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The ThinSat Program: Flight Opportunities for Education, Research and Industry

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ABSTRACT

The ThinSat is the next iteration of the flight proven PocketQube design. The ThinSat standard is based on a common bus architecture with set electrical and mechanical interfaces that simplifies the development of diverse payloads. The bus design includes power, C&DH, communication systems and has options for attitude control and determination. Participants in the program need only provide systems that conform to the available documented bus design. Virginia Commercial Space Flight Authority (Virginia Space) has secured payload capacity on the second stage of future Orbital ATK Antares rockets launched from the Mid-Atlantic Regional Spaceport at NASA Wallops Flight Facility in Virginia. Virginia Space and Twiggs Space Lab (TSL) will launch 60 ThinSats on their first mission in the Fall 2018 (on the OA-10 mission), and 80 ThinSats on each of the subsequent Antares ISS resupply missions through December 2024. Additional capacity may be added to meet increases in demand. The large number of deployments per launch means that ThinSats have the potential to surpass the opportunities for scientific discoveries, technical innovations and commercial applications that were enabled by the adoption of the CubeSat. ThinSats represent the next logical step in the small satellite industry, by further reducing development times, lowering technical barriers to entry, and reducing overall mission cost and complexity.

INTRODUCTION

The introduction of the CubeSat has radically increased the accessibility of space. CubeSats took advantage of cheap ride sharing opportunities to launch small, simple, high-risk missions with standardized designs. Their low cost allowed them to be developed by organizations with limited financial resources such as universities, schools and small businesses. This success has created new challenges as more universities are transitioning their efforts from educational programs towards research and new industries based around the commercial applications of CubeSats. As a result, the average CubeSat's have become more complex leading to higher costs and longer development times. Significant barriers to entry such as ground communication equipment (with associated knowledge of satellite communication and mission operations) and significant technical knowledge for space systems for integration and assembly still are issues for CubeSat developers. Additionally, concerns relating to space debris and increasingly crowded communication bandwidths are increasing the difficulty and work required to obtain the required licensing to launch and operate CubeSats. Originally conceived by Prof. Robert Twiggs, the PocketQube was a first attempt to create a satellite with an even smaller form factor to build on the successes of the CubeSat standard. Specifically, the goal was to increase educational opportunities around spacecraft. PocketQubes have been launched and demonstrated successfully on orbit several times. However, they never reached the wide spread acceptance that CubeSats did. This was mainly due to fact that PocketQubes did not have many significant advantages over CubeSats. They were still relatively complex to fabricate and assemble and required dedicated deplorers. Using the lessons learned from the PocketQube, the ThinSat mitigates their deficiencies and adds new capabilities. The standard is also pared to a program which significantly lowers the barriers to entry and provides plentiful launch opportunities to educational and other commercial and research institutions.

THINSAT EDUCATION PROGRAM

The Virginia Commercial Space Flight Authority (Virginia Space) and TSL in partnership with Orbital ATK, NSL (Near Space Launch), and NASA at Wallops Flight Facility, have developed an educational outreach initiative known as the ThinSat Program. The purpose of this program is to teach students in middle school and later grades on the iterative engineering design process, systems engineering, data collection methods and analytical processes, and atmospheric and space science. The goals of the ThinSat Program are to address many of the challenges created due to the success of the CubeSat and provide new opportunities for students, including: (1) decreasing the spacecraft development cycle time; (2) reducing the complexity and increase reliability; (3) providing regular launch opportunities, thereby increasing space access; (4) engaging students earlier in their education (4th to 12th grade); (5) reducing the burden of paperwork and licensing requirements; (6) mitigating the threat of space debris with short orbital life; (7) reducing the overall cost of spacecraft development and access to space; (8) creating a precursor program to CubeSat programs; and (9) creating a smaller spacecraft platform for valuable space research. For a comprehensive look at the ThinSat education program see [1].

In the first phase of the ThinSat curriculum, students will experiment with plug-and-play sensor chips developed by XinaBox Inc. that are easy to program and assemble. Then, students will build Flat-Sats, satellites on printed circuit boards to test on low-altitude balloons or drones.

