

Design and Manufacture of an Open-Hardware University Rocket Airframe using Carbon Fiber

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The amateur and university rocketry communities are rapidly reaching higher altitudes with more sophisticated rockets. However, most groups are still using heavy airframes made of metal or fiberglass. Commercial off-the-shelf airframes are either too expensive for low-budget university groups or too small to use as a platform for high altitude experiments. A capstone team of mechanical engineering seniors at Portland State University is developing a low-weight, modular carbon fiber airframe as an open-hardware technology for university rocketry. This team is continuing the work of a 2014 capstone team, who developed a carbon fiber layup process with promising results. This will enable low-budget groups like the Portland State Aerospace Society to explore high altitude science and compete in the university space race.

I. Introduction

The Portland State Aerospace Society is an interdisciplinary group of engineering students and alumni of Portland State University with the long term goal of putting a cubesat into orbit with their own rocket. Their current airframe, named LV2, has served for over 12 years, representing 10 of the group's 13 launches, and hosted experiments ranging from custom patch antennas and long range WiFi technology to GPS navigation and a cold gas reaction control system (figure 1). The LV2 platform is mostly constructed of aluminum with a fiberglass shell, with many of the parts having been fabricated in home garages. This makes for a robust but heavy design. Additionally, this airframe is built with a 4.5 inch inner diameter which PSAS's experiments have outgrown.

The new airframe being designed, named LV3, aims to address these issues. The LV3 platform uses a 6 inch inner diameter, modules composed of carbon fiber and thin aluminum coupling rings, a carbon fiber nose cone, and a carbon fiber fin section. All of the airframe components connect via standardized rings, to accommodate future experimental modules and flight configurations.

The cylindrical LV3 airframe modules already outperform the old design with an 80% reduction in weight and ??% increase in yield strength.

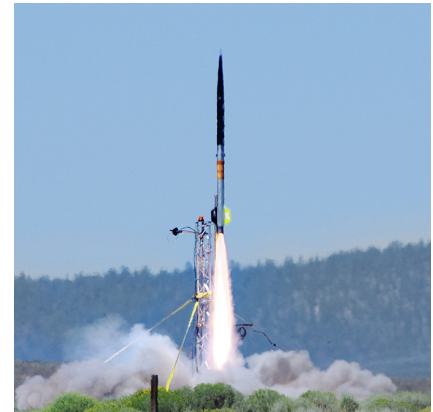


Figure 1. PSAS's LV2 rocket lifting off for the group's 13th launch. The custom cylindrical patch antenna can be seen as a brown band around the middle of the rocket.

II. Significance

This is a completely open hardware project, aiming to elevate the amateur and university rocketry communities. The knowledge generated by designing and building the LV3 airframe will be free to anyone wishing to copy or modify them.

Few rocket designs take advantage of the capabilities of composite materials. Existing designs fall into two categories. The first uses a single thick layer of the composite for both load bearing and as the skin of

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the rocket. The second features a thin composite layer for the rocket's skin, and relies on a metal frame for structural support. Neither of these designs realize the full potential of composites. The LV3 design relies on a three layer method: two layers of carbon fiber fabric sandwiching a honeycomb core (figure 2). This design maintains the high specific strength of single sheets of carbon fiber, while also increasing overall rigidity by preventing buckling and bending. The result is an airframe whose structure and skin comes from just two sheets of carbon fiber. The only metal necessary in this design is the aluminum used in the miscellaneous parts like the tip of the nose and the coupling rings which connect the carbon fiber modules.

III. Plan of Work

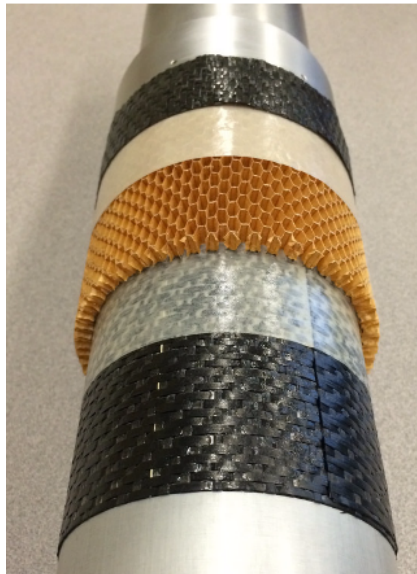


Figure 2. A cut away view of the layered LV3 design. From bottom to top: preimpregnated carbon fiber (black), adhesive film (eggshell), honeycomb core (brown), adhesive film (eggshell), preimpregnated carbon fiber (black).

The design of the cylindrical modules has already been completed, with promising results. These new modules achieved an 80% weight reduction over the previous LV2 modules, and exceeded the design strength. The present method of manufacturing the new LV3 modules is effective, but needs refinement. There are many steps that rely on the skill of the people assembling the modules. These steps need to be modified so that future PSAS groups and outside university teams will be able to replicate the LV3 design.

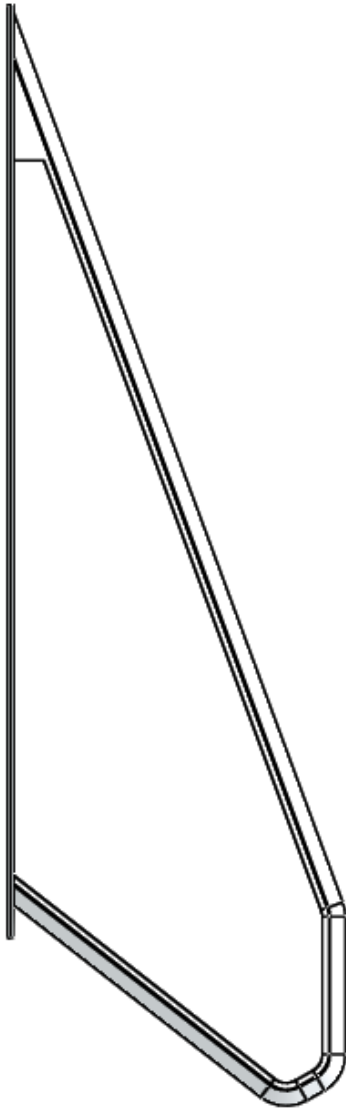


Figure 3. The proposed design for the aluminum frame that will form the edge of a fin on the LV3 rocket.