# Autonomous Blimp Modeling: A Feasibility Study and Annotated Bibliography


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# 1. Generic Complications:Not the best title

Due to the prohibition on face-to-face meetings during the COVID-19 pandemic, our project's focus has shifted from physical construction of a blimp, to:

1. a description of the design space for blimps along with an enumeration of the specific features and parameters
2. a description of the important performance characteristics and the metrics and environment for measuring them
3. an exploration of existing blimp models
4. an exploration and evaluation of existing modeling environments/packages/programs suitable for modeling blimps
5. an exploration and presentation of the relevant methods, technologies, and techniques needed (e.g the state/space problem, guidance based path following, trajectory linearization control theory) *problem to modeling
6. an annotated bibliography for bullets 1-5
7. an attempt to create and evaluate a configurable blimp model

The issues that are present is that the scope of the project for the autonomous blimp has changed to develop a simulated model prior to a physical prototype. This is to be the ideal solution for the current situation of COVID limitations, and to iterate upon a more efficient design path.

Due to the COVID complications, it is difficult to prototype a working and physical model of the blimp. This is due to the restrictions of meeting people and because of the physical location of the team members being geographically distant. If a physical model was to be pursued before a valid mathematical model was presented, the waste of resources (financial, time, material) could be significant.

The purpose of a simulated model is to reduce the end resource cost, and to quickly iterate the design to the best possible outcome before producing a physical prototype. However, Through academic researched articles, it has been shown that a simulation first approach can produce a better end quality design, with a lower overall resources. The investment in time at the beginning of pursuing a simulation based model first will be notable, but it will have a downward trending curve as familiarity with the program increases. Therefore, the learning curve will be steep at the beginning and plateau towards the end.

Through using a simulation, we will be able to look at several design aspects at the same time and compare them against each other. This can be beneficial, as we can explore design prototypes without the cost of time and materials. Through this design process, we can combine design characteristics that would benefit the overall scope of the project.

Another benefit of a mathematical model is that there will be a linkage of documentation that could prove to be advantageous to future work on this project. The documentation will show design criteria that we investigated. As well, with our simulations we will be able to prove through mathematical proofs that our calculations are accurate.

Overall, the implementation of a mathematical model through simulations will be advantageous to our current project and any future work with these concepts. The usage of a simulation will reduce the amount of resources used in the comprehensive design process. Finally, having a mathematical model can help us iterate on different design aspects to converge to an ideal finished product.

*** Removed from revision document, but is still relevant to final report ***

**There is a minimum needed for a working blimp. Starting this is an envelope that must be able to hold helium for a reasonable amount of time. Otherwise, there won't be any lift or payload capability. In terms of movement, the blimp will have a four-degree axis of movement instead of the typical six-degree axis of movement. The blimp doesn't benefit from rolling compared to planes. Propellers will be used for its primary movement. On the hobby level, all blimp use either brushed to brushless motors with propellers for their movement. For this application, the propellers will have shielding since it's in a space where it can potentially come into contact with people.**

# 2. Design space:

**Design Space Exploration** (DSE) refers to systematic analysis and pruning of unwanted design points based on parameters of interest. While the term DSE can apply to any kind of system. We can refer to electronic and embedded system design and can be used on different design scenarios in general. (wikipedia)
A tradeoff analysis between each of the implementation options based on a certain parameter of interest forms the basis of DSE. The parameter of interest could vary across systems, but the commonly used parameters are power, performance, and cost. Additional factors like size, shape, weight, etc.

Design Space:
placement of wheels
composition of tires
size of tires
weight distribution
engine displacement
gear ratio
fuel

Performance Parameters:
(determined by the design space):
top speed
acceleration
turning radius
stopping distance
"handling" (which like maneuverability, needs to be defined)

<u>Blimp Design Space</u>:
The listed parameters define a simplistic designated design space for the blimp's performance criteria.

- Size – 0.5 m -1 m
- Shape – Elliptical
- Volume – 2-3$m^2$
- Total Mass– 1 Kg
- Gondola Placement – Centered under center buoyancy
- Gondola Characteristics –
    - Material – High density 3D printable polymer
    - Machinability – Ideally one continuous piece
    - Modularity – Iterative placement of components
- Propeller Characteristics –

- Battery Characteristics – Rechargeable
- Envelope – Polyester Film PVC
- Gas– Helium, *He*
- Computing Placement – The geographical placement of the computing components of the blimp.
    - ECUs – A centralized ECU can be placed on the gondola's frame, or a data transmitter can be used to send data to an off-frame computer.
    - Sensors – Need to be integrated into the chassis of the blimp.
    - Motors – Are required to be on the frame of the blimp.
    - Servos – Need to be placed on the blimp's gondola/ frame that is configured by the mechanical engineering students.

