Designing An Impact Resistant Drone Base

Amanda Stull, Ben Randoing, Jackson Kennedy, Jessie Ou, Marc Chmielewski

Introduction

A team of Duke undergraduate engineers, led by Dr. Martin Brooke, is competing in the Shell Ocean Discovery XPRIZE competition to map the ocean floor with equipment that will be transported by autonomous drones.

- Problem: The existing drone base geometry is incapable of surviving crashes, and the 3D-printed joints often fail in the form of delamination between print layers.
- Motivation: The new frame will prevent Duke's expensive oceanography equipment from being damaged in crash landings. Additionally, this project helps explore the deep sea for future generations.
- Design Objective: To design a robust, scalable frame for the Duke XPRIZE drone that can withstand drops of up to 30 feet and carry a 40-pound payload.

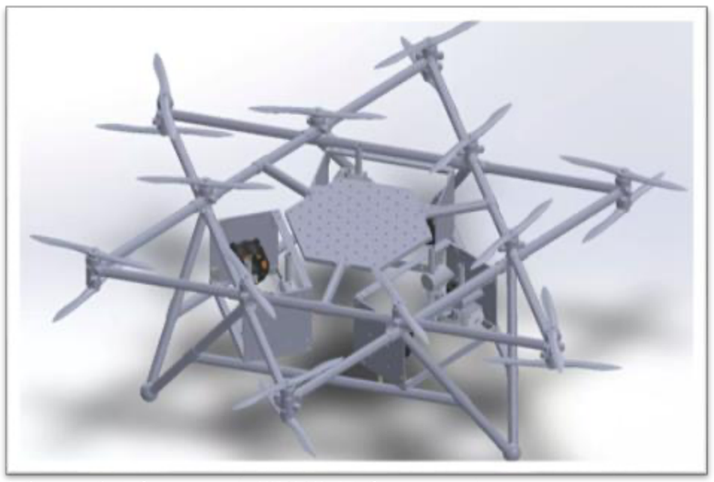

Figure 1. The current XPRIZE drone

Design Criteria

Design Criteria	Quantitative Specifications
Minimum Survivable Crash Height	*5 feet*
Supported Payload Weight	*≥ 40 pounds*
Weight of Frame	*≤ 20 pounds*
Target Survivable Crash Height	≥ 30 feet
Ease of Replication	< 48 hours
Ease of Assembly	Average Rating: 2.5
Cost of Prototyping Process	~ $300

*Design constraints are italicized, while design objectives are normal font.

Table 1. The project design criteria and their specifications

Final Design Solution

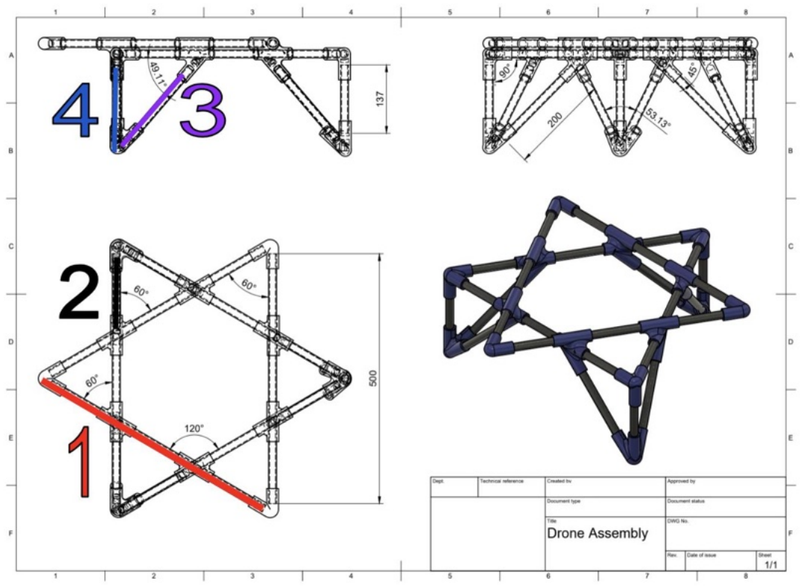

Figure 2. The orthographic projection of finalized drone frame design

Segment Number	Beam Name & Length
1	Side of Superimposed Triangle (500 mm)
2	Side of Top of Foot Triangle (167 mm)
3	Foot (236 mm)
4	Lunar Lander (102 mm)

