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Design Of Component-Based Software For Telemetry, Tracking And Commanding (TTC) Operations Of Nano Satellite

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ABSTRACT: PES Institute of Technology along with five other institutions is developing a nano-satellite for capturing images of the earth. The project is intended for students to understand and work with advanced space technologies. The satellite is built around subsystems such as, Attitude Control System, Electrical Power System and Mechanical Systems. The data distribution is handled by an On Board Computer (OBC) system which is interfaced to all the subsystems. On Board Computer is a microprocessor board where satellite software is executed. The OBC, after internal processing of satellite telemetry parameters sends the telemetry information using S-band transponder to the ground station. The telemetry information is received by a computer system through the ground station setup for receiving the satellite data. This paper, discusses the development of software which is used in the satellite control centre for carrying out TTC operations of satellite. The data is presented to the spacecraft operational personnel using graphics tools for further analysis of the spacecraft health. The design of ground station software is presented in this paper. We use the approach of component-based software methodology.

Keywords : Component-based, Ground Station, On Board Computer, Telemetry Tracking Commanding, Nano Satellite.

1 Introduction

THE prime endeavour for the construction of the nano satellite is to introduce the learning opportunity to the students through space technology. Thus the students are exposed to the skills of developing the satellite through different phases of analysis, design, fabrication, testing and operations. The major scope of this satellite is to capture the pictures of earth and send to the ground station. It is prepared to launch the satellite in a polar sun synchronous orbit at an altitude of around 650 km and inclined at an angle of about 99º. The orbital period is around 90 minutes; eccentricity is about 0.001 and semi major axis of about 7000km. The launch vehicle used for this purpose is a Polar Satellite Launch Vehicle (PSLV). The hardware components used are magnetic actuators, magnetometer, power sensors, sun sensors, thermistors, receiver, transmitter, camera and solar panels. The processor used here is UT32UC3A0512, which is of 32 bits, 512Kb memory and speed of 1.49 DMIPS (Dhrystone MIPS)/MHz which is necessary to achieve our mission. We are concerned with the development of software which is used in the satellite control centre for carrying out Telemetry tracking and Telecommand operations of satellite. The data is presented to the spacecraft operational personnel using graphics tools for further analysis of the spacecraft health. The design of ground station software is presented in the later section of this paper. We used the approach of component- based software methodology to adopt the plug and play feature to the software. In this paper we have elaborated on the ground station configuration of the satellite which is described in section II. The system design of the same is structured in section III. Section IV describes implementation of ground station software. Finally, the paper is concluded in section V.

2 Ground Station Configuration

A ground station of the satellite is being setup at PESIT for carrying out telemetry, tracking and commanding operations of the satellite. There is a requirement for design and development of “Spacecraft Health Monitoring and Analysis” software system for the Satellite control centre to carry out the operational activities. The schematic diagram for the same is presented in figure 1. The ground station is configured with 3 meter antenna dish, base band chain and computers to carry out the uplink and downlink activities. The imaging information is also sent to the ground station for further processing. The two-way communication between the ground station and the Satellite Control Centre (SCC) is via RS232 serial link. There shall be two dedicated computer systems which act as the main SCC operator console. The major control and monitoring activities of the satellite are carried out at these consoles. Fig 1 shows the interface between the ground Station and the Spacecraft Control Centre (SCC) in which all major activities are performed to control the satellite. The telemetry, tracking and commanding (TTC) system of the satellite facilitates sending of data to the ground station and also for commanding the satellite during its nominal operation. The telecommand is carried out by the ground station at PESIT using software developed specifically for this purpose. The transmission of telecommand from the ground station to the satellite is referred to as uplink. Similarly, reception of data from the satellite by the ground station is referred to as downlink. The TTC operations are in S Band with the uplink frequency of 2030 MHz and downlink frequency of 2240 MHz.

