University of Colorado
Department of Aerospace Engineering Sciences
ASEN 4018

Project Definition Document (PDD)

Balloon Deployment System (BDS)

Approvals

	Name	Affiliation	Approved	Date
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1.1. Project Customers

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1.2. Team Members

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2. Problem or Needs

High altitude balloons are a reliable way to gather atmospheric data, specifically regarding turbulence patterns in the stratosphere. The HALO heritage mission accomplishes this by launching a high altitude weather balloon to measure turbulence data at varying altitudes within the stratosphere. Currently the process of deploying these balloons requires more than one individual and poses a risk of damaging the payload and balloon. Due to the complexity of the deployment and size of the balloon it is nearly impossible to quickly and efficiently deploy a balloon by hand in windy conditions. With unpredictable weather conditions it is imperative to set up and deploy the balloon in a streamlined manner and avoid damage to the delicate data acquisition payload. The current deployment procedure is heavily limited by human reaction time and negatively impacts the safety and reliability of launch. A semi-automated mechanical system, demonstrated by the concept of operations in Figure 1, will provide a user-friendly and easily repeatable balloon deployment process with a higher success rate than launching by hand.

3. Previous Work

This project is a continuation of Professor Dale Lawrence's previous balloon project, Hypersonic Flight In The Turbulent Structure (HYFLITS), which aimed to collect turbulence data whilst in flight. This team is not directly involved with data collection or balloon functionality but will instead focus on balloon deployment. Currently, balloon deployment is slow and cumbersome; an individual can prepare/launch a balloon in roughly one hour. Additionally, windy deployment conditions create a tendency for the balloon payload to contact the ground, potentially damaging the sensitive equipment. This team will develop an affordable and portable system that allows for swift, hands-free deployment of multiple sensor equipped balloons. Hands-free operation allows for the technician to maintain two handed contact with the payload until it is sufficiently high enough to avoid any contact with the ground. Additionally, the apparatus will be able to hold the balloon sufficiently high such that strong winds cannot push the balloon into the ground and damage it. The portability and usability of the design will greatly improve use time and allow for more frequent, safe, and cheaper atmospheric turbulence research.

4. Specific Objectives

To achieve the minimum requirements of success for this project, a balloon launcher must be designed to release a balloon from 3m high at the users command, allowing enough time for the balloon to gain sufficient altitude before the user releases the payload and therefore avoid risking the payload swinging into the ground. In addition, assembly and disassembly must be performed in 5 minutes or less. The launchers must convey their state to the operator wirelessly and using battery power. Moreover, the balloon launcher must have a system that can support 10-20m long tethers to the gondola, as well as shorter tethers with in-flight unwinders. The launcher's design should be easily manufactured and reproduced. The total cost of production of the launcher must be less than $1000.

Level of Success	Portability	Launch Capabilities	Balloon Security	Cost
Level III	• Assembly Time <5 mins • Weight < 50 lbs • Tools: None • Travel Config.: 1m x 0.25m cylindrical bag	• Launches 1 or 2 balloons • Control Comm: Wireless • Release Command Remote: On user • Reliability: 30 test launches in 10 m/s sustained winds	• Sustained Wind Speed: 10m/s • Gust Wind Speed: 20m/s	• Unit Price: <$1000 • Materials: 100% off-the-shelf components

Level II	• Assembly Time <15 mins • Weight < 50 lbs • Tools: None • Travel Config.: 1m x 0.25m cylinder bag	• Launches 1 balloon • Control Comm: Wireless • Release Command Remote: Off user • Reliability: 20 test launches in 8 m/s sustained winds	• Sustained Wind Speed: 8 m/s • Gust Wind Speed: 15 m/s	• Unit Price <$1000 • Materials: 75% off-the-shelf components
Level I	• Assembly Time <15 mins • Weight < 50 lbs • Tools: multitool stored in case • Travel Config.: Fits in compact car trunk	• Launches 1 balloon • Control Comm: Wired • Release Command Remote: Off user • Reliability: 10 test launches in 1-2m/s winds	• Sustained Wind Speed: ~1 m/s • Gust Wind Speed: ~2 m/s	• Unit Price <$1500 • Materials: 50% off-the-shelf components

