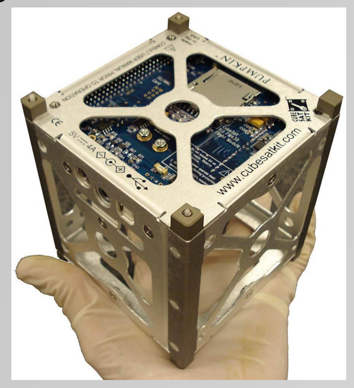
Manufacturing a Cheaper, Better CubeSat

Chris Howard, Eleonora Olsmats, Lillian Soucy
Department of Physics and Astronomy, University of New Hampshire, Durham, NH 03824

What is a Cubesat?

CubeSats, 10 cm cubic satellites, are cheaper alternatives to full sized satellites. They are used as secondary payloads in low earth orbit. The range of different CubeSat models and structure types is incredibly broad, with the 1U (10cm) CubeSat acting as a size baseline. All in common, they have to meet rigorous CubeSat criteria to withstand launch, temperature changes, and the vacuum in space. Such criteria also involve a maximum total weight of 1.33kg, a low coefficient of thermal expansion, and the use of low outgassing polymers. A complete list of the requirements can be found at http://www.cubesat.org.



Methodology

Using various advanced manufacturing techniques, such as laser cutters, water jets, lathes, mills, box breaks and TIG welding, a variety of CubeSat models can be created. This project included designing, creating and testing different materials and techniques to be used for different missions.

Observations

Welded Titanium:
The Titanium prototype has more inherent radiation protection, which would mean extra shielding would not be necessary. Simulations proved the titanium to have high durability. The titanium prototype required a more hands on manufacturing process with the use of TIG welding. The fact that titanium does not always burn up when entering atmosphere was also taken into consideration.This would not be a problem for the thin titanium used creating a high surface area to metal ratio. Finally, metal has a lower, essentially non existent, outgassing coefficient, which is an advantage.

Aluminium Frame with posts:
This frame had the benefit of stackable PCB's which makes it the easiest to assemble and modify . It was also the lightest model, with good stress and modal testing in the 50-90Hz range, but it had poor performance at higher frequencies (400-500Hz).

Laser Cut Acrylic:
Immediately apparent was that the acrylic lacked the durability that would be required for space. Deformation due to heat during the laser cutting process was not an issue, but when countersinking or screwing into the brittle acrylic cracking was a possibility if done too rough. Exposure to UV sunlight would make the plastic even more brittle, and PMMA has a high outgassing coefficient

Folded Aluminum:
During the folding of the aluminum prototype, the outside edge deformed slightly, which could be a problem in terms of having the appropriate dimensions to fit in the shuttle. Also, the aluminum was determined to be too brittle, especially if aluminum 6061 was used.

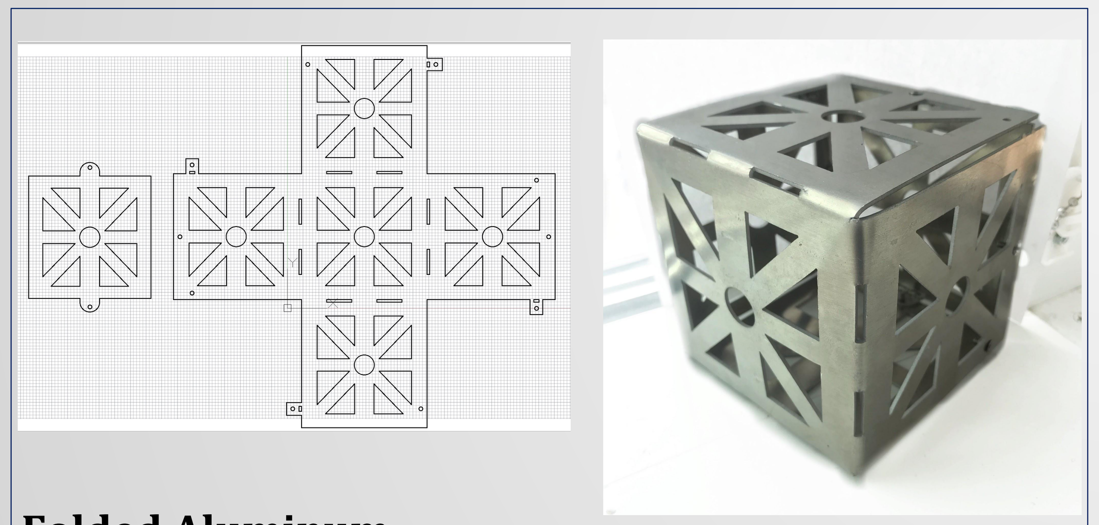
Manufacturing Process

Pictured above: Chris and Eleonora countersink and assemble a laser cut acrylic model at the UNH Makerspace. The acrylic model is the easiest to manufacture with on-campus facilities and minimal training.

