Introduction to Pratham, IIT Bombay's Student Satellite Project

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***Abstract* – 'Pratham', the first satellite under the Indian Institute of Technology Bombay (IIT Bombay) Student Satellite Project. The mission statement of Pratham is to provide a learning opportunity to students of the institute, empowering them with the skills to design and develop the Satellite and finally launch it into orbit with the help of Indian Space Research Organization (ISRO) to measure Total Electron Count (TEC) of the Ionosphere. This paper provides a brief overview of the various Sub-Systems involved in the Project, the structure and working of the Team and the various Design Phases completed since the inception of the Project in July 2007. The project also actively involves students from other universities by helping them make ground stations and through the virtual laboratory.**

***Keywords* – Student Satellite, Total Electron Count, Ionosphere, System Engineering, Pratham,**

I. INTRODUCTION

The IIT Bombay Student Satellite Project is a landmark project taken up by the students of IIT Bombay. It was envisaged that this project would increase the awareness and contribution to the Space Science and Technology field from the institute. Moreover, future satellites could be used as test-beds for new technology being developed within the institute and for space qualification of Indian technologies. 'Pratham' is the first satellite under this project. This is entirely a student initiative with mentorship provided by ISRO scientists and IIT Bombay faculty. Some of the details about Pratham are:

- Weight: ~10 kgs
- Size: 260X260X260mm (excluding monopoles and solar panels)
- Payload: Measuring Total Electron Count
- Orbit: 10:30 polar sun-synchronous, 817km altitude
- Downlink at 2 frequencies (145.98 and 437.455 MHz)
- Uplink used as kill switch (437.455 MHz)
- 4 months mission life
- Launch Vehicle Interface: IBL230V2 from VSSC

The mission statement of Pratham is to provide a learning opportunity to students of the institute, empowering them with the skills to develop the Satellite through various phases of Design, Analysis, Fabrication and Testing till the Flight Model is made, have it launched into orbit and then measure Total Electron Count of the Ionosphere. The project also involves students from other universities who can build ground stations to receive beacon signal and even measure TEC over their ground station. The mission statement is discussed in detail in Section II.

The challenge to build a Student Satellite was taken up by a handful of students in July 2007. The Department of Aerospace Engineering supported the project after the feasibility of the concept was proved. The project is truly inter-disciplinary with the student team comprising students from departments like Electrical, Mechanical, Chemical, Civil, Engineering Physics, etc. in addition to Aerospace. The team has managed continuity when senior students pass out by recruiting new students. Faculty members from Aerospace, Electrical, Mechanical and Computer Science have extended support through mentoring and reviewing. The Team Structure and the working of the Pratham Team are discussed in detail in Section III.

The project completed Requirements Capture in May 2008, Conceptual Design Phase in August 2008 and Preliminary Design Phase in December 2009. At various stages in its evolution, work was reviewed at IIT Bombay and also at ISAC. Currently, the project is in its Detailed Design Phase and the Qualification Model is being fabricated. The Timeline of the project is discussed in detail in Section III. The various Sub-Systems of Pratham that form the backbone of the Satellite Project are all discussed in detail in Section IV. The interaction of Pratham Team with students from other universities in India and abroad is discussed in Section V.

During the project much emphasis has been given to documenting detailed descriptions of the methodology and the results of the work done. All the documents referred to in this paper and the minutes of Pratham's review meetings are available at Pratham's website: www.aero.iitb.ac.in/pratham.

The Satellite is a 26 cm cube, hence it has six sides. The names of the sides are as follows:

Nadir Side: This is the bottom plane of the satellite. The Launch Vehicle Interface (LVI) is attached to the lower surface of this side.

Zenith Side: This is the top plane of the satellite. It is opposite the Nadir Side.

Sun Side: Since the satellite will be in a Polar Sun-synchronous orbit, this side will always face the sun. Sun Side

Antisun Side: This side never faces the sun. It is opposite the Sun Side.

Leading Side: The normal to this side, pointing away from the center of the satellite, points along the direction of the velocity vector of the satellite in orbit.

Lagging Side: The normal to this side, pointing away from the center of the satellite, points opposite to the direction of the velocity vector of the satellite in orbit. It is opposite to the Leading Side.

