Design of an Unmanned Aerial Vehicle Blimp for Indoor Applications

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***Abstract*— This paper presents the design of an unmanned aerial vehicle blimp (UAVB) which may be used for different indoor applications. It was equipped with a 3.8 GHz FPV camera that could transmit video data to a ground station. The design of the blimp was initially tested through a fluid flow simulation software that determines the drag coefficient which is in turn used to determine the optimal streamlined profile of the blimp. A 4:1 slenderness ratio was found to be the most efficient design in terms and speed and stability. This paper focuses on the creation of a blimp that includes selection of materials, profile making, microcontroller programming, and flight testing. Due to the limited lifting capacity of the blimp, careful consideration of the parts on the blimp was done. The blimp was able to fly successfully and maneuver throughout the testing area at speeds of 1-2 m/s and at an average height of 5 m.**

***Index Terms*— UAV, blimp, microcontroller, drag coefficient**

I. Introduction

Unmanned Aerial Vehicles are getting more and more popular due to it many commercial applications. The use of multi-rotors and fixed wing aircraft has been used in several applications(e.g. documentation or sporting events; police surveillance; agricultural needs of farmers; and infrastructure inspection). The UAV applications are getting wider due to the cost competitiveness compared to the conventional methods. However, one of the weakness of multi-rotor and fixed wing UAV systems are their limited flight time. With the use of UAV Blimps, it can provide several hours of operation without the need to refuel/recharge [1][2][3][4].

Mobile LTA airships have an advantage of low operating cost because it does not rely on propulsion for its lift. Today, LTA vehicles come in three types: as rigid, non-rigid, and semi rigid. Rigid balloons or Zeppelins are the most resistant to stress because of its frame. Non-rigid balloons or blimps cannot traverse rapidly as the lack of frame prevents too much motion. Fig. 1 shows the UAV Blimp designed for indoor applications at DLSU [5][6][7][8][9].

Although there are designs of blimps, there are only a few studies that focused on small UAV blimp design that can be used in indoor application and are highly maneuverable for a variety of applications. Powered blimps today are used for more recreational means. The cost of producing paired with the simplicity of powered blimp design allows them to be bought as a consumer product. The nanoblimp makes use of a standard helium party balloon and has remote control that powers a simple and lightweight motor system for horizontal movement and steering. These blimps can be used recreationally for "balloon dog fights" and party purposes [10][11][12].

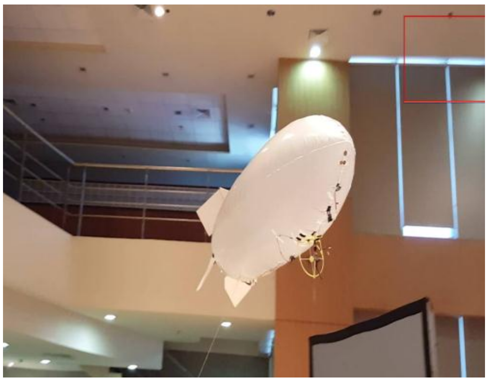

Figure 1. UAV blimp at DLSU

This study will be a significant endeavor in monitoring disaster operations and even simple surveillance operations on different kinds of events. UAVs are a key element within the concept of information dominance. Historically the greatest use of UAVs has been in the areas of intelligence surveillance and reconnaissance. While UAVs play an increasing role in these mission areas, people are just beginning to understand the operational impact of multiple UAV operations and their importance to 21st century. Normally UAVs that are being used are quad-copters and this type of technology has contributed to surveillance companies as we know today. Blimps on the other hand can contribute more in the field of advertisement and surveillance.

As a solution to improve disaster operations and rescue operations, the researchers explored more on the use of UAVs and how to improve on their usage. UAVs can travel in areas that are limited in sight and more importantly areas that are dangerous for on land rescue teams can get to. The researchers proposed to design an airship or balloon UAV that can travel to the said places. The balloon should be able to travel steadily and will be designed to be able to map areas affected by the storm.

This study will help in disaster operations which is a common event in the Philippines. An example is the aftermath of storms that pass by which has an impact in

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different areas, this will include mapping the areas and rescue operations. The study will also benefit surveillance technology as the researchers aim to create a blimp that is smaller in size in the same time will generates a good feed for surveillance operations.