<u>Blimp Performance Characteristics</u>

The following is a list of basic characteristics that can be altered to measure the success of a blimp against a set of design goals.

- Component Mass Range –
    - Servos –
    - Battery –
    - ECU –
    - Sensors –
    - Propeller –
    - Gondola –
    - Envelope –
- Speed – Speed is a function of balloon volume, balloon shape, and thrust (predominantly, the amplitude of the thrust).
    - Volume (inversely proportional) – An increase in balloon volume increases air resistance, which opposes the thrust.
    - Shape – This parameter is difficult to quantify, but it affects air resistance (the equations of which differ from shape to shape). Another consideration with shape is the ability to attach a gondola to contain electronic components. Some shapes will be more favorable to certain gondola styles than others.
    - Thrust (proportional) – More thrust, more speed.
- Maneuverability – Maneuverability is a function of mass, balloon volume, balloon shape, and thrust (predominantly the thrust vector or vectors).
    - Mass (inversely proportional) – An increase in mass negatively impacts maneuverability by increasing the inertia needing to be overcome to affect a change in direction.

- Volume (inversely proportional) – Regardless of the shape, an increase in volume equates to an increase in the surface area, which increases overall air resistance.
- Shape – While some shapes may be great for forward motion, the surface area seen perpendicular to other axes is generally greater, increasing the air resistance in those directions. A spherical balloon shape is the most universally maneuverable shape.
- Thrust (proportional) – Different from the speed characteristic, the thrust parameter (regarding maneuverability) is related to the direction of the thrust more so than its amplitude.

- Airtime – Airtime is a function of battery capacity and current draw.
  - Passive lift (lift from helium; proportional) – Passive lift increases airtime, but only as it approaches being balanced against the mass of the blimp. As the balance shifts one way or the other, thrust must be applied in greater amounts to keep the blimp afloat.
  - Battery capacity (proportional) – Larger battery capacity increases the time that thrust can be applied, at the cost of mass.
  - Current draw (inversely proportional) – With no change in battery capacity, decreasing current draw will increase the airtime, as the battery will be able to supply current for a longer period of time.

<u>Blimp Dynamic Spatial Definition:</u>

***Most information is taken from "*Flying over the reality gap: From simulated to real indoor airships*" journal. Will verify through personal proof and confirmation with other journal articles.

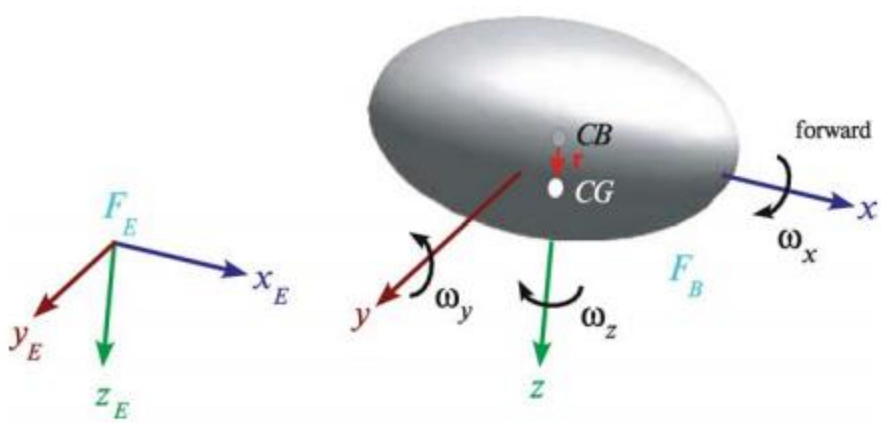



Figure # #: Illustrates the free body diagram of an elliptical shaped blimp

Newton-Euler Equation:

