SIMETRA Arrow

Embrace the Delta

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Visit us to learn more about the Arrow, the team, read our blogs and more! We will be available for live-chat all Open House.

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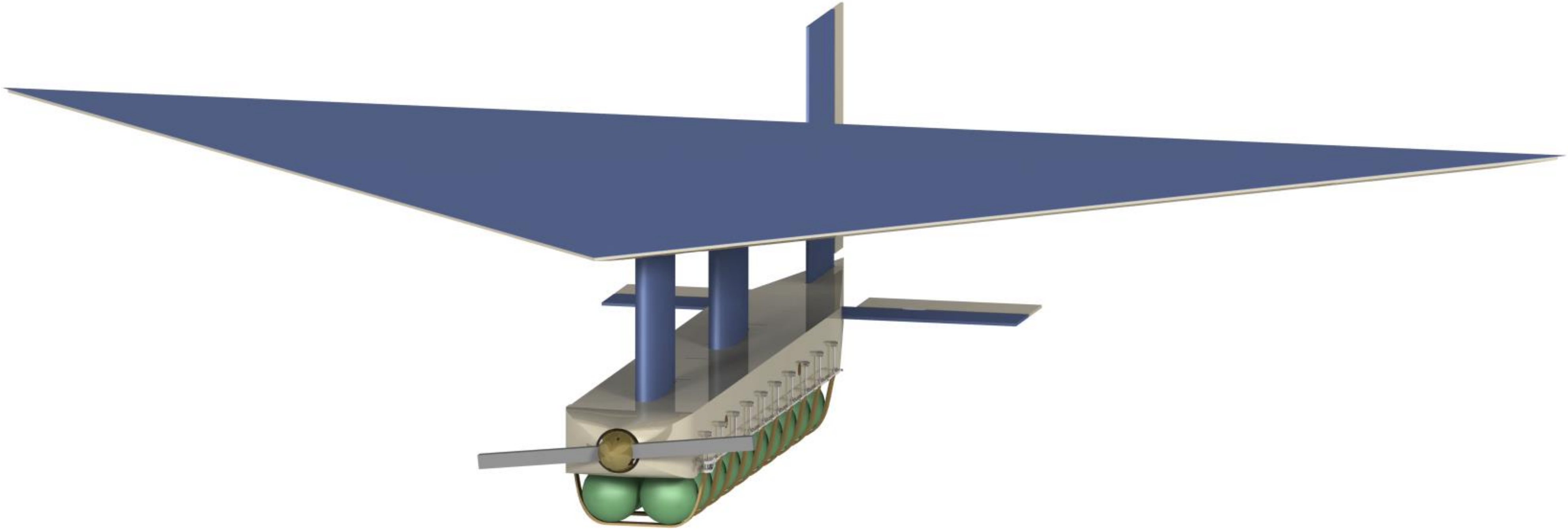
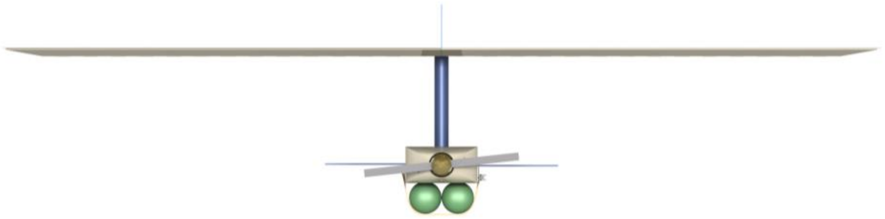
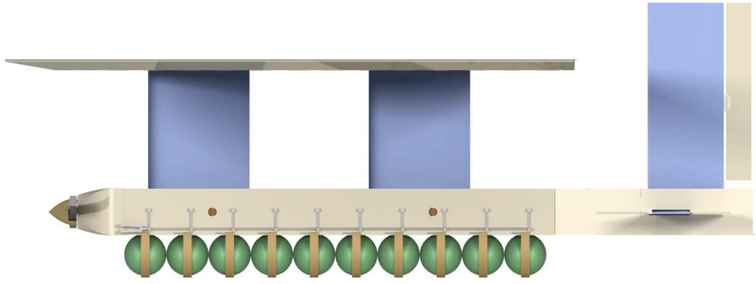
The Arrow