II. METHODOLOGY

Fig. 2 shows the flowchart of the methodology adapted in this study in the design of the UAV Blimp. Before designing the blimp envelope itself the researchers must first gather the materials needed. The materials are divided into multiple categories: Electronics, 3D-Printed parts, and the blimp material. The shape, length, volume and the motor thrust will be based on the weight of the materials the researchers have gathered.

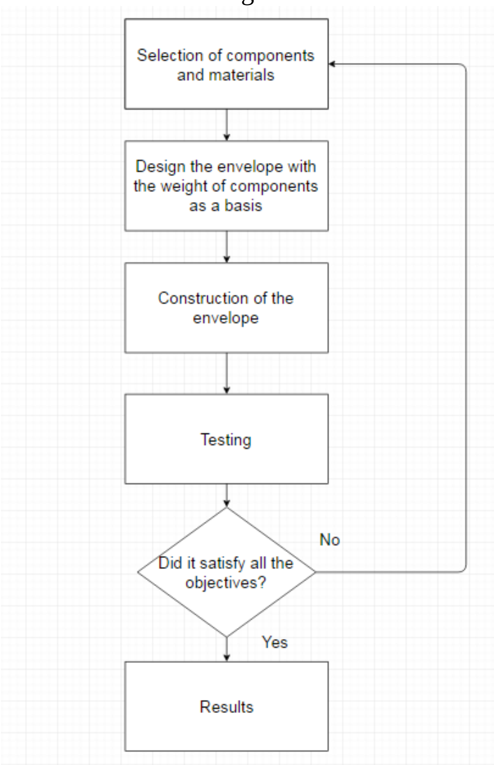


Figure 2. Flowchart of methodology in UAV blimp design

Unlike most RC aircraft like planes and quadcopters, the design of the blimp starts from the calculation of the weight because with the lift of helium (1g=1L), the volume of the blimp affects the design heavily. The volume of 550L will be kept constant while the diameter, and length will be changed in order to obtain the best diameter to length ratio. Multiple blimp profiles was simulated via SOLIDWORKS in order to find the most aerodynamic blimp that is feasible indoors. Aesthetics will also be a factor in the decision for the final design. The final blimp design is shown in Fig. 3.

The placement of the components will be dependent on the position of the tailfins since tailfins are responsible for the upward, downward, and left-right movement of the blimp. Additionally, the tailfins must be well positioned in order to propel the blimp to the right direction. After positioning the tailfins, a moment diagram was done in order to visualize the placement of the other components as well as the balance the blimp itself.. Velcro tape with a double sided adhesive was used in order to attach the components. The velcro offers less stability and more weight compared to scotch tape but velcro tapes have a less risk of tearing the blimp envelope if we choose to remove the components. The center of gravity of the blimp derived from the SOLIDWORKS data will act as the fulcrum and will be given consideredo when placing the parts.

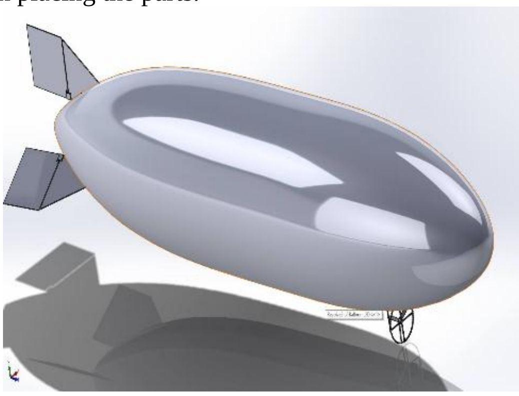


Figure 3. Blimp model

The blimp control revolves entirely on the Adafruit pro trinket. The hardware wiring is shown in Figure 4. The receiver receives the throttle, yaw, and elevator commands from the user which is then sent to the Adafruit which commands the servos. In addition, the Adafruit enables automatic maneuvering of the blimp through its connection with the servos. The ESC's and the motors on the other hand only receive commands from the RC since its main purpose is to provide thrust for the blimp which is best left to be constant during autopilot mode. The camera was also attached to the other ESC because the speed controller has a battery elimination circuit (BEC) which acts like a battery which then power the camera and the transmitter.

