Fall 2009

1337ARTS

Project Icarus:
A step-by-step recount of the original $150 balloon launch.

TAKING PICTURES OF SPACE

We always wanted to see what the earth looked like from space.

On September 2, 2009, we launched a camera attached to a balloon into near space. The capsule soared over 17 miles above ground, snapping beautiful pictures of the earth and capturing both the curvature of the earth and the blackness of space. After the balloon popped, the capsule floated back down to earth with a parachute. We retrieved the capsule with an onboard GPS phone that transmitted the landing location.

We were absolutely ecstatic about the launch success. We posted our pictures online and created a website dedicated to sharing out photos with the world. We also wanted to share the process with the public because we believe strongly in the Do-In-Yourself movement.

All components including electronics of our launch are available commercially. The project cost did not exceed 150 dollars, making it affordable to the general population. We wanted to show people that it does not take an advanced technical education to do awesome projects.

In this guide we discuss the logistics of our balloon launch. We included information on the design decisions we made as well as the challenges we encountered.

Caution:
Please contact the FAA before launch. Take steps to minimize chances of mid-air collisions.

9-2-2009

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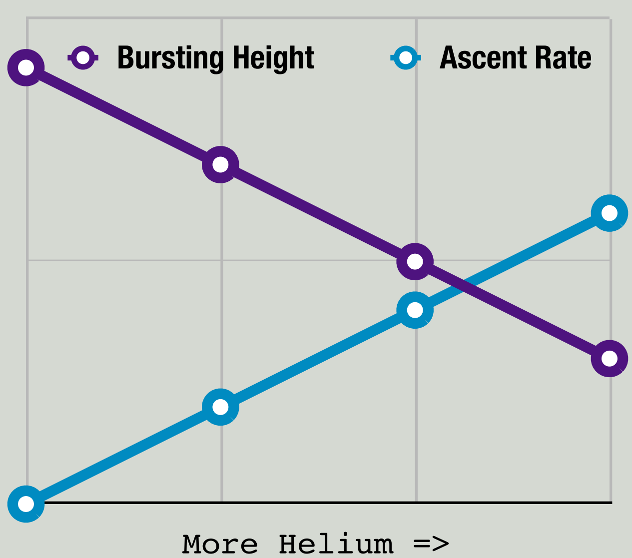
Weather Balloon

To accomplish our mission, a typical party balloon would not work. We bought a weather balloon from Kaymont. They sell meteorological weather balloons that are capable of reaching extreme altitude. Further information can be obtained from their website, www.kaymont.com. We used the 350g model, but we recommend something bigger. A bigger balloon allows for a higher burst altitude as well as a faster ascent

Helium

Helium occupies more space than air in the atmosphere and therefore provides buoyancy force. Like a boat on a lake, the helium lifts the balloon up. Elemental Hydrogen, unlike Helium, is flammable and explosive and therefore not recommended for use. As the balloon rises in the atmosphere, the pressure drops. This causes the balloon to slowly expand. At around 90,000 feet, the balloon expanded so large that it pops. The balloon at launch spans around 5 feet while at the time of the burst it will be around 20 feet.

We decided how much helium to pump into the balloon by first performing some research on internet. We found out that each cubic foot of helium can lift 28g. The term, free lift, is used to describe the difference in the amount of lift provided and the weight of the entire capsule. Each pound of free lift would mean 300 ft/min of ascent rate. For example, if we had 61 cubic feet of helium lifting a load of 800 grams, you would have 2 pounds of free lift and therefore an ascent rate of 600 feet/min. Increasing the free lift and therefore the ascent rate would decrease the total flight time of the balloon. The shorter the total flight time, the less likely our electronics will run out of battery power. Also, the less time our capsule spends in the air, the less distance the wind will blow our capsule too far. However, the more helium we inject into the balloon means the lower the bursting height. If we put too much helium in the balloon, the bursting height is too low.



WHERE TO GET HELIUM

- Local wielding gas supply company or party store.
- University/Research Institution.

The helium will come in a heavy and cumbersome steel tank that cannot be easily moved. Our 125 cubic feet tank stood 6 feet tall and weighed 100 pounds.

Electronics

THE HARSH ENVIRONMENT OF THE UPPER ATMOSPHERE

At 90,000 feet, temperature drops to a frigid -50 degrees C (-58 F). The frigid temperature slows the chemical reaction that powers normal batteries to a standstill. Even though the battery may be brand new, it will act as if it is dead. Air pressure in the upper atmosphere drops to a mere fraction of the level at the ground. Harmful cosmic radiations increase hundredfold. This may have an effect on sensitive electronics. Because of the lack of air molecules, heat transfer between the capsule and its surrounding tends to be poor.