II. MISSION STATEMENT

The IIT Bombay Student Satellite Project presents a wonderful learning experience to the students of working on a real life multi-disciplinary complex system. Learning enhancement through CDIO (Conceiving – Designing – Implementing – Operating) has been one of the major objectives of this project. The Mission Statement of Pratham is:

1. Acquiring knowledge in the field of Satellite and Space Technology.
2. Have the Satellite entirely designed by the student body of IIT Bombay.
3. Have the satellite launched, Measure TEC of the Ionosphere above IITB.
4. Involve students from other universities in our Satellite project.

Since a lot of importance has been given to learning, it is duly represented in the success criterion for the project.

TABLE 1: SUCCESS CRITERIA

Description	Mission Success
Flight Model ready	85%
Beacon Signal received	90%
TEC measurements at IITB	95%
Satellite functional for 4 months	100%

III. WORKING OF THE PRATHAM TEAM

The Pratham team is structured in a multi-tier fashion shown below. At the grass-root level are the Sub-systems and all students involved with Pratham are associated to one or more Sub-systems. The 7 Sub-Systems, namely Payload, Communication and Ground Station, Attitude Determination and Control, Power, On Board Computer, Structures and Thermals work independently of each other. The Integration and Quality Sub-Systems interact with all the other Sub-Systems to make sure the Project is going on in the right track and all Sub-Systems are working in sync and as per standards. The Public Relations Sub-System has the job of publicity, maintaining website, etc. on behalf of the team.

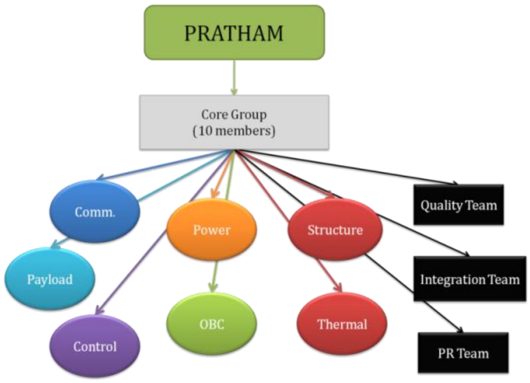

Figure 1: Structure of Pratham Team

At any time, there are about 20 to 30 students working on Pratham. In order to facilitate the working of the team, there is a very structured process of reviewing the work done by the team. Every week, the team conducts a meeting to review the progress of each of the Sub-Systems. When substantial work has been done by the sub-systems, they approach their respective faculty mentors for a review and discussion on future work. Similarly, the ISAC scientists are approached when they visit IIT Bombay or when the need is felt to visit them at ISAC, to clarify some crucial issues. Finally each of the design phases end with a rigorous review at IIT Bombay by the Faculty Mentors followed by a review by the team of engineers at ISAC headed by Mr. D.V.A. Raghav Murthy. The list of Faculty Mentors from IIT Bombay is given in Appendix 1.

The various Design Phases that have been completed till date are shown in Fig 2. During the month of April 2008, the Requirements Capture Phase of the project was finished. Total Electron Count was chosen to be the payload of the satellite and the requirements on the other sub-systems were found. Next, the Conceptual Design Phase was finished in August 2008, with reviews at IIT Bombay and at ISAC. The concepts behind the design of each of these Sub-systems were frozen in this review. After extensive work, the Preliminary Design Review was conducted in April 2009 at IIT Bombay followed by an extensive review at ISAC in December 2009. The designs of all the Sub-Systems were frozen and the go ahead was given for fabrication of the Qualification Model. During the month of May 2010, the Detailed Design Review is proposed to be held, where the Qualification Model of the Satellite shall be presented. If the project remains on schedule, the satellite shall be launched in December 2010.

Fig 2 also shows that change in the team size as the project progresses. Initially only a handful of students were involved in the proof of concept to IIT Bombay. During the first selection phase in October 2007, around 20 students were chosen from the institute through a selection process consisting of a quiz and then a presentation. With every passing year, some of the old students have left and new students have been added to carry the project forward. This has been facilitated by a strong Continuity Plan comprising of documentation of all design phases, minutes during reviews and combined working of juniors and seniors. The list of all students who have contributed substantially to the Pratham Project is given in Appendix 2.