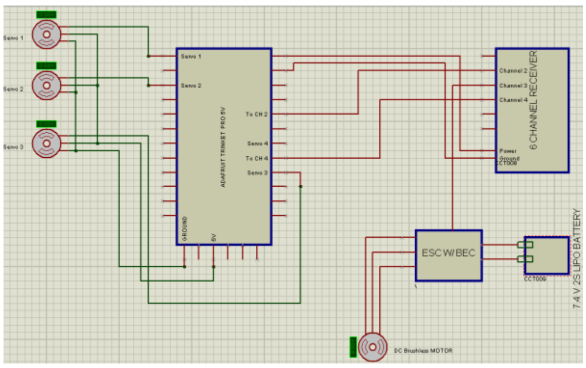


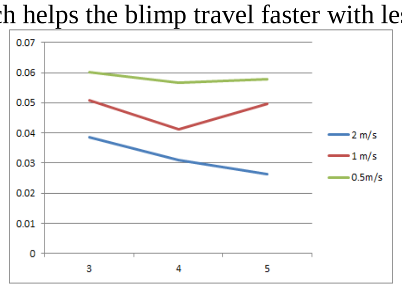
Figure 4. Hardware wiring

The programming language used in the Adafruit microcontroller is ARDUINO. ARDUINO is an open source program used for prototyping. The envelope would be initially filled with air to test the retention rate. Part of this test is also to see if the blimp would have any holes where the helium might seep through so it will be beneficial to test the envelope with air first rather than with helium. In case that there is a leak, it is advisable to cover it up with tape or if the leak cannot be solved with a single strip of tape alone, then it is advisable to just recreate the envelope. The overall velocity of the blimp will be tested through 2 parts with 3 runs each. The time for the blimp to go from position A to position B was recorded.

For the maneuverability test, it was done through measuring the blimps time to make full turns and time to control its elevation. The elevation test distance will be set to 5 meters in order for the researchers to be able to measure the time it will take the blimp to go from point A to point B while descending or ascending with just the right amount of distance.

III. Results and Discussion

Using Computational Fluid Dynamics, the researchers were able to determine the coefficient of drag and the drag force experienced by the streamlined shape. Fig. 5 shows the result of the drag coefficient experiments. Testing was done at three velocities - 2 m/s, 1 m/s, and 0.5 m/s which were the estimated frequent travel speeds of the blimp and at three length to diameter ratios - 3, 4, and 5 which were the acceptable range of balloon profile that allows steady flight. The least coefficient of drag for the balloon shape would determine the best profile but drag force ultimately determines the applicability of the design for the specific purpose. Drag force and coefficient of drag are among other factors that determine which balloon profile would be best used for the blimp design. The streamlined shape provides steady flow of wind which helps the blimp travel faster with less thrust.



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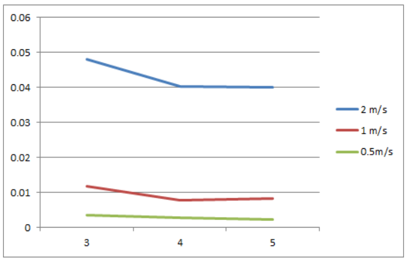


(b)

Figure 5. (a) Coefficient of drag v. Streamlined Length to Diameter Ratio at Various Speeds and (b) Drag Force v. Streamlined Length To Diameter Ratio at Various Speeds

The motor velocity test was done simultaneously with the thrust (Fig. 7) in order to have a linear data. The test was done 3 times each varying in the throttle level. These tests were done in order to find out how much these values change depending on throttle level and find the throttle level where there is a balance of power and weight. The researchers further tested the chosen shape at certain crosswind conditions. The crosswind direction was made perpendicular to the direction of the blimp as it causes the greatest effect compared to an angled direction The wind conditions chosen were at 0.5 m/s to 2 m/s at 0.5 m/s wind intervals. This was chosen because the blimp ideally can travel consistently to up to 2 m/s given battery conditions, motor capacity, and fin strength. Fig. 6 shows the velocity flow experienced by the balloon at various travel and wind speeds.

