DESIGN OF DATA ACQUISITION, COLLECTION, PROCESSING AND ARCHIVING SYSTEM FOR PRATHAM, IIT BOMBAY'S STUDENT SATELLITE PROJECT.

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ABSTRACT

The Pratham IIT Bombay student satellite project aims to develop an ionospheric map of the world by using the method of Faraday rotation. The success of the mission depends upon the intensity ofthe ground based network collecting the data. Currently, around 15 universities across the nation and1 international university are currently involved in the social goal. The National Atmospheric Researchlaboratory (NARL) has collaborated with the team and is willing to help in the post processing of thedata. It has also agreed to be a part of the ground station network to collect data for Pratham. It is of vital importance that the groundstations follow a consistent protocol with respect to each other asto the method of data collection, storage and archiving for it to be of use to the scientific community.The paper highlights the importance of using of the shelf components while creating the data acquisitionsystem. The data acquisition system consists of a set of antennae satisfying rigid conditions to maintainthe required level of accuracy in the collected data. The acquisition chain is automated using of theshelf components. The acquired data has to be filtered without tampering with its fidelity. Maintaining fidelity is very important as the variation of ionosphere is otherwise very difficult to capture if the noiselevels increase beyond a certain level. A complex set of filters including band pass filters, notch filters, anti aliasing filters and digital filters are to be used to filter out the noise and preserve the fidelity of thesignal. The collection of data is on the lines of the internationally recognized SEED format, which is used

by seismologists all over the world to share data. The paper also describes the post processing of datawhich includes conversion of the measured intensities into polarization angles and further into tomographicmaps. The data is in the IONEX format. There are 2 different formats, SEED and IONEX, for storageof raw and processed data. The data acquired by the other participating universities and NARL will beuploaded to the IITB server after post processing at their end. The archiving of data will be done on the Institut du Physics du Globe de Paris (IPGP) in France and Indian Institute of Technology Bombay servers. The data would be freely available and could be downloaded from www.aero.iitb.ac.in/pratham
Key Words: **TEC, polarization, tomography, ground station, social goal**

FULLTEXT

I. INTRODUCTION

Pratham (which means "the first" in Sanskrit) is a student satellite project that was undertaken by a group of undergraduate students of the Indian Institute of Technology Bombay. The satellite being built is a 260 mm cube and weighs nearly 10kg. Over the last four years the project has completed different stages of the design cycle and is currently in the detailed design and Integration phase. The project was initiated with a fourfold mission in mind with the main objective being learning and involving other students in the project.

In this paper, we present the data acquisition, collection, processing and archiving system that is being used at the IIT Bombay groundstation for the purpose of Total electron count (TEC) measurement. The paper also describes the design of the data collection system at the groundstation for achieving 99.9 % TEC accuracy which is necessary for scientific usage of the data.In section II, we give a brief introduction to TEC, its significance and the data acquisition setup used to measure it at the groundstation. In section III, we describe the collection methodology for TEC measurement. In section IV we shall elaborate on processing of the data and the archiving of the final derived results by collecting and processing data from students from across the country and beyond.

II.DATA ACQUISITION SETUP

A. Introduction to TEC

Total Electron Count or TEC is defined as the number of electrons in a column of unit cross sectional area, extending from ground all the way up to the end of the ionosphere. Units of TEC are electrons/m^2. There are two kinds of TEC measurements possible depending on the angle that the column of electrons makes with respect to the groundstation. If this column is vertical, then the TEC is referred to as Vertical TEC (VTEC) and otherwise it is referred to as Slant TEC (STEC). When referring to the TEC at a location, we usually mean the VTEC, unless otherwise stated.

TEC values are of great importance to the scientific community. The Indian subcontinent being close to the magnetic equator is rich in phenomena such as the Equatorial Ionization Anomaly (also known as the Appleton anomaly), the

Equatorial Spread F (ESF) and the Equatorial ElectroJet (EEJ). TEC is significant in determining the scintillation and group delay of a radio wave through a medium.

Pratham shall be measuring TEC over India and France, using the principle of Faraday rotation. When a linearly polarized radio wave passes through an ionized medium with a magnetic field in the direction of propagation, the plane of polarization rotates. This effect is called Faraday rotation.

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

where N – electron density, B-magnetic field of earth, θ- angle between the magnetic field and the direction of propagation of the radio wave, $\Delta\phi$ - is the change in angle of polarization, f – frequency of the wave.