Table 2. Labeled segments and their specifications

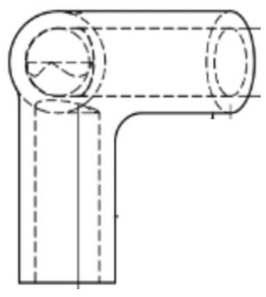

Figure 3. The top of frame lunar lander joint

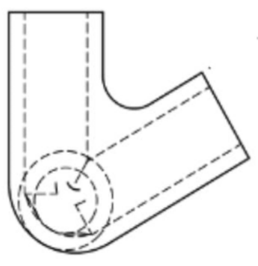

Figure 4. The top of frame corner joint

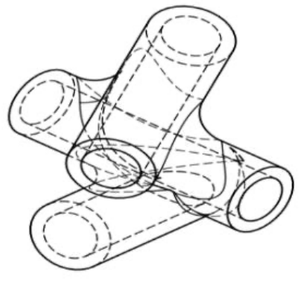

Figure 5. The top triangle superimposing joint

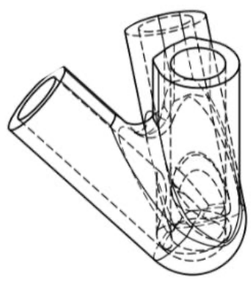

Figure 6. The foot joint

Testing

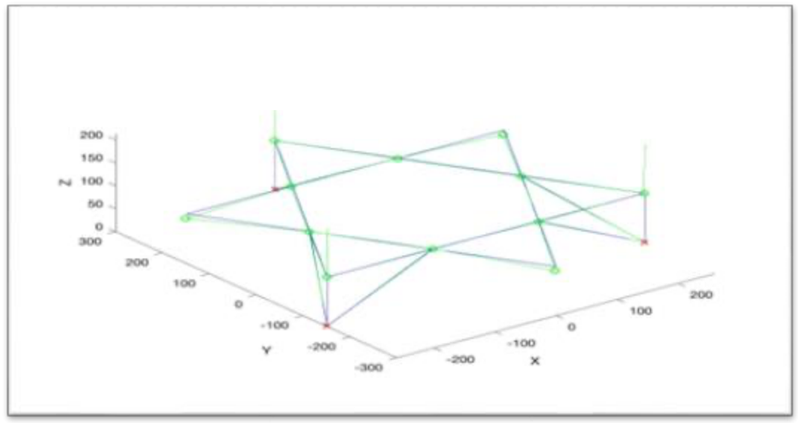

Figure 7. The MATLAB analysis of strain at each joint. Results: stress is evenly distributed across all joints, this test was successful

Test	Description	Result
Joint Drop Test	Individual joints dropped from 10-20 ft	Success, no joints broke
Ease of Assembly Test	Frame assembled by 2 team members	Success, no cracks and quick
Assembled Drop Test	Entire frame dropped from 5-15 ft	Success from 15 feet
Flight Test	Assembled drone flown to 10 feet and motors cut	To be performed

Table 3. Physical testing

Conclusion

The Duke XPRIZE team requires a redesigned drone frame that can withstand crash landings. Through the iterative engineering design process, the final prototype reinforces the current geometry by adding a lunar lander support beam between the edge of the top triangle and the foot joint. The final prototype has been tested for impact resistance and is able to survive a height of 15 feet.

- Limitations: The final prototype cannot be immediately scaled onto the current XPRIZE drone because the presence of top and bottom motors at all 6 points conflict positionally with the lunar lander beams.
- Future Work: Add shock absorption mechanisms, such as breakable pins, telescoping springs, and flexible joints; experiment with different 3D-printing filaments; upscale to the current XPRIZE drone size

Acknowledgments

The XPRIZE drone team A would like to thank the following individuals for contributing to the success of this project:

- Dr. Martin Brooke (Client)
- Dr. Henri Gavin (Technical Mentor)
- Dr. Ann Saterbak, Dr. Bucholz, and Dr. Lacroix (Professors)
- Noah Johnson (TA)
- Murad Maksumov (Lab Manager)