Camera-

This will capture the stunning views at 100,000 feet. We chose a standard point-and-shoot camera. We achieved automatic triggering of the camera through a software called CHDK. The majority of canon point-and-shoot cameras are supported. Be sure to visit http://mighty-hoernsche.de/ before making any purchases.

GPS Enabled Phone/ Satellite Messenger-

The phone/messenger sent the GPS coordinates of the landing location to a website we had. Please go to www.instamapper.com or www.accutracking.com for more information. Without GPS, it would have been impossible to retrieve the camera and its awesome pictures.

We found out in our tests that the battery life of the phone was too short for the predicted flight time of the capsule. We decided to supplement the battery with a Duracell USB charger powered by Lithium AA batteries. Keep in mind that these are specially designed batteries that have the ability to withstand extreme temperature.

Canon Point and Shoot

Camera Parameters

Shutter Speed

Shutter speed played an important role in the quality of the pictures produced. By lowering shutter speeds, we can take well exposed photographs in sub-optimal lighting. By raising the shutter, we reduced the blur that occurs when the capsule sways around during flight. We chose a sunny day so that we can take well exposed and sharp pictures during the flight. We used 1/800s shutter speed and received excellent results.

Write your own scripts or download pre-written ones online.

Interval Length:

Interval length refers to how often the camera takes a picture. Make the length too long and you miss some incredible moments of the balloon journey. Make it too short and your camera runs out of memory in the middle of the flight. We chose to take a picture every 5 seconds writing on an 8 Gigabyte memory card. On our camera, we turned up the setting to 7.2 MP on Fine Quality. Each picture turned out to be around 2 MB, and we had plenty left over at the end of our flight.

Power Saving:

We wanted to use as little power as possible. There was no need for the LCD screen to be on during the flight. Flash would be unnecessary on a sunny day. We adjusted all of the settings so that minimal power was used.

CHDK (Canon Hacking Development Kit)

Snapshot

CHDK is an open-source program that adds extra functionality to certain canon cameras. The adjustable shutter and automatic triggering features allowed our camera to take beautiful pictures of space. Other functionalities include motion detection, bracketing, and remote communication. The firmware does not replace the original firmware on your camera. It resides on the SD card.

Download the Kit at http://mighty-hoernsche.de/. Afterwards put the CHDK folder onto the home directory of your SD card. Follow instructions at http://chdk.wikia.com/wiki/CHDK_for_Dummies.

Accessories

Items we thought were helpful in the success of our mission but not absolutely required.

External Antenna:

We discovered that the external antenna increased our reception by one reception bar on the cell phone. We had no other way to test the signal strength. The antenna we plucked out of unused Wireless router. To obtain the correct connector, we used a U.fl to RP-SMA pigtail connector obtained from Radioshack. The RP-SMA end should connect with a wireless router antenna. The U.fl end should be able to connect with an external connector found on the back of the Boostmobile i290 cell phone.

Audio Beeper:

This audio beeper will allow you to locate the capsule in dense foliage. GPS can typically narrow the location of the capsule to a 20 feet radius. It will save you hours of time if the capsule happens to land in the wrong spot but will add weight to the capsule. We considered alarm clocks, smoke detectors, and electronics horns. The beeper should be placed on the outside of the capsule to maximize the sound propagation.

Flashing Lights:

Again this is for retrieval purposes. Flashing lights will help immensely if recovery happens during night. The positive effect is less during the day but still non-trivial. However, people might mistake the capsule for a bomb on the ground.

Lithium Batteries:

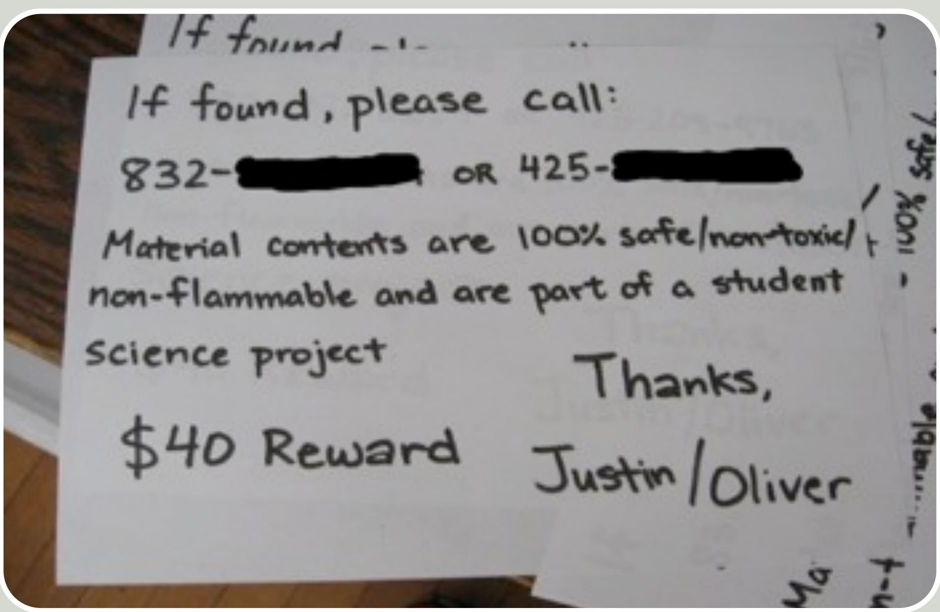
Not to be confused with Lithium-ion rechargeable batteries that are commonly used in cell phones, Lithium batteries last longer than regular batteries (8x according to Energizer). In addition, they can withstand the extreme temperatures of the upper atmosphere.