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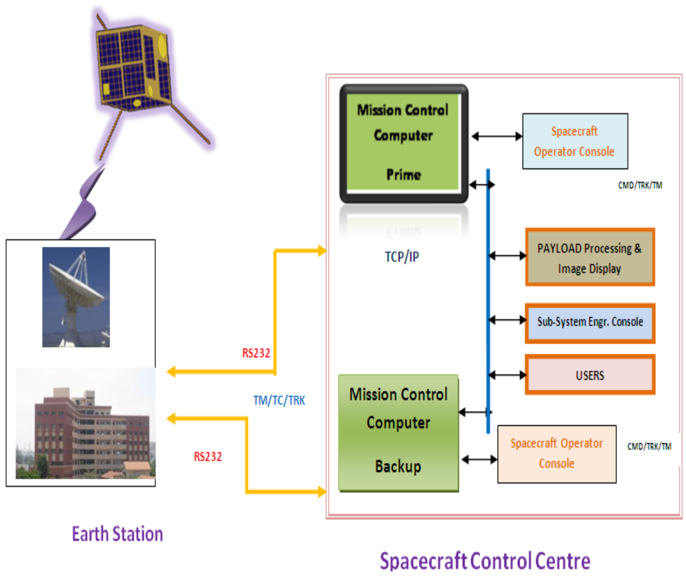

Fig. 1 Schematic Diagram of Spacecraft Ground Station

3 System Design

This section describes the design methodology of the ground station. This includes each subsystem component wise requirement specification, High level design and detailed design document. The role of the major software systems to be deployed to handle the entire activity of SCC and earth station is described here. This system is classified according to the respective functions namely, i) Telemetry data reception, recording, processing, status (subsystem health) monitoring, alarm reporting and data retrieval feature for offline application.(Telemetry Processing) ii) Spacecraft commanding (Telecommand) manual or auto commanding, CMD history maintenance and CMD status monitoring & alarm reporting. (Telecommand Control) iii) Spacecraft tracking in Auto/Drive mode and range data reception and storing in file and retrieval support at later use (Satellite Tracking). iv) Payload data acquisition and storing and image display in offline (Payload Processing). These are pictorially described using the use case diagram in figure 2.

i) Software Components and its elements

The software system is classified as: i) Telemetry Data Manager ii) Telecommand Manager iii) Tracking Data Manager iv) Payload Data Manager. Each of these managers performs most common activities, like Data Acquisition, Archival, Preprocessing, Distribution and Display (presentation). Along with these the TC Manager would take up an additional responsibility of commanding the satellite. The Tracking manager has an antenna driving capabilities for pointing to the satellite. However, payload data Manager would perform a minimum data processing to display the raw images.