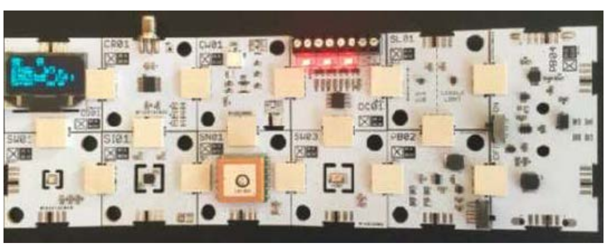

Figure 1: Flat-Sat of XinaBox Chips

For the program's second phase, students will design payloads to integrate in ThinSat engineering models that will be launched to an altitude of approximately 36 kilometers on high-altitude balloons. In the third phase, students will use data from the previous phases to develop the ThinSat payloads. These can be derivatives of the XinaBox chips, TSL Primary Boards with Expansion Board development opportunities for students, or custom developed payloads. XinaBox has a wide range of sensor "chips" for students to mix and match depending on their interests. The TSL Primary Payload Board (TSLPB) has many integrated sensors, including light and temperature sensors. The TSLPB provides six analogs and two digital signals that can be sent to the ThinSat bus through the NSL Connector as Analog/Digital outputs or as a Serial Payload Packet. In addition, the TSLPB has six I2 C digital sensors and one I2 C IMU module that can include an accelerometer, gyroscope and magnetometer in 3 axes. The TSLPB includes an Arduino Pro Mini 3.3V microcontroller (ATmega328P), that can be used for programing or monitoring using the Diagnostic Connector. The microcontroller provides the functionality for Serial Communications, use of an EEPROM (32K x 8Bits), 3 analog ports (8-bits), I 2 C interface and 7 GPIOs that can be used as 1 wire, Serial or SPI interfaces. In addition, the TSLPB also has the capability of supporting an expansion board, the TSL Secondary Payload Board (TSLSB) on which many additional sensors can be accommodated. For more info on the TSLPB see [2].

Figure 2: TSL Primary Payload Board

FLIGHT OPPORTUNITIES

Virginia Space has secured payload capacity on the second stage of future Orbital ATK Antares rockets launched from the Mid-Atlantic Regional Spaceport at NASA Wallops Flight Facility in Virginia. 60 ThinSats will be on the first mission (OA-10) in the Fall 2018, and 80 ThinSats on each of the subsequent Antares ISS resupply missions through December 2024.

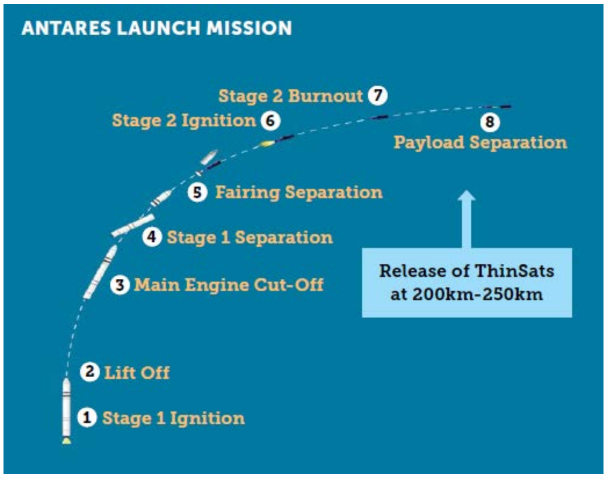

Figure 3: ThinSat Launch Profile

Additional capacity may be added to meet future increases in demand. The orbit for the Antares ride share ThinSats is expected to be 200 to 250 kilometers with a predicted orbital life of 5-7 days which mitigates debris concerns of the regulatory bodies. Each launch can theoretically carry up to 80 ThinSats depending on the demand. This means that solely using the Antares ISS resupply missions up to 480 ThinSats will have launch opportunities over the next 3 years. While the standard payload will belong to students TSL is opening these flight opportunities to education, research and industry organizations that wish to take advantage. At an estimated $30,000 per payload (with bus and launch) the program costs significantly less than a CubeSat launch. TSL hopes to coordinate these partnerships. Another attractive aspect of the ThinSat Program is a significantly reduced burden of paperwork as most paperwork and licensing is handled by TSL. The Antares mission launch approximately every six months. TSL is planning on selecting participating schools and partners at least 12 months in advance. The ThinSat Program provides a true “one-stop shop” space environment research opportunity for customers that includes a ThinSat bus, launch, environmental and acceptance testing, FCC and ODAR licensing, and an online interface for data collection and analytics. Participants only need to provide a payload and minimal information to have it fly in space and receive data.

