Glider Design for the 2024-2025 AIAA Design Build Fly Competition

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SPAROW (Subsonic Plane Autonomized with Reliable Optimized Wings) is a student-led project in the Space Hardware Club (SHC) at the University of Alabama in Huntsville (UAH). The goal is to compete in the annual AIAA Design Build Fly competition.In each year, the AIAA releases challenge requirements that specify the aircraft missions in the competition. One unique aspect of the 2025 challenge is to develop a fully autonomous glider that can be released from a carrier plane. The glider must be passively stable and light enough so that the speed of the carrier plane is not significantly impacted. The need for a lightweight glider and the limited manufacturing experience within SPAROW leads to a simplistic design. The SPAROW airframe division chose a delta wing configuration with downward wingtips in order to provide high stability while maintaining a low weight. The wing span of the glider must be less than fourteen inches, so the glider can fit underneath the carrier plane without affecting its flight. The material of the glider must be durable enough to withstand landing but have ease of manufacturability and a low cost. The airframe division performed trade studies on multiple materials to see what best fits the glider's needs. Overall, the glider must perform well in competition while adhering to the constraints set both by the AIAA requirements and SPAROW's internal limitations.

I. Introduction

SPAROW is a student team within the University of Alabama's Space Hardware Club. The team's goal is to compete in the American Institute of Aeronautics and Astronautics's (AIAA) Design Build Fly (DBF) competition in 2025. One unique aspect of the 2025 challenge is the need for the competition aircraft to release an autonomous glider mid-flight. The glider must land autonomously within a specific region designated by the competition.This competition parameter created many challenges for the SPAROW team.

Additionally, the glider must be passively stable and light, so that the speed of the carrier plane is not significantly impacted. The speed of the carrier plane is one of the primary score factors in the competition, so the impact of the glider on the carrier plane's speed was a driving design force, especially for wing configurations and material selections. The glider must also be durable enough to withstand landing without landing gear.

II. Glider Design Parameters

SPAROW created internal requirements for each aspect of the competition, including the glider design. These requirements were based on the competition requirements, performance parameters, and SPAROW's limitations. First, the challenge requirements were written out as a basis of SPAROW's internal requirements. Then, requirements were generated to ensure a high-scoring performance at competition. These requirements were then reviewed and edited based on internal limitations, such as cost, skill-level, time, and accessibility of materials.

The internal requirements served as a basis for the glider design. This ensured that SPAROW did not design past its means but would still create a product that would perform well in competition. The requirements could not be too specific or limiting, so that the glider team could still go through the engineering design process to create an optimal design.

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Tag	Description
SN1	Glider shall have a maximum wingspan of 14 inches
SN1.1	Glider must execute 180 degree turn before landing
SN1.2	Glider release altitude shall be between 200-400ft
SN1.3	Glider must fly a descending pattern until landing
SN1.4	Glider shall have a maximum weight of 0.55 lbs
SN1.5	Glider shall have elevons
SN1.6	Glider's flight controller shall be capable of self-calibration prior to release
SN1.7	Glider shall record flight path data on onboard data storage device
SN1.8	Glider's flight controller shall have an onboard barometer, IMU, and data storage reader/writer

Fig. 1 Internal Requirements

Figure 1 shows a sample of internally generated requirements. Each requirement has a tag that identifies the type and application of the requirement.

A sensitivity analysis script was written in MATLAB to visualize the effects a change in a specific parameter would have on the overall score. This allowed the team to decide which design aspects to prioritize to ensure the best score.

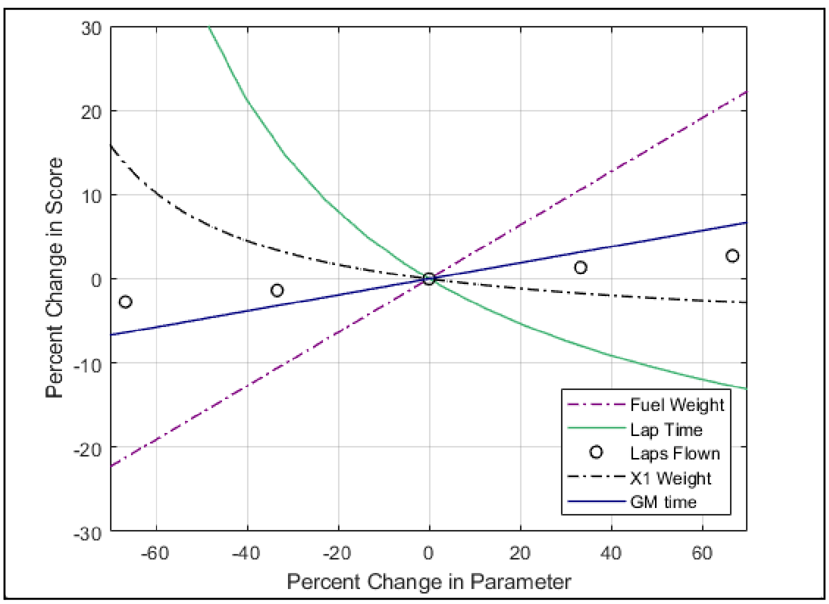


Fig. 2 Sensitivity Analysis

By studying the sensitivity analysis, the team found that the parameter with the highest rate of change was lap time of the carrier plane. The speed of the carrier plane became the driving factor of the glider design, leading to the design of a lightweight glider. The SPAROW team used both the internal requirements and the sensitivity analysis results as a basis for the glider design.