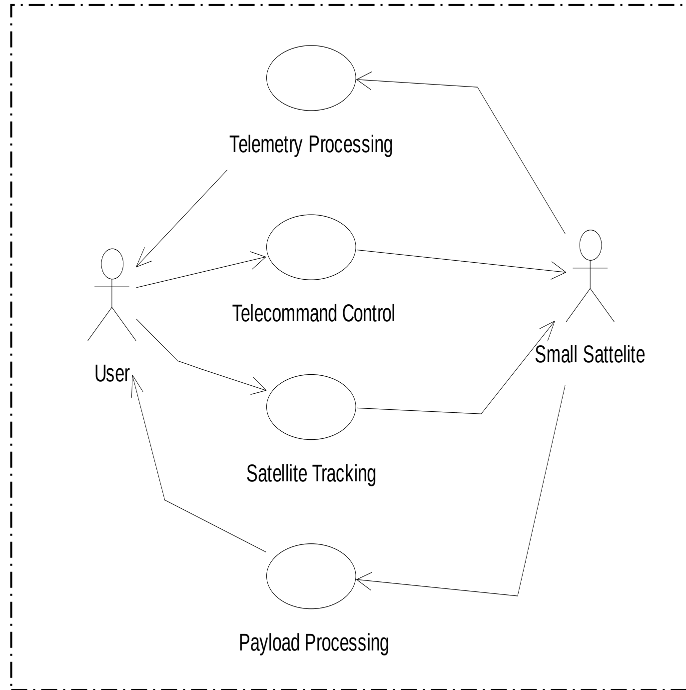

Fig. 2 Use case diagram of ground station software

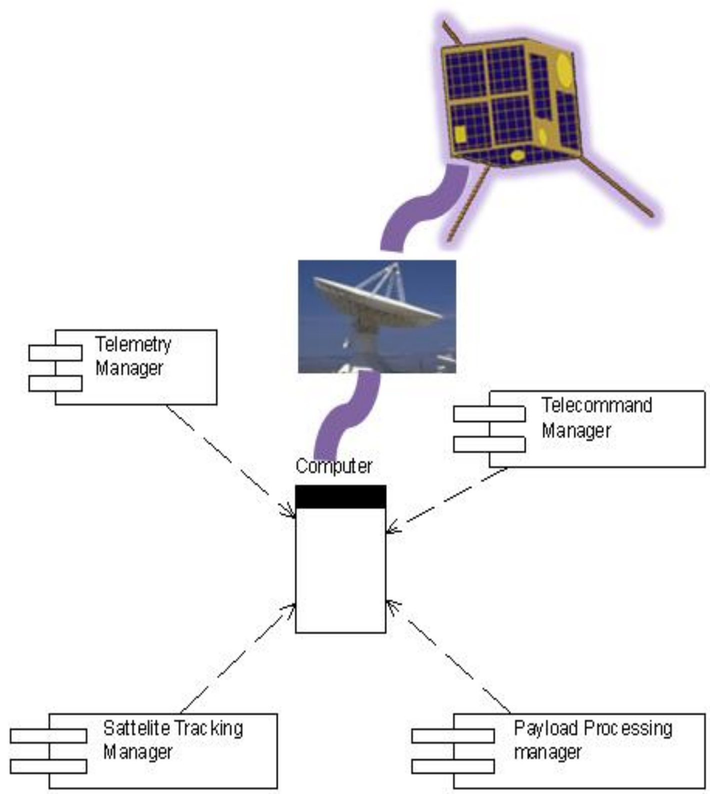

Fig.3 Component diagram of ground station software

3.1 Telemetry Data Manager

The telemetry data manager is responsible for obtaining the Onboard Telemetry data at the ground station. The demodulation and frame synchronization of the data is performed by the ground station equipment-Telemetry Interface Unit (TIU). This data is time stamped with the Ground Receive Time (GRT)

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and sent to SCC Computer via RS232 serial link. The telemetry data which is received from satellite is organized as data frames. The “Telemetry Data Acquisition” software receives the data and writes it in the shared memory and notifies the display module of the system. The “TM data Archival” s/w does some validation creates pass-wise TM data file and maintains a brief pass history file. Further, the “Real Time TM data processing” software does the EU conversion and updates the Parameter values in the shared memory. This data is distributed to the entire connected client machines by the processed “TM data server” software. The “Page Display” software displays the data on the terminal in formatted pages and the “Real Time Graphics” (RTG) software plots the data .The following section will describe about the task wise breakage of this software system. TM Data Manager consists of the software elements used for : i) TM Data Acquisition, ii) TM Data Archival, iii) TM Data Processing, iv) Real Time Page display, v) Real Time Graphics, vi) TM Data Server, vii) Parameter Table Manager, viii) Page Table Manager, ix) TM Data Retrieval Library, x) Event Recorder and xi) Event Data Offline Display.

3.2 Telecommand Manager

Through the uplink, the command is operated at the spacecraft level and its confirmation status is transmitted through the telemetry. This operation is managed by the telecommand manager. Besides controlling & operating the spacecraft for obtaining the status of the onboard subsystems some commands are uplinked from the earth station. The following section will describe about the task wise breakage of this manager. Tele-Command (TC) Manager Software Elements is used for: i) Tele-command Execution, ii) TC Data Acquisition, iii) TC Data Archival, iv) TC History Display, v) Software SOE. It also performs the activity of a tele-command directory manager and TC data retrieval library.