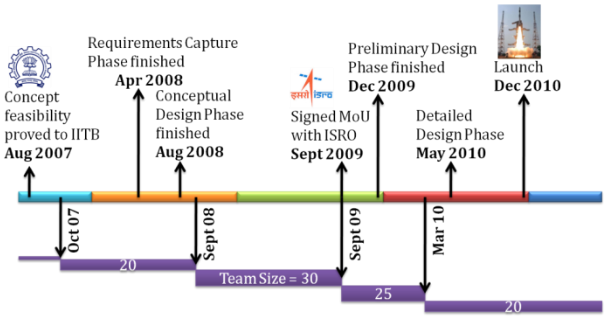

Figure 2: Timeline

IV. SUB-SYSTEMS OF PRATHAM

Each of the 7 subsystems within the Pratham Team (Payload, Communication and Ground Station, Attitude Determination and Control, On Board Computer, Power, Structures and Thermals) has predefined responsibilities. The job of the Integration Subsystem, headed by the System Engineer, is to give the critical parameters to these subsystems. They are also in charge of designing the structure of the Satellite and fitting all the other components of the Satellite and making it flight worthy. There is also a Quality Subsystem for the Quality Assurance of the entire project, as the satellite must have a probability of failure of less than 2% during its mission life.

A. Payload Subsystem

The goal of the Payload Subsystem is to measure the Total Electron Count (TEC) of ionosphere above Mumbai with 0.1 TEC units accuracy. If similar data is available from other ground stations across the country, a TEC map of the country will be made. The TEC data could be used for Ionospheric Tomography if the ground stations are on the same longitude.

A linearly polarized radio wave passing through an ionized medium with a magnetic field in the direction of propagation undergoes a rotation in the plane of polarization. This effect is called Faraday rotation. The relation between the rotation angle and the TEC is given by

$$\Delta\varphi = 4.87 * 10^4 * f^{-2} \int_{h_1}^{h_2} NB \cos\theta \; dl$$

where N = electron density, B = magnetic field of earth, Θ = angle between the radio wave and line of sight, Δφ = angle of rotation and f = frequency of the wave. Onboard the Satellite, two parallel monopoles transmit linearly polarized waves at two different frequencies (145.98 MHz and 437.455 MHz). The planes of polarization of the signals from the satellite, which have passed through the ionosphere, can be measured by crossed yagi antennae at the ground station. Measuring the difference between the planes of polarization for the two frequencies removes the need for measuring the attitude of the satellite precisely. The goal of measuring TEC upto 0.1 TECU accuracy places severe constraints on the parallelism of the monopoles, the polarization purity of the monopoles and the least count of the detector at the ground station.

B. Communication and Ground Station Subsystem

The primary goal of the Communication and Ground Station subsystem is to establish a communication link between the Pratham satellite and the ground station at IIT Bombay and measure the plane of polarization of the signals. Onboard the satellite, all the components of the Communication Sub-system is placed on the Antisun Side; with the exception of the uplink circuit which is placed on the Lagging Side. There are 3 pre-deployed monopole antennas, 2 of which are used for transmitting linearly polarized signals with a polarization purity of greater than 99.9% (30dB). The monopoles are mounted away from the Nadir Side to obtain the desired radiation pattern. There is a low bit rate Beacon at 145.98 MHz frequency transmitting throughout the world in OOK modulation. There is also a high bit rate (1.2kbps) 437.455 MHz CC1020 circuit for downlink of data only above India.

The frequency allocation process necessitated the need for satellite control in orbit using the Ground station, as per IARU regulations, if the satellite starts transmitting in a stray band. Thus, after deliberations with the frequency coordinators at IARU it was decided to have an uplink in the UHF band which would serve as the kill switch for the satellite incase the satellite starts transmitting at a non-allocated frequency. The uplink circuit onboard uses another CC1020 along with a LNA to increase the SNR of the uplink signal. It was decided to have the uplink as an autonomous unit, with a separate microcontroller for programming of the receiver and decoding of signals, so that any failure of OBC does not hamper the functioning of the unit.

At the ground station at IIT Bombay, 2 crossed yagi antennas and 2 single yagi antennas, mounted on a rotor, track the satellite to receive data and measure the plane of polarization of the two signals from the satellite. The ground station at IIT Bombay is setup at the terrace of the main building of Aerospace Department.

C. Attitude Determination and Control Subsystem

The goal of the Attitude Determination and Control subsystem is to stabilize the satellite after it's jettisoned from the launch vehicle during launch. It has to then maintain 3 axis attitude stabilization of the satellite. Onboard the satellite, there are 6 sunsensors (on all sides), 1 magnetometer (on Lagging Side), 1 GPS (on Zenith Side) for attitude and position sensing. There are 3 magnetorquers mounted along 3 different axes (on Zenith, Leading and Sun Sides) for attitude control. There is also a sunsensor board mounted on the Zenith Side where all the analog wires from the sunsensors converge, and the information is converted into digital signals by Multiplexer and Analog to Digital Converter and then sent to the On Board Computer.

