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MISSION "CAPTURE" SPACE DEBRIS MITIGATION SYSTEM

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Abstract— **space debris is turning out one of the main challenges for the various space activities. This document talks about the RF communication subsystem of the mission . The most effective means of reducing the space debris growth rate is by removing the satellites and other space instruments from orbits once they finish their mission (End-of-life disposal). Satellite communication includes two components- 1) On-board satellite system 2) Ground Station. Communication between satellite and ground station takes place in different modes 1according to the power, data etc. Important parts of this subsystem are Transceivers andAntennas**.

Keywords- space debries ,RFcommunication system ,on-boad satellite system, ground station ,transceiver and antennas.

I. INTRODUCTION

Space debris is the collection of objects in orbit of earth that are created by humans but no longer serve any useful purposes. This includes slag and dust from solid rocketmotors ,and surface degradation products such as small neddles,paintflakes,etc. The space debris is very hazardous if it collides with spacecraft or even a space walking astronaut. The main purpose is to express the mission profile as being ideal is to set a standard which has to be achieved by the system engineers. The following is the list of the objectives that determines the success criteria of our mission without any errors as expected in such a way that the actual value is as close to the desired values.

- Successful Antenna deployment in the desired orientation and itsverification.
- Successful Ground station telemetry and communication establishment
- Detumbling mode success and attain tri axisstability
- Successful Safe mode execution at any point oftime
- Drag enhancing and successful payloaddeployment
- Precise working of attitude determination and control system

The very important goal of the C&DH subsystem is to assure that the system is smart enough to interact with the different systems and co-ordinate their activities systematically and diligently and collect relevant details from different parts whenever required.

All subsystems are interconnected and work as a single unit. Hence a single flowchart to explain the entire mission seems very complex. Thus here are blocks of different flowchart for different subsystems that gives an elaborate explanation of their functions accordingly. Also, instead of having a haphazard overview of the flowchart, its explanation is also given for the easy understanding of the reader. The details of initialization, general details, effect of the operational mode on EPS and TT&C and other subsystems are explained in the design document.

In the capture II, the document talks about various operation mode of the satellite. In this chapter all the modes are explained in the respective section of this chapter named a,b,c, The chapter III gives the details about transceiver design and its specification. A complete information about antenna deployment and its working is given in chapter IV. The hardware implementation of mission 'CAPTURE 'is given the in the chapter V. The chapter V talks about the structure design after the deployment of theantenna.

II. OPERATIONMODES

The Telemetry, Tracking and Command subsystem is required to communicate with the ground station for up linking of ground inputs and down linking of the mission data acquired by other subsystems such as EPS, CDH, ADCS and Payload. The Mission "CAPTURE" involves 4 operating modes namely: Safe-Hold Mode, Detumble Mode, Mission Mode and Communication Mode. To change parameters of operating modes an uplink command is designed for each one of them. Uplink command consists of information for tasks which form the operatingmode.

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A. SAFE-HOLD MODE

In safe-hold operating mode, the on-board transceiver is powered on. The safe-hold operating mode is a low power usage mode designed to collect critical housekeeping data and hence, generating net positive power from the solar cells. Real-time satellite health data is broadcasted during this operating mode for analysing the state of the satellite in order to switch to another operating mode. Satellite remains in the Safe-holdmode until interrupted by a ground command or a power reset. The receiver will be in on state and can be commanded by a ground station anytime. The Real-Time transmission (Beacon) containing housekeeping data is transmitted actively at specific intervals.

Table 1. Safe-hold Mode DownlinkTelemetry

Quantity DATA	H/W	Interface	Bits	HEXChars
Time Stamp				
year	RTC	I_2C	12	3
month	RTC	I_2C	4	1
date	RTC	I_2C	8	2
hour	RTC	I_2C	8	2
minute	RTC	I_2C	8	2
seconds	RTC	I_2C	8	2
IMU				
X	IMU	I_2C	16	4
Y	IMU	I_2C	16	4
Z	IMU	I_2C	16	4
temperature	IMU	I_2C	16	4
Battery				
voltage	EPS	I_2C	10	3
current	EPS	I_2C	10	3
bus current	EPS	I_2C	10	3
current direction	EPS	I_2C	10	3
temperature	EPS	I_2C	10	3
Current				
5Vbus	EPS	I_2C	10	3
3.3Vbus	EPS	I_2C	10	3
transmitter	TCVR	I_2C	10	3
receiver	TCVR	I_2C	10	3
BootCount	Flash Storage	I_2C	12	3
Boot Time				
year	RTC	I_2C	12	3
month	RTC	I_2C	4	1
date	RTC	I_2C	8	2
hour	RTC	I_2C	8	2
minute	RTC	I_2C	8	2
seconds	RTC	I_2C	8	2
FlightComputer Temperature	ATSAM9260	A/D	12	3
Total			**274**	**69**