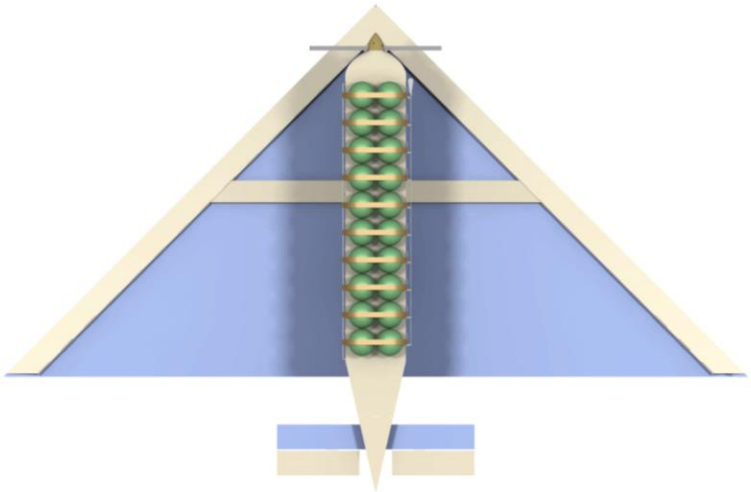


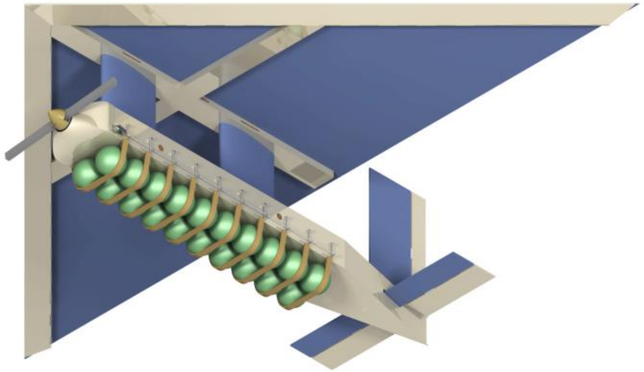
The Arrow

"You can't look at the competition and say you are going to do it better.
You have to look at the competition and say you are going to do it differently."
-Steve Jobs









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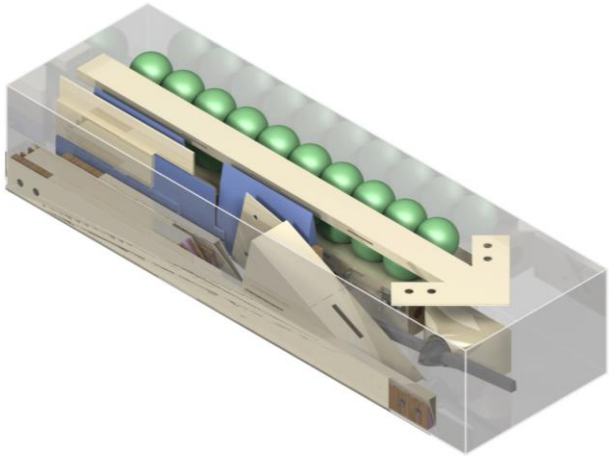
Mission

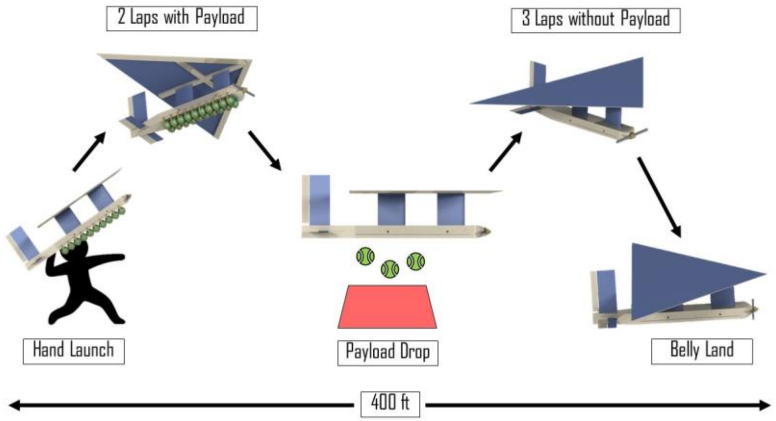
The Bronze Propeller Competition

"Semi-Autonomous Emergency Supply Aircraft"

The competition provides rules and guidelines to simulate the role of an emergency supply aircraft.

