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Dicosat-Research Satellite for a 5th Grader

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***Abstract*—The CubeSat A.K.A DiscoSat Satellite is an educational satellite scheduled to be launch in late 2015. Its main focus is to be a research unit for researchers as well as a learning model for young school graders. It will enable one to learn the in and out of running a real time satellite operations and communication. The primary goal of the project is to employ a small, CubeSat spacecraft to evaluate, demonstrate and validate a real time simulation for the students in mission coordinated teams, to control and operate a CubeSat in orbit. This will be a real time simulation for children to actual operate in real satellite control environments. The objectives of the CubeSat project will include a develop ground control and flight systems to be ready and a flight system to control and simulate the actions of a CubeSat. The systems will be child friendly to instigate an interest in the child for future aerospace and satellite research programs, while also developing a knowledge curriculum for satellite courses. The end goal is to have a deployable communication and software architecture across the world for research and development using the CubeSat satellites. In addition to the common bus structure, unique design traits (such as tethered gravity gradient control) and extensive hardware and software prototyping are discussed in the paper**

Keywords—CubeSat, Communication, Mission, Satellite, Aerospace

I. INTRODUCTION

The DISCOSat-1 mission is the first CubeSat mission to passively measure the frequency, velocity, and directionality of the small (~≤1mm) component of man-made and meteoritic material in low Earth orbit (LEO). While larger components of the space debris environment can be detected remotely, the distribution of small material – which comprises the vast majority of impacts on satellites – can only be detected in situ by analysis of returned exposed surfaces and is not yet well constrained. [1, 2, and 3]

The temporally resolved science data acquired by this 2U mission will guide models of the small size flux as relating to satellite hazards and influx of material onto the Earth. The Discovery Museum and Planetarium will leverage its assets to lead an educational satellite mission to inspire and engage the community through its education and public outreach programming, especially in the urban community of Bridgeport, Connecticut.

This educational mission will also engage and educate in K-8 science curriculum for 460 students, 70% of whom are from urban and underrepresented populations, at Discovery Magnet School; educational partner institution to Discovery Museum and Planetarium. Higher education and industry partnerships with University of Bridgeport and Hamilton Sundstrand will serve to educate and employ the future workforce through the design, development and operation of the satellite payload, strengthening STEM workforce skills for both graduate and undergraduate students.

II. SYSTEMS DESIGN

The mission is geared toward answering scientific research questions regarding the flux and characterization of small space debris particles in LEO. This is an active and important area of research that is highly important to future missions and is relevant to multiple NASA strategic goals [4]. CubeSat are deployed in groups of three from the Poly Pico satellite Orbital Deployed (P-POD), structured at CalPoly-San Louis Obispo [5].

A basic CubeSat-based stage was launched which acknowledged necessities of LEO-relied science missions was made also two distinct science and altitude controller systems was made to satisfy both science missions.

A. Mission Plan

Baseline is to launch CubeSat from the P-POD at 300-km altitude and 60 degrees.

The following is outline of mission

Day 0: Deployment from P-POD launcher, separation of CubeSat.

Day 1-10: Passive attitude unwavering into data-collecting formation.

Day 11-30: Science data gather and downlink.

Day 31-44: Mission margin, augmented data gathering.

Day 45: De-orbit and end-of-life.

B. Separation Procedure

The two CubeSat will go their distinct ways by a spring among both satellites as seen in CubeSat Design Specifications Document [4] which will give a velocity of 5 mm/s.

In DC/PIP mission specified friction equipment will bring CubeSat to zero velocity as they are launched of 10-meter tether. In GPS mission a slow drift will be present which will detach satellites to more than 100 meters and this action will be elaborated in section 5.

C. Mission Modes

Table 1 defines the modes of operation of the CubeSat system.

