laid in the lateral direction since the force in this direction is less. But we are still to get all the constraints. We have recognized this is a topic we need further assistance.

5.2.3 Geometric Parameters

For ease of control, the geometric axis and the principal axis of the Satellite must coincide. The Satellite must obey the 2 conditions for static stability

$$I_{xx} > I_{yy}, I_{zz}$$

$$I_{xx} < I_{yy} + I_{zz}$$

Here I_{xx}, I_{yy}, I_{zz} are along the principal axis. The use of a perfect cube is preferred because it reduces the complexity in meeting the above requirements.

5.2.4 Axis Alignment

The axis of the Satellite must coincide with that of the Launch Vehicle. Only then components with non-isotropic stress ratings on different sides can be placed properly on the Satellite. We are yet to finalize the axis of the Satellite as we haven’t talked to the Launch Vehicle formally.

Chapter 6: Launch Vehicle Interface

This chapter will cover all the essential features necessary to understand the launch process. It will cover the launch vehicle interfaces, launch loading parameters and external connections.

6.1 XPOD

After a detailed study of the possible launch vehicle interfaces available in the market, we wish to use the XPOD launch vehicle interface for our Satellite. The exact class of XPOD is yet to be decided. Here we have discussed this launch vehicle interface in detail.

XPOD stands for eXperimental Push Out Deployer (XPOD). It is an ongoing project at Space Flight Labs, UTIAS and details about the deployment mechanism can be found in www.utias-sfl.net/docs/gnb-ssc-2006.pdf. It has tubes having spring at base and the door pushes against satellite surface. The Satellite is equipped with anodized rails which slide on XPOD grooves. The door of the XPOD is held in place by Vectran cord. The Vectran cord is burnt when PSLV issues release command, allowing door to open and spacecraft to exit the XPOD. It is pPowered by NiCad (Sanyo KR-1100) battery pack (1.100 Ah). It has a Single-failure fail-operational design. It is qualified to 9.75g static, 13gRMS random vibration, thermal vacuum -35^{0}C to +65^{0}C.

XPOD size is Customizable for any nanosatellite dimensions. They come in varieties like Single & Triple which conform respectively to the standardized single and triple PPOD packages. They also come in GNB variety, which stands for Generic Nanosatellite Bus.

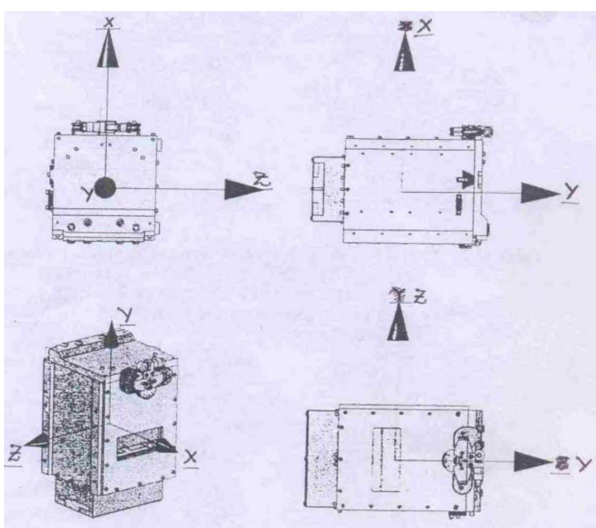

Figure 9.3. Axes definition of the combined Spacecraft / XPOD Single.

Figure 9: XPOD Single

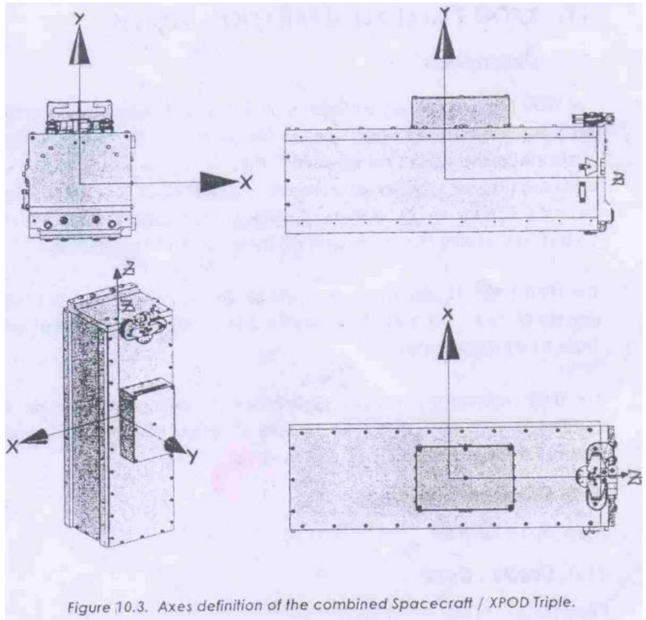

Figure 10: XPOD Triple

The pictures above show the XPOD Single and Triple. The Pictures below will show the XPOD-GNB deployment sequence and the base plate for XPOD-GNB. These pictures have been taken from the Interface Control Document for the PSLV C9 launch. The XPOD-GNB was used as the Launch Vehicle Interface for the CanX6 Satellite.