We are using this principle to compute the TEC over a region. We are transmitting linearly polarized signals from the satellite and measuring the change in their polarization angle.Using the average value ofthe Magnetic field over its path gives us:

$$\phi_f - \phi_i = 4.87 * 10^{-4} * f^{-2} * B_{avg} * TEC$$

where ϕ_f – final angle of polarization, ϕ_i- initial angle of polarization.

B. Data acquisition chain at IITB

We will be measuring the intensities of the signals at the two feeds of the crossed yagi. The ratio of these intensities will give us the polarization angle. We shall be using a RF gain and phase detector IC AD8302 at the groundstation for the purpose of measuring ratio of intensities. This IC takes two inputs INPA and INPB and gives a voltage o/p proportional to the level ratio of these signals in dB [2]

$$v = 0.9 + 0.6 \log_{10}(|\tan\theta|)$$

The following figure describes the setup for acquiring payload data at IITB.

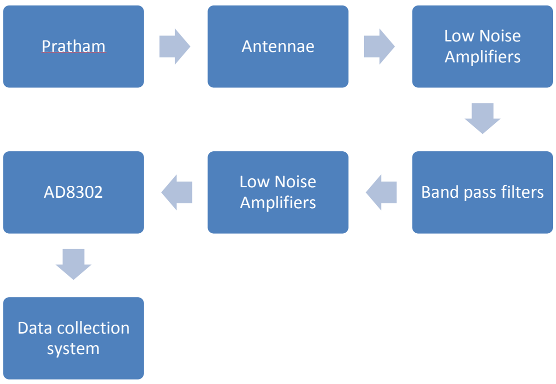

Figure 1: Data Acquisition setup at IITB

The setup consists of a band pass filter and a series of low noise amplifiers between the antennae and the AD8302. The band pass filter was customised to have the 3dB beamwidth very close to the center frequency. The characteristics of the bandpass filter are

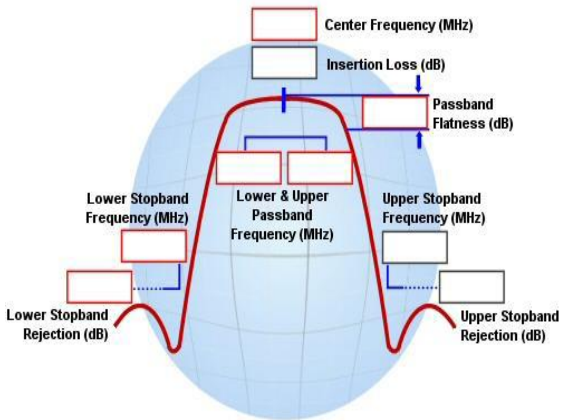

Figure 2: Characteristics of the bandpass filter

The following were the specifications of the various characteristics for the 2 bandpass filters

For filter with center frequency 145.98MHz

Center Frequency	*145.98MHz*
Insertion Loss of Center Frequency	<1dB
Passband Frequencies	145.5 MHz - 146.5 MHz
Insertion Loss of Passband	< 1dB
Low side Rejection Frequencies	91 MHz - 108 MHz (FM band)
Attenuation of Reject Frequencies	20-40 dB
High side Rejection Frequencies	400 - 440 MHz, 860 - 868 MHz
Attenuation of Reject Frequencies	20- 30 dB
Return Loss = VSWR	<1.2:1
Connectors	TNC-female (input and output)
Power Handling	1 W

For filter with center frequency 437.455 MHz

Center Frequency	*437.455MHz*
Insertion Loss of Center Frequency	<1dB
Passband Frequencies	437 MHz to 438 MHz
Insertion Loss of Passband	< 1dB
Low side Rejection Frequencies	91 MHz - 108 MHz (FM band)
Attenuation of Reject Frequencies	20-40 dB
High side Rejection Frequencies	470- 472 MHz 860-868 MHz
Attenuation of Reject Frequencies	20- 30 dB
Return Loss = VSWR	<1.2:1
Connectors	TNC-female (input and output)
Power Handling	1 W