Table 1. Mission Modes

Mission Mode	**Task**
1	Deployment/power on
2	Stabilization
3	Magnetometer calibration
4	Science data collection 5 Ground communication
6	Conserve power/recharge
7	Standby

Modes 1 and 2 are viable for launching and steady method initially. Mode 3, is where magnetometer detects peak amplitude Mode 4, gathers data which is main source 5, ground link, Mode 6, save power and recharge. Mode 7, standby mode only.

D. Internal and External Configuration

Figure 1 illustrates the structure where large toroid is gravity gradient and damper encloses tether launcher.in this figure and boom process of GPS also relates to this procedure links and science cards are placed in a stack I bottom face and batteries are outline in a detached box as seen in figure.

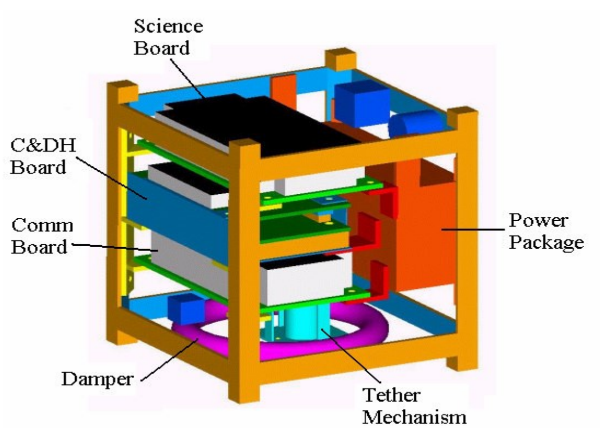


Figure 1. Internal Configuration

Figure 2 shows enclosure of outside structure but both structures give permission to an RJ45 Ethernet port and a kill switched recommended by CubeSat [4] while DC/PIP mission has a two patch antennae for conducting experiments and GPS mission has GPS antennae ad both of them have similar charges.

E. Mass Budget

Table 2 shows the budget for CubeSat missions of 1-kg maximum launch mass, 950 grams are for the subsystems and a 50 gram is secured and every subsystem's mass has a 5-10% subsystem occurrence and both of them is less than 900 grams.

III. SCIENCE MISSION

As stated above, the science objective of both missions is to take aerogel to measure space debris and its effect on outer planetary aircrafts. The scientific payload of this CubeSat is composed primarily of an Aerogel debris capture block, which will passively absorb material on impact and, through measurement of the directionality, size, and length of the impact streaks, permit calculation of the sizes, velocities, and frequencies of the impacts. Aerogel, a synthetic low-density porous material, has been extremely well characterized for this purpose, and has space heritage for impact capture of material through the successful Stardust mission. A small laser diode will illuminate the highly scattering aerogel, and a miniaturized stereo camera will allow photogrammetric measurements of the impact streaks. See Fig. 2 for an example of this phenomenon with a sample of aerogel that was impact tested as a pilot study at the NASA Ames Vertical Gun Range.

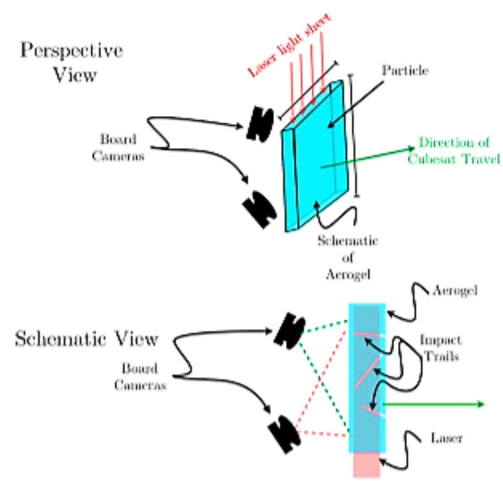


Figure 2 Baseline payload schematic.

A block of aerogel is positioned in the front of the CubeSat in the direction of travel. As dust particles impact the aerogel, they leave impact "trails" in the block. A laser (spread to a volume) is passed through the aero

While we anticipate the development and eventual construction of the photogrammetric camera optics will be optimized by the University of Bridgeport and its corresponding curriculum, we list here a baseline proposal using minimal passive off the shelf components that will meet mission requirements to prove feasibility.