Spray Paint:

We considered spray painting our capsule black to absorb more sunlight. That will increase the temperature within the capsule. The heat generated by the electronics should be enough, but painting it doesn't hurt! Be careful to buy special spray paint. Normal spray paint disintegrates the styrofoam.

Other Considerations

During our planning process, we went through many iterations of the equipment list. We considered shielding our electronics from the cosmic radiation but worried that the shield will impede the cell phone signal upon landing. We thought of putting an Android phone for better GPS tracking services but decided against it because of cost. We tried to solder lithium batteries directly on the cell phone but unfortunately the cell phone only accepted Motorola batteries.



Lost and Found Sign

We included a lost and found sign in case our GPS Phone never transmitted the GPS coordinates to us. With the sign, someone would have found our capsule after landing and called us! We included monetary reward to encourage the safe return of our capsule and its incredible pictures.

CONTAINER DESIGN

Camera Placement

A hole at the bottom gives you pictures of the ground while a hole at the side gives you horizon views. Try your best to make the hole as snug as possible with the camera to improve insulation. Gluing the camera to the hole is optional. On one hand it would increase the insulation but also it might impede the movement of the camera lens.

Disposable Hand-warmers

They provide a source of heat during the flight. WIth the correct insulation, the little heat that is given off by hand-warmers raises the temperature inside the capsule to within the operating ranges of the electronics. The chemical process of the hand-warmers actually slows down in the upper atmosphere because of the lack of oxygen, prolonging the effective period of the hand-warmers.

The capsule will insulate the electronics and soften the landing

We bought a styrofoam cooler at a local supermarket that was about 2x3 feet that came with a detachable lid. It satisfied our requirement of a lightweight insulating container with a large surface area. We used a Xacto Knife to cut out the holes in the styrofoam container. We cut out one hole for the camera lens and one hole for the antenna. We used zip ties and hot glue to properly secure the electronics equipment to the box. We used zip ties to attach the parachute to the capsule and rope between the parachute and the balloon. We put plenty of old newspaper for insulation in the capsule. Also, we crumbled up some aluminum foil to act as a radar reflector. Pilots can see our capsule and steer clear of it. We secured the antenna to the side of the outside of the container. The antenna is designed to work when it is perpendicular to the ground.

We made sure to properly insulate the capsule.

TESTING

Electronic Components - Make sure the electronics operate under low temperatures. We put the camera and the phone in our freezer while taking pictures and transmitting GPS locations. We also programmed the freezer to its lowest temperature to best simulate near-space conditions. We performed multiple tests to verify our results. To warm the capsule up, we attached hand-warmers. We considered purchasing dry ice for testing at even colder temperature but decided against it on the account of cost.

Testing increases chance of success!

Parachute- We made sure that the parachute was able to open when dropped. It is very important that the terminal descent speed is slow enough to prevent damage to electronics as well as property/ people on the ground. We tested our parachute by putting eggs inside of our styrofoam box and tossing the box off of a 5 story building. We were not satisfied with the landing speed of our box until the eggs did not break upon the box's impact. To slow down the descent, we added a bigger parachute. After our tests, we came up with a parachute that was 5 feet in diameter.

GPS Phone- We walked around with the GPS tracking for a couple hours. Afterwards, we noted the accuracy of the points as well as the frequency. We marked out the points where there was no reception. We repeated our walk with our external antenna installed and recorded the improvement. We obtained an average increase of two bars with our antenna. Also, 90 percent of the spots that were missing during the first test appeared in the second.

INFO@1337ARTS.COM

Want to contact us?

Email: info@1337arts.com to get in contact with us.
If we don't respond immediately, please be patient. We are students and have busy schedules! We would love to talk to you though!