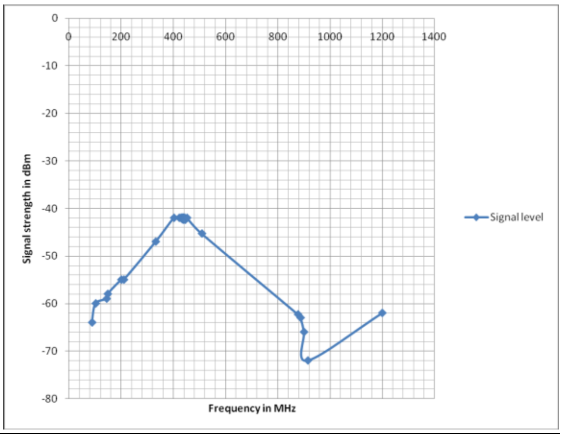

Figure 3: Frequency vs gain plot for filter at 437 MHz

II. DATA COLLECTION SYSTEM

After Pratham satellite will be successfully in operation from its final orbit, it will transmit two linearly polarized signals when flying over India and France regions. Crossing the Earth ionosphere these signals will be rotated by the Faraday effect. Stations located in India and France will record the signals and the angle of polarization of the received signals, thus allowing the computation of Total Electron Content of the ionosphere along the line of sight of the satellite-receiver. The downlink data of Pratham will be collected by all the ground stations and managed by the main server. A very simplified flow diagram looks as follows in which the acronyms stand for:

TLE : Two line elements for calculating satellite position

V-TEC: Vertical Total Electron Count

S-TEC: Slant Total Electron Count

GS: Ground station

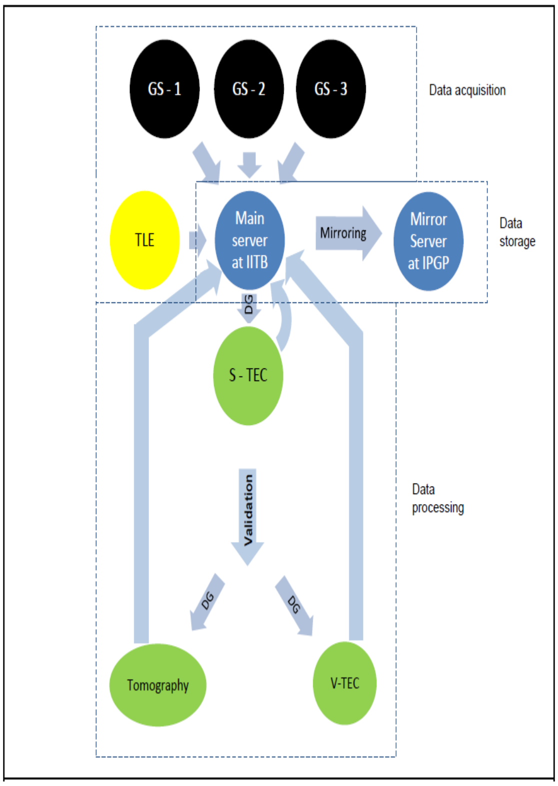

Figure 4: Process flow for data collection

Data collection implies data acquisition from all the ground stations to the main server. There are three important elements of the collection block.

1) IITB server

2) IPGP server

3) All ground stations (including IITB and IPGP)

The data collection will be managed by an ftp server at IITB. Another ftp server will be at IPGP. The other ground stations do not need to create an ftp server. But each GS should maintain its own data until the end of the mission. All data upload and download will be automated, using scripts. All ground stations including IITB and IPGP, will upload their data files to IITB server. Additionally, IPGP server will act as a mirror to the IITB server.

A. IIT Bombay server

The IITB server is the main server for Pratham data. All files sent by all the ground stations including IITB will be received and stored in the database at IITB. A small basic verification process needs to be implemented at IITB to check if all files have been correctly and completely uploaded before storing them in the specified location. This is in order to prevent data corruption at later stages. A verification message signaling successful completion has to be sent by both the remote servers to each other every time data transfer occurs between them. The server will remain on 24X7.

B. IPGP server

This is the secondary server for Pratham. It will maintain its own data in its database. Additionally, it will act as a mirror of the IITB server. So this server will not receive the data directly from all the ground stations. It will receive the raw and processed data of all the ground stations from IITB server as a single package. i.e. the IITB database will be mirrored online on the IPGP server daily. The server will remain on 24X7.

C. Other Groundstations

All ground stations will store their own data. They will send their data to the IITB server after every satellite pass. They will request the IITB server at the time of sending the data. All ground stations send the data to the main server only after the complete data has been retrieved

All ground stations have download access to all the data present in both IITB and IPGP servers.