III. Design and Modeling

Trade studies were performed on each design aspect of the glider. For example, the wing configuration of the glider was narrowed down to a swept delta wing and a flying wing. The two were then traded using a weighted decision matrix as shown in figure 3.

FOMs	Weight	Flying Wing		Swept Delta Wing	
	1/3/9	Raw	Weighted	Raw	Weighted
Mass	9	9	81	1	9
Cost	1	3	3	3	3
Stability	3	1	3	3	9
Totals			87		21

Fig 3 Wing Decision Matrix

The flying wing design was chosen due to its low mass. Mass was the driving factor of the decision, as shown above. The mass had to be low so as to optimize the speed of the carrier plane. The flying wing provided the lowest mass while still having a manageable cost. Despite having less stability, the flying wing was chosen because of the relative importance of mass over stability.

The initial glider design was then created based around the flying wing configuration. As shown above, the flying wing design had a low stability. Because of this, a slight inward sweep was added to the wing, as well as a dihedral. This optimized both mass and stability. Stability of the glider was important due to the control the glider must have exhibited in the air. The competition outlined a specific drop zone in which the glider must land after being released from the carrier plane. Even though the mass of the glider was prioritized over stability, the control and flight path of the glider were still important competition factors.

Another design factor that the SPAROW team had to consider was integration both with the carrier plane and electronics. Some internal requirements were created due to integration with the carrier plane, such as SN1 which requires the glider to have a wingspan less than 14 inches. This ensured that the glider would fit under the carrier plane and not interfere with its flight. The weight of electronics had to be carefully considered when finalizing the glider design. Light weight electrical components were used so as to increase the mass as little as possible. The placement of the electronics also had to be decided. The electronics were placed in the front of the glider, with a small plastic covering. The center of gravity and center of lift of the glider were then tested and components were moved to optimize glider performance.

Multiple designs were modeled in a 3D CAD software throughout the design process. Each design was evaluated and modified, and a final design was produced using the best parts of each design. These different designs prioritized different aspects of the competition. By combining them into one design, it ensured that the glider would be well-rounded and high scoring in competition.

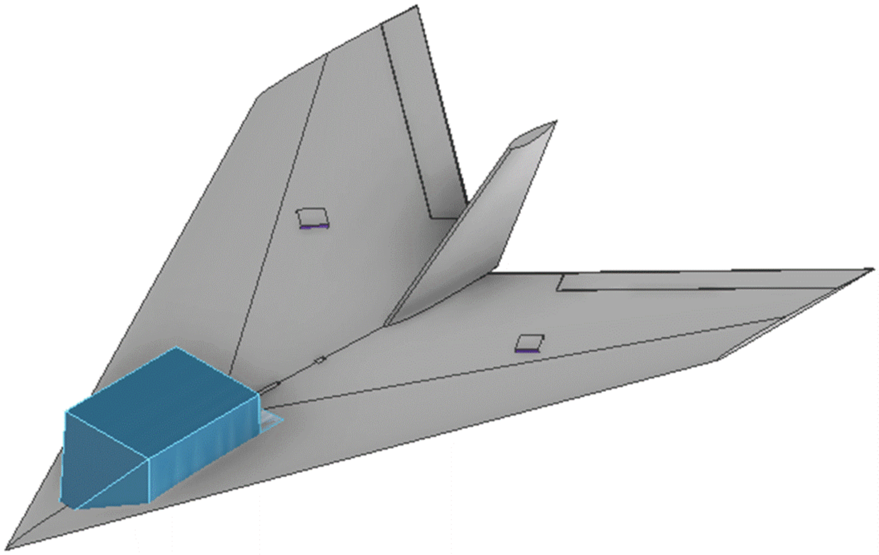


Fig 3 Glider CAD Model

Another part of the design and modeling phase was creating a drop mechanism that would allow the glider to release from the carrier plane mid-flight. The purpose of this mechanism was to ensure a clean release of the glider so that the flight path of both the glider and the carrier plane were unimpeded.

