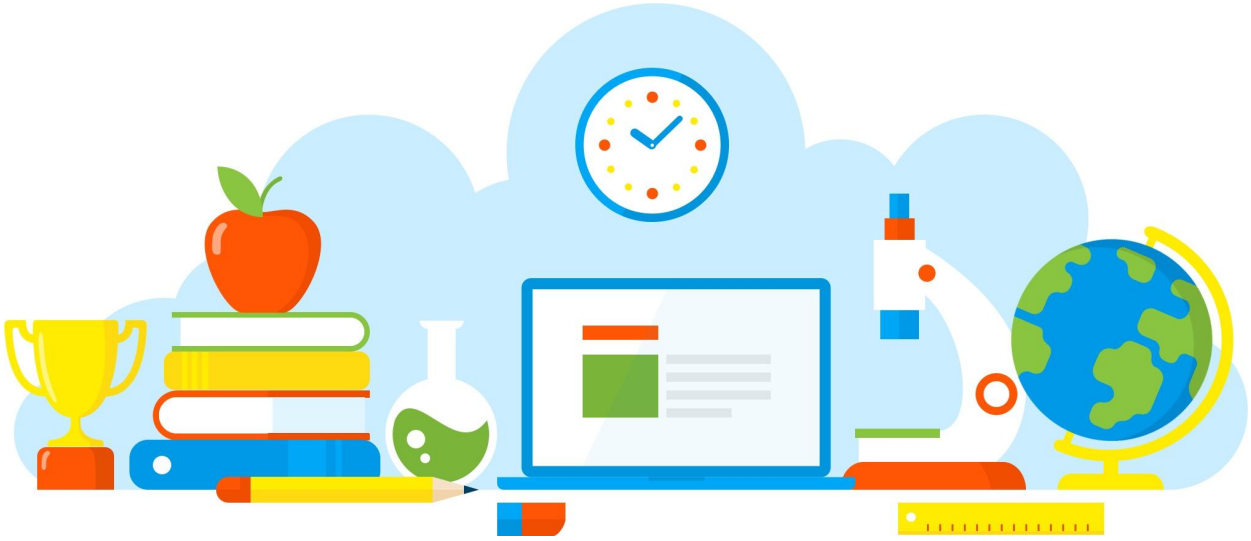

Launching a High Altitude Balloon

by

Vivify STEM Education

About Vivify

Vivify is a team comprised of two Aerospace Engineer friends, Natasha and Claire, who live in Texas. We met as college classmates and roommates at Texas A&M University and later left engineering careers in the Department of Defense and Air Tractor to pursue our passion for STEM education. Learn more of our story here.

Our goal is to bring engineering to life—to vivify learning—for kids of all ages. Please connect with us so we can learn how to better serve your students!

- Natasha & Claire, The Vivify Team

info@Vivifystem.com

Connect with us for free STEM resources!

Subscribe to our newsletter and receive access to a library of free STEM resources through www.vivifystem.com. Follow us on social media or listen to "The STEM Space" podcast for more resources and ideas. We also welcome you to join "The STEM Space" Facebook group to connect with other educators across the world.

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To get the most from this course, here are our suggestions:

1. **Watch and take notes.** Write down ideas that can help you plan your event.
2. **Write down your questions!** Write down questions you have right now below that you hope we will cover. We want you to be prepared to jot down the answers as you learn them. And please write down questions that arise as you go through this course. We would love to hear from you and address anything that may help you!

Useful links:

Weather Balloon Blog Posts

High Altitude Science

Weather Balloon Project

ABOUT THIS ACTIVITY

Students will use the engineering design process to launch a payload on a weather balloon to the upper atmosphere and safely recover it. Students work in teams to understand the science behind the balloon launch, design and build a scientific payload, select the launch site using predictive modeling and weather conditions, launch the balloon, and analyze the collected data. *Note:* This is an intensive activity that involves a high risk of losing the payload due to equipment malfunction, human error, or other factors.