3.3 Tracking Data Manager

Tracking is the prime activity at the SCC to locate the spacecraft and control the position of the ground station, antenna to acquire TM data from spacecraft. It is also used to uplink the tele command to the spacecraft and downloads the payload data without any intervention during the pass. The following section will describe about the task wise breakage of this software system. The function of the tracking manager is to interface with the antenna to provide the look angles for tracking the satellite. Tracking Data Manager consists of the software elements used for i) Tracking Data Acquisition ii) Antenna Program Drive iii) Antenna Auto Drive iv) Tracking Data Archival, v) Tracking data History Display and vii) Tracking Data Retrieval Library.

3.4 Payload Data Manager

The primary object of the mission is to demonstrate the capability of building the small satellite system and use it for remote data sensing application. This mission carries a 1/2-Inch 3-Megapixel CMOS Digital Image Sensor with resolution 2,048 x 1,536 pixels. The special feature of the camera is Digital Clarity™, Image sensor technology with high frame rate, windowing capability, auto focus, snap short mode, Skip and Bin Modes and Smaller Format Resolution (QXGA to UXGA, SXGA, XGA, SVGA, VGA, CIF, QVGA, QCIF, etc). During the pass the image data is captured and recorded in the onboard memory and downloaded at a convenient time at a subsequent pass. The onboard system has the capability to store 2 to 3 scenes of data in the onboard memory. In the onboard, data is compressed in JPEG format and recorded. During the down loading of image, data is received at the earth station and transmitted via RS232 link to the spacecraft control centre. At the control centre the data is acquired and stored in the file system in a systematic way for further use. Also proper backup and restoring operation and housekeeping operations are carried out using software which is completely managed by the Payload Data Manager. Payload Data Manager consists of the software elements used to: i) Payload Data Acquisition and ii) Quick Look Display The figure 4 shows the class diagram of the ground station TTC software