A. Science Goals

The measurement of size-frequency distribution of uncontrolled material (including both natural micrometeorites and man-made space debris) is generally accomplished for larger material through ground and space-based radar (for LEO) and optical (HEO) methods. These techniques can measure material down to 0.5 cm (with some data down to 0.2 cm) in diameter. In general, it is assumed that the debris population exceeds the natural meteoroid population for all sizes - except between 30 and 500 µm (UN Report on Space Debris, 1999).

The millimeter and sub millimeter regime, however, which dominates the distribution in terms of mass and number and still poses significant risk to small satellites, is difficult or impossible to characterize remotely and requires in-situ detection through craters on returned space flight hardware surfaces or dedicated detectors. Previous measurements of this regime, notably the Long Duration Exposure Facility (LDEF), and analysis of returned space hardware such as the Shuttle, have established a relationship for flux Fig. 3. Analysis of LDEF pits indicated that some impacts were clustered in time, and also pointed to the existence of a sub millimeter population in elliptical orbits. These studies are generally not time-resolved and cannot directly recover the directionality or velocity of the impact (although inferences can be made from crater appearances as on the LDEF). Additionally, the influence of secondary cratering (where ejected from the primary impact artificially increases the number of "pits" on a surface) can cause overestimation of the flux. The photogrammetric aerogel method proposed here, on the other hand, can recover the size, speed, directionality, and flux of these particles directly.

The length and width of any given impact trail can be related to the initial velocity, size, and composition of the impacting material based on extensive calibration of aerogel (e.g., Kearsley, A, et al., 2012 Experimental impact features in Stardust aerogel: How track morphology reflects particle structure, composition, and density, MAPS 47(4) among others). We also plan to complete additional calibration testing at the NASA Ames Vertical Gun Range for the mission. Based on our current baseline imaging setup, we anticipate measurement of tracks less than 0.1mm in size.

Therefore we can define two main science goals for this mission:

What is the time-resolved flux of the small scale regime of material in LEO?

2) Can different populations of material (meteoritic vs. man-made) be identified from their velocities or directionalities?

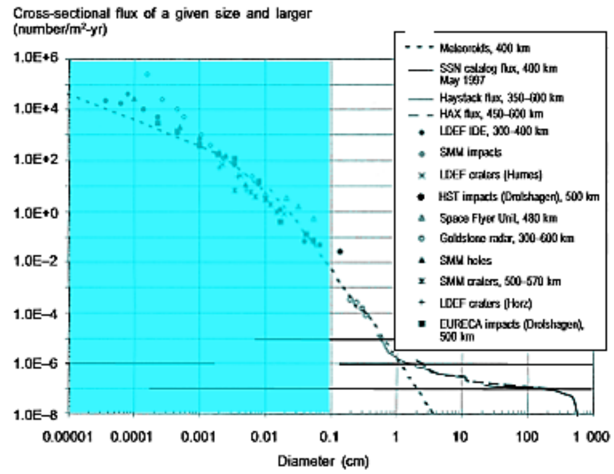


Figure 3 Flux of given size or larger of space debris as a function of diameter. Sizes sensitive to this study are indicated by the shaded blue region. From UN report on Space Debris 1999.

B. Specific Relevance to NASA

Understanding the near-earth flux of orbital material is a high priority for NASA, both for future human exploration and for the preservation of autonomous satellites, as indicated by the dedicated NASA JSC Orbital Debris Program Office. Although the small size distribution under study here is limited in the danger it poses to ending larger missions, small satellites and exposed surfaces (such as optical components) are still highly susceptible to damage from this regime. Additionally, this mission has the potential to yield data that will speak to the relative fluxes of man-made vs. natural meteoritic material.