The aim of the subsystem is to determine the position of the satellite in space within 1km accuracy as required by the payloads subsystem. It also has to determine the attitude of the body frame of the satellite with respect to orbit frame with a 2-3 deg error in all 3 Euler angles. Then, it has to control the satellite such that the body frame coincides with the orbit frame with an accuracy of ±10 deg in all 3 Euler angles.

During the phase when the satellite is just ejected into orbit, called the detumbling phase, a B dot controller is used. When the rates are within a small range, the nominal control linear law is switched on. A deterministic algorithm is used for finding the attitude of the satellite. The simulation result of the attitude control law is shown in Fig 3. The control strategy is tested extensively by Monte Carlo simulations and On Board Computer in Loop Simulations (OILS).

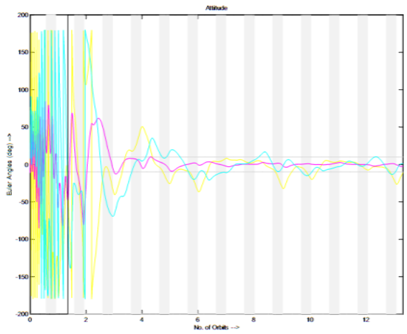

Figure 3: Variation of Attitude with Time from Launch to Nominal Mode

D. On Board Computer Subsystem

The On Board Computer subsystem comprises of one circuit board with dimension 12.8 x 12.8 cm mounted on the leading side of the satellite and it interfaces with all sensors, actuators, power, SNAP and communication boards and has two Atmega 128 microcontrollers. It is the only place onboard the satellite where all the computations are carried out.

Before flight, the OBC is required to conduct preflight checks of all subsystems. While in flight, the OBC performs all tasks in a cyclic manner, repeating very task within a fixed frame time of 2 seconds. The OBC collects health monitoring data of various components in the system and stores it, to be transmitted later when the satellite is over India. This “Health Monitoring” Data (or HM data) consists of Attitude data, Position data, data regarding various loads as seen by the Power sub-system, and the associated timestamps. It executes the control law by taking inputs from the sensors and controlling the actuators. It interfaces with the power microcontroller and acquires satellite health data. In case the power subsystem indicates inability to supply power, OBC must take appropriate shut down measures. During downlinking of data, the OBC must perform the control law execution and data downlink simultaneously.

E. Power Subsystem

Power System efficiently provides power to all sub-systems at the required voltage levels. The power system comprises of one circuit board with the microcontroller, battery protection circuit, voltage regulators, current distribution switches, etc. which interfaces with all the onboard systems. The power circuit board with dimensions of 12.8 x 12.8 cm is mounted on the Sun Side. For power generation, there are solar panels on 4 sides of the satellite (Zenith, Leading, Lagging and Sun Sides). The battery and the battery box are mounted on the Nadir Side.

Power subsystem is responsible to manage power from the solar panels and battery and distribute it to the various subsystems. In case of low power it intimates the OBC microcontroller and switches off the subsystems in the following order, when the threshold voltages are reached:

- Monopole 2 (Downlink at 437.455 MHz)
- All control sensors and magnetorquer
- OBC circuit
- Beacon circuit (145.98 MHz)
- Power circuit

It is the only subsystem that remains on during the launch and switches on other subsystems once the separation from launch vehicle is detected by the SNAP circuit. It switches on the other subsystems in following order:

- Power circuit
- OBC circuit
- Beacon circuit (145.98 MHz)
- All control sensors and magnetorquer
- Monopole 2 (Downlink at 437.455 MHz)

It also collects health monitoring data from loads and switches off loads in case they draw excessive current.

F. Structures Subsystem

The satellite structure is a cube with 6 panels of 3mm thickness joined using helicoil inserts and bolts such that each panel is joined to its adjacent panel at 4 points. Thus each panel has 16 points at which it is connected to some other panel. The Nadir Side is interfaced with the LVI using 8 M6 inserts. The structure is made by milling out the panels from blocks of Al 6061 T6 with a minimum tolerance of 100 microns for all dimensions. The structure will be anodized after fabrication and then assembled.

The aim of the Structures subsystem is to validate the Satellite will be able to withstand the loads during launch. All the components should be safe and working after the launch. The Satellite structure should also be able to withstand the thermal loads arising in the orbit. Hence, the satellite is modeled using Ansys and the launch loads are applied to it. Some of the results of these simulations are shown below.