Weather Balloon Challenge

Students will use the engineering design process to design and launch a payload on a weather balloon, also known as a high altitude balloon, to the upper atmosphere (up to 100,000 feet!) and safely recover it.

INCLUDED IN THIS HANDOUT

1. Project Overview
2. Resources & Links
3. How It Works
4. Project Tips
5. Team Assignments

MATERIAL LIST

- High Altitude Science Eagle Pro Weather Balloon Kit
- Helium
- Ultimate Lithium Ion Batteries: AA, AAA, 9V
- Micro SD Card (Flight Computer)
- Go-Pro Camera, SD card, back-up battery
- Audio Beacon
- Gloves
- Clipboard
- Duct tape
- Experiment: What do you want to spend to near-space?
- Label or marker for adding contact information to payload
- Spring scale to measure amount of helium in balloon
- Lighter
- Laptop for tracking balloon and transferring data
- Tool box

PROJECT OVERVIEW

What can be more exciting than launching a balloon into near-space and seeing footage of the Earth from above? A weather balloon project involves designing a payload and using a helium balloon to send it up to 100,000 feet into the stratosphere! The balloons used are very similar to weather balloons that scientists send every day all over the world for weather data. Amateurs have begun to use similar technologies to conduct their own balloon launches, and many companies provide very affordable solutions for schools to host their own balloon launch.

For this project, students work in teams to understand the science behind the balloon launch, design and build a scientific payload, select the launch site using predictive modeling and weather conditions, launch the balloon, and analyze the collected data. This is an ultimate real-world project. Just substitute "student" for "scientist", and this is exactly how scientists in industry and government labs send experiments into the atmosphere!

STEM Connection

Because of the multiple aspects to the project and endless experiment selections, students have an opportunity for many areas of learning. An example of some of the STEM topics covered from a balloon launch and experiment:

- ***Science***: Changes in atmosphere, Physics of balloon flight, Design of experiment
- ***Technology***: GPS satellite tracker, Temperature and pressure sensors, Predictive modeling software
- ***Engineering***: Building payload with size and weight limitations
- ***Mathematics***: Analysis of sensor data, Impact prediction calculations, Helium calculation

Tailoring Project Goals

A balloon launch project can be experienced at various levels depending on time constraints, skill level of students, and comfort of instructor. One possible project may focus on the changes in atmosphere and launch the balloon with a camera and basic sensors. Another project may focus on engineering design, and students can build a more complex payload to host a larger experiment. Teachers can tailor the project based on a current unit of learning or allow students in an after school program to dictate the objectives. Examples of experiments:

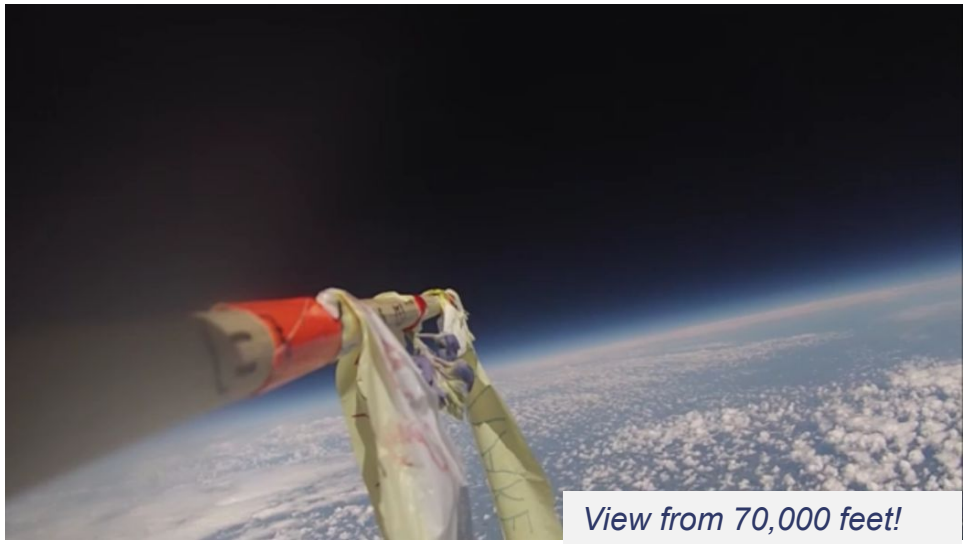
- Pictures and videos of the Earth's atmosphere and curvature
- Exposure experiments to items such as seeds and mold
- Light and temperature sensors
- Carbon Dioxide/Ozone detectors
- Solar cell measurements
- Latex balloon expansion
- Humidity measurements