The drop mechanism between the carrier and plane as seen in figure 4 utilizes a hook which goes through the entirety of the glider to secure it vertically, while a rear block also extending the height of the glider acts as a horizontal constraint. A servo can activate the hook, pushing it forward and releasing the glider to fall downward. The glider is held upside down, which then allows for its lift vector to propel it down and away from the carrier, ensuring a clean separation.

This integration and detachment mechanism drew directly from SN1.4 with a weight limit of .55 lbs. Due to this weight allowance, the glider is to be constructed out of lightweight materials, which directly led to the materials often being strong enough for flight, but severely limiting the ideas for detachment. A common issue with many deployables is that if they generate their own lift, they can often rise swiftly after deployment, sometimes colliding with the primary carrier. There are a great many strategies to avoid this, with the most prominent being to launch deployables out via some sort of mechanism. However, due to the glider's materials and lightweight design meant that deploying as such would incur undue risk. Thus, we mounted the glider upside down in effort to ensure clean separation with the knowledge that the design could be implemented so that it would be simple to flip right side up and restabilize.

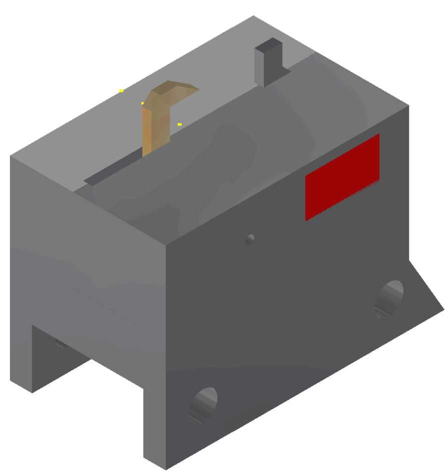
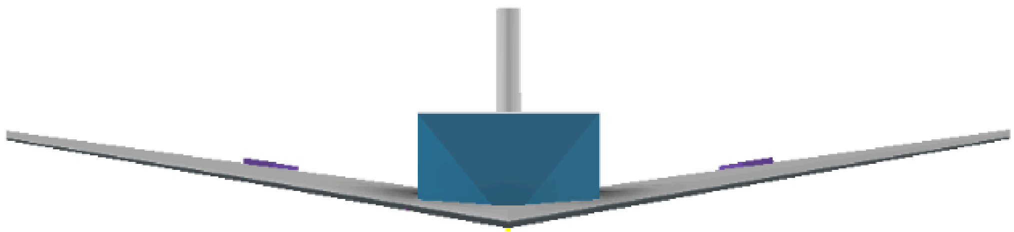


Fig 4 Drop Mechanism CAD

IV. Material Selection

Another important design factor was the materials SPAROW would use to make the glider. Once again, the driving force of this decision was the mass of the glider. The SPAROW team traded several materials for the body of the glider, including expandable polystyrene (EPS) foam and polyurethane foam. EPS foam was ultimately chosen due to its low weight, high durability, and relatively low cost. The team chose a plastic covering for the electronics because of its negligible mass.

The team also chose to reinforce the bottom of the glider with a fiberglass fabric. Because the glider does not have landing gear, the bottom surface will take the brunt of the landing force. By strengthening the bottom through the use of fiberglass fabric, the durability of the glider is increased, meaning the team can perform more tests before the competition. The glider will be mounted to the carrier plane upside down, so the fiberglass fabric will give a stronger surface to which the drop mechanism can attach.



Color	Material	Area
	EPS Foam	Body, vertical stabilizer, and elevons
	Fiberglass Fabric	Underside of body and elevons
	Plastic	Electronics covering

Fig. 5 Material Diagram

V. Prototyping and Testing

An initial model made to test integration with the release mechanism and to test basic aerodynamics was created. This consisted of a basic model with the shape of the glider and maintaining below the 0.55 lb weight limit. It was able to successfully connect with and deploy from the drop mechanism several times. It deployed a majority of the times tested, with all issues coming from the electronics issues or glider foam catching, all of which are set to by patched. A hook mechanic with rear stopper was thus proven a working way of deploying the glider.

This same model was able to successfully glide a few feet, thus performing a proof of concept for the glider's aerodynamics and ability to behave like stable flight through brief, unpowered tests. The electronics side has also begun testing with a larger model to access the handling of a glider controlled purely through elevons. This larger glider has massive wings and is very stable, thus making it optimal for developing the electronics knowledge to be utilized by the competition glider.

VI. Conclusion

SPAROW intends to compete in the 2025 AIAA Design Build Fly Competition. The goal of the team is to obtain an average score at competition and to build the knowledge and skills of the team to use in future competitions. The glider is an integral part of the 2025 competition. The design has been improved through many cycles of the engineering design process and the finalized design. Prototyping and testing of the glider has confirmed the design choices the SPAROW team has made. SPAROW looks forward to competing in this year's DBF competition and hopes to compete again next year.

VII. Acknowledgements

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