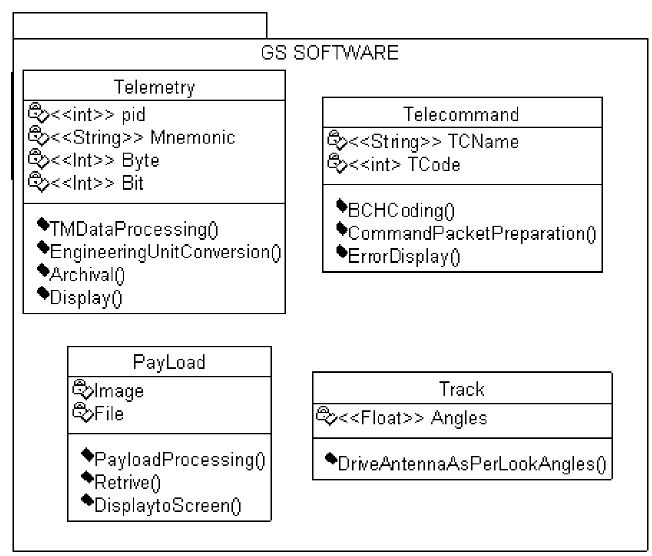

Fig 4: Class diagram of ground station software

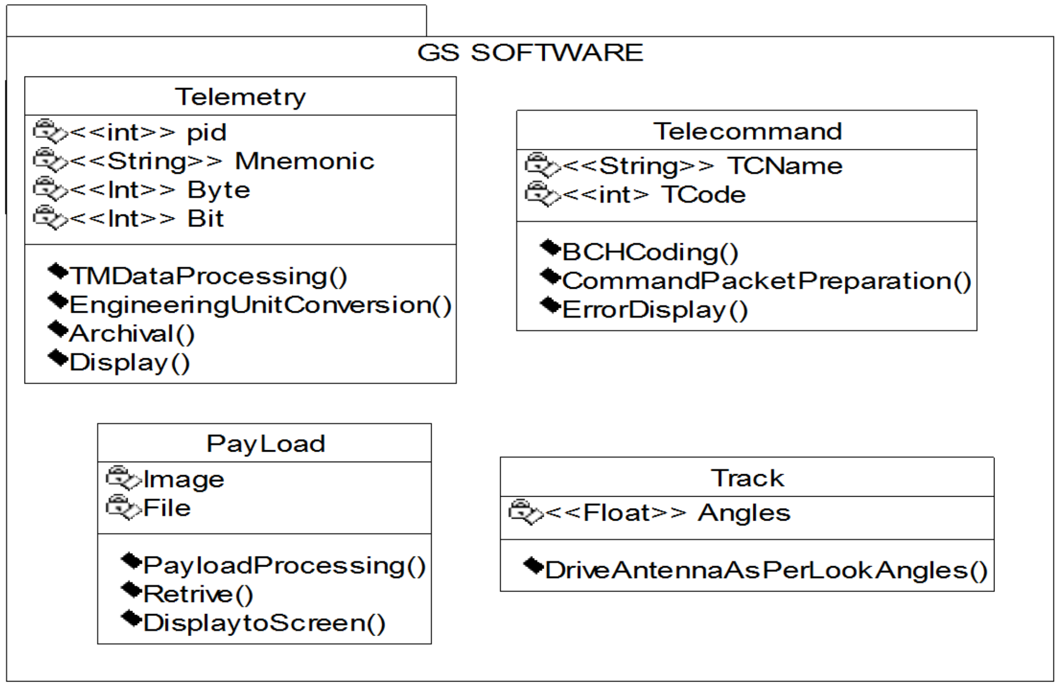

Fig 4. Class Diagram of Ground Station Software

The software is designed to provide a Graphical user interface in an interactive mode. The menu driven GUI system can facilitate the user to select the sub system page through the click of button. Following figure provides the conceptualization of the layout of the Health Monitoring system which consists of the identified pages. Fig 5 shows the GUI layout which has all the software components for users whereas Fig6 shows the GUI layout only for the commanding component.