All ground stations have permission to upload their own primary data on IITB server. No server or GS has permissions to edit any primary data. IPGP server has permissions to mirror the IITB server. All primary and processed data have public read-only access.

The mirroring from IITB to IPGP will be a daily 1-step process. Mirroring will occur at a fixed time of the day.

III. DATA PROCESSING

The data processing at the main server can be divided into three levels. The first level includes basic verification of the incoming data from all ground stations. The second level generates the S-TEC from the raw data. The third level validates and filters the S-TEC data and generates the final products : V-TEC/Tomography.

A. Level 1 (Primary validation)

The incoming primary data files from a GS initially stored in the "TEMP" folder are validated. This validation includes :

1) File count.

2) Header line count for each file.

3) Data column count for each file.

- If the file count is incorrect, the client GS will be requested to resend the data maximum 5 times after which logging will be done.
- After validation, if **all** the files sent by the GS are correct, they will be sent to their intended location.
- If the files are partially/completely incorrect, the files will be maintained in the temp folder.

- The correct files once sent to the intended location will be deleted from the TEMP folder.

B. Level 2 (S-TEC)

The raw data files contain voltage values at pins VMAG and VPHS of the AD8302. These values being related to the intensity ratio and phase respectively can be used to calculate the S-TEC and phase difference between the two signals.

- The raw data will pass through the Data Generator software #1 and S-TEC will be generated.
- These S-TEC files will pass through the second stage of validation. This validation will check if :
  - S-TEC generation is possible
  - the generated S-TEC is erroneous (basic verification)
- A quality flag based on the results of the validation will be attached to every S-TEC data file.

Condition	Q - Flag
If generation is impossible	0
If S-TEC is generated but not reliable (-ve/out of range)	1
If S-TEC is properly generated	2

- The S-TEC values if generated will be stored in the S-TEC file with the corresponding time stamps and satellite coordinates.
- The S-TEC files with the quality flag, with or without the S-TEC values will be stored in "PROC" folder.

C. Level 3 (V-TEC/Tomography)

- The generated and validated S-TEC data can now be used to generate the secondary data, the final products. V-TEC & Tomography.
- But before that, the S-TEC files undergo a third set of validation automated/manual (TBD). After this validation, only the S-TEC files with appropriate S-TEC data will be sent to the next stage of processing for V-TEC and tomography generation.
- V-TEC/Tomography will be generated from the S-TEC file and stored in a separate file.
- The V-TEC/Tomography file will contain the V-TEC/Tomography values along with the time stamps satellite coordinates and piercing point coordinates.
- The file will be stored in the "PROC" folder.

D. Level 4 (V-TEC/Tomography)

Logging of the data management at the main server will be automatically made at 5 stages for every set of files (daily data from every GS). The 5 stages of logging are:

- 1. Data received from a GS (Number of files received).
- 2. First level validation results. (Names of erroneous files and type of error "head" or "data")
- 3. Quality flag of the S-TEC generated (0/1/2)
- 4. V-TEC generated (Boolean –0/1)
- 5. Tomography generated (Boolean –0/1)

- The 5 log files in that GS's log folder will be updated every day with the corresponding log entries.