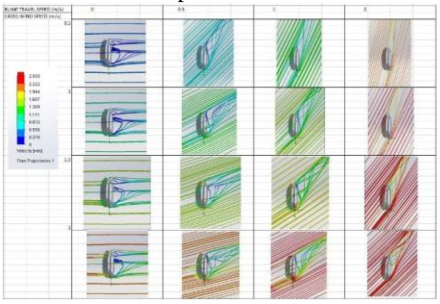
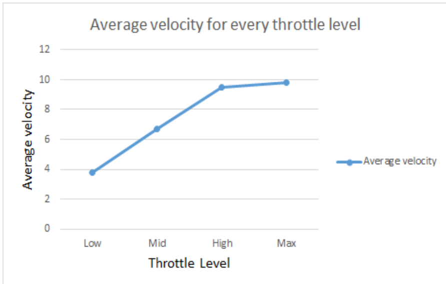


Figure 6. Velocity flows at various conditions

To determine the wind conditions where the blimp can be considered maneuverable. The researchers used the resultant velocity from the travel speed and the crosswind direction. The researchers decided that when the balloon's angle has reached a value greater than 45 degrees then the blimp will have too difficult of a time to maneuver and thus unusable in the specific weather condition. The researchers have determined that under the given conditions, the balloon can safely travel to up to 2 m/s crosswinds when the blimp is travelling at high speeds.



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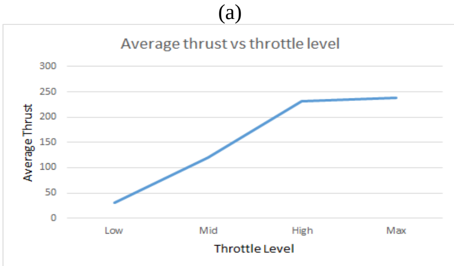

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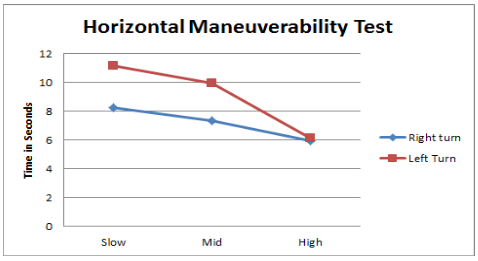
Figure 7. (a)Average velocity vs. throttle and (b) Average thrust vs throttle

According to the results the motor thrust of the low throttle level suggests that it is not large enough to make the airship stay airborne. Mid throttle level and above shows that there is enough force for the blimp to stay airborne since the thrust is large enough. The data shows that between the high throttle level and the max throttle level has a difference of 6 grams of motor thrust, this data proves to be helpful because with this the researchers refrained from operating the motor at full throttle because it may damage the battery in the long run.

The retention rate of the blimp was first tested with air as it was filled at 6:15 PM on a Sunday and to be checked at 7:30 AM Saturday. The result was that it only lost a small amount of air upon checking. In the actual day of testing, helium was used to fill up the envelope starting at 9:00 AM and it lost a noticeable amount upon checking at 7:30 PM. Currently, there are no known methods as to how to compute for the actual retention rate of the envelope.

An envelope with a volume of 550 liters did carry the payload provided by all our attached components. But even though the volume of the envelope can deliver about 0.557 kg of lift, it did not achieve its supposed altitude of about 110 m. One of the probable reason is maybe there are discrepancies in the weights of the components. Some of component might not have been accounted like the multitude of wires were used to elongate our connections, or even the different types of tapes were used. A blimp was balanced by placing small objects such as coins in a position to counter weight the unbalanced side. By varying the distances of the components from the center of the blimp equilibrium was achieved

The overall velocity of the blimp was tested through a straight line course with a distance of 10 meters. Each speed setting was tested three times. Flying the blimp in the low setting speed is not recommended because the low setting speed is not capable of lifting the blimp; this causes the blimp to fly in a descending manner. Flying the blimp at the full setting is also not recommended because this has the tendency to shorten the life or even fry the batteries. The medium setting on the other hand satisfied the required speed that allows the blimp to fly straight without descending. As a result, the blimp requires a velocity higher than 1m/s to be able to hover. The maneuverability test (Figure 8) was done by measuring the time it took the blimp to make one full turn and time to 5 meters in elevation.