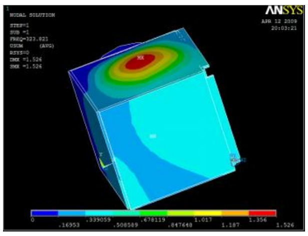

Figure 4: Mode1- Anti-sun side breathing

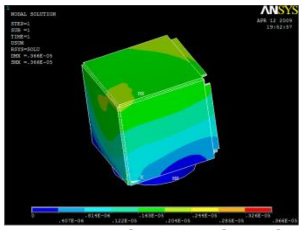

Figure 5: Displacement plot under static loading

G. Thermals Subsystem

The Thermals subsystem aims to maintain a cycle of temperature within the satellite within the narrow range (0^0C to 40^0C) which lies around the normal terrestrial temperatures, minimize spatial gradients of temperature, dissipate excess heat generated by components and maintain sensitive components within their specified functional ranges of temperature. The thermals subsystem essentially uses passive methods to maintain temperatures in the required ranges and dissipate localized heat generated by circuits. The only active part in the thermals subsystem is the heater used as a redundancy measure for maintaining the battery temperature. The satellite structure is used as a heat sink to dissipate heat generated by circuits and monopoles. The solar panel is made on aluminium substrate and isolated from the structure by 3mm thermal washers. LE tapes behind the solar panel and on the satellite surface ensure thermal control inside the Satellite.

H. Integration Subsystem

The Integration subsystem, lead by the System Engineer, has the job of bringing all the subsystems together to make a complete system. Some of the tasks of this subsystem include:

1) Defining the System and Sub-System Requirements

The V-model is a graphical representation of the systems development lifecycle. It summarizes the main steps to be taken from the initial conceptual design of the system to the final validation of the system. The figure below shows the V-model followed by Pratham Satellite.

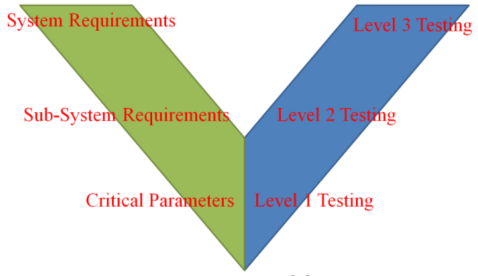

Figure 6: V Model

The Mission Statement and the Environment (space, launch vehicle, etc.) give rise to System Requirements. These System Requirements are handed down to the individual Subsystems. The Subsystems also interact with each other to give Subsystem Requirements. Finally from all these requirements come the Critical Parameters which the individual Sub-Systems have to design and satisfy. Similarly, the critical parameters are tested by the Subsystems in Level 1 testing. 2-3 Subsystems get together and do Level 2 testing where the interaction between these Subsystems is checked. The final Satellite level testing is done in Level 3 testing like vibration testing, etc.

Level 2 Testing: OILS (On-board computer In-Loop Simulation), as the name suggests is a setup for simulating the on-board computer with inputs similar to those that it may experience in the satellite. It is part of the second level testing and will help identify bugs and shortcomings of the hardware and software of the On-Board Computer. In short, the objective is as follows: To setup an arrangement to do hardware in loop simulation of the onboard computer with the exact inputs and outputs it is supposed to receive in space, and thus verify its performance.

2) Defining the Operational Sequence

It is an essential part of a good design methodology to document the entire life of the system/product, in order to cover all possible scenarios that the system may face. For Pratham we have divided its life into the following stages

1. Manufacture and Transport phase
2. Integration and testing phase
3. Pre-flight Checks (Checkout tests)
4. Launch
5. Detumbling: When that angular rates are above 0.1 degree per second.
6. Nominal Operation without downlink: Rates are less than 0.1 deg per second and the satellite is not over any ground station (India and France). Only the Beacon is transmitting.
7. Nominal Operation with downlink: Rates are lower than 0.1 degree per second but the satellite is over a ground station and is transmitting at 437.455 MHz also.
8. Safe Mode: when the battery voltage is very low for operation; Power subsystem starts switching off loads in a pre-programmed sequence.
9. Emergency mode: When a load draws excess current it is switched off and the situation is reported to the OBC. The Power micro-controller periodically tries to power up the defective load.

3) Wires, Connectors and Routing of Wires

Pratham uses space grade MicroD 9pin and 15pin, Right angle Horizontal, Board-to-wire-type PCB mounting connectors. The Wire Routing Process is described below.