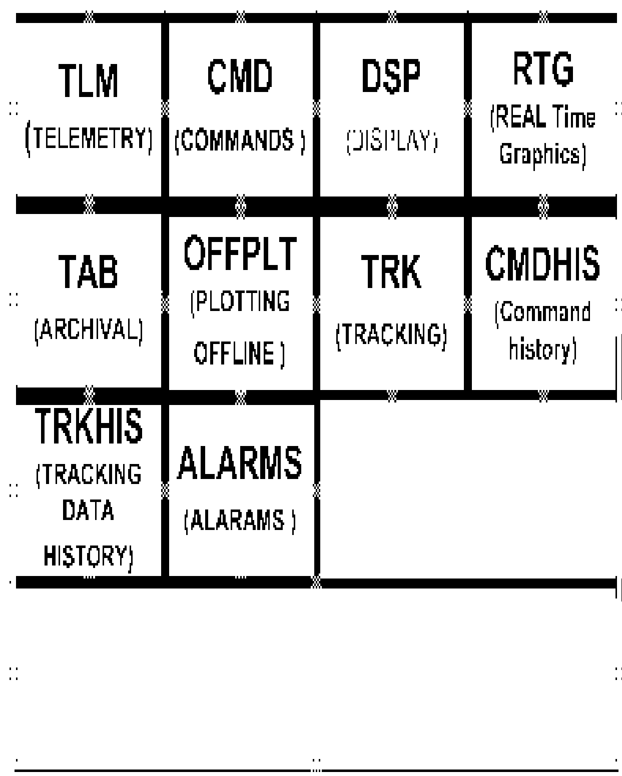

Fig-5 GUI Layout for user

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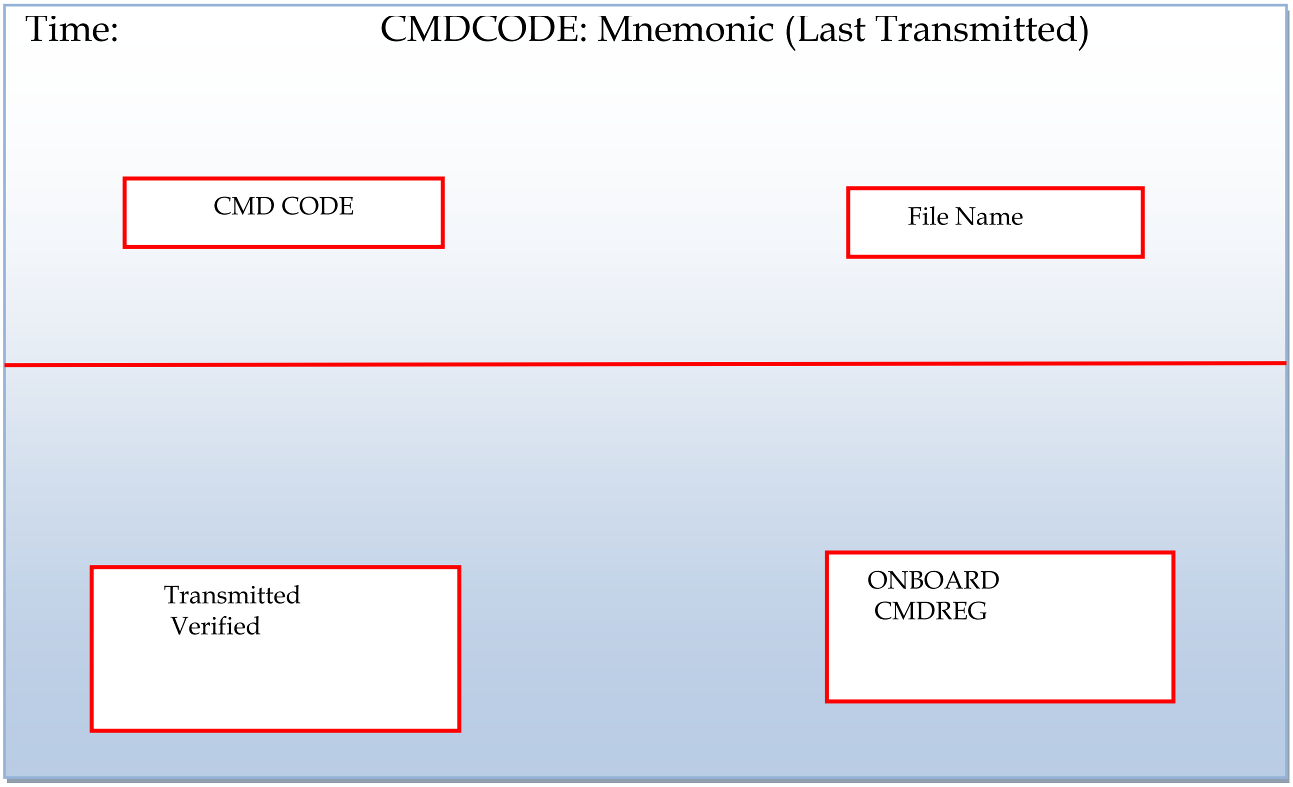

Fig-6 Description of the command code display

4 Implementation

This section describes the implementation algorithms for telemetry processing and telecommand control software. It also presents the typical output screenshots of the software module. Wherever components were not ready, stub modules were used for integration and testing. Requirement traceability metrics is being maintained for design, implementation and testing. Simulated data with all possible expected error conditions incorporated in test data have been used for testing the software. System load computation and system performance analysis is carried out.

4.1 Algorithms

1. Telemetry Processing

Step 1: [Read the incoming frame from the receiver]

Receiver->Decoding->Digital Signal->Data Conversion->RS232->PC

Step 2: [Archival: Store the frame in file]

Step 3: [Extract the data from frame]

Specific_Bits(Frame)

Specific_Bytes(Frame)

Step 4: [Engineering unit conversion as per database]

Step 5: [Send to display Screen]

2. Telecommand Control

Step 1: [Select the command]

Step 2: [Validate the command]

Step 3: [BCH Coding]

BCH Coding:

- BCH coding can be explained in the following steps:
- For any integer m ≤ 3 andt< 2m-1 there exists a primitive bch code with following parameters :
  - n=2m -1
  - n-k ≤mt
  - dmin≥2t+1
- This code can correct 't' or few random errors over a span of 2m-_1 bit positions.
  - The code is a t-error correcting BCH code.
- For example, consider m=6, t=3
  - n = 26-1 = 63
  - n-k=6x3=18
  - Dmin=2x3+1=7
- Hence the code would be (63,45).
  - Which explains that the codeword length is 63
  - Generated parity bit length = 63-45 = 18 bits
  - We assumed t=3, hence this code can detect and correct 3 error bits.