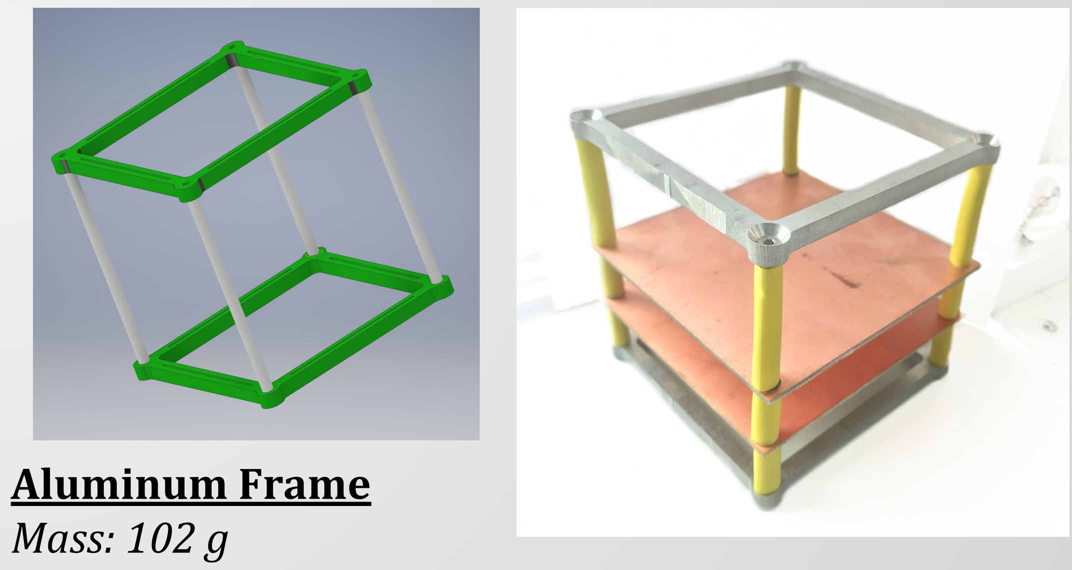
CubeSat Prototype Frames

Pictured above: The titanium and aluminum frame cubes. The titanium model was chemically anodized to have a color gradient finish. The aluminum frame is lacking spacers and PCB's (see final model) .

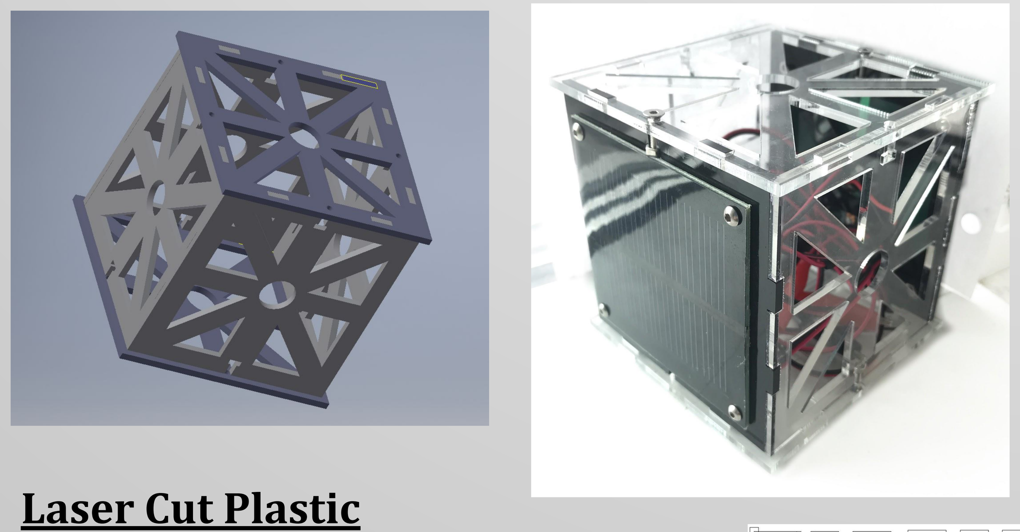
Prototypes



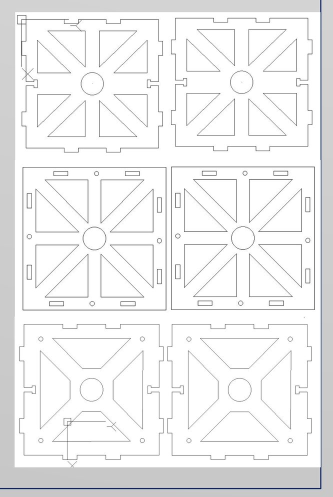
Folded Aluminum
Mass: 183 g
Material Cost: $10
-Water jetted Aluminum 6061
-Folded using box breaks and clamps
-Top screws on
-All metal with 2D manufacturing