Stage 1: Conceptual - The number of wires going from one board to another along with their tentative path is sketched. This stage plays a major role in making the internal configuration layout.

Stage 2: 2-Dimensional model is made, using the Engineering Drawings of panels. Detailed path of the wires are decided along with the location of the harnesses. Thumb rule of radius of curvature at any bend to be greater than 6 times the diameter of the bundle is followed.

Stage 3: 3-Dimensional model is made using a true to scale wooden model the final length of wires was calculated. In addition the curvatures to be given to bundles when routing from one face to another is also maintained as per the thumb rule.

4) Integration Sequence

For Mechanical Integration of a complexly connected system it is very necessary to decide a sequence of integration activities so as to avoid complications relating to accessibility at later stages. Integration Sequence for Pratham will be written in utmost detail starting from the first panel and ending with the last screws to be turned.

5) Configuration Layout

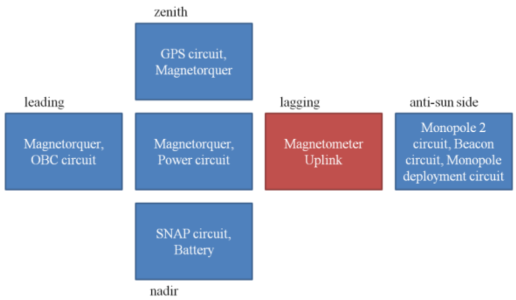

Figure 7: Internal Configuration Layout

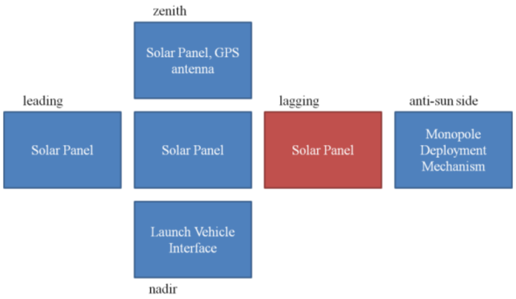

Figure 8: External Configuration Layout

6) Maintaining Weight Budget

TABLE 2: WEIGHT BUDGET

Component	Mass(kg)
Zenith	0.67
Nadir	1.22
Anti-Sun Side	0.65
Sun Side	0.63
Leading	0.65
Lagging	0.64
LVI(FE ring only)	0.7
Battery Box	0.04
Battery Pack	0.3
Monopole1	0.0162
Monopole2	0.0162
Monopole3	0.0162
Monopole holder	0.01
Monopole holder	0.01
Monopole holder	0.01
Solar Panel(Zenith)	0.3
Solar Panel(Leading)	0.35
Solar Panel (Lagging)	0.35
Solar Panel(Sun Side)	0.35
Torquer1	0.21
Torquer2	0.21
Torquer3	0.21
Total	**7.5586**

Estimated combined mass of connectors, screws, helicoils, coatings, paints, RTV = 2kg (upper limit)

I. Quality Subsystem

Quality Assurance refers to planned and systematic production processes that provide confidence in a product's suitability for its intended purpose. The Quality subsystem is responsible for maintaining the quality standards within the Satellite project. A goal has been set to keep the probability of failure during the mission life of Pratham to less than 2%. Accordingly electrical QA are carried out for all the subsystems. The weightage given to each of the subsystems and the final calculated values are shown in the table below. Mechanical QA is more difficult to handle since it is always assumed to be ~1, i.e. there is no scope for any failure. Hence there are large safety factors in all our designs. As a part of QA, a clean room of 1000,000 class has been built for the fabrication and storage of the satellite and its components.

TABLE 3: APPORTIONED ELECTRICAL RELIABILITY TO DIFFERENT SUBSYSTEMS

Subsystem	Apportioned Reliability
Communication	0.9980
Power	0.9950
Controls	0.9990
On Board Computer	0.9950
Thermal	0.9995
Structure and Mechanisms	1.0000
Integration	0.9990

V. OTHER UNIVERSITY STUDENTS

Students in Pratham have strongly felt that it is their duty to spread the knowledge and experience that they have gained while working on the project, to the students all over the country. This has not only benefited other students in other universities by bringing them closer to space science and technology, but the students belonging to Pratham have also learnt a lot from this process.