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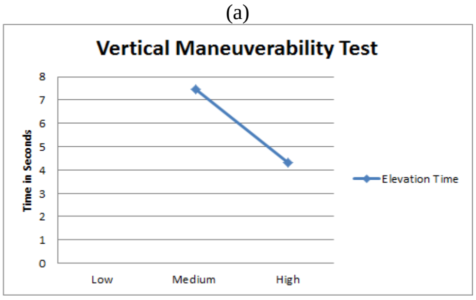

(b)

Figure 8. Maneuverability Tests. (a) Horizontal and (b) Vertical

Based from the results shown above, it takes the blimp more time to make a right full turn. This is because the positions of the right and left servo holders are not equal based from their distance to the center. A slight difference in distance can affect the blimp's flight. Moving the servo holder's position will cause the blimp to be unbalanced; this will cause the blimp to be harder to control.

The elevation test relied heavily on the performance of the left and right fins. Because of the blimp's lifting ability due to helium, the blimp didn't have trouble to ascend and descend. A low speed motor setting cannot lift the blimp even with the help of the fins and the blimp's lifting capability. The results of the maneuverability test show that the blimp cannot be flown in small spaces because the time it takes to make full turns is proportional to the radius of turn, causing the blimp to require a wider space for flight. The blimp showed more than satisfactory results for maneuverability, which means that the blimp is capable of a stable flight.

IV. Conclusions

The researchers was able to design a small scale unmanned aerial vehicle blimp, that can perform surveillance operations using the on-board controller and equipment Based on the flight test, the researchers were able to successfully assemble, operate, and maneuver the blimp. The blimp was able to fly at speeds of 2 m/s and at an average height of 5 m. The flight test was done in a covered auditorium. Based on the test results, the researchers was able to reach the objectives of the study. The researchers were able to choose the most efficient design for the scale, speed, and surroundings of the vehicle through Computational Fluid Dynamics (CFD), which became the basis for the actual design of the blimp.

In the future, the researchers would like to test other materials to improve the performance of the blimp. The installation of a GPS system, barometer, and other sensors will be considered to expand the flexibility of the blimp.

Acknowledgment

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References

[1] T. D. Crouch, "Lighter than air," *An Illustrated History of Balloons and Airships*, Johns Hopkins University Press, 2009.

[2] D. Froomkin. (2014) "Billion Dollars Surveillance Blimp to Launch Over Maryland" [Online] Available: https://firstlook.org/theintercept/2014/12/17/billion-dollar-surveillance-blimp-launch-maryland/

[3] C. Freudenruch. (2001) "How Blimps Work" [Online] Available: http://science.howstuffworks.com/transport/flight/modern/blimp/htm

[4] T. Fukao, K. Fujitani, and T. Kanade, "An autonomous blimp for a surveillance system," *Intelligent Robots and Systems*, December 2003, 2003.

[5] "How Does Bluetooth Score Over Infrared Technology?" [Online] Available: www.thekip.com/how-does-bluetooth-score-over-infrared-technology/ (2011)

[6] H. W. Huang, "PIC microcontroller: An introduction to software and hardware interfacing," NY: Cengage Learning, 2005.

[7] S. Lacroix, I. Jung, P. Soueres, and E. Hygounenc, "The autonomous blimp project of LAAS/CNRS current status and research challenges,"

[8] D. Lainer, D. Sarafconn, and M. Menghini, "Development of an autonomous blimp" Worcester Polytechnic University, 2011.

[9] M. Tayyab, U. Farooq, Z. Ali, M. Imran 4, F. Shahzad, "Design of a blimp based unmanned aerial vehicle for surveillance," *International Journal of Engineering and Technology*, vol. 5, no. 1, pp. 519-529, 2013.

[10] R. Heller, G. A. Landis, A. F. Hepp, and A. J. Colloza, "Heated atmospheric airship for the titan environment: Thermal analysis," *Nasa Center for Aerospace Information*, p. 3, 2012.

[11] C. Stockbridge, A. Ceruti, and P. Marzocca, "Airship research and development in the areas of design, structures, dynamics, and energy systems," *International Journal of Aeronautical & Space Science*, vol. 13, no. 2, pp. 170-187, 2012.

[12] V. Sabella, "Automated flight control of an unmanned blimp," NSF Summer Undergraduate Fellowship in Sensor Technologies, pp. 56-57; 63-64, 2001.

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