B. DETUMBLE MODE

In this operating mode, satellite is stabilized in its three axes. Detumble operation is carried on till desired orientation for the mission is achieved. The operation is a sub routine of the main program and is initiated by a ground command. The detumble mode is a relatively power intensive operation compared to the safe-hold mode. Based on the predetermined threshold values for angular rates of the satellite and the available power the detumbling task is performed. The detumble operation can a terminate autonomously if the angular rates match the desired values or it can be terminated by a ground command. The detumble telemetry is recorded into the flash storage at specified intervals. The recorded data is down linked during the communication operation.

Table 2.Detumble Mode Downlink Telemetry

Quantity DATA	H/W	Interface	Bits	HEXChars
Time Stamp				
year	RTC	I_2C	12	3

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month	RTC	I_2C	4	1
date	RTC	I_2C	8	2
hour	RTC	I_2C	8	2
minute	RTC	I_2C	8	2
seconds	RTC	I_2C	8	2
IMU				
X	IMU	I_2C	16	4
Y	IMU	I_2C	16	4
Z	IMU	I_2C	16	4
temperature	IMU	I_2C	16	4
Solar Panel				
voltage1	EPS	I_2C	10	3
voltage2	EPS	I_2C		
voltage3	EPS	I_2C	10	3
voltage4	EPS	I_2C	10	3
voltage5	EPS	I_2C	10	3
voltage6	EPS	I_2C	10	3
current1	EPS	I_2C	10	3
current2	EPS	I_2C	10	3
current3	EPS	I_2C	10	3
current4	EPS	I_2C	10	3
current5	EPS	I_2C	10	3
current6	EPS	I_2C	10	3
Side				
temperature1	EPS	I_2C	10	3
temperature2	EPS	I_2C	10	3
temperature3	EPS	I_2C	10	3
temperature4	EPS	I_2C	10	3
temperature5	EPS	I_2C	10	3
temperature6	EPS	I_2C	10	3
Battery				
voltage	EPS	I_2C	10	3
current	EPS	I_2C	10	3
currentdirection	EPS	I_2C	10	3
temperature	EPS	I_2C	10	3
Special Downlink				
Angular Rates				
initial	IMU	I_2C	16	4
final	IMU	I_2C	16	4
Battery Capacity				
initial	EPS	I_2C	16	4
final	EPS	I_2C	16	4
TOTAL			**434**	**109**

Table 3.Detumble Mode Uplink Command

Description	Bits	Hex	ValueDescription
Operating modeID	8	2	01Detumble Mode =01
Beaconinterval	8	2	XX (00toFF) 00 corresponds to 30 s; Xonds to increments of 10s; The freq. can be varied from 10 to 2550 s (42mins)
Batteryvoltage	8	2	XX (00 to FF) Signed two's complement Responds to 7.0v; each increment is 0.01 v
Loopcoun	8	2	XX (00 toFF)
Ybound	8	2	XX (00 to FF) 00 corresponds to thedefault
Zbound	8	2	XX (00 to FF) valueof 0^0/s. Bounds range from0 to2^0/s
Total	104	26	01XXXXXXXXXXXXXXXXXXXXXXXX

C. COMMUNICATION (COMMS) MODE

Detumble and Mission operation telemetry data acquired during the respective operating mode is stored in the flight computer flash storage. The communication operating mode is designed as a sub routine of the main program to transmit the stored data to ground station. Based on the data type requested in uplink command, the communication operation implements one of the two telemetry access functionalities. Similar to the detumble operation the communication mode is a relatively

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power intensive operation. Based on the available power resources the satellite proceeds to access mission validating data for a particular operating mode and prepares to downlink it to a ground station. This operation terminates autonomously or through ground control.

