Brigham Young University

AUVSI Capstone Team (Team 45)

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# Airframe Subsystem Summary

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| AF-008 | 0.1 | 02-19-19 | Initial Draft for Subsystem Engineering | Tyler Critchfield | Ryan Anderson |
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# 1 Introduction

This artifact summarizes the final design of the Nimbus Pro airframe that was selected during the Concept Development stage. Models and testing procedures of the airframe are included, as well as a summary of what has been done and still needs to be accomplished. The advantages of the current concept in achieving our key success measures are described.

# 2 Design Description

The Nimbus Pro airframe is a fixed-wing plane with a large storage capacity and large wing span made of polystyrene (Fig. 1). It was selected during Concept Development for its long span and spacious fuselage. Since the last design review, we successfully constructed the new aircraft, carefully planned component placement to achieve a desirable center of gravity (CG), and successfully flew 15 flights with the Nimbus Pro. Our first flight ended in a crash (see AF-004), after which we quickly glued it back together and continued flying with it. Our flights have mostly been with a remote controlled (RC) pilot, but recent flights have also integrated with autopilot (for tuning gains). We've also integrated with the UGV drop mechanism and vision subsystems.

*Figure 1: Fully-constructed Nimbus Pro airframe before its first flight.*

A detailed procedure for constructing the plane is beyond the scope of this artifact. It suffices to say that the procedure follows basic principles and steps of foam aircraft construction, as follows:

- Glue fuselage sections together
- Attach proper servos and control horns to each control surface
- Attach motors and ESCs to wings
- Attach tail pieces
- Install all electronic hardware/wiring
- Ensure connectors and joints are properly secured and strengthened if necessary
- Attach/connect wings

The CG was carefully placed to optimize performance using an aerodynamics model, as explained in AF-011. The following modifications were made to the airframe based on our application and integrated hardware:

- Holes were made in the main compartment hatch for the R/C and Ubiquiti antennas. There is dedicated space further back in the plane for these components, but placing components there moved the CG back too far for an acceptable static margin. Care was also taken to space the Ubiquiti antenna far from the GPS antenna to avoid signal interference.
- The GPS slot on top was not used and taped over. The GPS was instead placed inside the nose of the plane to move the CG forward.
- The servos we selected were larger than the airframe was designed for. Because of this, some foam and plastic was removed from servo locations using razor blades, a hot metal tool, and wire cutters to allow them to fit.
- A foam wedge was inserted underneath the tail to increase the tail incidence angle (see further details below).
- Because the motor power wires are so thick, we bypassed the electrical connector that came with the airframe. Small holes were drilled into the wing connector pieces to allow for the large wires to extend from the ESCs in the wings to the fuselage.
- In general, most components were placed as far forward as was reasonable to move our CG forward and increase our static margin. Artifact AF-014 visually depicts the placement of major components in the plane to ensure optimal CG placement.

In Concept Development, we considered adding wing extensions to increase total span. This would help the plane fly slower by increasing lift. Flying at a lower velocity would then help us achieve higher performance in our key success measures (specifically obstacles hit, waypoint proximity, characteristics identified, and accuracy of payload drop). In order to decide if wing extensions would be worth it, the aerodynamic benefits of extensions were modeled and compared to the relative cost of manufacture (See AF-012). In summary, it was decided that any extra benefit to extensions would not be worth the time and effort required to design, implement and test these extensions.

One unanticipated modification we've made to the aircraft is the placement of a foam wedge underneath the tail of the plane. Interestingly, the factory design has no tail incidence. Though we predicted problems, we decided to see if the plane would fly without this modification. (Slight instability could be accounted for with our autopilot.) It did fly, but it had a consistent tendency to want to pitch forward, making it difficult to take off and fly RC. The plane was modeled and an incidence angle of 7.5° determined the optimal condition (see AF-009 and AF-011). After installing the tail wedge, this problem was averted. The plane is now stable and flies very near the design speed we had originally planned for.

The design drawing and a more detailed description of the wedge is included in AF-010.

*Figure 2: A foam tail wedge installed underneath the tail of the plane to increase its incidence angle and improve stability.*

# 3 Testing

As described further in Artifact AF-013, we have done extensive flight testing to ensure our airframe performs as expected. In the past couple of months, we have had several productive flight tests with manual RC control and multiple successful flights while controlling with autopilot. While flying, it is very stable and flies at an average of 15 m/s. These outcomes show that our airframe works and is very capable to integrate with the other subsystems. Not only have we flown it with some autopilot control, we have also shown it can hold the imaging subsystem camera and the UGV subsystem. Both have demonstrated their subsystems can work with the plane while in flight (i.e. the vision subsystem can effectively take high-quality photos in-flight and the UGV subsystem can safely deploy from the plane while in-flight). From these results, we are very confident our airframe will integrate well with all three subsystems in the competition.

# 4 Conclusion

Our airframe is fully assembled (with slight modifications) and has proven to consistently fly reliably. All of our key success measures depend on the airframe flying well - and many of them can be improved if the airframe flies with a low velocity. Our design and modifications ensure the airframe does fly slowly, which will help minimize obstacles hit, waypoint proximity, and error when dropping the UGV payload. It also improves image quality to identify more characteristics. The plane has flown successfully under R/C and autopilot control, and the vision and payload drop systems have functioned successfully in flight. We fully expect all three subsystems to successfully integrate with the airframe during flight.