- To simulate an emergency, the aircraft and payload must be delivered to the competition site in an 11x7x36-inch box and be ready to fly within 5 minutes. For versatility on various terrain, a hand-launch is required.
- The aircraft must fly 2 laps of a 600-foot course, drop its payload in the drop zone, and return via a flight of 3 further laps.
- Emergency supplies must make it to the intended recipient quickly and accurately. Thus:
  - The payload is dropped without human intervention
  - The payload must land within a 20x20ft drop zone, or a 40x40ft zone for half the points
  - To encourage prompt delivery, the score is multiplied by $(120/Time)^4$
- An Emergency could easily require more payload than one flight could deliver, so the competition is cumulative over all runs completed within the four-hour competition.

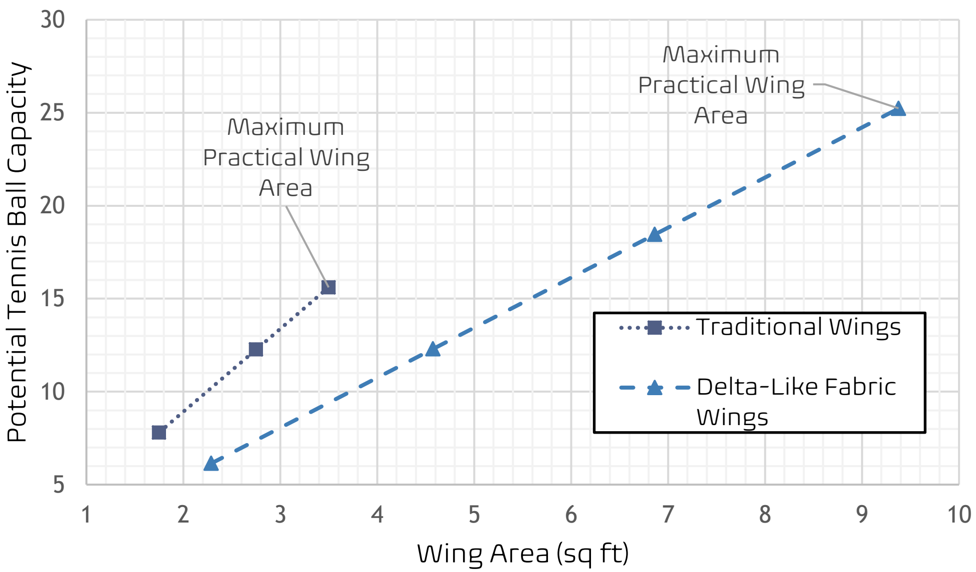




Why Choose The Arrow?

- Early mission analysis concluded that the number of balls on target is the most important aspect of the competition. The Arrow was designed to maximize the space left in the box for the tennis ball payload once the aircraft is packed.
- Our competition analysis (see plot to the right):
  - assumes a traditional wing C_L of 1, and a Fabric Wing C_L of 0.6
  - bases the ball capacity off a payload mass fraction of 0.4
  - considers practical space inside of the box to cut each line off at an achievable wing area.
  - shows that a collapsible fabric wing, even with a lower C_L, has the potential to carry more balls than a traditional wing given box size restrictions.
- The flexibility of the rubber band-based drop mechanism combined with the external payload bay and stabilizing holes on the belly allow the Arrow to safely carry the tennis balls throughout the phases of flight.

Potential Tennis Ball Capacity of Traditional Rectangular Wings and Fabric Delta Wings