5. High Level Functional Requirements

	Functional Requirements	Rationale/Explanation
FR 1.0	One person shall be able to set up with no tools required for assembly/disassembly.	Ease of use and self contained kit for the user to bring to site.
FR 2.0	The setup shall take less than 5 minutes to set up/disassemble.	Quick deployment of the balloon.
FR 8.0	The launcher (for each balloon) shall collapse into a cylindrical storage/carrying bag of 1 m length and 25 cm diameter.	Ease of transport.
FR 3.0	Balloons shall be held 3m or more above the ground and 6m apart in the case of a 2 balloon launch.	Avoid balloon ground damage or balloons becoming entangled.
FR 4.0	Payload shall not hit the ground during setup and deployment.	Avoid damage to payload instruments.
FR 5.0	The balloon deployment system shall hold 1 or 2 balloons and be launched within 1 s of each other.	Allow multiple deployments if required for data gathering.
FR 6.0	No heating of the launcher or sharp edges on the launcher. Launcher shall hold the rubber balloon neck (not tether).	Avoid potential damage to balloon
FR 7.0	The launching system shall function in 10 m/s sustained wind, with up to 20 m/s gusts.	Allow launches in a wide range of wind conditions.
FR 9.0	The system shall be hands-free (hands will hold payload) communication of commands/launcher status between user and launch device.	Allow single person launch with hands-free for payload release as balloon rises.

FR 10.0	Battery powered launcher/release mechanism.	Remote area launch capability.

5.1 Concept of Operations (CONOPS)

The following figure details the mission-level CONOPS for the BDS. The launch date and location will be predetermined to suit the needs of the HYFLITS data requirements. Once the location is reached by vehicle, the operator will walk to the final launch location with the BDS in travel configuration. Setup of the BDS will require no more than one person and will take approximately five minutes. Once the BDS has been deployed, the user will first load the balloon, then attach the payload while the BDS is in loading configuration. The user will then proceed to put the BDS in launch configuration; the 'arm' and 'launch' commands will then be given while the user stands downwind of the BDS with payload in hand. Once the balloon is overhead, the user will release the payload and begin to disassemble the BDS.