POTENTIAL APPLICATIONS

Engineering and Technology Development

The low cost and high launch cadence of the ThinSat makes it an ideal way to fast track development of new space technologies. A constant difficulty with high risk space missions is a lack of state of the art technology with flight heritage. This also presents a barrier to market entry for small business and startups that first need to fly and prove their technology. ThinSats represent an economical way to demonstrate a part or system in a space environment. The price for CubeSat flight demonstrations may be unobtainable to these enterprises. The competition for flight opportunities can also be a barrier to getting technology flight proven in a short period of time. ThinSats can act as technology demonstrators launching individual components or systems into space. The low cost and short lead time can allow organizations to launch and achieve higher technical readiness levels within the span of longer-term programs and projects. There is also little risk for delayed missions due to the volume of launches and the ability for payloads to be easily integrated into new ThinSats. This can help mitigate risk in larger more expensive space missions. The OA-10 mission has a ThinSat that carries a novel supercapacitor that is having its maiden space flight.

Earth and Atmospheric Science

The altitude range of 100 to 300 kilometers is formally referred to as extreme low earth orbit (ELEO). This region is of great interest as it represents the transition from atmosphere to space. It is affected by space solar storms and flares from above and from below by terrestrial weather. Despite this, it is a region of the atmosphere that has not received much attention due to limited orbit lifetimes for satellites at that altitude. It is also unreachable by research balloons or fixed wing aircraft. While sounding rockets and traditional SmallSats have targeted this area for study the costs have proven too high for regular missions. Thus, the ThinSat Program offers a rare opportunity for atmospheric scientists and other interested organizations to study the ELEO environment. Deploying large constellations of ThinSats in orbit at once, over multiple launches can achieve a volume of atmospheric data available for research that has never been available to the scientific community before. The data gathered by all the student payloads may be made available to the scientific community. A number of ThinSats per launch will have Langmuir probes. This instruments is used to determine the physical properties of plasma such as the electron temperature, electron density, and electric potential of a plasma. Energetic particle detectors alongside the probes will be used to determine the relative environment or “space weather” at the relevant altitude. The US Naval Academy developed a ThinSats payload on the OA-10 which contains an experiment to characterize the location and distribution of abnormalities in the ionosphere and then analyze their effects on GPS and other satellite-to-ground transmissions.

Life Science and Exo Medicine

Gravity has been a constant in biological experiments since their inception, but with the advancement of spaceflight technology new opportunities have arisen that allow the effects of gravity on biological processes to be studied. One of the fundamental tenets of biological research is the reproducibility of results, without the ability to reproduce the results of an experiment it is difficult to determine the efficacy of the procedure and the reliability of the data. As such, most biological experiments utilize large sample sizes, many biological replicates, and many repetitions to ensure the validity of the results. Until now it was near impossible for many institutions to economically justify the expenditures and resources required to conduct biological research in microgravity. There is very limited space aboard launch vehicles, driving up the cost/payload, lowering the frequency of bio-payloads launched, and therefore data yield is low and validation is difficult due to smaller sample sizes, fewer repetitions, and inherent error found when prototyping/testing new technologies. The ThinSat Program addresses each of these issues and opens the door to fast-paced, affordable, compact, standard, and repeatable microbiological experimentation. It has the potential to be a game-changing technology, especially for smaller institutions and organizations wishing to get a start in the field. OA-10 contains an experiment that will monitor growth rates of bacterial strains in a microgravity environment. The measurements will be compared to growth rates in normal terrestrial conditions.

