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VT ThickSat: A Scalable Chassis in the ThinSat Program

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ABSTRACT

This paper presents a scalable design of a small satellite chassis for the ThinSat Program. This versatile chassis will fly on Virginia Tech's ThinSat mission in 2020, VT ThickSat. By incrementing the volume of the satellite chassis, students from Virginia Tech introduce a unique capability that combines the ThinSat's rapid deployment with upscaled payload sizes. The scalable solution reflects an expansion of the original ThinSat 1T chassis up to nearly that of a 1U CubeSat. Enabling the accommodation of larger educational and research payloads using the same proven flight hardware as the 1T option, a family of alternative vehicles for institutions previously constrained to the more expensive CubeSat platform can be realized for low-altitude, short-duration missions. The chassis design offers an attractive alternative to educational CubeSat builds, putting the experiment in primary focus rather than using resources on a build-to-suit vehicle design. With rapid development capabilities and reasonable cost, the capability described here introduces an incremental synergy for nanosatellite space applications as well as building the potential to test and prove out further capabilities for the entire SmallSat community.

PROJECT BACKGROUND

The need for a flexible small satellite platform grew out of the original mission objectives for the project. The team at Virginia Tech was tasked with planning, designing, and executing a low-Earth orbit mission to deploy a flexible carbon fiber boom structure, and verify deployment via photography onboard the spacecraft. The deployment mechanism seen in Figure 1 and the camera assembly was intended to occupy the space of roughly a 1U-sized cubesat, but the satellite only needed to operate for several days to complete the mission. This short-duration plan amplified the effect of cost on achieving mission success, so any solutions to mitigate vehicle development and manufacturing cost were sought out.

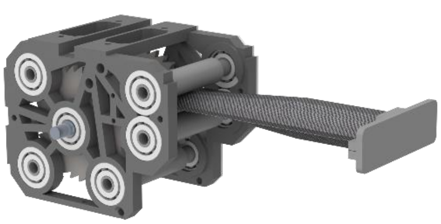

Figure 1: Flexible boom deployment mechanism

Cost reduction was especially important for the satellite chassis, which is available in the cubesat format from only a handful of suppliers at roughly comparable prices. With an expectation of needing to modify the chassis once purchased to accommodate the boom deployment mechanism and camera viewport, non-off-the-shelf options were kept in play. The need to find and build flight boards, radios, and other vehicle subsystems with a cubesat chassis added weight to the decision to select the Virginia Commercial Space Flight Authority (Virginia Space) partnership ThinSat program over more conventional options.

The ThinSat program consists of a partnership of Virginia Space, Twiggs Space Lab, Northrop Grumman Innovation Systems, and NASA Wallops. The spacecraft are launched on the Northrop Grumman Antares vehicle during commercial resupply missions to the International Space Station. The program was conceived to lower the cost of space access for K-12 classes, so students can send payloads on a high-altitude balloon and then to space for short-duration experiment missions.[1]

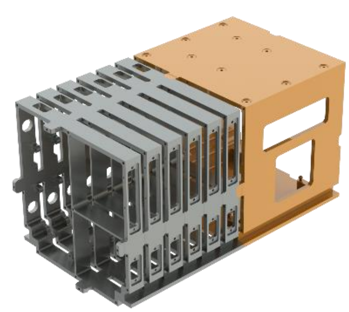

Figure 2: ThinSat chassis stack in deployment configuration with normal 1T architectures (gray) and the Virginia Tech 6T architecture (orange)

Most schools in the program complete a small pre-built biological payload, learning aspects of mission design, coding, and vehicle design along the way. The satellites themselves are joined into one strand by solar panels and are deployed as a group. As can be seen in Figure 2, the vehicle chassis are approximately one sixth the thickness of a 1U cubesat. This unit is called a 1T.[2]

DESIGN REQUIREMENTS

Virginia Space

Due to the number of unknowns in building an expanded version of an existing satellite chassis, external requirements from Virginia Space and Northrop Grumman were restrictive. Given time to mature, the building of expanded chassis segments could have relaxed requirements, or a different set of restrictions from the original 1T sections. Most notably, the chassis was required to be constructed from billet aluminum, of either 6061-T6 or 7075-T6. This requirement imposed the most on design freedom, limiting the possibilities of leveraging the flexibility of sheet metal or composite materials. In addition, tight dimensional tolerances were required along the exterior edges of the chassis to prevent sticking in the tube-like deployer. In the end, an architecture was settled on that met these requirements with minimal disruption to the core functions.

