EMBRY-RIDDLE Aeronautical University
SCHOLARLY COMMONS

Beyond: Undergraduate Research Journal

Volume 5 Article 4

December 2021

Vertically Air Lifted High Altitude Light Launch Apparatus (VALHALLA)

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Cover Page Footnote

Thanks to Mr. Bill Russo and the COE for allowing us to work in their lab space. Thanks to ERAU IEEE for their support and guidance on this project and their overall club support. And thanks to COE/COA faculty for their guidance, consulting, and overall recommendations to the project.

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Purpose

Amateur rocketry has been around for decades, with the first amateur rocket launches occurring in the 1950s due to the Space Race and the Cold War. A hurdle many students and amateur rocket teams run into is being unable to obtain a high altitude affordably or achievably for their flight. This severely hinders the amount of research that can be done and limits the obtainable amount of usable data acquired. The purpose of the Vertically Air Lifted High Altitude Light Launch Apparatus (VALHALLA) is to enable collegiate level amateur rocket groups to perform higher altitude research at a cost within their reach. VALHALLA aims to be highly reusable targeting around ninety to ninety-five percent reusability. Since the project's primary expense is setup-based and not variable, VALHALLA can be utilized by different universities for a gradually decreasing cost following each use. Initial launches will be the most expensive ones performed, whereas the later launches are expected to be less expensive. By enabling various universities and groups to perform high-altitude research, VALHALLA also pushes the boundaries of what research can be done and helps to make spaceflight safer for everyone.

Introduction

VALHALLA consists of three major sections: the support stand, the platform, and the Helium recycling system. The support stand keeps the platform and rocket off the ground, before being deployed into the air to prevent damage during transportation. It is made of structural steel to hold up the weight of VALHALLA and the rocket payload before arriving at a launch site. The platform is approximately sixty-four square feet in area, and thus the support stand is mounted onto wheels to provide more accessibility and maneuverability in different terrain conditions. VALHALLA's platform is made of an Aluminum honeycomb sheet, about one inch thick with a three-foot diameter hole in the middle to make way for the rocket. It folds over in the middle to provide practical transportation and storage capabilities. The balloon arms of VALHALLA's HABs are attached to the four horizontal sides of the octagonal platform to direct the Helium up and through to the balloons for liftoff and descent. These arms are detachable to provide possible transportation and movement when the platform is not being utilized. There will be three automatic activation devices (AADs) on the platform to hold the parachutes in place during flight. These will be triggered if the balloons stop functioning or fail to provide a controlled descent back to the ground. AAD deployment will be triggered by an altimeter where once rapid descent is detected, the AADs will activate, and the parachutes will deploy on their own. The parachutes can be deployed manually from the ground station if needed, and the AADs can activate from this command station. These parachutes are designed with a factor of safety of two to three in mind to ensure safety during all stages of the launch and recovery. Lastly, the balloons of VALHALLA use helium tanks to pump and retrieve Helium to provide altitude and attitude control during all phases of operation.

Statement of Results

With the primary objective of providing a high-altitude platform for collegiate level rockets, determining the lift system to reach such an altitude is critical to the project. The size of balloons needed to lift a target mass to a target altitude was determined and was graphed while varying these parameters over the expected range. These graphs show the exact dependence of balloon size on these parameters as a direct exponential relationship. Due to VALHALLA's current configuration, balloon radius is one of the most critical design considerations.

If the radius of the balloons is too large, long arms are required to support the balloons farther away from the center of the vehicle, and heavier ones are needed to resist the increased bending moment due to that increased distance. Figures 1 and 2 were produced based on the ISA standard atmosphere and used the ideal gas law to determine the properties of Helium at varying altitudes.

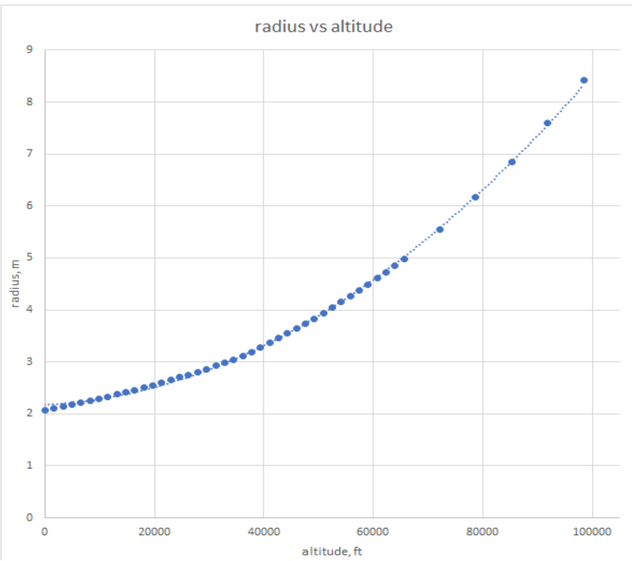

Figure 1. Balloon radius versus altitude

As observed in Figure 1, the radius is exponentially dependent on altitude. Reducing the max altitude target from 100,000 feet to 80,000 feet would reduce the required balloon radius by over 35%. Despite the volume, and thus lift, of the balloons growing with the cube of the radius, the thinning of the atmosphere grows quicker than the increase in lift. The altitude then becomes very expensive in a design sense as the platform approaches the target height due to this factor.