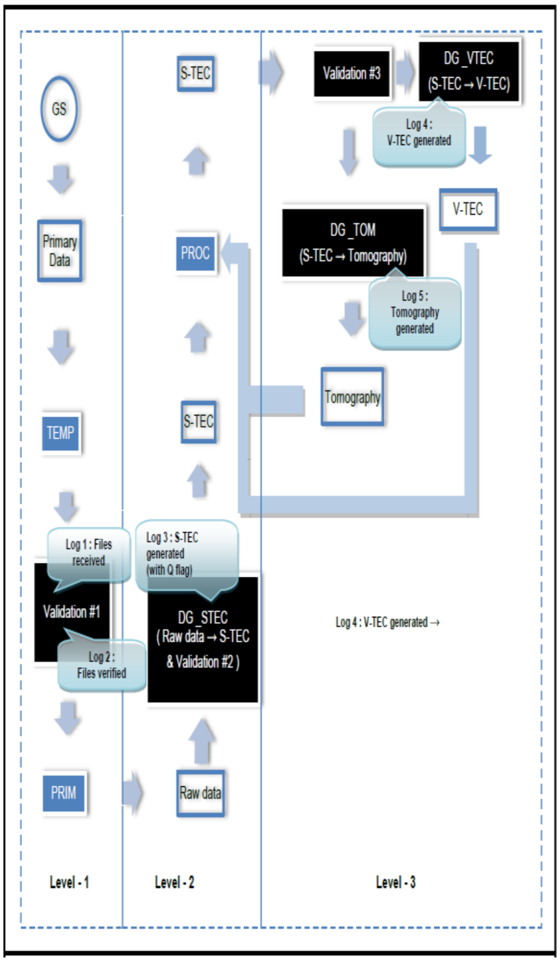

Figure 5: Data processing flow diagram

IV. DATA ARCHIVAL SYSTEM

The data storage occurs in two stages.

1) At the GS (including IITB and IPGP).

2) At IITB and IPGP servers.

The primary data are first stored in the ground station's own database. This also includes IITB and IPGP ground stations. Then these data are sent to and stored in the IITB server which is in turn mirrored by IPGP server.

Primary data: These are the basic data, directly collected by the GS during satellite pass.

- RAW_PRAT_SSSS_yyyy_ddd_hh _mm_ss.txt (Raw data)
- OREF_PRAT_SSSS_yyyy_ddd_hh _mm_ss.txt (Orientation data)
- AUX_PRAT_SSSS_yyyy_ddd_hh _mm_ss.txt (Auxiliary data)
- TEL_PRAT_SSSS_yyyy_ddd_hh_ mm_ss.txt (Telemetry data)

Processed data: These are the secondary data and come after processing and validation.

- STEC_PRAT_SSSS_yyyy_ddd_hh _mm_ss.txt (S-TEC)
- VTEC_PRAT_SSSS_yyyy_ddd_hh _mm_ss.txt (V-TEC)
- TOM_PRAT_SSSS_yyyy_ddd_hh _mm_ss.txt (Tomography)

Characteristic data: These are the data relate to the physical characteristics of the ground station.

- CHAR_PRAT_SSSS.txt (Characteristic data)

Logging data: This is the daily log of the data received and processed by the IITB server.

- LOG_PRAT_SSSS_REC.txt (Received files log)
- LOG_PRAT_SSSS_V1.txt (Verification 1 results log)

- LOG_PRAT_SSSS_STEC.txt (S-TEC generation log)
- LOG_PRAT_SSSS_VTEC.txt (V-TEC generation log)
- LOG_PRAT_SSSS_TOM.txt (Tomography data generation log)

A. Database structure

The following are the salient features of the database structure at IITB and IPGP SERVERS All data will be stored in a folder named "PRATHAM". This folder will have sub-folders:

- CHAR: This folder will contain text files corresponding to each GS with information about that ground station's characteristics.

- LOG: This folder will be contain further sub-folders corresponding to every GS.

Each of these folders will contain 5 log files corresponding to the 5 log entries elaborated further in this document.

- TEMP: This folder will hold the incoming data from every GS and act as a buffer. All primary data will first be verified in this folder before sending to the intended location. Once verified and sent, that data will be deleted from this folder.

- DATA: This folder will hold all the downlink data of Pratham. The data folder will have more sub-folders with names as "yyyy", specifying the year of the start of that particular data acquisition.

All such folders will have further sub-folders with their names as "ddd" specifying the day of that year.

For example, acquisition with a starting date of 1st Jan will be stored in a folder named "001".

- Each of these folders will have 2 sub-folders "PRIM" and "PROC".

- "PRIM" will contain the primary data of all ground stations for that day.

- "PROC" will contain the processed data of all ground stations for that day.