Step 4: [Prepare Command Bit pattern]

Step 5 : [Send command to the ground transmission system

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for sending to satellite]

4.2 Typical output (Software Screenshots)

The fig 7 captures the incoming raw telemetry data and latest valid frame of data is shown.

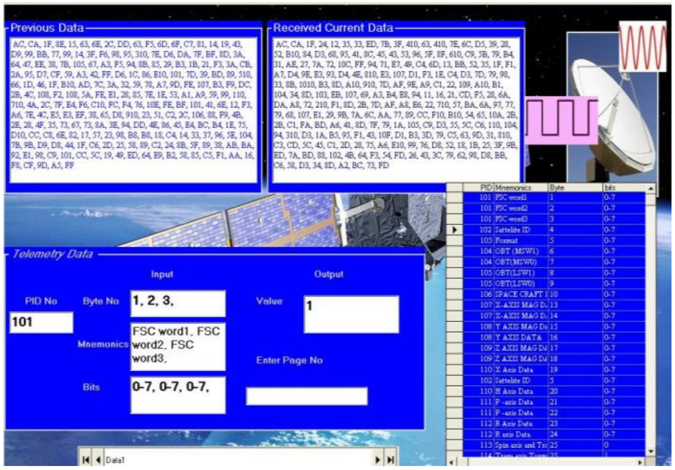


Fig. 7 Telemetry Module

Command code can be entered in the following GUI (fig 8).

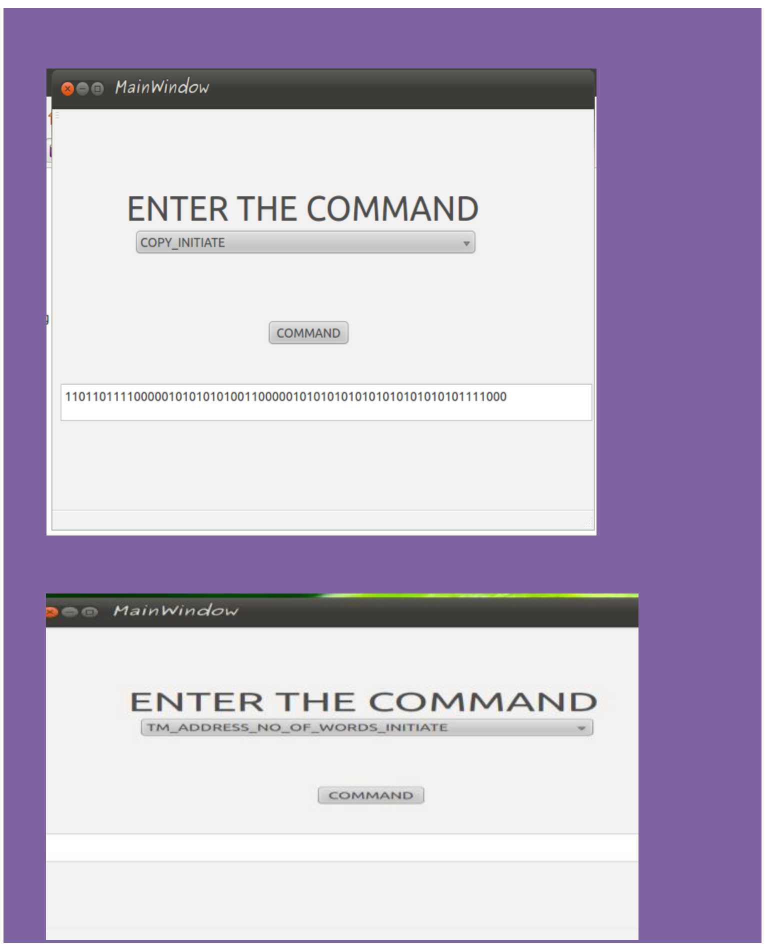
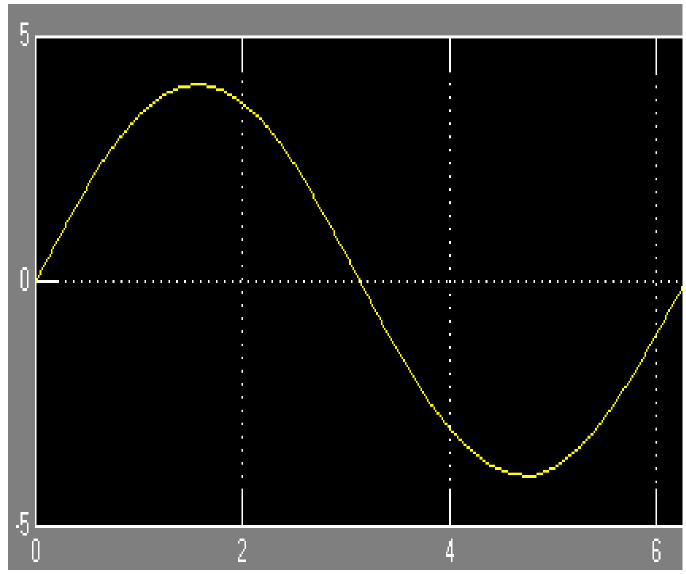
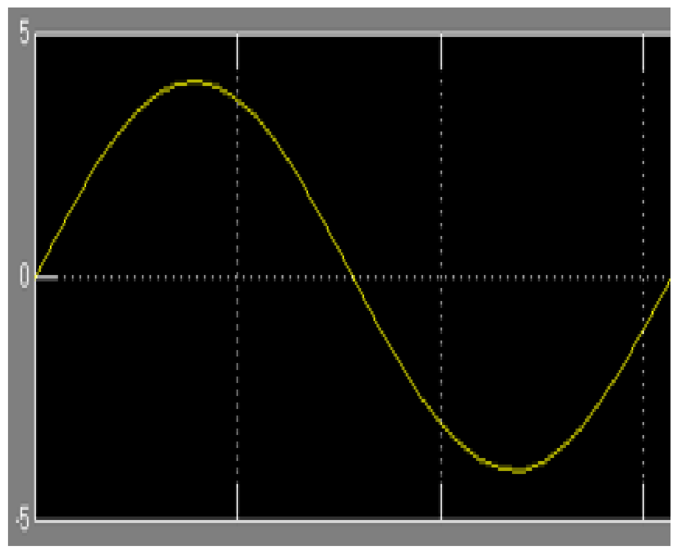