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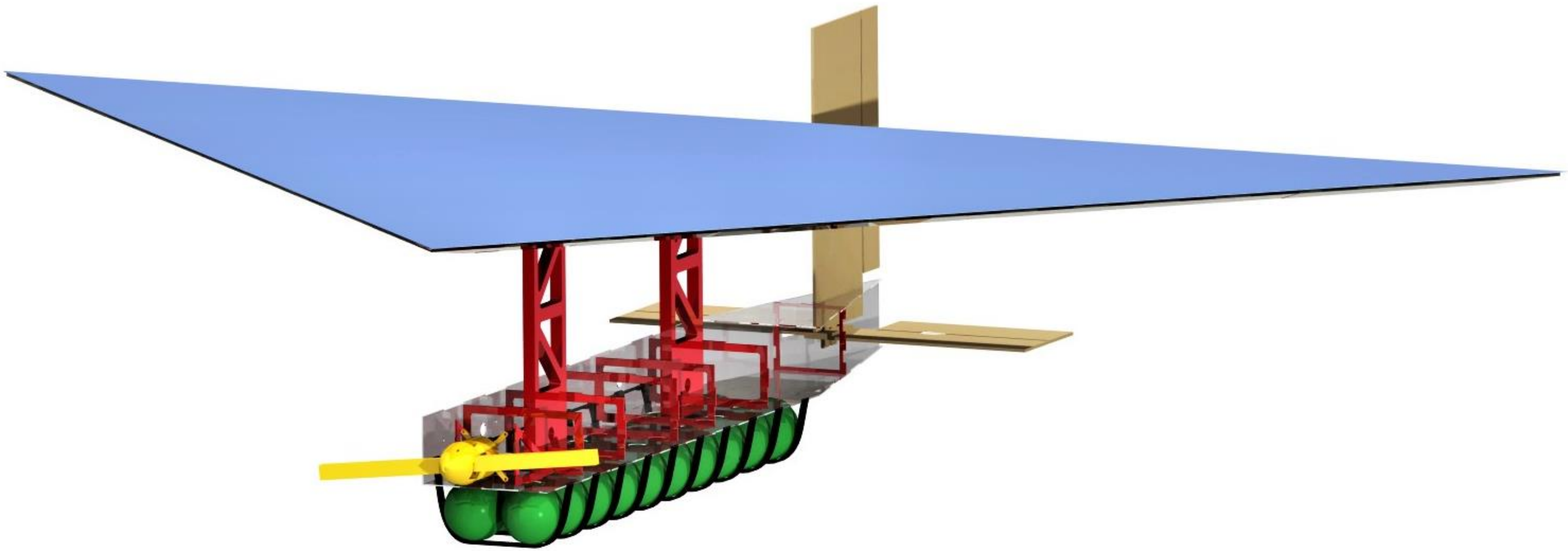
Systems Integration



■ (blue)	Aerodynamics	■ (tan)	Stability and Control	■ (black)	Payload Release Mechanism
■ (red)	Structures	■ (yellow)	Propulsion	■ (green)	Payload

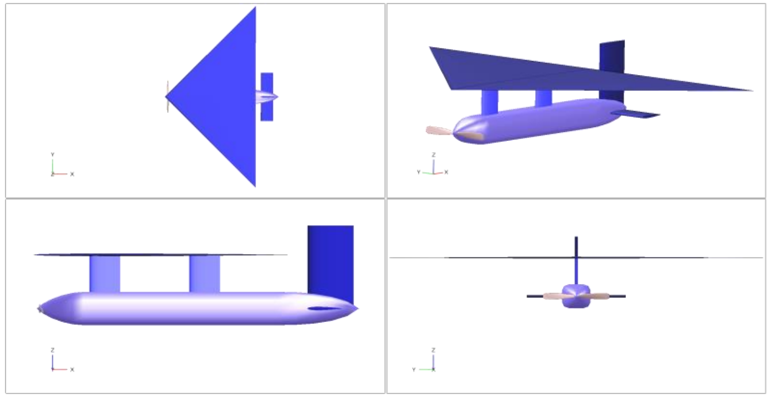
Aerodynamics

Objective: Determine the relevant aerodynamic performance requirements and design an appropriate lifting surface.

Aero Features	
Configuration	Delta Wing, Conventional Tail
Wing Geometry	45 degree sweep (AR=4)
Wing Area *(square feet)*	7.96 ft^2
Wing Span *(feet)*	5.64 ft
$C_{L\,MAX}$	0.9
L/D_{MAX}	10
VSTALL *(feet per second)*	35 fps
Analysis	• Custom Excel Tools • VSP Aero • Nicolai Drag Method

Delta Planform

- The aero surface of the wing is formed from a leading-edge spar, which has a sharp, triangular cross-section to aid in generating vortex lift, and a top surface of tensioned ripstop nylon. To reduce weight and complexity, there is no separate lower surface.
- A 45-degree sweep was chosen to maximize the area of the wing while minimizing the length of the leading-edge spars.
- The sweep angle strikes a compromise between available empirical data and desired stability characteristics.