Note: "Weather balloon" and "high altitude balloon" (HAB) are used interchangeably to describe this project.

In addition to this scientific learning, it is important to note the interpersonal and communication skills students gain through the process. Students will experience the engineering design process from initial conception to final launch with all the failures along the way. Through this experience, students will build their confidence along with strengthening the useful skills of: ***team work, communication of ideas, scientific writing, data analysis, and research.***

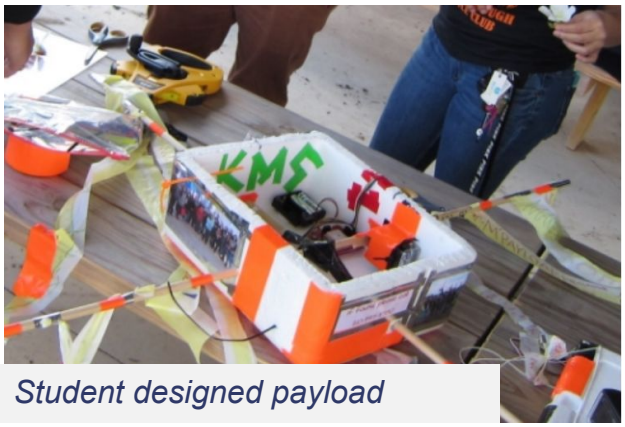
Weather Balloon Project

Inflating balloon with helium



View from 70,000 feet!

Streamers on payload included messages from students



Student designed payload

High Altitude Science Balloon Kit

RESOURCES

Balloon Launch Videos (YouTube)

- 2015: CIS Harlandale Middle School Weather Balloon Launch https://youtu.be/8oC90nnkYXQ
- 2016: CIS Kingsborough Balloon Launch 2016 https://youtu.be/9RtptsrNA6s
- 2017: CIS Space Club Weather Balloon 2017 https://youtu.be/d1ZEm4u7pQo

Vivify Blog Posts:

The series of blog posts on the Vivify STEM website details our adventures in conducting this project with a group of middle school students during an afterschool STEM program. You can find the series here:
http://www.vivifystem.com/search?q=weather%20balloon

Helpful Websites

- http://www.hobbyspace.com/NearSpace/
- http://www.highaltitudescience.com/
- http://www.diyspaceexploration.com/introduction-to-high-altitude-balloons/
- Experiment examples: http://www.nasa.gov/centers/glenn/technology/explorers_balloons.html
- Tutorial: http://www.instructables.com/id/My-Space-Balloon-Project-Stratohab-Success-High/
- DIY High Altitude Balloon
- HAB Lessons Learned
- AIAA Space Weather Balloon
- Weather Balloon Project

Examples of interesting launches:

- Hello Kitty in Space
- Toy Robot in Space
- Rubber Chicken in Space
- Paint Balls in Space
- Mission to Space- Full GoPro Flight With Arduino & DIY Payload

Humans jumping from the edge of space:

- Felix Baumgartner's supersonic freefall from 128k' - Mission Highlights
- Alan Eustace - Record-Breaking Near-Space Dive Leaps from 135,000 Feet

Students researching equipment instructions

How it Works

The goal of high altitude balloon projects is to launch a payload to the upper atmosphere and safely return it back to earth. The balloons used are very similar to weather balloons that scientists send every day all over the world for weather data. Amateurs have begun to use similar technologies to conduct their own balloon launches, and many companies provide very affordable solutions for schools to host their own balloon launch.