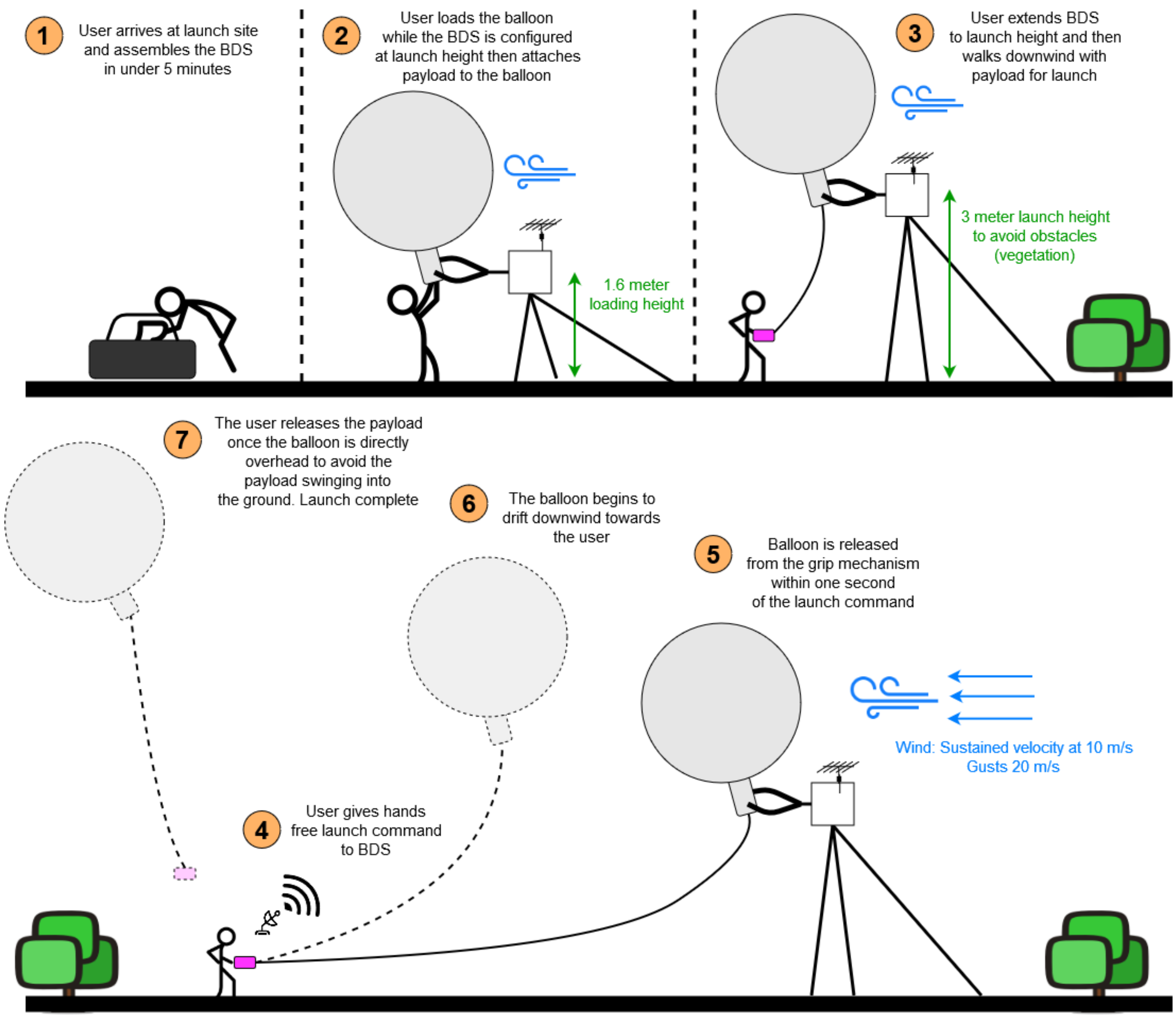

Figure 1 - Concept of Operations

6. Critical Project Elements

● Testing

It is critical to design a testing procedure for a balloon system that is intended for a single use to avoid damaging actual weather balloons. This procedure must be repeatable and low cost to keep the project within the allotted budget of $5000. Testing must also include replicated aspects of "worst case scenario" conditions to confirm the design meets requirements such as releasing in sustained 10 m/s winds and gusts up to 20 m/s. It will be difficult to test within specified launch conditions, because a normal day does not have 10 m/s - 20 m/s wind.

● Ease of Use

A critical element of the final product includes the ability for a single user to easily transport the device to the launch site and assemble it. This entails keeping the launcher's weight under 50 lbs, limiting the size to fit in a 1m x 0.25m diameter bag, and maintaining the ability to assemble the launcher in under 5 minutes. This will be difficult to accomplish because the device will need to release a balloon from a height of 3 meters and be stable enough to withstand heavy winds while meeting these requirements. The device must also incorporate an element of adjustability once assembled to allow for balloon mounting at a lower height before it is elevated to the full 3m launch height. Another critical aspect encompassed by ease of use includes incorporating a wireless, hands-free launch command that will still operate successfully with background noise and potential interference.

Launch Conditions

A critical element of the final product includes the ability for the device to keep the balloon steady, meaning that an anchoring device is necessary. This will be difficult to accomplish because the anchoring device needs to be able to keep the balloon-mounted structure from falling over during sustained 10 m/s wind and up to 20 m/s gusts keeping in mind that the structure must be relatively light weight and will need to resist the balloon lift as well. It is also critical that the device has little to no heat transfer from the sun or electronics. This limits the type of materials that must be used as well as the cost of the material.

Materials

Robustness, weight, stiffness, and thermal conductivity considerations will make finding the correct structural materials for the launcher a challenge. The design requires the structure to withstand high winds without toppling over or bending beyond a reasonable tolerance. In addition the parts must fit together tightly and not become loose after multiple rapid assemblies/disassemblies potentially in sandy/dusty environments. Finally the materials used and design must be free of protrusions that could damage the balloon or allow for heating that could weaken the balloon's surface.