Virginia Tech

Where the external requirements dictated the maximum allowable size, shape, and material, the internal requirements were purely focused on functionality and integration with the other subsystems. The use of the spool and rollers necessitated an entirely open center cavity. This requirement defined the manufacturing planning, moving from an initial concept chassis milled from a solid block of billet in one piece to a multi-part assembly seen in Figure 3 that is constructed around the internal components.

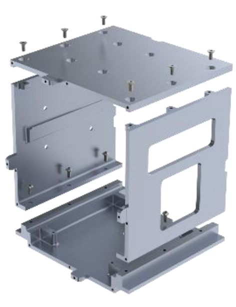

Figure 3: Exploded view of chassis assembly

The use of an additional control board for the camera as well as mounting solutions for the deployment mechanism also required added features. To maintain consistency with the previously manufactured hardware, wall thicknesses are the same as the original 1T chassis section. Experience from past integration and assembly problems led to the use of part location features on the interior walls, allowing the vehicle to be assembled with minimal instruction and no prior knowledge.

MANUFACTURING CONSIDERATIONS

During previous iterations, the chassis machining was attempted with a waterjet cutter. This failed, as seen in Figure 4, when the jet deviated from the normal, cutting into the wall of the chassis.[3] The failure was the impetus for designing a multi-part assembly instead of attempting to cut the chassis as one part. The move to multiple parts also eliminated the original 5T plus 1T architecture, allowing the team to start from a clean sheet design.

Figure 4: Waterjet cutting failure with uneven dimensions

While the move to multiple parts increased the feasibility of manufacturing, the increased part count and small features required a commercial machine shop to complete the parts to the desired specifications.

This initially was thought to increase the cost to produce the chassis, putting it over more traditional cubesat offerings, but that was not the case. As quoted, ordering two chassis examples totaled $2980.00, which yields $1490.00 for each. This is more expensive than a comparable 1U cubesat chassis from a company such as Pumpkin Space Systems, which sells a solid wall 1U for $925.00, but the custom chassis contains all the features needed, where the Pumpkin chassis would need further modification to integrate well with the other subsystems.[4] As the need for more custom chassis increases, it is reasonable to expect the cost to reduce further, even if slight modifications are required.

Finally, the use of billet aluminum for chassis construction requires the application of a Type III anodization coating to protect against corrosion in the space environment. This is similar to the required preparation process to ready a commercial chassis for launch.

INTEGRATION

Test assembly will be carried out prior to launch at Virginia Tech facilities, and final integration completed at Twiggs Space Lab and Northrop Grumman assembly labs. The construction of two chassis instead of one, while increasing the cost, allows for constant clean room storage of the flight model while the additional test article can be used for test assembly, outreach, and rough handling. Holding on to the test article following the launch can help fulfill the education aspect of the program and serve as a future reference for engineering students.

As seen in Figure 5, the satellite will be assembled from completed subassemblies. The deployment mechanism, camera, and control board are installed following chassis assembly, and finally end plates containing solar cells are attached. The completed vehicle will be mated to the other ThinSats in the flight, and then loaded onto the Northrop Grumman Antares before launch.

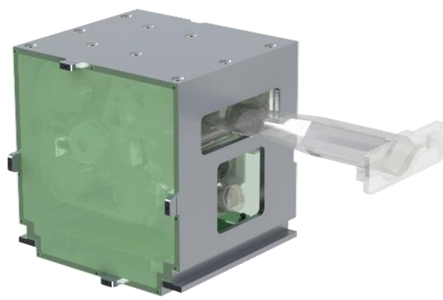

Figure 5: Full assembly of VT ThinSat

CONCLUSIONS

The successful expansion of the ThinSat architecture has many useful applications moving forward. This represents a more flexible paradigm for small satellites, especially regarding testing components prior to flight on larger, more complex vehicles. Access to a low-cost, scalable platform that can rapidly return useful information from low earth orbit is crucial to the rapid prototyping future of space. The expansion of a small satellite chassis in small increments offers options from the basic 1T upward, entirely driven by user requirements rather than what is available from manufacturers.

The development of this flexible platform also has implications for educational institutions. Failure rates of collegiate and K-12 cubesats is high, and mitigating risk is important to secure buy-in from educators, students, and administrators. A low-risk, low-cost option that can be turned from concept to completed vehicle in an academic year can introduce more students to space and space-based experiments, paving the way for a robust development of talent in the industry at a young age.

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