The GPS antenna is a small patch antenna measuring 2x2 cm. Two antennae are used on opposite sides because it is unpredictable which of two sides will be zenith-pointing (this is discussed more fully in the Attitude Control section). The antennae are connected to a GPS board specially designed by Cornell University [6], which samples GPS data at 79 Hz, corresponding to about 100-meter data resolution at a 300-km orbit.

The greater separation of the GPS CubeSat as compared to the DC/PIP satellites enables them both to transmit simultaneously without encountering interference problems for some portion of the mission. This doubles the maximum amount of data that can be downlinked, expanding the data taking region to +/- 20° latitude.

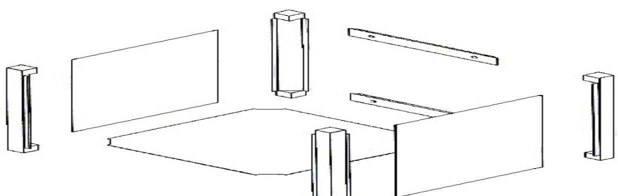
C. Magnetometer

Both science missions utilize a magnetometer to determine when the satellite is within the desired data-taking region. The chosen magnetometer is a Honeywell 3-axis solid-state magnetometer. Fluctuations in the total magnitude of the Earth's magnetic field are used in combination with an assumed satellite attitude to estimate the satellite's position. The magnetometer will be periodically calibrated on-orbit to ensure that science data are taken within the proper region.

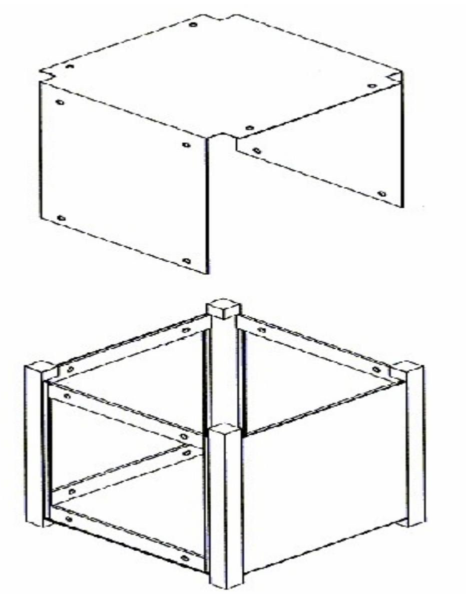
IV. COMMON SUBSYSTEM DESCRIPTION

A. Structures

Model has three body parts called, rails, beams, and panels, all of which are composed if 7075 Aluminum where the rails are four parallel edges and beams make up eight other edges of CubeSat where d- rails have a U-shape as we see in Figure 4



a. Exploded view



GPS mission	Budgeted		Estimate				
Subsystem	Percentage of Total	Allocated Power (W)	Standby Power (W)	Peak Power (W)	Peak On Time (%)	Average Power (W)	Variance (W)
Thermal	11%	0.14	0.002	2.01	7%	0.14	0.000
C&DH	11%	0.14	0.05	0.30	30%	0.13	0.02
Communications	16%	0.21	0.10	1.00	5%	0.15	0.06
Science - Board	42%	0.55	0.00	2.00	27%	0.54	0.01
Science - Magnetometer	5%	0.07	0.00	0.025	100%	0.03	0.04
Total Allocated	85%	1.11	0.15			0.95	0.15
Contingency	15%	0.20				0.20	
Total Power	100%	1.30				1.15	0.15

b. Assembly

Figure 4. Structural components

And here ADCS and science have similar platforms use.

B. Power

The components of the satellite will be packaged into the standard 2U CubeSat form factor (Fig. 4). The CubeSat will use body-mounted fixed solar panels. The satellite is designed to be compliant with NASA's LSP-REQ-317.01, CalPoly SLO CubeSat Design Specification (CDS) revision 12. Any hazardous materials (none are expected) shall be identified and only used as allowed by AFSPCMAN 91-710.

