Thapar University Student Satellite Initiative

In consultation with

INO, Canada

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About Thapar University

Thapar University (TU) was established on 8 October 1956 when foundation stone was laid by the first President of India Dr. Rajendra Prasad as an Engineering College named Thapar Institute of Engineering and Technology. Thapar University offers Post-graduate and undergraduate programs in Engineering, Science, Management and Social Sciences. At TU we strive to maintain an environment that encourages scholarly inquiry and research, a spirit of creative independence and a deep commitment to academic excellence. We see our students as unique individuals with different interests and aspirations. The diverse programs and activities aimed at developing quality of mind, ethical standard, social awareness and global perspectives, let the students shape their own TU experience and grow. Our alumni have excelled in varied fields such as business and industry, administrative and regulatory services, research and education and social and human rights organizations.

Thapar Technology Campus is synonymous with a diverse community that is committed to scholarship, entrepreneurship, research and development. Our University is ranked amongst India’s top technical universities by independent research organizations. The combination of programs, facilities and above all the people has created a learning experience that is stimulating, supportive and challenging, while providing a competitive edge.

Introduction

A large number of groups all around the world are currently working on the design and development of small satellites. Especially for students and universities a satellite project can only be realized if the total project cost remains modest. As the cost of a spacecraft is, amongst other things, related to complexity of the system and the absolute size of the satellite, a very small satellite is the perfect opportunity for these groups to participate in space engineering and space science.

The space age started with the launch of very small satellites, although this was more a necessity than a design choice. As soon as launcher capacity increased, satellite volume and mass increased accordingly to accommodate larger payloads and to increase the lifetime of the spacecraft. However, throughout the decades, Small satellites have always found a place in the space sector as a relatively cheap and fast way to access space with new concepts and technologies. For small countries and local initiatives such as research institutes and universities small satellites function as a relatively easy way to join the frenzy of the space race. With the recent advances in the efficiency of electronics, semiconductor technology and increased computing power it became possible to take satellite miniaturization to the next level.

However, in 2003 a new level in satellite miniaturization was reached when six so-called CubeSats were launched into orbit. CubeSats are very popular among universities and other non-commercials groups and around the world as a CubeSat means moderate mission cost. Furthermore, during the past few years a complete infrastructure and design framework has been set up, of which the participating teams can benefit. Over 50 teams worldwide_have developed their own CubeSat which includes *Stanford University (USA), Cornell University (USA) ,Tokyo University(Japan) , University of Toronto (Canada)* to name a few.

Thapar University Student Satellite Initiative

Thapar University Students Satellite (TUSSAT) project is a project taken up by students of Thapar University. Its primary aim is to generate interest, provide knowledge and create experience in the satellite development. Under this project students have started working on TUSSAT – I. The aim and objective of TUSSAT – I project is to develop a fully functional, low cost, low mass microsatellite which can be made within a time frame of 18 Months and launch it into orbit.

This project will enable students and faculty members to gain knowledge and to have hands on experience with a real satellite mission with collaboration of various departments of University. It will empower students with the skills to develop the Satellite through various phases of Design, Analysis, Fabrication and Testing until the Flight Model is made.

Students have been given a unique opportunity to participate in the design, implementation, integration and testing phases of the satellite project. The design of the satellite will be kept simple with more emphasis on reliability rather than precision as this will be our first mission.

In this regard we have already talked to ISRO who has readily agreed to mentor us. Once we are through with an initial design we will be submitting our reports to ISRO which will review it and suggest possible flaws.

FOREST FIRES

Forest fires are among the major causes of degradation of forests in India. As per an estimate by the Forest Survey of India *(the State of Forest Report,1995*) which is based on field inventory, about 53% of India's forest are prone to fire; of this 9% forest area is affected by frequent fire while in 44% have occasional fires. The ecological and socio-economic consequences of forest fires in India include loss of timber, bio-diversity, wildlife habitat, wood and other forest products, damage to water and other natural resources, loss of natural regeneration etc. Bahuguna (2002) estimated that average annual loss due to forest fires in country is about Rs. 440 crore (US$ 100 millions).

Effective forest fire control measures become difficult in India due to lack of timely information on forest fire occurrence. FSI is monitoring forest fires of the country since 2004 using remote sensing based system developed by the University of Maryland (USA) and NASA viz MODIS Rapid Response System.

