Balloon Assisted Launch System (BALS)

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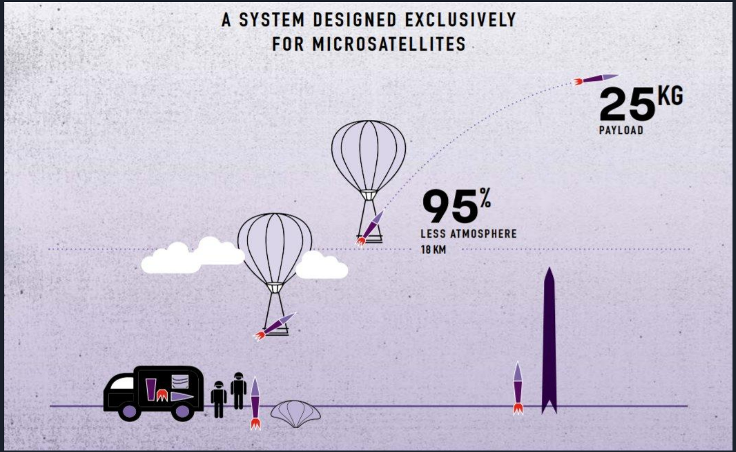
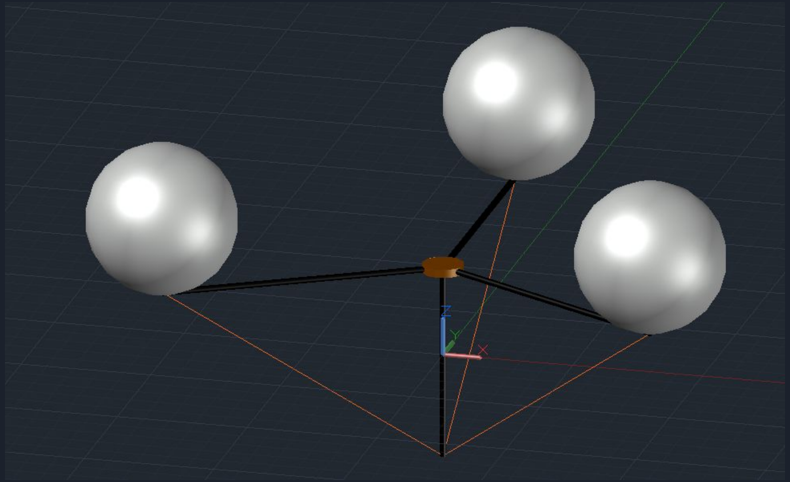
Introduction/Goals

- Send a rocket above the atmosphere before it is launched into orbit
- Cheaper and easier than launching from the ground
- Less loss from atmospheric drag and gravitational effects due to less fuel on board



https://phys.org/news/2018-04-rockoons-satellites-space-accessible.html

Previous Work



- Design selection
  - Why three-balloon design?
  - Outriggers to keep balloons away from rocket
  - Boom rod to provide more stability
  - Paracord tied from bottom of boom rod to end of each outrigger
  - E-match charge(s) to pop balloon(s) for safe recovery

Goals for This Semester

- Initially, we wanted to get the balloon structure up to 10,000 feet before launching
- Due to unexpected instability issues, we were unable to launch from this altitude
- With every new obstacle to overcome, there were new issues to account for

Calculations

- Terminal velocity is the maximum rate of climb for the stand
  - This is how you determine the acceleration you want versus the area that you get

$$v_t = \sqrt{\frac{2ma}{\rho A C_D}}$$

- Coefficient of drag is the same for three balloons as one balloon

$$C_D = \frac{D}{\frac{1}{2}\rho v^2 A}$$

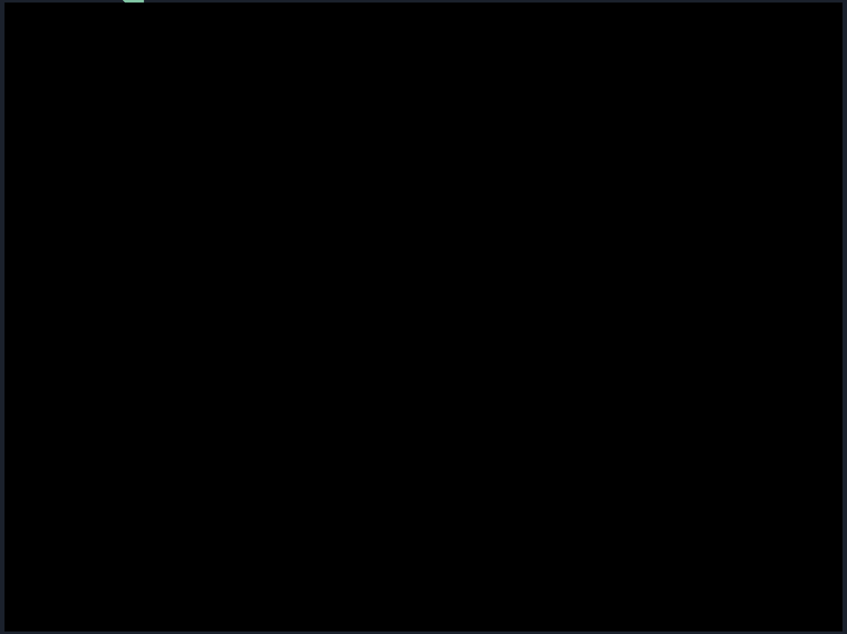
- Buoyant force of balloon(s)

$$F_b = \rho V g$$

Small Scale Tests

- Small-scale design needed to be completely refined before scaling up
- Three-balloon design was moderately stable
- Given the small motor size, the stand did not move much until the rocket was clear of the launch rod
- Using an e-match on an expanded balloon is effective at popping the balloon
  - Balloon material selection is very important
- Electronics box/code worked well for the altitudes that it was tested on

Videos of Small Scale Scale Launch



Click screen and open in new tab to watch videos

Stability of Stand on Small-Scale Launch

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Scaling Up to Full-Scale

- First issue encountered was the hollow carbon fiber rods instead of solid
  - We did this to save weight, but they were not as sturdy as the solid rods
- Rods were not 120 degrees apart due to the launch pad structure
  - This led to more lift on one side than the other
- Rocket being so heavy raised the center of mass too much
  - We believe that this was the main cause of the instability that was experienced
  - One way to overcome this could be going back to a similar design to the first 3-D printed launch pad
  - Our next recommended solution would be to add more weight at the bottom and keep the three rod design

Assembled Full-Scale Structure

Accomplishing a Remote Launch

- Legally required to launch within 20 degrees of vertical
- Launch at specified altitude
- Arduino Nano paired with altimeter and gyrosphere
- Electronic matches allow for launch and balloon pop

Future of Project

- Develop better way to pop balloons
- Come up with a way to hold the rocket in the event of an aborted mission
  - If the rocket should go to elevation and need to be brought down, it would currently just slide off the launch rod when a balloon is popped
- Lower center of mass of the entire structure
  - Shorter rocket, slight design change of the launch pad, bigger stand, etc.
- Remote override of launch/controlled remote launch
- More stable/rigid system
- Air Traffic Control clearance for higher altitude

Video of Full Scale Launch

Click screen and open in new tab to watch videos

Aftermath of Full Scale/What we Learned

- Full-scale rocket led to instability - must lower center of mass
- Hollow tubes sway in wind and crack from rocket thrust - Use stronger rods in future testing
- Need metal plate to protect base for multiple launches from one stand

Thank you for your time! Any questions?