All high altitude balloon launch systems have the same basic components:

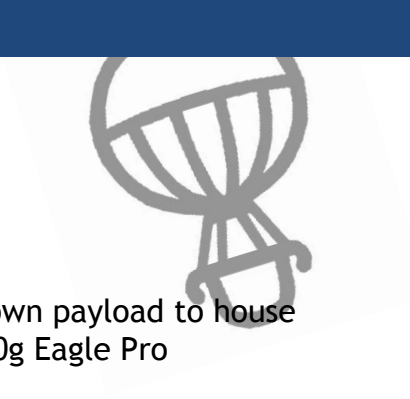
- ***Balloon*** - When filled with helium, the balloon provides the lift for carrying a payload up through our atmosphere. The balloon will expand as atmospheric pressure and temperature drop, and around 80,000 - 130,00 ft the balloon bursts. The trip to the edge of space is about a 2 hour journey.
- ***Parachute*** - The parachute keeps the payload from falling too fast as it re-enters our earth's atmosphere. After about a 45-minute ride home, the parachute brings the payload in for a gentle landing.
- ***Payload*** - The payload houses a GPS satellite tracker, camera, and any other scientific instruments and payloads students wish to send to the edge of space. The structure of the payload is typically a lightweight frame or foam-rubber box depending on supplier.

Why does the balloon float?
The latex balloon floats once it has filled with an appropriate amount of helium, a gas that is less dense than the air in our atmosphere. In other words, as long as the weight of the helium plus the balloon latex is lighter than the air it displaces, the balloon will float. This can also be explained in terms of a buoyancy force pushing upward becoming greater than the weight of the balloon and helium. A simple animation that shows this can be found here. The concept of density can also be explored with helium having less density than the atmosphere's main gases of nitrogen and oxygen. Bottom line: we need enough helium to provide enough buoyancy force to lift the payload.

What happens as it moves upward?
As the balloon reaches about 100,000 feet, it will pop! Why? As the balloon journeys upward, it will experience less and less pressure. This causes the helium of the balloon to expand and stretch the latex skin of the balloon. For a deeper understanding, you can introduce the ideal gas law equation (PV=nRT). When balloons rise in the atmosphere, the surrounding temperature decreases and the pressure decreases, so according to the ideal gas law equation, the volume must increase to compensate for the change. And then what happens? The volume continues to increase until a balloon initially 6 feet in diameter stretches to 30 feet and bursts!

How will we retrieve the balloon?
After the burst, the remaining payload will start to plummet back to earth. Without anything to break the fall, everything would hit the ground at a terminal velocity of 124 mph! Such a speed would destroy anything in the payload, so a parachute is used to slow the descent. It is attached in such a way that the flight train keeps the parachute shut during launch, but when the balloon bursts and the air rushes past the parachute as it falls, the material will be forced open and slow the fall. A second part to this question is actually finding the balloon. The payload can travel quite a distance, so a reliable tracking device must be installed.

Project Tips



Preparing Payload

Students can decide to either purchase a pre-made payload kit or design their own payload to house the equipment for launch and recovery. We recommend the purchase of the 600g Eagle Pro Near-Space Kit from High Altitude Science for $700. The kit contains:

- ***Eagle Flight Computer*:** Ability to record pressure, temperature, altitude, and GPS. Worked great, but it wasn't weather proof. So all data is lost if you land in water!
- ***Delta Flight Frame:*** A light and strong wooden frame to attach all hardware. Very easy to build and put together. The frame always landed upright, which is a must for recovery.
- ***Camera Mount:*** To fasten a Go-Pro or other camera to capture the action! (camera not provided)
- ***Near Space Balloon:*** Latex balloon that will carry your experiment to the stratosphere. We recommend starting with a smaller size as it will be easier to manage on launch day.
- ***Parachute***
- ***Inflation Nozzle and gas regulator:*** For filling up balloon with helium. Very easy to set-up and safe.
- ***Spot Trace Satellite Tracker:*** GPS tracker for recovering balloon. A $150 annual service subscription is required. We also purchased the Gen3 tracker as a back-up for recovery.
- ***Eagle Flight Manual:*** A manual with details on launching and recovering balloon. We found this manual was missing a lot of critical information that we had to search for elsewhere.

