SAE Aero Design Competition (Regular Class)
"Ponderosa Pilots"

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PONDEROSA PILOTS

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Abstract

The SAE Aero Design Competition aims to challenge undergraduate and graduate engineering students to design, manufacture, and test a payload-carrying aircraft. Some design challenges presented to this year's team have included: oversized payload (soccer balls), a 100-foot takeoff runway, and various size and power restraints. To solve such a design problem, the team conducted research and analysis, designed several alternative solutions, built prototypes, and tested designs computationally, analytically, and empirically. A final solution took the bold approach of building a compact, high-lifting aircraft that exploited the competition scoring equation. The team's finalized design was submitted to SAE through technical drawings and documentation in February, and in the following two months, the team finished testing and manufacturing the final, full-scale design solution.

Sponsored by W.L. GORE and Associates, the team managed manufacturing and travel budgets, as well as a strict schedule in order to complete this project. In addition to furthering their education and knowledge in Aircraft Design and Analysis, the team also learned lessons in Project Management and Professional Relations. Despite the cancellation of SAE's physical events due to the COVID-19 pandemic, the team will be able to represent themselves and NAU's College of Engineering during SAE's Virtual Events on May 15th 2020. The outcome of this project shows that the team's work on this project was successful. It furthered their own professional and educational development, as well as provided useful insight to future SAE Aero Design Competition teams at NAU.

Requirements

- 100-Foot Take-off Runway
- 400-Foot Landing Strip
- 10-Foot Maximum Wingspan
- 1000-Watt Power Limit
- Fully-Enclosed Oversized Payload (Soccer Balls)
- Misc. Material Restrictions
- Time Limits

$$FS = Flight\ Score = 120 * \frac{2 * S + W_{steel}}{b + L_{cargo}}$$

S = Number of Spherical Cargo Carried on a Flight
W_{steel} = Regular Boxed Cargo Weight (lbs)
b = Aircraft Wingspan (inches)
L_{cargo} = Length of Cargo Bay (inches)

[1]

Analysis

The planform shape of the wings and lifting body were optimized by iterative simulations guided by a plot of aspect ratio (span divided by average chord) versus coefficient of lift. This led us to give the plane an aspect ratio of 2.55 and shrink the plane to be as small as possible while still enclosing the soccer ball cargo[2]. Kinematics and simulations were used to optimize lift per span and assure that any selected design could take off in under 100 ft. The analysis accounted for phenomena such as 3D wing tip vortex effects, which, at these Reynold's numbers, have a significant effect via induced drag and induced angle of attack [2].

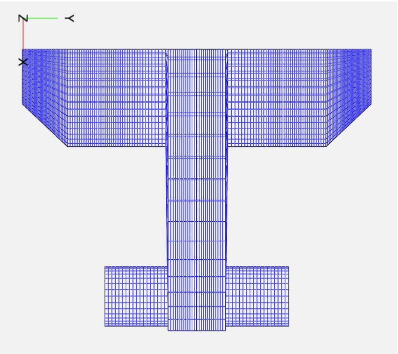


Fig 1. Open VSP Model

Since the scoring equation is lift divided by span, and a significant amount of span is required to house the soccer ball cargo, it was decided that the cargo bay would be a lifting body as to not waste span. The cabin airfoil profile was chosen considering coefficient of lift and drag, and height to span ratio [3]. This last parameter is important to maintaining overall aspect ratio. Finally, the wing airfoil section had a high coefficient of lift (~2.5) but relatively low lift per drag. This trade off was made to increase lift per span and therefore score.

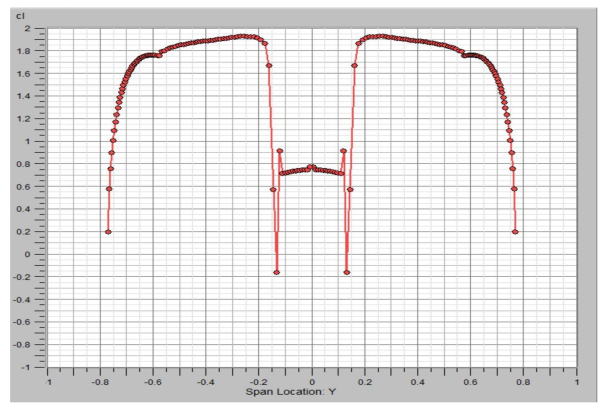


Fig 2. Span wise 3D coefficient of lift

Manufacturing

- Particle board and 3-D prints for airfoil templates
- Hot nichrome wire cutter used to cut foam lifting bodies
- Aluminum structural members
- Epoxy used to compile sections and attach horns
- Thin blade to cut foam slots for servos
- Silicon and tolerance fit servos into place