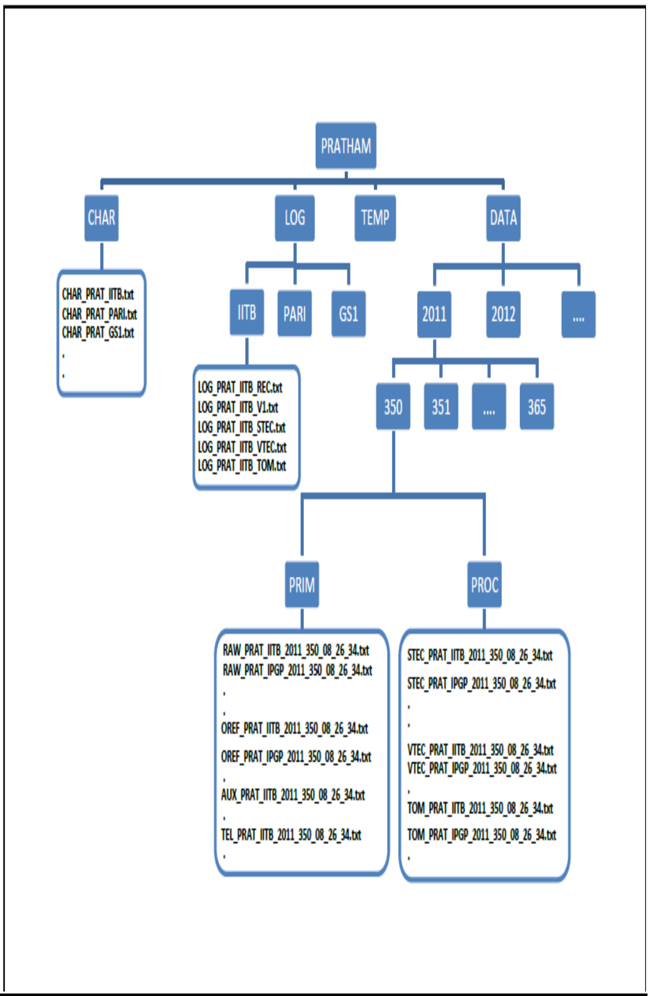

Figure 6: IITB and IPGP Database structure

The following is the database structure for other Groundstations:

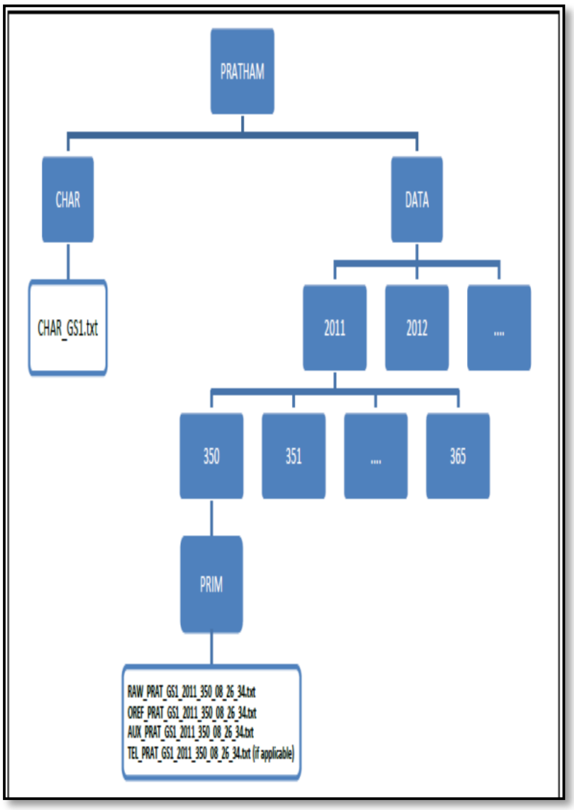

Figure 7: Database structure for other GS

B. File format

This section contains details about the file format being used for the storage of data. The scheme is inspired from the SEED data format that is used by seismologists to share data and is aimed to facilitate sharing of data between different ground stations and the central server. The following table represents the format of stationids that would be assigned to each participating ground station

Station ID	City	Country	Lon (E)	Lat (N)	H (m)	Institute
IITB	Mumbai	India				IITB
PARI	Paris	France				IPGP

Figure 8 Station IDs

Abbreviation	Meaning	Example
ssss	Station ID	IITB
yyyy	Year of acquisition	2011
ddd	Day of the year with 1st Jan as 1 & 31st Dec as 365/366	050
hh	Hours UT (24)	08
mm	Minutes UT (60)	26
ss	Seconds UT (60)	34
Start_time_UT	Universal Time at the moment of first data acquired *(This should be the same as the time in the file name)*	2011-050T08:26:34Z
End_time_UT	Universal time at the last data acquisition. *(This is the same as the last time stamp in the file)*	2011-050T08:26:34Z

Figure 9 Abbreviations used in file names

Calibration info and station characteristics file called CHAR_PRAT_SSSS.txt will contain the following information :

- Position of antenna measured by GPS (Lat/Long/Alt)
- Reception function of Antenna 145, including cross-talk with 437 :
- The 3dB bandwidth of the antenna along with the F/B ratio.
- Reception function of Antenna 437, including cross-talk with 145 :
- The 3dB bandwidth of the antenna along with the F/B ratio.
- Automation mechanism :
- Use of rotor or any other hardware mechanism. Other devices and hardware involved in the acquisition chain with a brief

description of the chain. The tracking and automation software used.