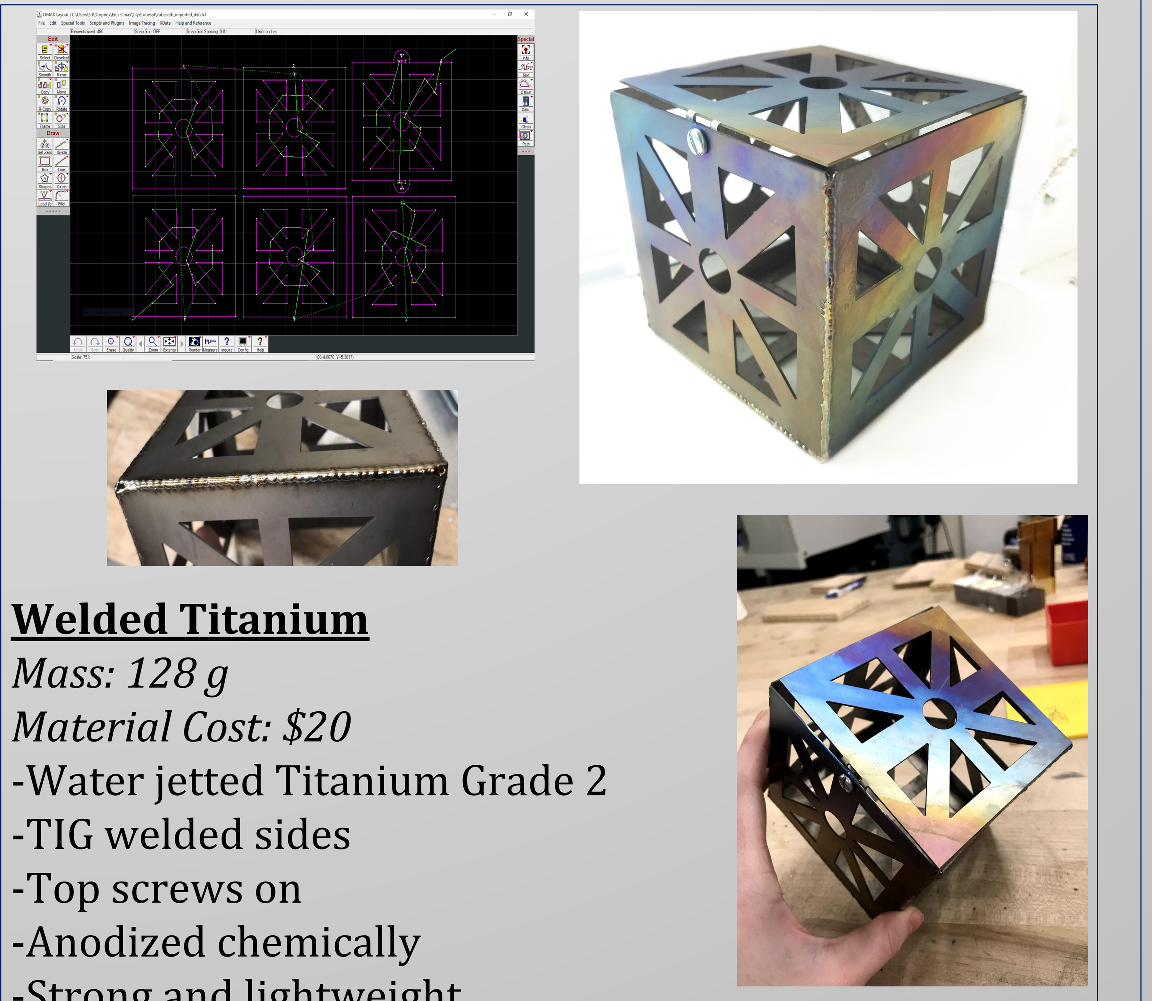


Aluminum Frame
Mass: 102 g
Material Cost: $12
-Water jetted frame pieces
-Posts drilled and tapped on lathe
-Rubber tubing to change PCB board spacing