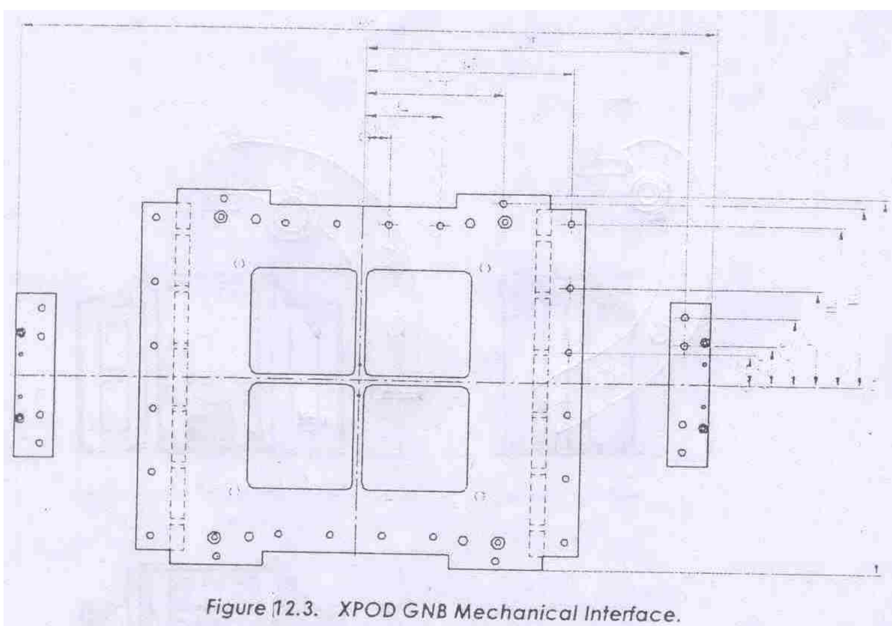

Figure 11: XPOD GNB Mechanical Interface

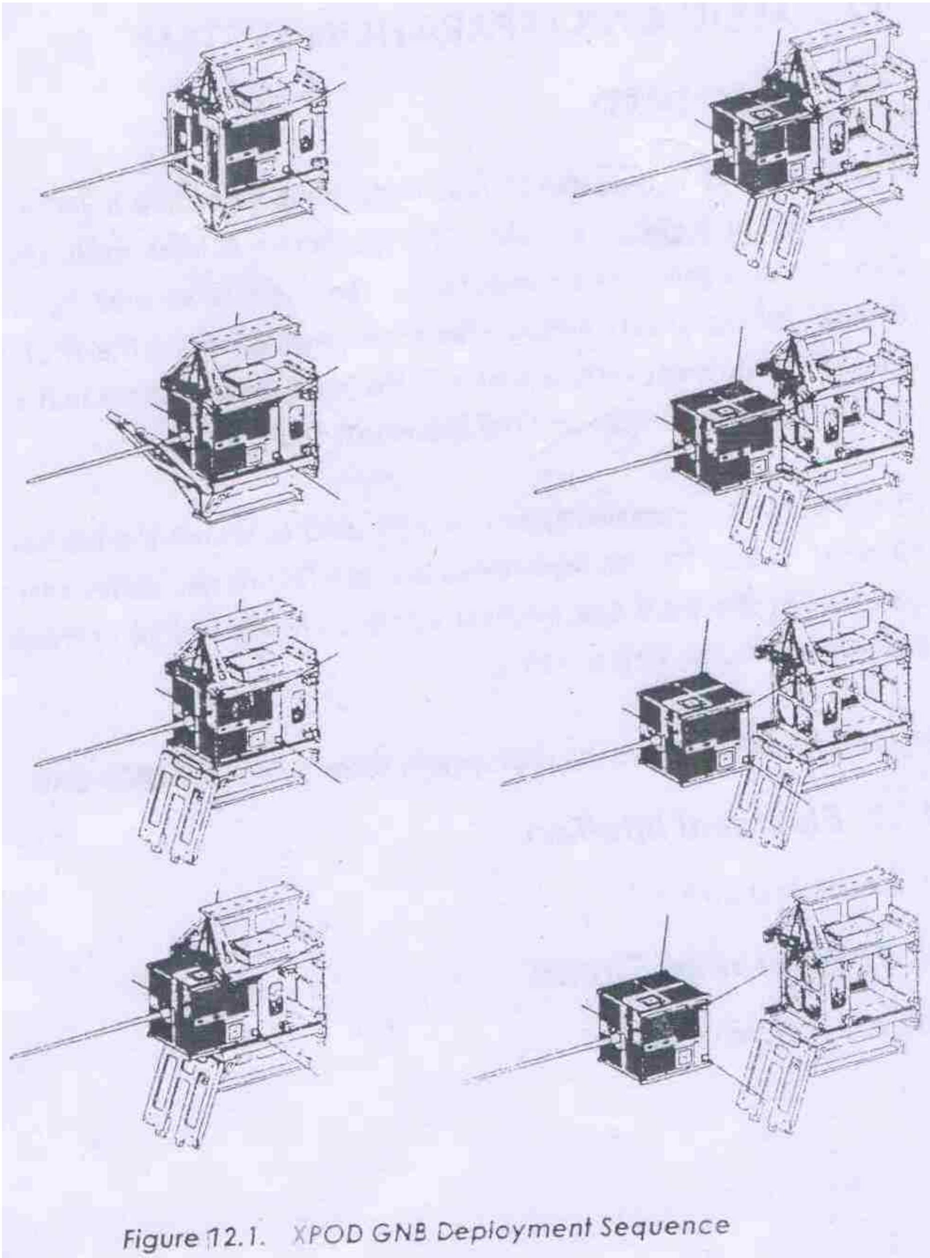

Figure 12: XPOD GNB Deployment Sequence

The XPOD uses a spring separation system. Some of the parameters of the 3 XPODs are tabulated below.

TYPE OF XPOD	SEParatioN VELOCITY	FREE LENGTH	STROKE LENGTH	INITIAL FORCE	SPRING CONSTANT
Single	1 m/s	130 mm	99 mm	22.82 N	230.48 N/m
Triple	1 m/s	340 mm	307 mm	14.92 N	48.58 N/m
GNB	1.55 +/- 0.1 m/s	235 mm	156.5 mm	95.3 N	609.1 N/m

Table 7: XPOD Separation System

The XPOD has 2 connectors

- Dsub-9 Socket type (M24308/4-1 GF-L)
  - Separation Signal Connector Pin
  - Gives command from PSLV to XPOD to deploy
- Dsub-15 Socket type (8635-15P012)
  - Separation Telemetry Signal Connector Pin
  - Gives status of deployment success

Table 9-1. XPOD Single Separation Signal Connector Pin Assignment

Connector Type: Dsub-9 (M24308/4-1 GF-L) Connector on the LV side shall be PIN-TYPE Connector on the separation system side is SOCKET-TYPE		
Pin	Signal	Value
1	Separation Signal	28V ± 4V, 0.7 to 1.4A
2	Separation Signal	28V ± 4V, 0.7 to 1.4A
3	Separation Signal	28V ± 4V, 0.7 to 1.4A
4	Separation Signal	28V ± 4V, 0.7 to 1.4A
5	Separation Signal	28V ± 4V, 0.7 to 1.4A
6	Return/GND	GND
7	Return/GND	GND
8	Return/GND	GND
9	Return/GND	GND