Fig. 8 Telecommand Module

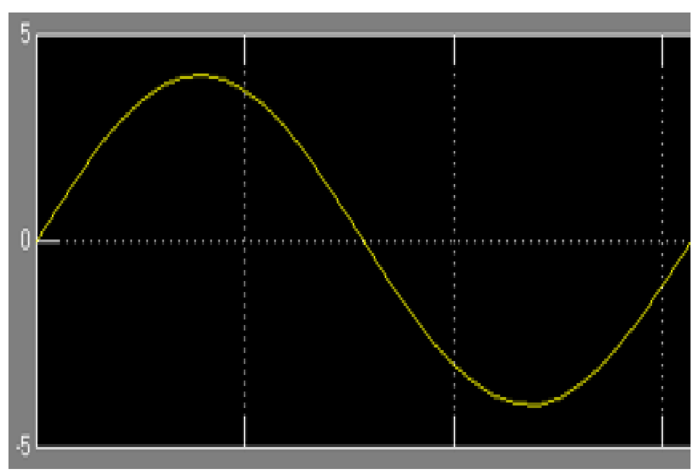
The real time plot is illustrated below. The parameters to be plotted as well as the time scale are selectable (fig. 9)



Yaw Data



Pitch Data



Roll Data

Fig 9. Display the Real Time Graph

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5. Conclusion

The design of component-based software for ground station to control the satellite has been presented. The design is general in nature and can be adapted to different satellites by providing corresponding database. Costeffective, userfriendly and optimized software with userfriendly interface has been implemented and it serves as a guideline for future nano-satellite missions. The feedback from the operation teams is used for further improvement in the existing software.

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