Laser Cut Plastic
Mass: 164 g
Material Cost: $9
-Laser cut Acrylic
-Held together by slotted tabs and t-slot joints with screws
-Protective overhang for solar panels
-Dimensional

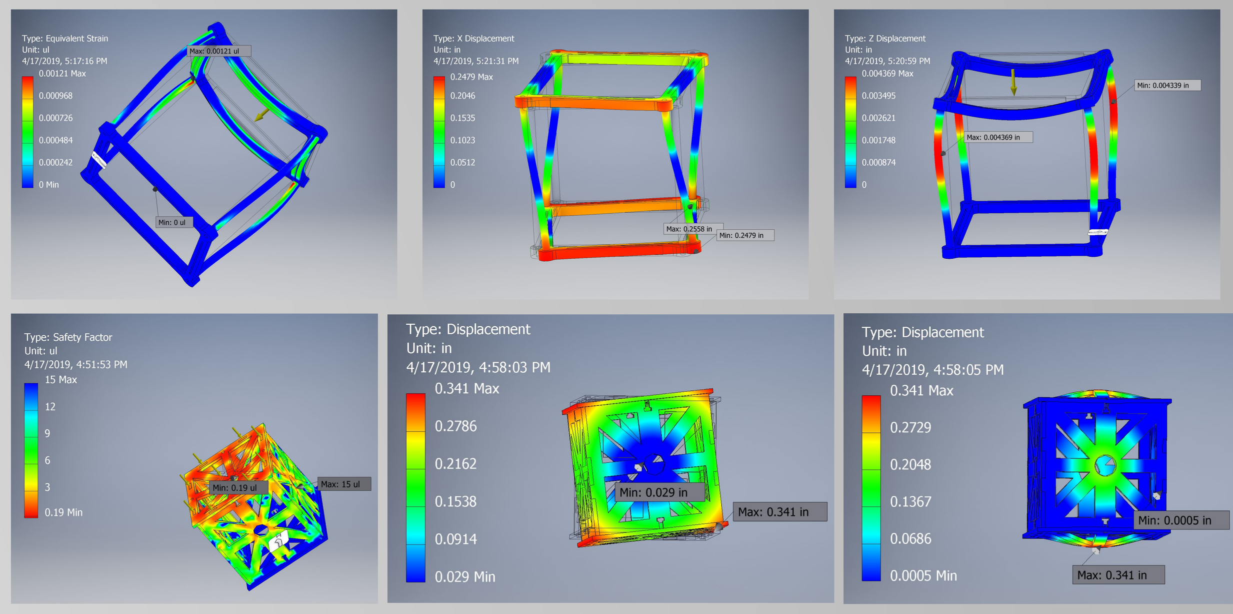




Welded Titanium
Mass: 128 g
Material Cost: $20
-Water jetted Titanium Grade 2
-TIG welded sides
-Top screws on
-Anodized chemically
-Strong and lightweight

Simulated Testing

Shown below are the various cubesat prototypes we built undergoing simulated stress and modal testing. This checks for resonant frequencies, wobbling, and deformation under the forces that the frames would undergo in an actual launch into space.



Conclusions

Based on the observations and simulated testing, we found that some of our models are not suitable for a launch into space. The folded aluminium CubeSat was made out of aluminum 6061, which is space grade aluminum, but very brittle. This was not ideal for folding, and the tabs and joints showed signs of cracking. In the same way, the laser cut acrylic (PMMA) model was not competitive in the durability tests. An acrylic frame also wouldn't be allowed to launch due to its high outgassing coefficient. This left the welded titanium and aluminium post frames as successful models. The benefit of the aluminum post model is the ease with which components and PCB's can be added, modified, and troubleshot. The titanium model, on the other hand, provides the best protection and radiation shielding of all the models. Outgassing is not an issue with titanium and it is incredibly strong and durable. The goal for future research is to streamline the manufacturing processes for the aluminum post and titanium models, as well as make modifications for specific missions.

Acknowledgments

Advisors James Clemmons and Marc Lessard
Laser cutting equipment provided by UNH makerspace
Template provided by UNH ESRC Poster Printing Services
Poster funding provided by CEPS Dean's Office
Shop and materials provided by Harvard's CBS NEcore

References

http://www.cubesat.org

Cubesat Design Specification (REV 13) . The CubeSat Program, Cal Poly SLO, static1.squarespace.com/static/5418c831e4b0fa4ecac1bacd/t/56e9b62337013b6c063a655a/1458157095454/cds_rev13_final2.pdf.