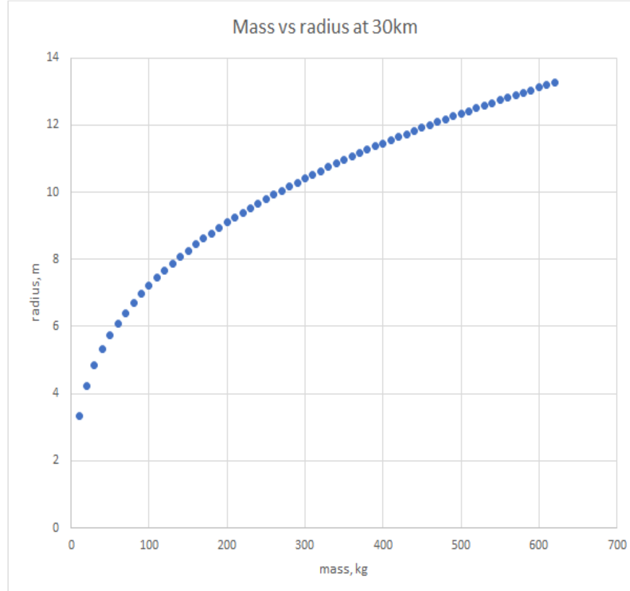

Figure 2. Balloon radius versus mass at 30 km

In Figure 2, the atmospheric conditions are held constant, so the cubic expansion of lift is more prominent. The radius of the balloons is now less dependent on overall vehicle mass. The vehicle mass is thus less expensive in a design sense for max altitude. The importance of this for VALHALLA is that a subtle increase in balloon radius provides a much larger increase in maximum mass allowed. Thus, an easy way to enable a margin for a too-heavy vehicle or payload has been identified.

With the above analysis in mind, project VALHALLA operates under a couple of conditions. The first is that decreasing the target altitude enables a smaller, more manageable, and less costly vehicle. Secondly, when mass exceeds the design value for a particular design, the vehicle is not significantly affected. Therefore, less mass optimization will occur so that the project may stay on time and budget.

After finding these insights into the finalized version of VALHALLA, the focus shifted to the prototype. This prototype is of the same configuration as the final flight vehicle but is designed for a low altitude flight and is a more manageable size. As the balloons are the critical part of the vehicle by size and importance, they set the dimensions of the prototype. Ten-foot diameter clear vinyl advertising balloons were selected for several reasons.

Firstly, for durability, as they are designed for daily use. They provide a payload of eighty pounds with the four balloons required, much more than smaller options considering the size increase. 600-gram latex balloons were selected for the inner air bladders. Sitting inside each vinyl balloon, these latex balloons serve to separate air, used for buoyancy and stability control, from the Helium.

Another consideration for the prototype is the Helium Recovery System (HRS). Helium recovery saves up to thousands of dollars per flight and conserves the already scarce Helium resource. To do so, a compressor stores Helium from the balloons into a storage tank in flight to reduce lift fore and allow VALHALLA to descend. At the low altitudes the prototype will fly at, the atmosphere is considered roughly constant. Any quantity of Helium above the amount required for neutral buoyancy will eventually lift the prototype to the target altitude. Because of this, it is only necessary for the HRS to store a small amount of Helium to reach the required accent and decent rates. Most Helium will stay in the balloons and can be recovered with ground equipment, saving weight and cost for the flight vehicle. It allows the concept and operation of the HRS at a small scale on the prototype to be tested before investing in the custom hardware required for the final build of VALHALLA.

Analysis of Results

From the work that has been performed so far with the project, it was determined that the scale of this project is more ambitious than anticipated. One of the four HABs was inflated and attached to the platform to get a more accurate idea of the scale of what is being worked with and the size requirements of it. A tethered test flight in the Fall of 2021 will give a better idea of how the platform reacts to forces such as weight, drag, and lift. Both will determine if the scale is accurate for the project or not. Like the aircraft that carried the shuttle, the platform is substantially larger than the rocket that is attempting to get to a high altitude (1:6 size ratio roughly, rocket to platform) but doing so has ensured that there are the necessary safety components, as well as control mechanisms, to ensure a safe flight for VALHALLA, the payload and everyone else in the airspace too.

Discussions of Uncertainties

There are still multiple unknowns for the project and the specific operations of the launch. Launch day conditions are crucial to have correct. Strong winds and poor weather drastically change all aerospace operations, and this project is no different. An idea for how much Helium will be needed, as well as the size and weight of the tanks, has been estimated but will need to be finalized later. Lastly, the total weight of the whole apparatus is still a significant uncertainty. Items can be accounted for such as payload and Helium tanks, but smaller items such as wiring, paracord, and plumbing do not yet have final numbers. These will be determined in due time, but a heavier than expected weight is planned if the estimations are far off.

Updates Since Original Draft

The original approach has been reevaluated since the Fall of 2020, and the focus of the project has shifted. While the plumbing system was finalized as planned, the parachute design was not finished until the Fall of 2021, effectively pushing the timeline out one year.

The updated timeline is shown below:

- SPRING 2022: Design parachute deployment systems and AADs
- FALL 2022: Construct system wiring and test circuits
- SPRING 2023: Assemble components on prototype platform. Prepare for test flights.
- FALL 2023: Diagnostic testing and low altitude tethered testing of systems.
- SPRING 2024: Mk.0 work and implementing necessary changes to VALHALLA

The goal is to have VALHALLA operational by the end of 2021 so necessary data can be gathered before working on the Mk.0 model. This depends on how the pandemic and restricted lab time changes what can and cannot be accomplished with the system.

Conclusion

Project VALHALLA is an ambitious, groundbreaking aerospace project happening right now. With the Coronavirus, the timeline has been altered slightly, and some of the supply lines have been delayed, but the project is still getting the final design changes made so construction can begin. Thanks to the IGNITE grant provided by the Office of Undergraduate Research, the facilities and labs provided by Embry-Riddle, and the immense support of the faculty and the students, the project can continue being worked on and achieve some groundbreaking results soon for supporting and furthering the work that can be done with amateur rocketry and the data accessible and collectible to everyone at higher altitudes than ever before.

Per Aspera Ad Astra