Figure 13: XPOD Dsub-9 Connector Pin Assingment

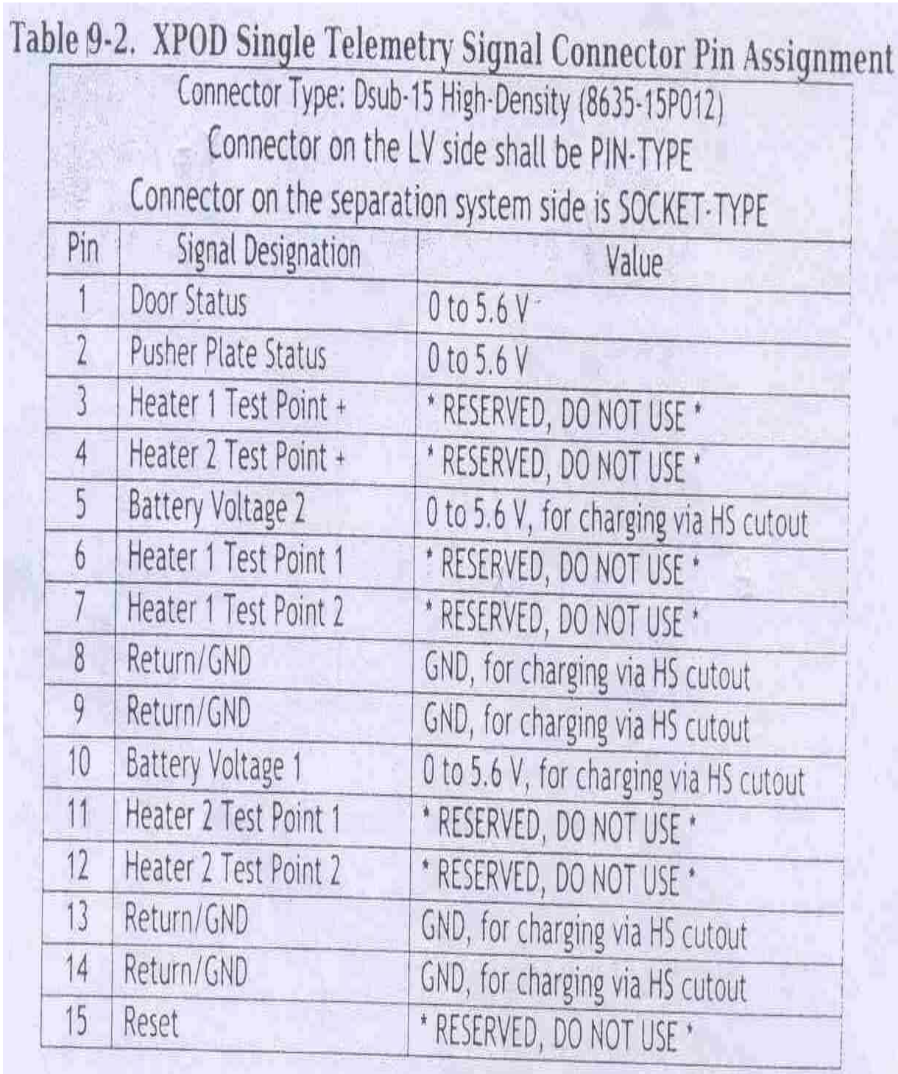

Table 9-2. XPOD Single Telemetry Signal Connector Pin Assignment

Connector Type: Dsub-15 High-Density (8635-15P012) Connector on the LV side shall be PIN-TYPE Connector on the separation system side is SOCKET-TYPE		
Pin	Signal Designation	Value
1	Door Status	0 to 5.6 V
2	Pusher Plate Status	0 to 5.6 V
3	Heater 1 Test Point +	* RESERVED, DO NOT USE *
4	Heater 2 Test Point +	* RESERVED, DO NOT USE *
5	Battery Voltage 2	0 to 5.6 V, for charging via HS cutout
6	Heater 1 Test Point 1	* RESERVED, DO NOT USE *
7	Heater 1 Test Point 2	* RESERVED, DO NOT USE *
8	Return/GND	GND, for charging via HS cutout
9	Return/GND	GND, for charging via HS cutout
10	Battery Voltage 1	0 to 5.6 V, for charging via HS cutout
11	Heater 2 Test Point 1	* RESERVED, DO NOT USE *
12	Heater 2 Test Point 2	* RESERVED, DO NOT USE *
13	Return/GND	GND, for charging via HS cutout
14	Return/GND	GND, for charging via HS cutout
15	Reset	* RESERVED, DO NOT USE *

Figure 14: XPOD Dsub-15 Connector Pin Assingment

The XPOD GNB has no side plates thus allowing any pre-deployed structures to slide out / translate freely during deployment, eg the VHF antenna in CanX-6. After conducting simulations of our antennae, we concluded that our antennae will snap off at the root due to launch sine vibrations itself (Harmonic analysis – Fixed-free cantilever, length 170mm, circular section of radius 1mm – 3 material cases of 6061 T-6 aluminium, annealed copper and 304 grade Stainless Steel - Analyzed in ANSYS10.0). The root stress when the qualification sine sweep test was performed exceeded yield stress in all cases. Hence we have to deploy the antenna even if we want to use any of the XPODs.

A comparison between XPODs and PPODs is given below. It is felt by us that we must go for an XPOD for our first Satellite, Pratham.