VSP Model of the Arrow

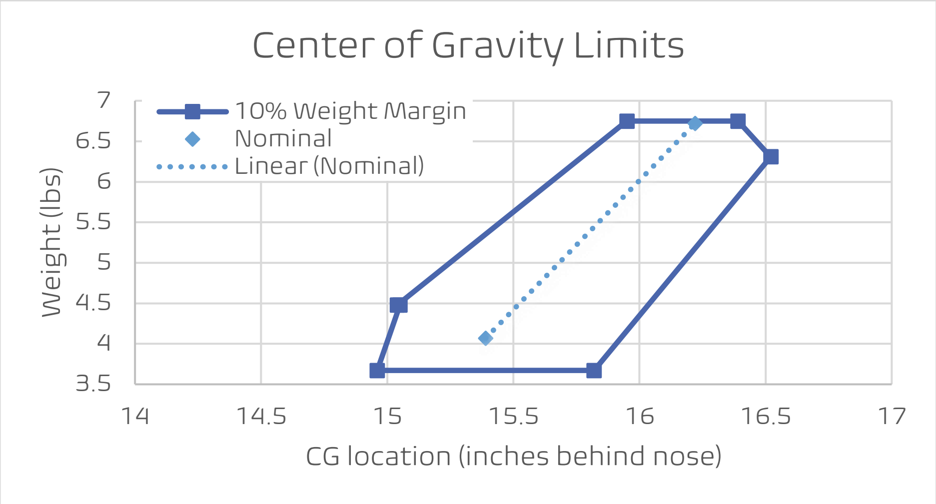
Innovative Aero Surfaces

- Aerodynamic design is centered around the 8 square foot fabric delta wing. The delta wing is collapsible, larger than our smallest team member, and able to be rapidly assembled for a fast deployment.
- The wing was sized based on a wing loading obtained from Raymer's sizing equations, which showed that turning performance was the limiting factor. From this we selected a wing loading of 0.79 pounds per square foot.

Stability and Control

Objective: Design a system of stabilizing and control surfaces to maintain smooth, and precise flight for all phases of flight.

Stability and Control Features		
	Payload Onboard	Payload Released
Static Margin *(% chord)*	5% chord	9% chord
Maximum Incidence *(degrees)*	9.7 deg	8.7 deg
Minimum Incidence *(degrees)*	-15.5 deg	-10.5 deg
Total Weight *(pounds)*	6.75 lbs.	4 lbs.



- The tail design provides high levels of maneuverability in flight, while minimizing size to more comfortably fit in the box.
  - Balanced control margin with available volume inside box
- Stability analysis ensures that all controllability criteria are met.
- Designed to handle the significant change in weight and center of gravity.

Tools and Methods Used

- Longitudinal Stability Analysis
- Lateral Directional Stability Analysis
- Vehicle Sketch Pad
- Custom Stability Analysis Spreadsheet Tool

Propulsion

Objective: To develop a system that would minimize power usage during the turn maneuver, while supplying enough power to all other phases of the mission.

Propulsion Package Selection

- Cross-disciplinary analysis was employed to determine the most effective and appropriate propulsion system
- Propeller Selection was based off standard Raymer propeller sizing equations. Out of numerous propeller cases, the final propeller was chosen based on performance as well as clearance with respect to the wing.
- Analyzed flight requirements:
  - Take-off/Hand Launch
  - Climb
  - Turning
  - Steady-level
- The hand launch condition had the highest power required by the battery, directly impacting the motor size.


APC 12x12

Motor


Propulsion Features	
Propeller *(diameter x pitch)*	12x12 APC Propeller
Battery *(Nominal Volts, #Cells, mAhr)*	14.8 V, 4s, 3200 mAhr, 30C
Motor	Great Planes Rimfire .32 42-50-800 Outrunner Motor
Cruise/Max Level Speed *(feet per second)*	75 ft/s
Power Available (Watts)	1178 W
Endurance *(seconds)*	732 s
Total System Weight *(pounds)*	1.51 lbs.