PRE-LAUNCH

FAA REGULATIONS

Remember that there are other flying objects occupying the same airspace. Be sure to take all necessary precautions against a mid-air collision. The airspace above United States is governed by the Federal Aviation Authority. For other countries, please consult the appropriate agency for further rules. Balloon launching is illegal in some countries. Please check before attempting. If you are launching in the US, notify the FAA before launching. The number to post an NOTAM (Notice to Airmen) is 1800-WXBRIEF. Predict the flight of the balloon by using University of Wyoming's website and inform the FAA of it. We put aluminum foil in our capsule as a radar reflector so that other flying objects can see the balloon. Also, we did not put any hazardous or flammable material on board.

The full list of regulations can be obtained from the FAA.

Weather

The weather should be completely sunny with minimal wind. If it is not bright enough, then the pictures will be under-developed. Minimal wind decreases the chance of blurring and also reduces the preparation needed to launch a balloon. Even the slightest wind gust can knock the balloon out of your hand during filling.

FAA notice

Be sure to Notify the FAA at least 24 hours before launch. Technically balloons under four pounds are unregulated. But notifying the FAA decreases your chance of flying into restricted airspace. Be sure not to launch near military installations--stay at least 100 miles away.

Suitable Launch Site

Site should be relatively flat with no obstacles such as trees or lights poles that could snag the balloon after launch. Be sure that the field is a public space and not trespass on other people's property.

Balloon Trajectory Prediction

Given the launch location, predicted maximum altitude, and time of launch, the website gives a general idea of the landing location. Visit http://weather.uwyo.edu/polar/balloon_traj.html .

RETRIEVAL

BoostMobile phone Motorola i290 with GPS and Web Functionality

Since this is a cellphone, the capsule must land in an area of cell phone coverage. Make sure to attempt transmitting only when the cell phone is on the ground. It is against FCC regulations to operate a cell phone in the air. The instructions for the downloading the programs can either be found at www.accutracking.com or www.instamapper.com. We tested the cell phone by walking around to observe the timing of the GPS signals. We did not increase the cache size to its full setting, and as a result some of our flight path is lost. Also, to increase our chance of finding the capsule, we turned on cell tower location transmission. This feature allows the phone to send off the location of its cell tower if a GPS location cannot be fixed. For the plan, we chose the web add-on option with the pay-and-go plan. With this selection, our cost was only 35 cents per day because we did not make any calls nor send text messages.

SPOT Satellite Messenger/Tracker

If we had a more generous budget, we would have chosen the SPOT satellite messenger. Since the device communicates through satellites, it can operate almost anywhere. The messenger will automatically send GPS location updates every ten minutes. The device stops transmitting above 60,000 feet, and does not restart until around 15,000 feet during the descent. This device increases the reliability and the success rate of a near-space balloon launch.

Different Types of GPS coordinates:

There are multiple ways of displaying a given location on a map. Be sure to verify the units on your GPS systems before proceeding. The three different formats: (Degrees, Minutes, Seconds), (Decimal, Degrees), and (GPS Coordinates). Forgetting to account for units can mean a difference of miles! There are online converters that can transform between different units.

GPS TRACKING SOFTWARE	ACCUTRACKING	INSTAMAPPER
	$5.99 a month with one month free trial	Free, same functionality as Accutracking

OLIVER YEH

The Dreamer.
Motto: Live as if there is no tomorrow.

At MIT, I made a name for myself coming up with awesome but ridiculous ideas. Last summer, I biked across Canada with my friend Thomas Moulia (MIT '10). Along the way, we hiked around Banff national park and witnessed some of the most amazing views in the world. We slept at golf courses, abandoned houses, church lawns, and carnival booths.

Last spring, Thomas and I decided to build a raft out of Poland Spring bottles, and we rafted across the Charles River with our homemade contraption. This spring I wanted to see what Boston looked like from the air. I tethered a balloon and a camera with fishing line to the ground. After getting some beautiful pictures, I wanted to go higher!

JUSTIN LEE

The Meticulous.
Motto: Let's prepare for tomorrow

I am a first year graduate student in MIT's Department of Mechanical Engineering (focus in volume holography). For undergraduate work at MIT, I studied physics and biology.

In my free time, I like to build things and blog about cancer science & anthropology. I hope to someday help develop medical technologies to aid cancer prevention, diagnosis, and treatment.

For this project, I went along with Oliver on one of his lower-level launches in the Spring, and he expressed his desire to go even higher -- to take "space pictures." Over the summer, we teamed up and did a lot of background research into what were the difficulties of such a task and what we needed to have/do in order to maximize our chances for success. It was truly a great experience.

Why Did We Do it?

Because we wanted to see what the Earth looked like from near-space.

Three Things Oliver Does For Fun

- Biking
- Tumbling (Gymnastics)
- Brain puzzles

Celebrities Justin Hopes to Meet:

- Jessica Alba
- Caitlin Kinney

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Any money raised will go a long way in helping us keep our website running and funding future work.