When preparing the payload, students will need to build the hardware to house the equipment, prep the Go-Pro camera, and attach the flight train. Students also must develop launch procedures and practice how to inflate and tie off the balloon. This part of the launch is the most intimidating. High Altitude Science had some good tutorials here. Another concern is the Go-Pro camera battery. After some research, we bought a battery extension pack to increase the battery life.

Selecting an Experiment

What are the effects of near-space? The balloon will reach the stratosphere and experience the following conditions:

- Pressure: Air is 1/4% density of sea level
- Temperature: Ranges from -60 to 0 degrees Celsius
- Radiation: Balloon will travel through ozone layer and experience increased UV radiation

Students should think about these conditions can be incorporated into a science experiment sent into the payload. The Eagle Flight Computer can be purchased to capture temperature and pressure data to accompany the experiment. Examples of past experiments: pictures and videos of the Earth's atmosphere and curvature, exposure experiments to items such as seeds and mold, light and temperature sensors, carbon dioxide/ozone detectors, solar cell measurements, and yeast growth.

Project Tips

Launch Site

We used Google Maps to survey different launch sites. The site will make or break your launch as it will affect how successful your launch and recovery will be. During launch, if you have any obstacles, you may damage the balloon during release. What to keep in mind for this important decision:

- 10 miles from a major airport
- Balloon should not fly over a major city
- Avoid bodies of water
- Open area for releasing balloon in up to 10 mph winds

Recovery Efforts

A critical part of the project is recovering the balloon. Please note that this project is very risky, as human error, weather conditions, or a multitude of other events can cause loss of the balloon and payload. We were able to successfully retrieve 3 out of 4 launches, but the one lost was due to stolen data! To maximize the recovery, some tips for your project:

1. Use two recovery systems such as 2 GPS trackers or an APRS radio as back-up
2. Make sure the payload will land upright so the GPS tracker can connect to the satellite
3. Write contact information on the payload
4. Make payload colorful and easy to spot including reflective materials
5. Add an audio beacon to help with recovery

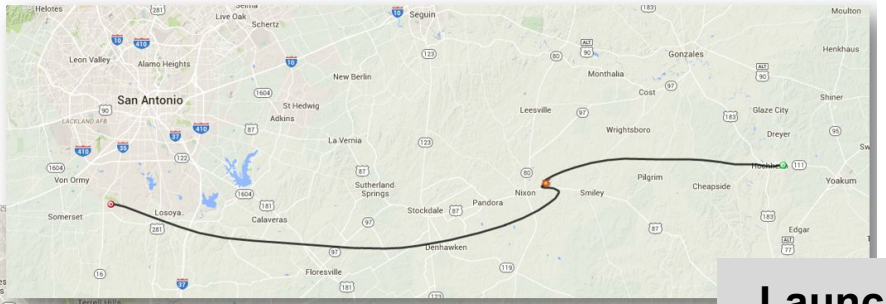
Your balloon can land more than 100 miles away from the launch location! You can predict your possible landing site with this website: Balloon Trajectory Forecast. This allows you to create a Google Earth KML file to see your trajectory over land using Google Earth. Students really enjoyed looking at the trajectories using various weather data! I recommend doing this for a couple weeks leading up to the site to get a range of possible landing sites. You won't have very accurate weather data until the day before the launch, but you can at least get an idea of potential landing sites.