XPOD	PPOD
▪ Documentation difficult to obtain ▪ Cheaper ▪ Can be tailored to any required dimensions using the Generic Nanosatellite Bus concept of flexible sizing of any XPOD SS to the requirements of the satellite in question ▪ Pre-deployment possible ▪ Surface mounting of components allowed ▪ Purchase requires negotiation with UTIAS for launch services	▪ Documentation freely available ▪ More expensive ▪ Only comes in fixed dimensions of – 50 x 100 x 100 mm 100 x 100 x 100 mm 100 x 100 x 200 mm 100 x 100 x 300 mm 300 x 200 x 100 mm (Mega) ▪ Pre-deployment prohibited ▪ Surface mounting of components prohibited ▪ Purchase can be made freely even online but finally verified by CalPoly

Table 8: Comprison between XPOD and PPOD

6.2 Flight Environment

- Vehicle acceleration levels – (Earth's gravity included)
  - Load factor – 1.25
  - Longitudinal – +7g / -2.5g
  - Lateral – +/-6g
- Stiffness requirements – (Base fixed condition)
  - Fund Freq Longitudinal – > 90Hz
  - Fund Freq Lateral – > 45Hz
- Coupled Loads Analysis –
  - Waived for nanosatellite payloads
- Interface match-mate checks –
  - Interface checks with flight deck will be carried out
- Sinusoidal and Random Vibration Test Levels

	FREQ. RANGE (Hz)	QUALIFICATION LEVEL	ACCEPTANCE LEVEL
LONGITUDINAL AXIS	5 - 10	10 mm (0 to peak)	8 mm (0 to peak)
	10 - 100	3.75 g	2.5 g
LATERAL AXIS	5 - 8	10 mm (0 to peak)	8 mm (0 to peak)
	8 - 100	2.25 g	1.5 g
SWEEP RATE		2 Oct/min	4 Oct/min

Figure 15: Sinusoidal Vibration Test Levels

Table 15-2. Random Vibration Test Levels

Frequency (Hz)	QUALIFICATION PSD (g^2 / Hz)	ACCEPTANCE PSD (g^2 / Hz)
20	0.002	0.001
110	0.002	0.001
250	0.034	0.015
1,000	0.034	0.015
2,000	0.009	0.004
g RMS	6.7	4.47
Duration	2 min/axis	1 min/axis

Figure 16: Random Vibration Test Levels

Following are the list of Spacecraft launch operations.

- Minimal ground operations required
- Functional test of separation systems conducted
- GSE used to charge XPOD
- S/C GSE used to charge S/C battery
- S/C GSE connected to check S/C health
- P+ deck pre-assembled on PSLV EB
- S/C-SS packages assembled on LV decks
- Connectors mated and status verified
- Heat shield assembled – further access prohibited

- In case launch is delayed by >30 days, batteries will be recharged through the heat shield cutout

6.3 External Connections

6.3.1 Remove Before Flight (RBF) Pin

The RBF pin is a mechanical switch that allows the satellite to be safely transported and packaged without activation. It is located on specified access area on the side of the satellite. The pin while inserted deactivates the satellite and prevents the batteries from discharging, but when pulled out prior to integration on the LV connects the onboard electronics to the power system of the satellite. "[The RBF pin]… consists of a plunger that will remain inserted as the satellite is integrated into the launching device. After such time, the launch switch is depressed by the satellites adjacent to it in the deployment mechanism thus preventing power-on as the remove-before flight plunger is extracted." The RBF pin generally uses double redundancy as a safety measure. Power circuit board has to be located on the side that contains the pin.

U-Leicester CubeSAT (Pumpkin module) – RBF switch is connected to the onboard microprocessor and voltage at the pin gives the required signal – Linear power regulation system is on OBDH circuit board

SwissCube – RBF pin is connected to the power system

6.3.2 Kill/Launch Switches

They are Mechanical switches with press/release action. They are depressed by the launch interface when contained inside the box on the Launch Vehicle. They are released on ejection into space, so they allow connection between satellite systems and power system. They are implemented usually with multiple redundancies. Generally a mechanical or electronic delay circuit is placed so that powering on occurs after the specified delay after the instant of launch.

6.3.3 Deployment Switches

Detect instant of successful deployment and activate timer circuit / send signal to processor in satellite.

6.3.4 Access Port (USB Port)

To interface with satellite during onground checks. To test satellite before integration with LV

6.3.5 Battery Charging Port

Interface to charge batteries before integration with LV.

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