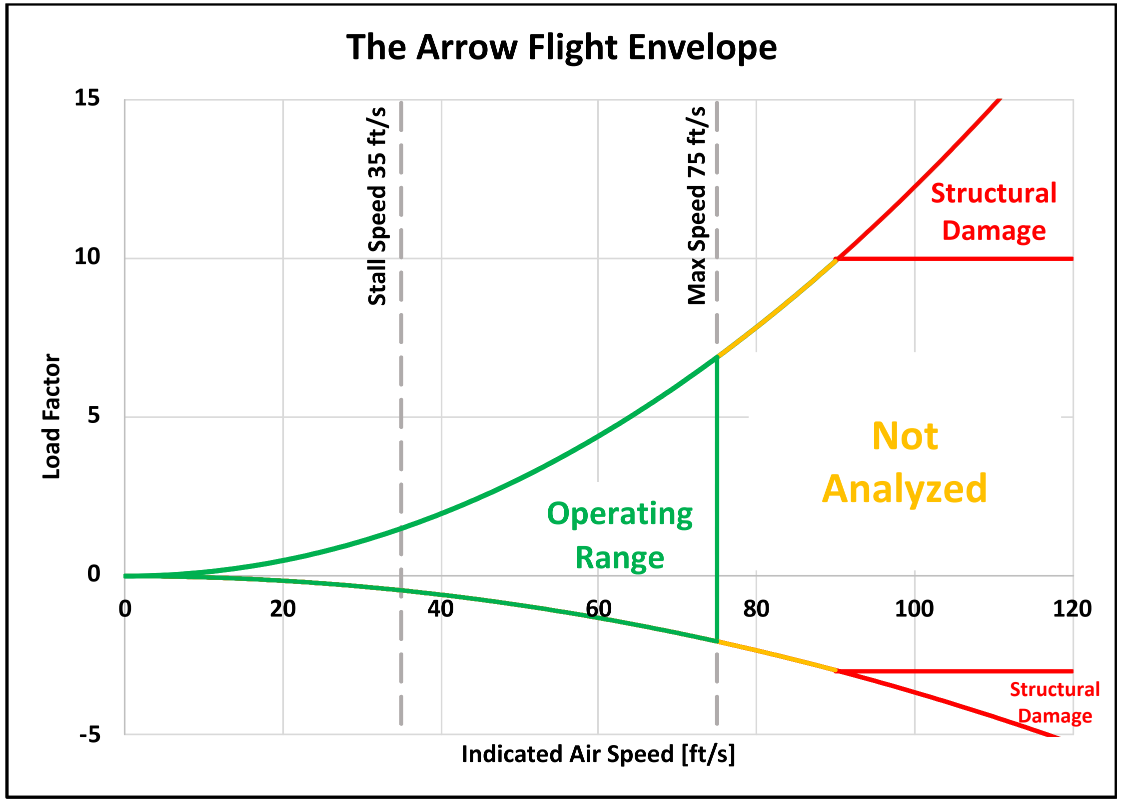
Tools and Methods Used

- Raymer propeller and engine sizing equations
- MotoCalc8
- Euler time-step analysis for hand launch
- Custom propulsion analysis software using VBA

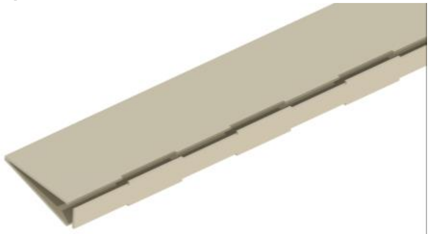
Structures

Objective: To ensure the structural integrity of the vehicle throughout the mission and develop the appropriate methods of construction.

Structural Features	
Construction	Semi-Monocoque
Safety Factor	1.5
G - loading	+10/-3
Primary Materials	Balsa wood, Bass Wood, Rip-stop Nylon
Load Cases	• Bending in wing • Torsion at wing mount root • Buckling at the fuselage



- The structure is primarily designed to withstand the different loadings encountered during flight.
- The analysis is performed at the critical locations of the vehicle, which are the wing, the wing mount, and the fuselage.
- The highest load and deflection occurs at the wing.
  - Maximum Bending Stress of 0.95 ksi
  - Maximum Deflection of 0.11 in
- Control Surfaces consist of laminated wood sheets.
- Castle pattern used on the vehicle part is utilized for the ease of assembly.



Tools and Methods Used

- Fundamental Mechanics of Material
- Euler-Bernoulli Beam Theory
- Custom Structural Analysis Excel Spread Sheet

Release Mechanism

Objective: Develop mechanism that will deliver maximum payload in a designated drop area

Release System

- Selected to release maximum payload capacity
- The balls retained by rubber bands pressing them against the fuselage
- Stored on the exterior of the aircraft for quick and easy release
- Autonomous release method by Arduino and GPS was determined to be most reliable
- Tennis balls released by actuated servo unhooking rubber bands

Power Supply

- Separate powering system from main propulsion system
- LiPo battery minimizes weight
- Powers GPS and Arduino

GPS

- Provides for an accuracy of up to 0.3 feet at the flight efficient speed of 75fps based on trajectory analysis .