THINSAT BUS DESIGN

Each ThinSat will weight approximately 280g and has dimensions of 111.1 x 114.2 x 12.5 millimeters as shown in Figure 4. Of these dimensions, approximately 50% of this volume will be reserved for the payload. This will normally be filled with a student payload such as the X-chips, TSL boards, or custom student developed payloads. The design is meant to fit in the CubeSat form factor allowing ThinSats to use a standard 3U Canisterized Satellite Dispenser (CSD) as shown in Figure 5. A 3U volume is equal to 21 ThinSats (7 per U). There is also the option of having ThinSats that are thicker than the standard ThinSat. ThinSats are referred to in thicknesses of T which is equivalent to around 12.5mm. For example, a 2T ThinSat would have dimensions of ~111.1 x ~114.2 x ~25 millimeters. A standard ThinSat is referred to as being one T. Variable numbers of Individual ThinSats can be grouped together to form “Strings” in multiples of 3 (i.e. 3,6,9,12, etc.). The Stings are grouped according to mission requirements and payload specificity in to a “Stack”. The ThinSats Stacks are locked into the CSD using two rails on every third CubeSat. Tabs on all four sides hold the ThinSats in place.

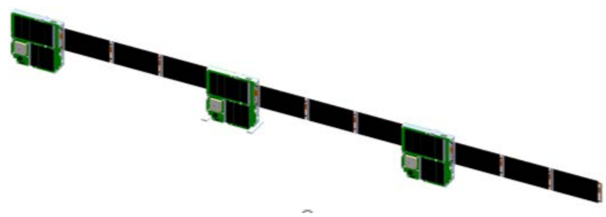

Figure 4: ThinSat String

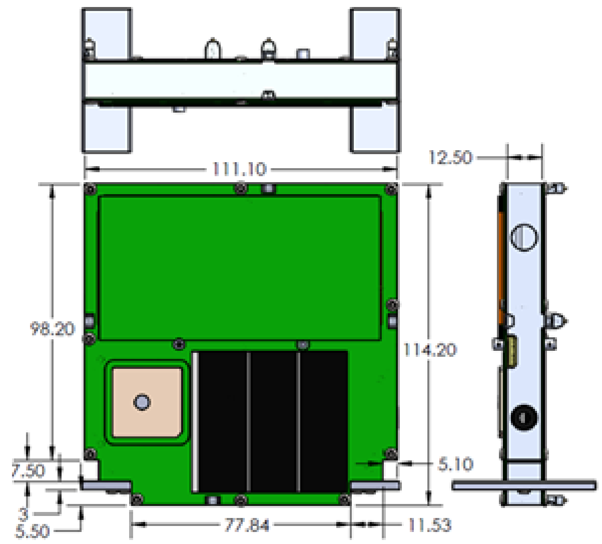

Figure 5: ThinSat with Rails Dimensions (mm)

Figure 6: 3U "Stack" of 21 ThinSats

Articulating fanfolds or wires are used to group ThinSats in to strings. They are comprised of PCBs and nitinol wire with a distance of approximately 30 cm in-between individual ThinSats. Some of these articulating fanfolds will contain solar arrays to generate additional power for the string of ThinSats. The articulating fanfold choice is also dependent on the payload and mission requirements The CSDs can contain any combination of String lengths, ThinSat thicknesses or even CubeSats. For example, one 3U CSD may have two strings of six ThinSats and three Strings of three ThinSats. The specific layout of each CSD will depend on the given mission's requirements and payloads.

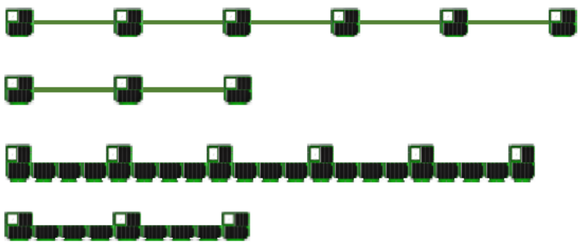

Figure 7: ThinSat Grouping Examples

ThinSats buses have two configurations: Mothership and Daughter-ship. Both configurations include the same Globalstar radio, C&DH and electrical power systems. If the ThinSats are part of a String, each String will have at least one Mothership and any number of Daughter-ship(s). Each Mothership contains a GPS and foldout camera. Some Motherships contains an energetic particle detector and plasma probe board. The Mothership's camera and GPS allow satellite tracking and attitude determination.