A. National Ground Station Workshops

The aim of Pratham was to educate students in the field of space technology and fallout of this was the social goal. The social goal aimed at conducting workshops for students from other universities, making them acquainted with the basics of satellite communications and guiding them to build their own Amateur Ground station. The Communication and Ground station Subsystem has also designed low cost (<Rs25,000) ground stations to measure TEC for students from other universities. There already have been 2 national workshops and around 8 other universities from across the nation have attended them along with professionals from the field. Currently 4 out of the 8 universities have completed design and characterization of the antennae and are in the process of designing the ground station circuitry. The list of universities that were involved with the project:

- Thapar University, Patiala
- Saveetha Engineering College, Chennai
- Faculty of Engineering Technology, Saveetha University, Chennai
- Atharva Engineering College, Mumbai
- BVCOE, Navi Mumbai
- BIT Mesra, Extension centre Jaipur
- GGTIM, Bhopal
- Jiwaji University, Gwalior

B. Collaboration with IPGP, France

Pratham Team entered in collaboration with Institut de Physique du Globe de Paris, France; according to which Pratham shall switch on both the onboard transmitters over IPGP, France. In return, IPGP shall share the TEC data collected over France and store Pratham Satellite’s TEC data at their TEC data storage facility. IPGP shall also help Pratham team in designing the payload and processing Pratham Satellite’s TEC data.

C. Virtual Labs Experiment

In an attempt to spread the learning produced in the project to an even larger audience, Pratham Team has decided to web-enable some of its simulations to make a Virtual Laboratory. The thermals section of the Virtual Laboratory is already working on Pratham's website. This endeavor is supported by Center for Distance Engineering Education Programme (CDEEP), IIT Bombay and Ministry of Human Resource and Development (MHRD).

VI. ACKNOWLEDGEMENTS

We wish to thank the Department of Aerospace Engineering and all the Faculty Mentors of IIT Bombay for their support and guidance in this project. We wish to thank Mr. D.V.A. Raghav Murthy and his team of engineers from ISAC and Mr. Jaykumar from VSSC for their support. We would like to thank Dr. B.N. Suresh for reviewing our progress during his visits to IIT Bombay. Finally we would like to thank Prof. K. Sudhakar, Prof. P.M. Mujumdar, Prof. H. Arya and Prof. H. Hablani for their continued support and encouragement for the project.

VII. REFERENCES

[1] Requirements Capture Report

[2] Conceptual Design Review Report for Payload Sub-System

[3] Conceptual Design Review Report for Communication and Ground Station Sub-System

[4] Conceptual Design Review Report for Attitude Determination and Controls Sub-System

[5] Conceptual Design Review Report for Power Sub-System

[6] Conceptual Design Review Report for On Board Computer Sub-System

[7] Conceptual Design Review Report for Structure Sub-System

[8] Conceptual Design Review Report for Thermal Sub-System

[9] Conceptual Design Review Report for System Engineer

[10] Preliminary Design Review Report for Payload Sub-System

[11] Preliminary Design Review Report for Communication and Ground Station Sub-System

[12] Preliminary Design Review Report for Attitude Determination and Controls Sub-System

[13] Preliminary Design Review Report for Power Sub-System

[14] Preliminary Design Review Report for On Board Computer Sub-System

[15] Preliminary Design Review Report for Structures Sub-System

[16] Preliminary Design Review Report for Thermals Sub-System

[17] Preliminary Design Review Report for Mechanisms Sub-System

[18] Preliminary Design Review Report for System Engineering and Integration Sub-System

[19] Preliminary Design Review Report for Quality Sub-System

VIII. APPENDICES

A. List of Faculty Mentors

Name of Faculty Mentor	Department
Prof K. Sudhakar	Aerospace
Prof P. M. Mujumdar	Aerospace
Prof H. Arya	Aerospace
Prof H. B. Hablani	Aerospace
Prof S. P. Bhat	Aerospace
Prof K. Chatterjee	Electrical
Prof B. G. Fernandes	Electrical
Prof K. N. Iyer	Mechanical
Dr K P Ray	SAMEER
Prof Madhu N. Belur	Electrical
Prof Krithi Ramamritham	Computer Science
Prof R. K. Pant	Aerospace
Prof K. K. Isaac	Mechanical
Prof U. N. Gaitonde	Mechanical
Prof R. K. Shevgaonkar	Electrical
Prof R. N. Banavar	Systems and Control
Prof D. K. Sharma	Electrical
Prof R. P. Shimpi	Aerospace
Prof Girish Kumar	Electrical
Prof Kavi Arya	Computer Science
Prof B Bandyopadhyay	Systems and Control