$$M\upsilon \;=\; \Sigma\, F_{external} \;=\; F_r + F_p + F_D + F_C$$

$$^{6}\,\mathbf{C}(\boldsymbol{\nu}) = \begin{pmatrix} 0 & 0 & 0 & 0 & -m'_z v_z & m'_y v_y - m r_z \omega_x \\ 0 & 0 & 0 & m'_z v_z & 0 & -m'_x v_x - m r_z \omega_y \\ 0 & 0 & 0 & -m'_y v_y + m r_z \omega_x & m'_x v_x + m r_z \omega_y & 0 \\ 0 & -m'_z v_z & m'_y v_y - m r_z \omega_x & 0 & -I'_z \omega_z & m r_z v_x + I'_y \omega_y \\ m'_z v_z & 0 & -m'_x v_x - m r_z \omega_y & I'_z \omega_z & 0 & m r_z v_y - I'_x \omega_x \\ -m'_y v_y + m r_z \omega_x & m'_x v_x + m r_z \omega_y & 0 & -m r_z v_x - I'_y \omega_y & -m r_z v_y + I'_x \omega_x & 0 \end{pmatrix}$$

Blimp Design Goals

Ideally, a blimp design would be simultaneously fast, maneuverable, and be able to stay in the air for a long time. Realistically, each of our characteristics come with tradeoffs with respect to each other. For example, increasing the airtime by increasing the battery capacity will undoubtedly increase the mass, which would result in worse maneuverability. Increasing speed (by increasing the thrust) would lower airtime (by increasing current draw).

Since the design characteristics are—while not exactly mutually exclusive—somewhat incompatible, it becomes important to decide which of the characteristics are most important. Perhaps a slow and long-lived, but highly maneuverable blimp is desired. It may be that the goal to be achieved is a blimp that can maintain a position, very accurately, for a long period of time. Figure 1 shows an incomplete graph of potential tradeoffs for improving design characteristics by changing parameters associated with the characteristic. As an example, improving airtime by decreasing current draw would potentially result in lower speed, as the motors would have to spin slower in order to facilitate lower current draw.

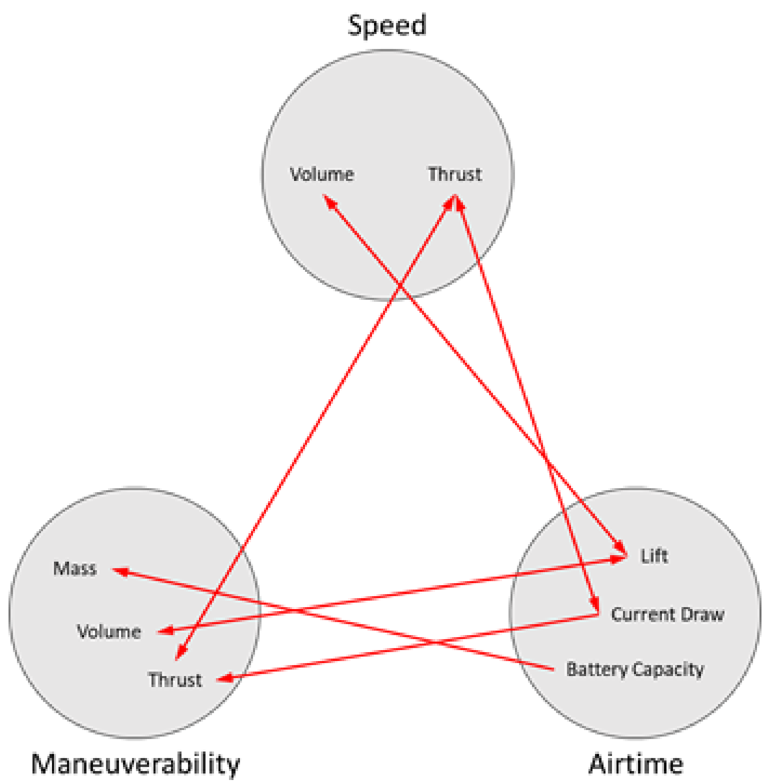



**Figure 1 -** Potential tradeoffs between design characteristics

# 3. Metrics and Test Suite:

Think of a race car:
***design space*** (very simplified):
placement of wheels
composition of tires
size of tires
weight distribution
engine displacement
gear ratio
fuel

***Performance characteristics***
(determined by the design space):
top speed
acceleration
turning radius
stopping distance
"handling" (which like maneuverability, needs to be defined)

***Metrics*** (how are the above measured):
"top speed is measured on a straight track, allowing n seconds to achieve top speed which must be sustained for at least 5 seconds..."
"acceleration is measured on a straight track. from an idle/stopped position, vehicle is accelerated as quickly as possible over a distance of 1/4 mile while being timed."