Table 4. Communication(comms) Mode Uplink Command

Description	Bits	Hex	Value / Description
Operating modeID	8	2	02 Comms Mode =02
Beaconinterval	8	2	XX (00 to FF) 00 corresponds to30)
Battery voltage	8	2	XX (00 to FF) Signedtwo's complementinteger;
Data type	8	2	XX Detumble - 01; Mission Ops -03
Pagenumber	12	3	XXX Starting page number in memory
Numberofpages	12	3	XXX Number of pages to transmit.
Commsinterval	8	2	XX (00 to 99) Transmission interval; starts ms
Transmission Repetitions	4	1	X (0 toF) Number of repeats of broadcast (0 to 15repetitions)
Total	68	17	02XXXXXXXXXXXXXXX

Table 5.Communication(comms) Mode Downlink Telemetry

Quantity DATA	H/W	Interface	Bits	HEXChars
Time Stamp				
year	RTC	I_2C	12	3
month	RTC	I_2C	4	1
date	RTC	I_2C	8	2
hour	RTC	I_2C	8	2
minute	RTC	I_2C	8	2
seconds	RTC	I_2C	8	2
Battery				
voltage	EPS	I_2C	10	3
current	EPS	I_2C	10	3
current direction	EPS	I_2C	10	3
temperature	EPS	I_2C	10	3
Transmitter				
voltage	TCVR	I_2C	10	3
current	TCVR	I_2C	10	3
temperature	EPS	I_2C	10	3
MISSION MODE TELEMETRY DATA / DETUMBLE MODE TELEMETRY DATA				
TOTAL			118	33

III .TRANSCEIVER DESIGN

ISIS TRXUV VHF/UHF Transceiver [1], *fig.1* is a full duplex system with telemetry, telecommand& beacon capabilities on a single board. Its design is based on the transceiver on-board Delfi-C^3 satellite (2008). Some ofits notablefeaturesareadditionalCW(Morsecode)beaconmode, receiver loopback mode (usable as transponder [2], for ranging or uplink checking), on-board AX.25 command decoding. Heritage in Space since its first mission in 2012 (PWSAT). VHF and UHF amateur RF bands are being used for communications; these enable radio amateurs worldwide to receive satellite data using a modest equipment setup. The transceiver doubles as the transponder for radio amateurs. The linear transponder will relay a 40 kHz wide pass band from the UHF band to the VHF band. This provides a very flexible system. If necessary, the transponder can be used for Doppler tracking to accurately determine the satellite's orbital parameters. Compatible with most of the Power Systems and On-BoardComputersusedinCubeSat.

fig.1: ISIS TRXUV VHF/UHF Transceiver

Transceiver Specifications

Power supply 6.5-12.5VDCTransmitterfrequencyrange 145 – 148MHz(VHF)Transmitpower 22 dBmaverage

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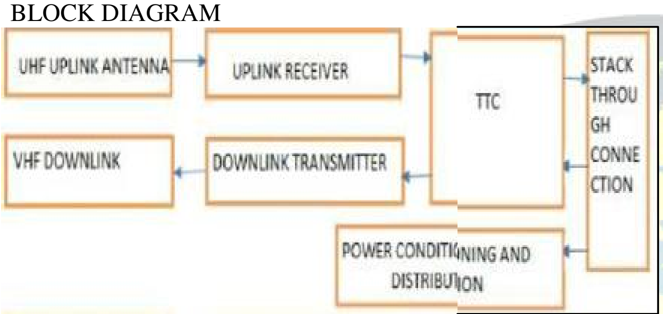
Transmittermodulationscheme Binary PhaseShiftKeying(BPSK)
Downlinkdatarate 9600 bp
Receiverfrequencyrange 430-439MHz(UHF)
Receivermodulationscheme Audio Frequency Shift Keying(AFSK)
Uplinkdatarate 1200bps
Protocol AX.25
Interfaces 104 pin Cube SatKit stackthrough connectorcarrying:
6.5-12.5V DC power supply
I_2C bus interface
RF input / output: SMA, female, 50 ohm

BLOCK DIAGRAM



IV. ANTENNA DEPLOYMENTMECHANISMS

The dipole antenna for transmission and reception are of length 35 cm and 100 cm respectively.These antennas are coiled and stowed inside the frame provided (Fig 2.a). The UHF dipole antenna on the either side is brought together, similarly is the VHF antenna and the feed lines from these antennas are connected to coaxial connectors. The other end of the transmitting and the receiving antennas are locked with the help of a latch. The latches on the opposite sides are connected together using a nylon wire. These nylon wires (in blue) which is fed in and is surrounded by a filament. Nylon fibre is used to apply required tension to prevent deployment of the antennas. When the voltage is applied, current flows through the coil, this eventually heats up the nylon wire, the tension is released, the latch is opened and the antenna gets deployed.