TUSSAT-I Payload

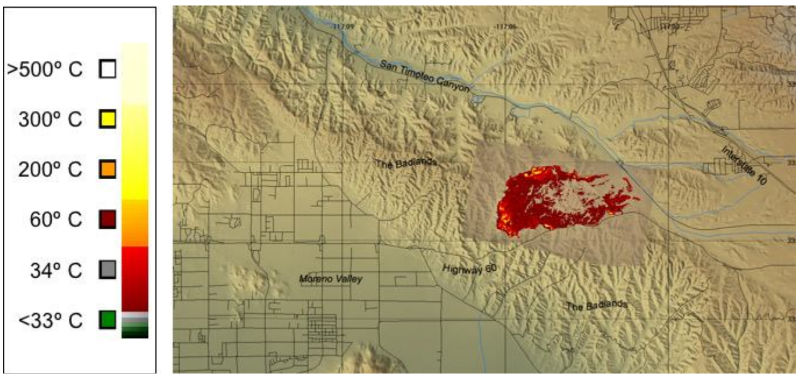
Mission objective:

The mission objective of the fist student satellite of Thapar University is to develop a single, prototype satellite that will provide thermal imagery for mapping forest fire.

Microbolometer – A microbolometer is a specific type of bolometer used as a detector in a thermal camera. It is a grid of vanadium oxide heat sensors atop a corresponding grid of silicon. Radiation from a specific wavelength strikes the vanadium oxide and changes its electrical resistance. This resistance change is measured and transformed into a temperature that can be represented graphically.

Because a microbolometer is an uncooled thermal sensor, it provides high resolution without the exotic and expensive cooling methods such as liquid nitrogen required by earlier sensors that made them expensive to operate and unwieldy to move. Also, older thermal imagers required a cool-down time in excess of 10 minutes before being usable.

Sample Picture by a Microbolometer:



Technical Requirements

Orbital

The orbital requirements will be considered as mission information in support to the trade-off activities that may need to be performed.

Parameter	*Value*
Orbit altitude	650 km
Ground sampling distance	5 km

Camera

The lifetime requirements will be considered as mission information in support to the trade-off activities that may need to be performed. No assessment or accelerated life test will be performed to verify the design against these requirements.

Parameter	*Value*
Array format	256x1
Readout mode	self-scanning
Spectral band – center wavelength	10 +/- 0.1 um
Spectral band – FWHM	4 +/- 0.1 um
NETD (10 Hz equivalent)	< 150 mK @ 300 K scene
FPA temperature control with uploadable set point	FPA temperature stabilized within ± 10 mK using a thermo-electric cooler
Storage lifetime	36 months
Mission lifetime	12 months

Spacecraft resources

Parameter	*Value*
Power	< 5 W
Mass	700 g
Volume	15 x 9 x 9.5 cm^3
Power rails	+5 V, (+/-12 V may be required)

Thermal environment

Parameter	*Value*
Allowable flight temperature	+10 to +18°C
Survival temperature	-45 to +70°C

Radiation

The radiation requirement will be considered as mission information in support to the trade-off activities that may need to be performed. No assessment or reliability analysis will be performed to verify the design against this requirement. Also, to minimize the cost, commercial grade electronic components are used. The microcontroller used in the design has however flight heritage on other nanosatellite missions.

Parameter	*Value*
Radiation hardness	10 krad over 12 months

Random vibration

Frequency (Hz)	*Level*
20	0.026 g^2/Hz
20-50	+6 dB/oct
50-800	0.16 g^2/Hz
800-2000	- 6 dB/oct
2000	0.026 g^2/Hz
Overall	14.1 grms

The deliverable for this work package is a look-up table allowing the on-ground processing of the raw data to produce top of the atmosphere calibrated radiances or brightness temperatures.

Benefits:

- ✓ Helps in estimating the areas affected by particular fires.
- ✓ Helps in understanding the Level-of-damage estimation on the basis of remote sensing from space can also be of considerable help in terms of catastrophe management because it is both time-saving and cost-effective
- ✓ Helps in analyzing and planning of post-fire restoration actions, allowing more investment to be targeted at the areas that are most badly affected.
- ✓ Wilderness fires are an important contributor of carbon dioxide to the atmosphere, so Information about forest fires is also of strategic value for protocol implementation and treaty verification.

Various Subsystems in a Satellite:

Communication & Ground Station:

Communication subsystem is used to transfer the data which includes health monitoring as well as telemetry data from the satellite to the ground station and also to send various commands from the ground station (We are still working on whether we require an uplink or not).
It is divided into two modules:-

- On Board Communication
- Ground Station

On Board Communication takes the data from the on board computer, compresses it, converts it to the proper format and transmits it to the ground station by the use of transmitters.

Ground station identifies the beacon emitted by the TUSSAT, restores the link with satellite and receives the data. The Ground station consists of antennas and computers with proper software uploaded so that data can be decoded to the useable form.

We are currently working on a downlink frequency of about 437 Mhz. We plan to use a patch antenna on board for data transmission and crossed Yagi-Uda antennas to receive data on the ground station.