## Metrics

Table 1: A listed set of measured key blimp performance indicators.

| | |
|---|---|
| Length | 0.5-1 m |
| Volume | 2-3 m^3 |
| Airbag material | Polyester film PVC |

| | |
|---|---|
| Flight altitude | 0-200 m |
| Duration of flight time | 0.5-1.5 h |
| Engine horsepower | 1 Horsepower |
| Load | 0-2 Kg |
| Operation Environment | Indoor Office Space and possible outside application |
| Simulation Program | Matlab Simulink |
| Gas | Helium |

**Size metrics**
We need to design balloons within 1-2 meters so that they can easily pass through lab doors or narrow places.

**Airbags:** It's filled with helium to provide lift, and there's an auxiliary airbag inside. The airbags on the blimp are made by Polyester film PVC and are effective in preventing helium leakage and have a long life.
Auxiliary airbags: a small, auxiliary airbag inside an airship that can control and maintain the shape and buoyant power of an airship by flushing and defying during flight;

**Propulsion:** Powering the take-off, landing and aerial hover of an airship. The airship's power output will be provided by a brushless motor. The maximum speed of the brushless motor is approximately 8000 ret. This will provide more power and torque to power the blimp. The size of the motor is as small as possible, which is to prevent the motor from taking up too much load weight. And the motor has enough power to cope with the effects of bad natural weather on the blimp. The motor can still maintain the stability of the blimp when faced with medium and low wind speeds.

**Dynamic metrics**
The choice esult in reduced efficiency of the motor.
So I need a smaller engine that provides stable output power to the airship.

**Sensor module**
Sensors are designed to measure the airship's vof engine should provide enough power and torque for the airship, but there are also high-speed motors that require more

precise control. Brushless motor anti-jamming capacity is insufficient. Brushless motor pits can lose some power due to high winds or strong convective air, which requires predicting the loss of motor power in advance for a more accurate power output. Due to the structural reasons of the brush motor, the contact resistance of the brush and shifter is very large, resulting in a large overall resistance of the motor, because the resistance is relatively large which will make the motor heat up faster. This will rarious real-time state parameters in the air, such as flight altitude, real-time wind speed, and real-time speed per engine. Because the airship has a limited load and is susceptible to interference, the acquisition of real-time data is very important. Sensors should choose small size, light weight, small energy consumption, high precision, stable performance of the equipment.

**Wireless communication module**
This module mainly completes the interaction between real-time data in airship flight and ground control.

**The power supply**
The battery is primarily responsible for powering the control system. The airship uses 3.7V lithium-compliant batteries. The controller needs to convert the 3.7V voltage into the operating voltage of each chip based on the chip used. Lithium battery size is 57 x 29 x 10mm (L x W x H) Battery Volt:3.7V,Battery capacity: 1800mAh .

Test Suite

For simulation testing with airships we need to consider the payload of the airship. How to ensure that the blimp can fly smoothly in the case of high air flow from the outside world. And we need to test whether our engines can handle high wind speeds. Whether the airship can land smoothly in the event of too high wind speed.

**Hardware testing**
The structural strength test of the Blimp

1. First of all, it is necessary to test whether the airship made by PVC can produce no deformation under the influence of the wind, and whether the pressure of helium inside the blimp meets the requirements of the test. Whether the balloons made of PVC materials can maintain stable working performance in complex weather conditions.
2. Does the pod and the position of the motor installation affect the pneumatic effect of the ball.
3. Whether the blimp can rise smoothly to an altitude of 0-200 and be able to work steadily.

The power test of the Blimp

1. The first step is to check that the motor's mounting position is effective in powering the blimp.
2. Test whether the power output of the motor can bring the blimp to the desired speed within a specified time.
3. Test whether the motor can keep the blimp stable when the wind speed is strong.
4. Whether the motor can reasonably distribute the output of the power, and be able to respond to the host computer's instructions in a timely manner.
5. 

Testing of software and smart devices

Test Suite Definition

*Needs to be formatted better

- Prerequisites?