For tracking, most use the SPOT GPS device. This device will be used to track the payload throughout the entire flight. The location is posted on the SPOT website once every 10 minutes. I found this to be the most reliable way to track the payload without using a HAM radio. SPOT uses it's own satellite network to send it's location directly to their website. The only problem is that SPOT, like other GPS devices only tracks under 60,000 ft. You will not be able to track the payload after that point until the balloon pops and falls back under 60,000 ft. This device requires a $100 / year operating agreement and a $50 / year charge for real time tracking.

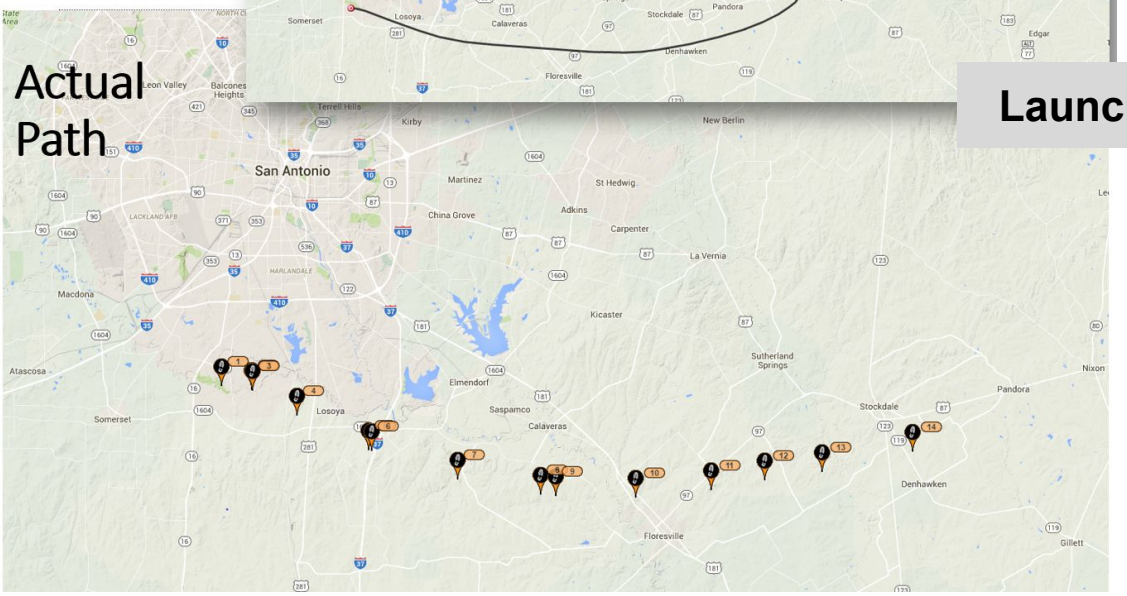
The next page shows the predicted (Balloon Trajectory Forecast) versus actual path of our balloon launch in south Texas. There are two graphics because the GPS signal was lost after 60,000 feet.