B. List of Students who have contributed to Pratham

Name of Student	Subsystem	Contribution to Pratham
Saptarshi Bandyopad hyay	Project Manager and System Engineer	Founding member of the project, has been responsible for the integration and mechanical design of the satellite along with contribution in Controls, Payload and Social goal
Shashank Tamaskar	Controls Head and Project Manager	Founding member of the project, has been responsible for the initial development of the control law and Kalman filter
Ashish Goel	Former head of Payload	Developed the TEC payload and tomography algorithm
Kartavya Neema	Former head of Communication and Groundstation Subsystem	Developed the initial layout of the Onboard circuitry and design of Groundstation antennae
Jhonny Jha	Present Project Manager and Communication and	Developed the Onboard Communication circuitry and designed the Groundstation at IITB and other universities

	Groundstation Subsystem Head	
Mallesh Bommanahal	Former Core Group Member and Member of controls	Developed the control law in its initial form
Sanyam Mulay	Core Group Member for System Engineering	Developed the weight and power budget and Operational sequence for the satellite
Deepika Thakur	Core group member for Communication	Conducted the National workshops as part of social goal and designed the IITB Groundstation
Prashant Sachdeva	Present head of OBC Team	Developed the software for the OBC and designed the setup for OILS
Vishnu Sresht	Former Head of OBC Team	Developed the concepts behind the OBC
Pratik Chaudhari	Former member of OBC Team	Developed the atmel board for OBC
Ameya Damle	Former Head of Power and Quality Team	Developed the Power and OBC hardware and was responsible for quality assurance measures
Jaideep Joshi	Present Head of Controls	Developed the deterministic control law and the Kalman filter
Haripriya	Core Group Member	Developed the design and configuration layout of the satellite
Manas Rachh	Present head of thermals	Developed the thermal simulations of the satellite and is responsible for the thermal design; created an online LAB using the simulation codes as part of social goal
Niranjan Parab	Former Head of Structures	Developed simulation models of satellite in ANSYS and conducted preliminary vibration testing of the satellite
Subhasis Das	Former head of Payload	Developed the Matlab codes to be used for TEC computation
Mayank Chaturvedi	Head of Mechanisms and Integration	Designed and modelled the qulaification model of the satellite alongwith the Snap mechanism
Mehul Tikekar	Former head of Power subsystem and Member of Quality Team	Developed the initial design of the Power board and initiated Quality assurance measures for other subsystems
Ramnath Pai	Former Core Group Member	Conducted Random, Modal and Harmoic analysis of preliminary satellite structure and conducted preliminary vibration testing of Engineering model
Ankit	Head of	Conducted Random, Modal

Chiplunkar	Structures	and Harmoic analysis of qualification model of satellite structure
Hussain Manasawala	Member of Communication	Developed and designed the flight models of PCB for telemetry, beacon and Uplink
Nikunj Bhagat	Member of Communication	Developed the code for telemetry circuit and beacon circuit to be used by the OBC
Siddharth M	Former Member of Communication	Developed code for onboard beacon
Viraj Deshpande	Former Member of Communication	Developed the real time tracking mechanism for the Groundstation
Yashovardhan Chati	Core Group Member for Controls	Developed the control law and conducted robustness analysis using Monte Carlo Simulations
Vaibhav Unhelkar	Core Group Member for Controls	Developed the control law and conducted robustness analysis using Monte Carlo Simulations, also responsible for sensor characterisation
Amol Patwardhan	Former Member of Communication	Tested the Amplifiers and LNA and designed the onboard circuitry
Sanket Diwale	Member of Integration team	Developed wire routing models and designed the qualification model of the satellite
Mihir Patel	Member of Integration team	Developed wire routing models and designed the qualification model of the satellite
Nithin Mannil	Member of Thermal subsystem	Developed models for thermal simulations
Sachin	Member of Thermal subsystem	Developed inhouse code for thermal simulation of the satellite body
Harshit Mittal	Member of OBC Subsystem	Developing setup for OILS
Pranay Jain	Member of OBC Subsystem	Developing setup for OILS
Chiraag Juvekar	Member of OBC Subsystem	Development and design of Power and OBC PCB's
Ajinkya Bapat	Member of Communication	Developed mechanism for monopole holder and tracking of satellites
Mayank Vibhuti Jha	Member of Communication	Developed mechanism for monopole holder and tracking of satellites
Narendra Shriradkar	Former member of Power	Developed and designed the initial Power board
Varun Jog	Former Member of Payload	Finalised polarization measuring circuitry at the Groundstation