Launching Mechanism

The launching mechanism is vital to the mission success. It is the piece of hardware that directly attaches to the balloon. The balloons cannot be damaged so the launching mechanism is inherently constrained. The mechanism must be made of a material that will not scratch the balloons. It also must firmly hold the balloons without squeezing too hard, lest it puncture the balloon or lead to a failed launch. But if the mechanism grips too loosely, a gust of wind may cause an early launch. The mechanism must be simple to operate. The balloons are to be launched by one person, so the launching mechanism must be operable singularly while simultaneously preparing the balloons. The mechanism must also be durable, allowing for multiple launches.

7. Team Skills and Interests

Describe the areas of expertise and/or interests of the team members on your project, and relate them to the critical project elements identified above.

Critical Project Elements	**Team member(s) and associated skills**	**Team member(s) and associated interests**
Mechanics	Aufa Amirullah - Aerodynamics / Propulsion Peter Hurst - Aerodynamics/Materials Austin Konnath - Welding / Mills Jake McGrath - Lathes / Mills / Welding Patrick Paluszek - Manufacturing / Dynamics / Aerodynamics / Thermodynamics Jack Soltys - Solidworks / CNC Machining Kyler Stirewalt - Lathes / Mills / Welding - Structure / Aerodynamics / Lathes Sebastian Urrunaga Chenshuo Yang- Structure/Aerodynamics/Thermodynamics	Aufa Amirullah - Welding/ 3D Printing/ Manufacturing/ Solidworks Peter Hurst - Welding / Machining / 3D Printing Chenshuo Yang - Welding/3D Printing Jake McGrath - 3D Printing
Electronics	Austin Konnath - Soldering Patrick Palusze - Wiring / Soldering Jake McGrath - Electrician since 2015 Sebastian Urrunaga- Wiring / Soldering	Peter Hurst - Wiring/Soldering Jack Soltys - Wireless Communications Kyler Stirewalt - Wireless Communications Jake McGrath - Wireless Communications
Software	Aufa Amirullah - MATLAB / C++ / Assembly Language / DATCOM/ HTML/ CSS/ JavaScript/ Data Structure/ Algorithm Peter Hurst - MATLAB / C++ / Python Jake McGrath - iOS, Android, Web, Full Stack / Python / C++ / MATLAB / Java Script / Swift / Kotlin / Java / HTML / CSS / C / C# / Etc. Grant Norman - DAQ / MATLAB / Python / C# / Java / Lua / LabVIEW	Aufa Amirullah - iOS/ Android/ Embedded Jake McGrath - Embedded Systems Jack Soltys- Embedded Systems Patrick Paluszek - Python, Embedded Systems
Logistics	Aufa Amirullah - Data Analysis/ Risk Management/ Testing Peter Hurst - Systems / Testing / Risk Management Grant Norman - Systems / Testing Patrick Paluszek - Data Analysis / Systems / PM Experience Jack Soltys - PM Experience Jake McGrath - PM Experience Sebastian Urrunaga- PM Experience / Systems Chenshuo Yang - Systems / Testing Austin Konnath - PM Experience / Testing	Aufa Amirullah - Safety or Risk Management/ Testing/ Data Analysis Chenshuo Yang - Safety or Risk Management Kyler Stirewalt - Group Management Patrick Paluszek - Systems Engineering

8. Resources

Critical Project Elements	**Resource/Source**
Testing location/site	Prof. Lawrence
Construction sites	Machine shop (ITLL, Aero Lab)

General Supplier	McMaster-Carr
Electronics Mentor	Trudy Schwartz

9. References

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[2] "High Altitude Lifting Orbiter (HALO)," *Ann and H.J. Smead Aerospace Engineering Sciences* Available: https://www.colorado.edu/aerospace/current-students/undergraduates/senior-design-projects/past-senior-projects/2019-2020/high-altitude.

[3] NIOSH Lifting Recommendations. (n.d.). Retrieved September 08, 2020, from https://www.osha.gov/SLTC/etools/poultry/additional_material/niosh.html

[4] "One-Person Balloon Launcher in support of AFOSR Hypersonic Flight in the Turbulent Stratosphere." Dale Lawrence. University of Colorado Boulder, Department of Aerospace Engineering Sciences.

[5] Waters, Thomas R. *Applications Manual For the Revised NIOSH Lifting Equation*. www.cdc.gov/niosh/docs/94-110/pdfs/94-110.pdf?id=10.26616/NIOSHPUB94110.