- Mathematical model of blimp (Software)
  - 6 degrees of independent movement
  - Air drag simulation
  - Payload simulation
  - Motor simulation
- Helium leak test
- Stable hover test
- Rotation Test
- Point A to B path

# 4. Infrastructure and Environment of the Blimp:

When it comes to the infrastructure of a blimp, it is the underlying system(s) that will sustain the functionally of a blimp. The blimp has helium for its primary lift and is battery powered for it's autonomous functions and movement. A landing zone or airport is needed for its resupply. Since the airspace the blimp will be traversing is indoors, human intervention will serve that purpose if the majority of the time the blimp will remain in the air. A dedicated space would be better if there will be durations where the blimp isn't in flight at certain times in the day. Whether it's human interaction or a specified zone, the primary lift is refilled and its battery charged or replaced. This zone should also serve as a data dump for the blimp if the information is stored on board.

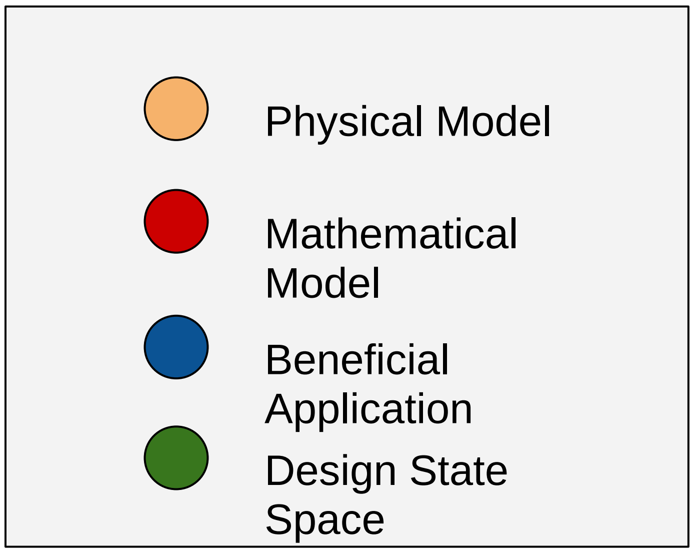
Infrastructure? Structure?

Environment:
**Office:** low ceiling, doors, more than one floor, objects to avoid or that can damage blimp. Needs better maneuverability to avoid collisions, protection against hurting people around. Communication through wifi?
**Warehouse:** could be scaled up, more room to fly,  enough maneuverability to avoid large objects, Communication through wifi,RC, other?

# 5. Annotated Bibliography(Short Paragraph meta desc. of paper)

Also to write more about each document.

Annotations should be crisp. Don't waste words. Get rid of "looks into", "goes into significant detail". Just say what the contribution of each paper is.



## ● **Modeling and Control of Swing Oscillation of Underactuated Indoor Miniature Autonomous Blimps**:

Citation:

*Tao, Qiuyang & Tan, Tun & Cha, Jaeseok & Yuan, Ye & Zhang, Fumin. (2020). Modeling and Control of Swing Oscillation of Underactuated Indoor Miniature Autonomous Blimps. Unmanned Systems. 09. 10.1142/S2301385021500060.*
https://www.researchgate.net/publication/340883576_Modeling_and_Control_of_Swing_Oscillation_of_Underactuated_Indoor_Miniature_Autonomous_Blimps

Summary:

This report goes into the basic setup of a circular autonomous blimp (developed at Georgia Tech). It describes their dynamic model calculations for the pitching. The paper goes into the background of linearization of their equations to come up with benchmarks of their data that they collected. As well, the paper explores the oscillation motion with graphical representation of the motion captured. The paper also goes into the calculations of buoyancy, lift, the moment of inertia. All calculations were done in Matlab.

System Specs:

Electronics Mass: 107.24 grams
PCB: Arduino Uno & XBee attachment
Flight Endurance: 2 hours
Helium Mylar Film: ~8 grams
Program: Matlab

## The Visual Inspection Methodology for Ceiling Utilizing the Blimp:

Citation:
*Nitta, Yoshihiro et al. "The Visual Inspection Methodology for Ceiling Utilizing the Blimp." Procedia Engineering. Vol. 188. Elsevier Ltd, 2017. 256–262. Procedia Engineering. Web*.
https://www-sciencedirect-com.proxy.lib.pdx.edu/science/article/pii/S1877705817320349

Summary:
This report describes the advantages blimps could offer over drones for inspecting buildings for structural damage. The report offers minimal design considerations but goes into detail on which electronics are used.