Attitude Determination and Controls:

The ADCS (Attitude Determination and Control System) is the part of the Satellite where position, velocity and orientation are determined and controlled. TUSSAT needs to orient, rotate and stabilize itself so that power, communication and payload subsystem can work properly. This will be achieved by Attitude Determination and Control Subsystem. The main tasks of this system are:

- To stabilize the satellite after the launch by reducing and controlling the spinning rate
- To determine where the payload is pointing at in order to take appropriate data.
-To position it so that effective communication can be established with

ground.
-To orient it to optimise the power received by the satellite.

At present we are working on using magnetometers and sun-sensors for orbit determination and validation from the orbit model and GPS device present on board. We are planning to use magnetotorquers to control the attitude of the satellite.

Structure:

The purpose of the structural subsystem of a satellite is to provide a simple and sturdy structure that will survive the launch loads and a suitable environment for the operation of all subsystems thought all phases of mission life, while providing an easily accessible data and power bus for debugging and assembly of components. Moreover the structural subsystem will carry support and mechanically align the spacecraft equipment.

Structural design shall aim for simple load paths, a maximisation in the use of conventional materials, simplified interfaces and easy integration. Due to weight constraints the structure should be the lightest possible to allow more margins for other subsystems.

The various steps to be followed for structure design include:

1. Create a 3-D model having all components in their various positions using software such a ProEngineer or Solidworks.
2. Test the model for static loads as well as harmonic vibrations to be followed by the structure during launch using softwares such as ANSYS 12 or ABACUS.
3. Change the design and again carry out different analysis till we get an acceptable structure.

Thermals:

A Thermal Control System (TCS) is a system that needs to maintain all the temperatures of all hardware items of a satellite within their allowable and specified temperature limits. The TCS has to perform this task during all mission phases of the satellite while using as little system resources as possible. In general, the satellite thermal control engineer has a number of techniques at his disposal to control the temperatures of the satellite.

Such techniques are:

- *Passive thermal control* such as paints, finishes, coatings, radiators and Multi-Layer Insulation (MLI),
- *Semi-active thermal control* such as louvers and Maltese crosses,
- *Active thermal control* such as heaters, pumped fluid loops and refrigerators.

In case of nano and pico-satellites there is a relatively large surface area compared to the internal volume of such small satellites and are subject to relatively large heat inputs from external sources such as direct Solar radiation and Earth infrared radiation. Combined with highly integrated systems that can dissipate large amounts of power in a small volume this requires the careful design of the thermal control system. Furthermore, small satellites are typically orbiting the Earth in Low Earth Orbit (LEO) which results in a large number of thermal cycles as the satellite is alternating between being in the shadow of the Earth and being exposed to direct Sunlight. The use of commercial components and parts with a typical temperature range of -40ºC to +80ºC or less is also an important factor in the need for thermal control for these types of spacecraft.

Power Subsystem:

The power supply will rely on batteries and solar panels, which will be placed on the surfaces of 5 out of the 6 sides of the satellite.
The available power on board the satellite will depend on the amount of daily sunlight on the solar panels to re-charge the batteries as well as on the environmental effects in the orbit.
The power system then transmits the power to all other TUSSAT-1 components as per the need.

As of now what we have done for the power subsystem includes

1. We have found out how to calculate the amount of power falling on each surface from direct sunlight of the satellite. We are currently working on calculating the exact power available to us using MALAB (We are doing all calculations using a dummy orbit as we will not be sure about our orbit for a very long time. We are also

considering on how to include the affect of MPPT in these calculations.)

2. We are also studying albedo and finding out if it can be a source of power for our satellite.
3. We have also developed a basic circuit for our power board. We are currently working on making a small model of a circuit with same basic features.
4. Our circuit will include solar cells, MPPT, microcontroller, battery, and battery protection, voltage regulators according to various possible loads and voltage protection for all loads.
5. We have also studied various solar cells and found triple junction GaAs cells to be the best for our purpose.
6. We have found out Lithium –Ion batteries to be the best suited for our purpose and will choose a battery depending on the mass constraint and the maximum power we can store.
7. It will also be providing health monitoring data to the On Board Computers.

On Board Computers:

The on board computer is the brain of the tussat. Its major task is to make the autonomous TUSSAT function properly.It keeps a check on the working of the other subsystems.On board computer has a direct interface with ADCS, POWER, PAYLOAD and COMMUNICATION subsystem.

Its major tasks are:-
a) Collects the data from ADCS sensors, executes the control algorithm and then drives the actuators.
b) Collects the data from payload sensors, health monitoring data from power microcontroller and store it on board.
c) Compress the data and transfer it to the communication microcontroller for the proper downlink.

Failure of OBC components may result in failure of TUSSAT mission, so a lot of emphasis is placed on robustness and resistance of the OBC to errors and that may occur.