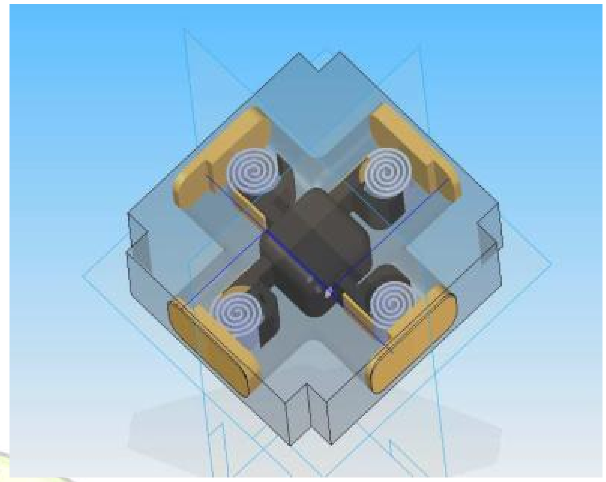


fig.2.aCoilingandstowingofUHFandVHFantenna

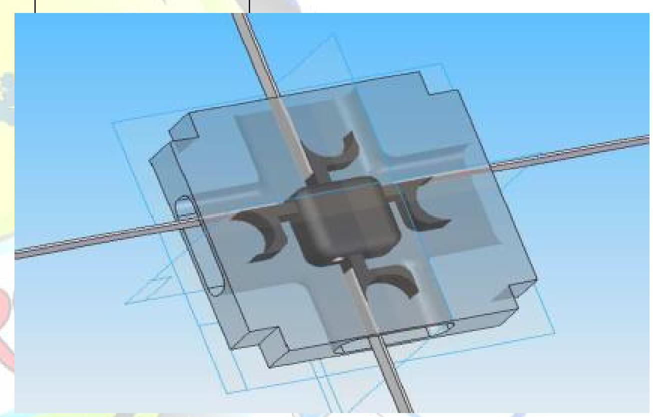


Fig2.b 3D view of the antenna after deployment

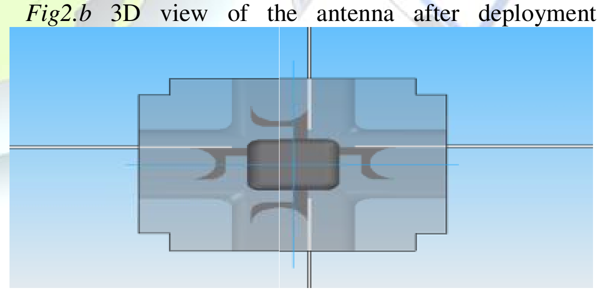


Fig 2.c Top view of the antenna after deployment

V. HARDWAREDESIGN

1) ADCS :The CAPTURE Sat emulating debris hasthe following sensors and actuators which help to demonstrate Debris Mitigation.

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- **Inertial Measurement Unit (IMU):**

The IMU contains Tri-Axial Magnetometers (I2C interfaced to the C&DH), Accelerometers (I2C or SPI interfaced to the C&DH) and Gyroscopes giving their measurements in X, Y and Z axis, it is a MEMS Sensor and is SPI interfaced to the C&DH Unit allowing a Full DuplexCommunication.

- **GPS Receiver Module:**

The modules available can be interfaced to the OBC either using RS232 or a TTL Serial Interface, with the help of this module the Aranea Sat's position can be easilydetermined.

- **SunSensors:**

Sun sensors are interfaced to ADCS board using A/D Pin. Due to the geometry of the solar cells, at any instant when the spacecraft is in the Sun-lit phase only three of the solar cells will be able to view the Sun.

- **Single Axis Reaction Wheel:**

The Reaction Wheels can be interfaced using RS485 protocol as the chosen OBC supports the protocol which is capable of higher bit rates and faster performance .The chosen device supports RS232 hence a converter(RS232-RS485) is used to improve its efficiency .

- **Magnetic TorquerRods:**

The torque rods are used for attitude control based on the Earth's magnetic field. These rods are connected to the ADCS board using Driver.

2) EPS:

The EPS Unit having to control the different Voltage and Current levels have to be analyzed using an AD Converter as the signals received are analogue values.

The sensed temperature values are the house keeping data that has to be regularly checked for the maintenance of the EPS Unit.