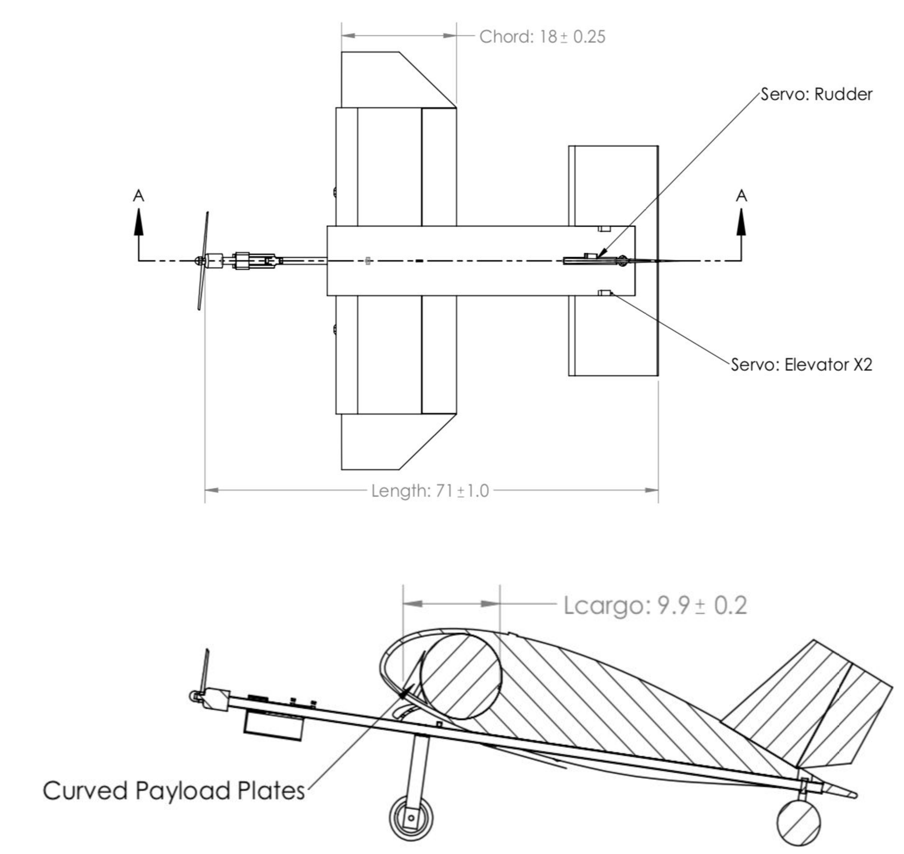
Prototypes/Testing

Prototypes:
Mark I, Mark II, Mark IV, Mark V

Iteration	Mark I	Mark II	Mark III	Mark V	Mark VII
Pros	Learned manufacturing techniques	Could take off unloaded in 100 feet	Leading edge slats allowed 30ft take off	Lighter, tail dragger holds optimal angle of attack	Can take off loaded within the 100 foot limit
Cons	Couldn't take off at all, very heavy	Couldn't handle payload well	Not enough pitch control in flight	Elevator set to incorrect angle	Harder to taxi and take off

Testing:
Propeller Testing,
Stress Testing,
Flight Testing

Final Design



Design Features:

- 60-Inch Wingspan
- S1223 Airfoil [3]
- Tapered Wings
- Leading-Edge Slats
- One (1) Soccer Ball
- Airfoil-Shaped Cabin ("Ballfoil")
- Taildragger Configuration
- Conventional Empennage
- 6 lbs Cargo Capacity
- 9.9-Inch Cargo Bay

Results & Conclusions

The 2020 SAE Aero Design Competition presented teams with a brand new design challenge that encouraged engineers to design aircraft with a high lift-to-span ratio. Over the course of this project, the Ponderosa Pilots were able to apply research on aircraft design and aerodynamics to the construction of their design solution [4, 5]. Through both simulated and physical testing, the team was able to prove the effectiveness of their design and ensure that it would fulfill certain engineering requirements.

Although the circumstances surrounding the COVID-19 pandemic prevented final testing and participation in the SAE competition, the team is satisfied with the progress made on their project. The Ponderosa Pilots were able to construct and test several prototypes, which eventually led to a final design that would have fared well in the SAE competition. The team's future work includes: final, full-scale testing [when possible], and participation in SAE's Virtual Events (May 15th, 2020).

References

[1] Society of Automotive Engineers, "2020 SAE Aero Design Rules," [Online].
[2] J. D. Anderson, Fundamentals of aerodynamics, New York, NY: McGraw-Hill Education, 2017.
[3] "S1223 (5.64%) (S1223-il)," Airfoiltools.com, 2019.
[4] D. Scholz, Aircraft Design, Berlin: Springer, 2012.
[5] Budynas, R., Nisbett, J. and Shigley, J., 2016. Shigley's Mechanical Engineering Design. New York: McGraw-Hill.

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