- Type of data acquisition according to one of the following configurations :

Type of data acquisition	Phase measured	Intensity measured	Tangent measured	Co tangent measured	Beacon decoded	Telemetry decoded
1	Yes	Yes	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	No	Yes	Yes
3	No	Yes	Yes	No	Yes	Yes
4	Yes	Yes	Yes	No	Yes	No
5	Yes	Yes	Yes	No	No	No
6	No	Yes	Yes	No	No	No
7	Yes	Yes	Yes	No	Yes	No
8	Yes	Yes	Yes	Yes	No	No
9	Yes	Yes	Yes	Yes	Yes	No

Figure 10 Acquisition type

So the final file format would incorporate the station id, location of the groundstation and the various characteristics of the

Station_ID	4 characters	Station code
Location	3 words:[deg:min:sec][deg:min:sec][m]	Station location: latitude,
Satellite_Tracking _ID	1 word: PRATHAM	Satellite tracked
3db_bandwidth_145	1 word: [Hz]	3db bandwidth of the 145MHz antenna
F-B_ratio_145	1 word:	Front to back ratio for the 145 MHz
3db_bandwidth_437	1 word: [Hz]	3db bandwidth of the 437MHz antenna
F-B_ratio_437	1 word:	Front to back ratio for the 437 MHz
Acquisition_type	1 word	The type of acquisition
List of devices and their significance in the acquisition chain.		
A brief formal description of the acquisition chain.		
Name of tracking software with a link to its webpage.		

Figure 11 File format

V: CONCLUSION

Thus, the data acquisition, collection, processing and archival techniques are tailored to provide the scientific community with the maximum amount of data that the project can possibly do. The systems are made using off the shelf components and are ingenous in that they create a simple yet holistic structure for post launch operations of the satellite.

VI. REFERENCES

[1] K. Bhuyan, S. B. Singh, and P. K. Bhuyan, “Application of generalized singular value decomposition to ionospheric tomography,” AnnalesGeophysicae (2004)

[2] P. V. S. Rama Rao, S. Gopi Krishna, K. Niranjan, and D. S. V. V. D. Prasad Ann., “Temporal and spatial variations in TEC using simultaneous measurements from the Indian GPS network of receivers during the low solar activity period of 2004–2005,” Geophys., 24, 3279–3292, 2006.

[3] Andrew J. Hansen, “Real-Time Ionospheric Tomography Using Terrestrial GPS Sensors,” Stanford, 1995.

[4] Smitha, “Data Processing and Instrumentation for TEC,” Vikram Sarabhai Space Center (VSSC), India

[5] Balanis Constantine, “Antenna Theory”, Wiley Publication,2009

[6] National RadioAstronomy Observatory website: http://www.tuc.nrao.edu/

[7] Critical Design review of Thermal Subsystem of Pratham, IIT Bombay Student Satellite,www.pratham.iitb.ac.in

[8] Critical Design review of Communication and Groundstation Subsystem of Pratham, IIT Bombay Student Satellite, www.pratham.iitb.ac.in
[9] Critical Design review of Payload Subsystem of Pratham, IIT Bombay Student Satellite, www.pratham.iitb.ac.in
[10] ModelWeb Catalogue and Archive Website: http://ccmc.gsfc.nasa.gov/modelweb/models
[11] SaptarshiBandhyopadhyay, Jhonny Jha,KartavyaNeema et al "Introduction to Pratham, IIT Bombay"s Student Satellite Project" at *ISSSC* (Indian Small Satellite Systems Conference) held at ISAC, Bangalore, India, April 2010
[12] SaptarshiBandhyopadhyay, Jhonny Jha,KartavyaNeema et al "Measurement of Total Electron count of the Ionosphere and the Social goal of Pratham, Indian Institute of technology Bombay's first student satellite" at International Astronautical Congress, Prague, Czech Republic, October 2010