Beyond the baseline components for mission success (Communication, avionics, etc.,) a block of aerogel will be

Table 3. Power Budgets

examined from behind by a stereo camera. A set of accelerometers will trigger during an impact event; these will be calibrated pre-launch under hypervelocity impact conditions A laser diode will illuminate the CubeSat block after the event and the cameras will take images, store them, and send them to earth on subsequent passes for examination (along with a time stamp). The 3D location and size of the new impact track will be determined on the ground and analyzed for size, velocity, and directionality. As time progresses, we will build up a size vs. velocity (and time) plot of impact debris.

Power subsystem utilizes Tecstar triple junction 26.5% effective solar cells to give out the output and unregulated bus for solar batteries are from 7V to 12V, and the power system gives a voltage of 5V +/- 1% at up to 600 mA current.

Table 3.1. Power Budgets

Table 3 and 3.1 depicts power budget where 1.3W orbital average power (OAP) is viable.1.1W is in place of subsystems which provides 0.2W (15%) system occurrence but OAP links are 0.67W for the DC/PIP mission and 0.95W for the GPS mission.

C. Communications

Regular band link was given for CubeSat so that frequency bands can be achieved and flight system can utilize quality specimens.

Transceiver— which has Tekk KS 960 viable amateur-band Trans the CubeSat had drawbacks in space.

The primary modifications are as follows:

- Get rid of board from the enclosure
- Disconnected the power regulation components
- Lessen transmission power
- Switch all electrolytic capacitors
- Transceiver weighs 145g, which can support a 1kg system.
- Powerful control units have to be separated which lessens mass and reduce power use.
- Gear of transmission power has to be decreased for allocation where commercial needs of trans receiver is 2W transmit, but power allocation promote 1W power and electrolytic capacitors have to be switched for durability in space

Antenna— has downlink frequency of 437.49MHz where dipole allows for longer links and communications and better altitude manipulations. Restrictions are detached and every half is rolled to a single nylon wire which goes through a resistor and after launching CubeSat current will go through making antenna unfurl

Ground Stations— various ground stations can be needed to get and retrieve all science information

*Command & Data Handling*__the Command & Data Handling (C&DH) has on board flight computer and for securing data and other interfaces.

On-board Computer—The Tattletale 8v2 processor was utilized and is viable in shelf [7] possesses contains 9 analog lines and two RS-232 ports for distributing information and it was also cost effective. Tattletale can monitor speed of clock which enables CubeSat to reduce C&DH use of power.

Software— loop design is utilized and named TxBASIC which detects telemetry, communications state, location of satellites whose aims are science, links, and fault reaction.

Science function shows that satellite is close to retrieve information.

DC/PIP mission	Budgeted		Estimate				
Subsystem	Percentage of Total	Allocated Power (W)	Standby Power (W)	Peak Power (W)	Peak On Time (%)	Average Power (W)	Variance (W)
Thermal	11%	0.14	0.002	2.01	7%	0.14	0.000
C&DH	11%	0.14	0.05	0.30	30%	0.13	0.02
Communications	16%	0.21	0.10	1.00	5%	0.15	0.06
Science - Board	42%	0.55	0.00	1.50	17%	0.26	0.29
Science - Magnetometer	5%	0.07	0.00	0.025	100 %	0.03	0.04
Total Allocated	85%	1.11	0.15			0.67	0.44
Contingency	15%	0.20				0.20	
Total Power	100%	1.30				0.87	0.43

Communications function depicts transceiver indicates that it is got a beacon alert from a ground signal and transports information and it check satellite status and fault reaction just like software.

Fault response takes place if any other function finds peculiar data. And after analysis it recalls status or health functions such as a too hot or too cold function response

V. SUMMARY & CONCLUSION

Refined design was made, versatile CubeSat bus and is applicable for LEO-based science missions where two altitude choices for important detach and specification needs.

The scope of the project enabled every student to contribute. This experiment studied Pico satellites which is an asset for LEO type information and CubeSat theories will have its rewards will minimum costs and any one of the missions can carry out missions and has even more possibilities in future engineering

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