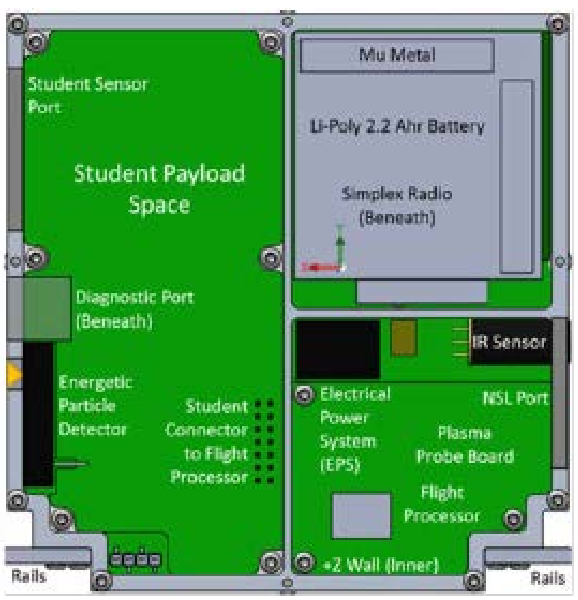

Figure 8: Daughter Board Configuration Layout

PAYLOAD SPECIFICATIONS

Students and partners are given great freedom for developing payloads. The only thing payloads must do is conform to set electrical and mechanical interfaces and it can fly on any ThinSat, on any deplorer, on any mission. The payload requirements do not change depending on the String type or length. The standard payload area is ~107 x ~52 x ~10 millimeters. For thicker ThinSats (i.e. 2T or greater ThinSats) the allowable depth of the payload increases by increments of ~10 millimeters.

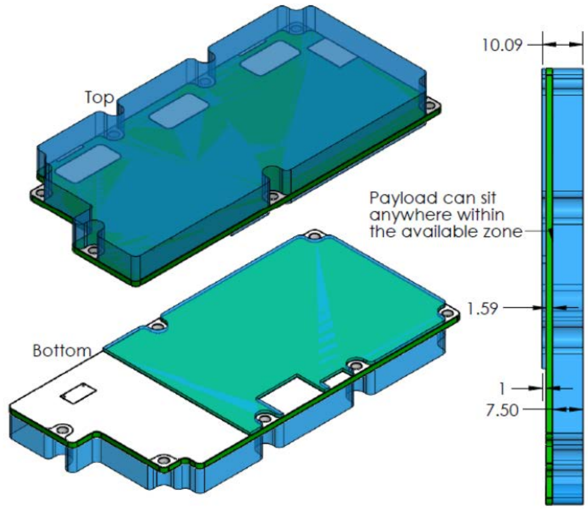

Figure 9: Payload Space for Standard ThinSat

All electronic interconnects and power are done through a single NSL 20-pin connector. While not necessary, NSL suggests all payload developers include a payload diagnostic port for technicians to test your payload during integration and testing. Each ThinSats can generate around ~1.25W for payloads to use.

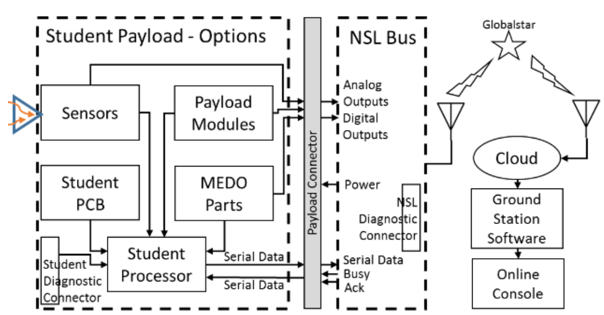

Figure 10: Payload Electrical Block Diagram

For more technical information on the ThinSat payload and operation requirements see [3].

END USER INTERFACE

Participants in ThinSat Program, whether they be student or otherwise, will have a user-friendly and secure online portal that will allow them to view data collected from the ThinSats. This portal is called the Space Data Dashboard. It will also act as a hub for the data analysis and collaboration amongst the schools participating in the education program. Organizations will be able to receive data from their payload real time via the Global Star network. Custom tools and interfaces can be made with program partners.

CONCLUSIONS

The ThinSat Program is targeted at students for education and STEM outreach. However, there will be significant scientific and commercial opportunities. TSL and NSL are looking to facilitate partnerships with both private and public organizations to provide low cost launch opportunities using ThinSats. The ThinSat Program can be view as a one stop shop to get a payload in to orbit. ThinSat represents an extraordinary opportunity to provide plentiful and economical access to space.

ACKNOWLEDGMENTS

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