The electronics used are a microcontroller that is an open-source 8-bit RISC-based platform, an Arduino Micro, two motors and two servos. The Arduino Micro controls two servo motors with 2ch pulse-width modulation signals and two motors with two digital signals. With one of the servos in control of the wifi enabled camera and the other to move the vertical motor arm. The camera used is 1/9 inch CMOS sensor with 300,000 pixcels and 802.11 b/g Wi-Fi interface. The two motors attached to the gondola control the horizontal and vertical motion of the propellers respectively. The system is powered by three batteries. Two 3.7V Li-Po batteries power the motors and servos and the last one is a rechargeable battery to power the wifi camera.

System Specs:
Total Mass: 300 grams
PCB: Arduino Wifi Micro
Flight Endurance: 1 hour
Helium Aluminum Film
Cost: $350

## **A Flight Control and Navigation System of a Small Size Unmanned Airship**:

Citation:
*Jinjun Rao, et al. "A Flight Control and Navigation System of a Small Size Unmanned Airship." IEEE International Conference Mechatronics and Automation, 2005, July 2005, doi:10.1109/icma.2005.1626776.*
https://ieeexplore.ieee.org/document/1626776

Summary:
This report described in detail the H/ W and S/ W and flight controllers for a blimp used in a designated simulation space. The report goes into extensive detail about what hardware and software they used. It also goes into detail about the controllers used in their system with: Fuzzy Controller, elevator controller, and a heading controller. Authors also describe the design space of the blimp and use Matlab to calculate the necessary parameters. The paper also describes how they simulated the blimp in Matlab to get a better understanding graphically and spatially for their design.

System Specs:
Helium Volume: 50 m^3
Payload: 15 kg
Max. Velocity: 60 km/h
Program: Matlab

## **Flying over the Reality Gap: From Simulated to Real Indoor Airships**:

Citation:

*Zufferey, Jean Christophe et al. "Flying over the Reality Gap: From Simulated to Real Indoor Airships." Autonomous Robots 21.3 (2006): 243–254. Autonomous Robots. Web*. https://doi-org.proxy.lib.pdx.edu/10.1007/s10514-006-9718-8

Summary:

The report goes into extensive detail about mechanics theory. It goes through the detailed proof of the dynamic modeling of the blimp so that it could be employed later in a simulation. The Newton-Euler equation is used to link the acceleration to the moments and forces applied to the blimp. The simulation model is done through Webots and a targeted path coordination was optimized through it. The team also looked at image recognition with the usage of simulations.

The electronics and hardware is detailed in the following. Three thrusters (8 mm DC motors, gear and propellers), a forward-looking 1D camera (Taos inc. TSL3301) with 50 active pixels covering an horizontal field of view of 70◦, an anemometer, a vertical distance sensor (SharpTM GP2Y0A02YK), a MEMS piezoelectric rate gyro (AnalogDevicesTM ADXRS300) measuring yaw rotation, and an electronic board featuring an 8-bit microcontroller running at 20 MHz (MicrochipTM PIC18F452) together with a Bluetooth module (MitsumiTM WML-C10-AHR) for bidirectional wireless communication with a ground station. On-board energy is provided by a 1200mAh Lithium-polymer battery, which is sufficient for 2–3 hours autonomy. Further details on the microcontroller board, wireless link, and camera.

System Specs:

The envelope measures:  110 × 60 × 60 cm

Lift Capacity: 200g

Parts: 3 DC rotors, ID Camera, vertical distance sensor, gyro, 1200mh lithium battery and 8bit microcontroller running at 20 Mhz

## **Self-Sustainability in Nano Unmanned Aerial Vehicles: A Blimp Case Study**:

Citation:

*Palossi, Daniele et al. "Self-Sustainability in Nano Unmanned Aerial Vehicles: A Blimp Case Study." ACM International Conference on Computing Frontiers 2017, CF 2017. Association for Computing Machinery, Inc, 2017. 79–88. ACM International Conference on Computing Frontiers 2017, CF 2017. Web.*
https://dl-acm-org.proxy.lib.pdx.edu/doi/abs/10.1145/3075564.3075580

Summary:

The report goes into detail about how to achieve low power consumption using duty cycle, as the blimp rotor was turned on and off. It does not go into detail hardware but has some list of materials. Also they used a solar cell attached to the blimp to extend the flight time, and they argue that it can stay several hours flying.

Basic mathematical equations are employed as a way to describe a blimp, but not significant importance towards our use case.