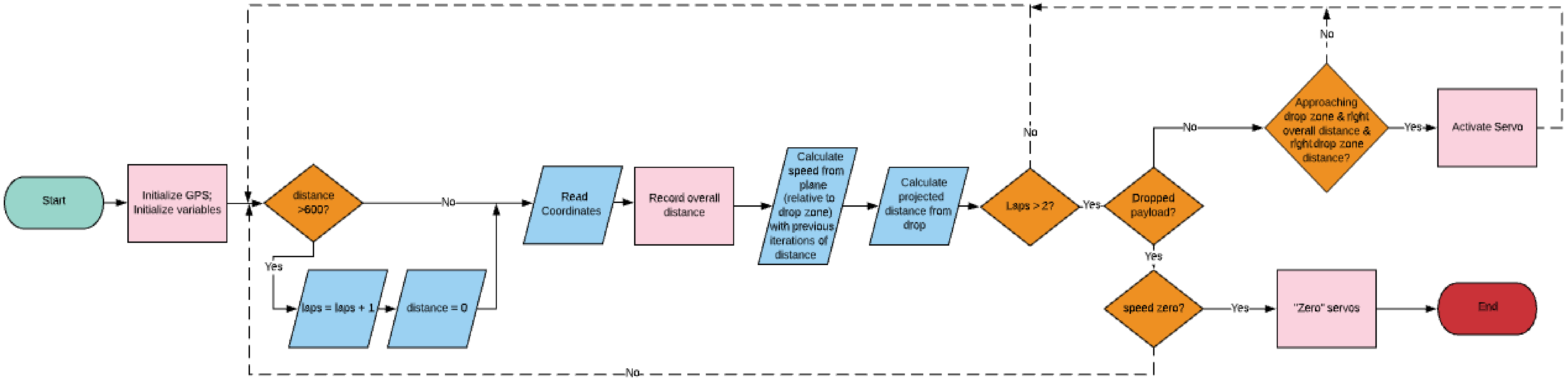
Release Mechanism Features	
Payload Capacity	20 tennis balls
On-board Computer	Arduino Micro
Location System	SparkFun GPS-RTK2
Release Method	Futaba BLS651
Battery *(Nominal Volts, #Cells, mAhr)*	Onyx LiPo 3s 11.1v 1200mAh

Methods Used

- Trajectory analysis
- 2-D push – pull force dynamics
- Two Body tension dynamics

Release Mechanism

Visual flow chart of the autonomous payload release program



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References

1. Anderson, John D. *Introduction to Flight*, 5th edition. McGraw-Hill, 2005.
2. Cross, R. Physics of overarm throwing. American Journal of Physics, 72(3), 305–312. 2004. doi: 10.1119/1.1634964
3. Gundlach, Jay. *Designing Unmanned Aircraft Systems: A Comprehensive Approach, 2nd Edition*. American Institute of Aeronautics and Astronautics, 2014.
4. Hibbeler, R. C., and Yap, K. B., Mechanics of Materials, Harlow: Pearson Education., 2018.
5. Hoerner, Dr. Sighard F. and Borst, Henry V. Fluid-Dynamic Lift. L.A. Hoerner, 1975.
6. McCormick, Barnes W. Aerodynamics, Aeronautics, and Flight Mechanics. John Wiley and Sons, 1979.
7. Miller, S., The Bronze Propeller Competition, https://www.wichita.edu/academics/engineering/aerospace/The_Bronze_Propeller.php
8. Raymer, Daniel P. *Aircraft Design: A Conceptual Approach,* 5th edition. American Institute of Aeronautics and Astronautics, 2012.
9. Warchol, Matthew L. "An Investigation of Flexible Rogallo Type Wing Aerodynamics and the Applications to UAVs", The Ohio State University, 2009.

THANKS!

Team Simetra would like to thank the Aerospace Engineering staff, and especially Dr. Miller for a great learning experience. Through the natural struggles that come with senior design, everyone comes out of his classes a better engineer. We are sad to not be able to fully participate in the Bronze Propeller Competition and see our plane fly but have still found great value in our experience. Wichita State is blessed to have such an excellent Senior Design course.

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