Project Tips

Predicted Path

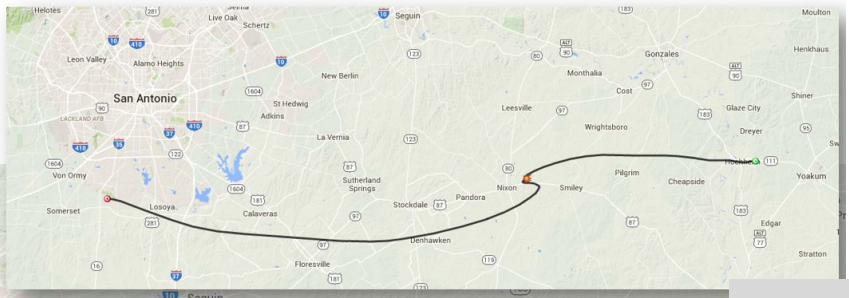


Actual Path

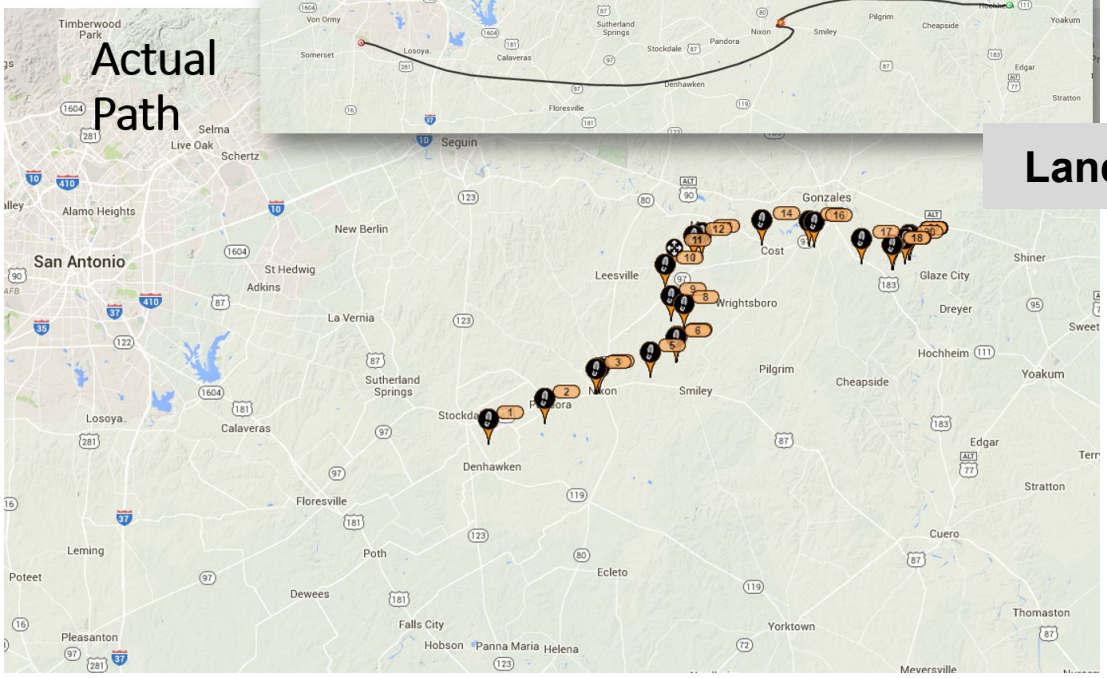


Launch

Predicted Path



Actual Path



Landing

Team Assignments

The following are recommended teams for the weather balloon project. Team sheets are provided to outline the roles and responsibilities of each team in supporting a successful launch and recover of the weather balloon and experiment.

1. **Payload Specialists**: Design and build payload to keep equipment safe during launch and landing.
2. **Mission Control:** Manage logistics for a successful launch and recovery.
3. **Mission Specialists:** Design and conduct a science experiment during flight including capturing flight data.
4. **Media Specialists**: Capture and edit GoPro footage from launch and document the project.
5. **Recovery Team:** Successfully retrieve the payload and data.

Weather Balloon Team Application

Name: _____

You will be assigned to a team to ensure a successful weather balloon mission. This is an application for you to rank the order in which you would prefer to be on each team. You may not get your first choice. Please rank the teams in order from what you would like to be on most (1) to what team you are least interested in being a part of (5).

Your Ranking (1-5)	Team	Description
	Payload Specialist	Design and build payload to keep equipment safe during launch and landing.
	Mission Control	Manage logistics for a successful launch and recovery.
	Mission Specialists	Design and conduct a science experiment during flight including capturing flight data
	Media Specialists	Capture and edit GoPro footage from launch and document the project
	Recovery Team	Successfully retrieve the payload and data

Give a brief answer to why you want to join your first choice team: _____

_____

_____

_____

Do you have any experience that would help you contribute to your first choice? If yes, please explain.

_____

_____

_____