The journal does describe the power usage management with software and NRF51 firmware to optimize the system as a whole.

System Specs:

The blimp measures: 0.4m3

Weight: 55g

Parts: solar panel, MCU , battery, harvester and rotor.

## Autonomous airship path following control:

Citation:

*Zheng, Zewei, Huo, Wei, & Wu, Zhe. (2013). Autonomous airship path following control: Theory and experiments. Control Engineering Practice, 21(6), 769–788.*
https://doi.org/10.1016/j.conengprac.2013.02.002

Summary:

The report looks into the mathematical model and simulation framework for the movement of a blimp 3D space. This is done  through its simulation data and practical testing afterward. Goes into significant detail about how the mathematical model is achieved. The students used the guidance-based path following (GBPF) principle and trajectory linearisation control (TLC) theory to explain their dynamic modeling.

As well goes into controller diagrams and explanations of it.

Specs:

Length: 13.2 m
Diameter: 3.38 m
Volume: 80m^3

## **Gaussian Processes and Reinforcement Learning for Identification and Control of an Autonomous Blimp**:

Citation:

*Ko, Jonathan et al. "Gaussian Processes and Reinforcement Learning for Identification and Control of an Autonomous Blimp." Proceedings - IEEE International Conference on Robotics and Automation. N.p., 2007. 742–747. Proceedings - IEEE International Conference on Robotics and Automation. Web.*
https://ieeexplore-ieee-org.proxy.lib.pdx.edu/document/4209179

Summary:
The academic goes into the basic knowledge of the below topics and summarizes other academic articles. The article does a good job looking at the topics in a holistic and simplistic manner. The topics can be easily understood due to the summarization of other academic articles and the high arching overview of them. A benefit of this article is that it has links and references to all the articles that it reviews. The article also goes into a simplistic overview of control systems and autonomous control systems.

Topics:
- -Motion Control
- -Navigation Control
- -Control Methods (PID)
- -Controlling Algorithms
    - -Backstepping Controls
    - -Model-Predictive Control
- -Autonomous Control Systems

## **Autonomous airship path following control:**

Citation:

*Wang, Yue et al. "Altitude Control for an Indoor Blimp Robot." IFAC-PapersOnLine 50.1 (2017): 15990–15995. IFAC-PapersOnLine. Web.*
https://www-sciencedirect-com.proxy.lib.pdx.edu/science/article/pii/S2405896317325363

Summary:

This report goes into detail briefly the parameters for the altitude control model, create simulation and apply it to the physical blimp. The end goal is for an autonomous blimp with a feedback loop of position of the environment to navigate.

System Specs:

Total Payload: 250 grams
PCB: Arduino FIO
Flight Endurance: 1 hour
Envelope: nylon 132cm length, 94cm diameter
Sensors: ultrasonic sensor, IMU, Camera,
Xbee unit, 3 mini rotors.
Simulation: matlab Simulink

## Experimental Pitch Control of an Unmanned Airship with Sliding Ballast:

Citation:
*Alsayed, Ahmad, and Eric Lanteigne. "Experimental Pitch Control of an Unmanned Airship with Sliding Ballast." 2017 International Conference on Unmanned Aircraft Systems (ICUAS), 2017, doi:10.1109/icuas.2017.7991326.*
http://hdl.handle.net/10393/36594

Summary:
The report describes the mathematical model, simulation and experimental results of a blimp with a gondola with and without wind disturbances. Author wanted to develop a close-loop control for a blimp using altitude and pitch using the gondola on a rail that can move as one of the inputs. Blimp was simulated in Matlab/simulink and control used a matlab GUI. simulation results were compared to experimental data/tests.

Topics:
-Motion Control
-Navigation Control
-Control Methods (PID)
-Controlling Algorithms (matlab GUI)
-Autonomous Control Systems

System Specs:
Total Payload: 350 grams
PCB: Nano Wii board
Flight Endurance: 1 hour
Envelope: 2 Mil polyester
polyurethane lm with 90 Shore A hardness
length is 1.83 m, volume 0.39 m3, and diameter is 0.6 m.
Sensors: bluetooth modules, IMU, 2 mini rotors.
Simulation and control: matlab Simulink / GUI
Battery: 2 cell 7.4V

# Revision

Revision 1.0: 03/18/2021: Initial document
Revision 1.1: 03/22/2021: Formating
Revision 1.2: 03/31/2021: Organization of Bibliography, Dylan F.