3) TT&C:

Antenna Deployment:

Two antennas for Uplink/Downlink has to be deployed after powering the EPS/C&DH unit, for the deployment a hardware switch in the form of GPIO pins are used to initiate the deployment mechanism within TT&C board interfaced with OBC. After the event a flag is raised indicating the status.

The transceiver board containing the modulation and demodulation schemes is interfaced to the OBC. The transmitter is connected by a 5-wire interface and receiver is interfaced through SPI.

4) PAYLOAD:

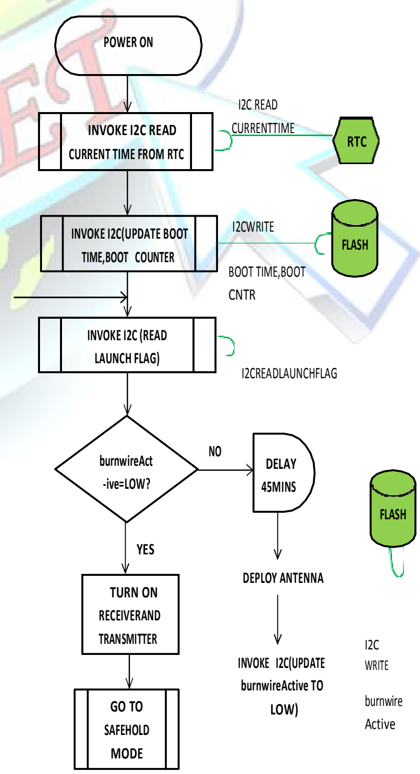
Payload container, electrostatic generator (vande-graff),

Metallic fibres – 1 micron thick, electrical insulation for its container from space-craft, super-capacitor or capacitor, I.R.camera, external magnetometer with telescopic boom, accelerometer.

VERIFICATION OF ANTENNA DEPLOYMENT :

- SATELLITE HANDSHAKE VERIFICATION: The receiver and transmitter is turned on, if the burnwir Active value is LOW. The receiver and transmitter frequency is tuned which enable. Telemetry is transmitted by transmitter. If the data is received by the satellite itself this verifies the deployment ofantennas.
- GROUND STATION HANDSHAKE VERIFICATION: The receiver and transmitter are set to their default frequencies. Telemetry data is transmitted. If the ground station receives signals, it establishes a hand shake by sending data to it. Satellite on receiving data verifies deployment.

ground the deployment is verified



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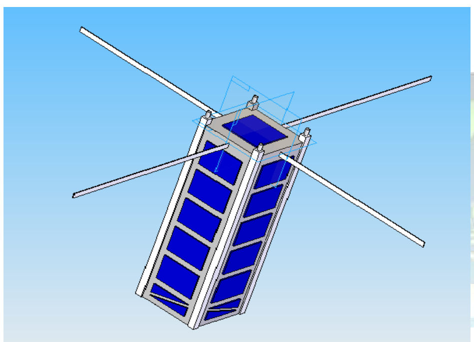
VI. STRUCTUREDESIGN

The Cube Sat structure was designed using Solid Edge software to ensure that all components fit together without interference, according to the specifications given above.It follows the 3-U form factor of the dimensions 30×10×10 cm^3. The plyload and its container take up ~0.7 tot 0.8-U of the structure. The structure is covered with solar arrays on all sides which are used for power supply throughout the system, as is clear from the fig.4.There is an antenna deployment mechanism at one of the 10×10 cm^2 sides, the other having the payload.



VII. CONCLUSIONANDFUTUREWORK

The mission 'CAPTURE' aims at removing various space debris revolving in near earth orbit. The very important goal of our mission CAPTURE is to assure that the system is smart enough to interact with the different systems and co-ordinate their activities systematically and diligently and collect relevant details from different parts whenever required. The payload plays a key role in he entire mission. Our payload releases the spindle shaped fiber which is electrically polarized and helps in debrismitigation.

Our work was also supported in part by ISRO through PES University , Bangalore. A proposal of our work was submitted to ISRO.

In future, our work shall be further carried out by ISRO and would make it as a successful launch in near future.

Acknowledgement

I would like to thank DR..SharanAsundi of TUSKGEE University ,USA.I wish to express my profound thanks to PES University ,Bangalore for their contribution in building such module. Our work was also supported in parts by INDIAN SPACE RESEARCH ORGANIZATION(ISRO).I would also like to thank ISRO for their support in our mission.

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