National Aeronautics and
Space Administration

NASA Student Launch ARW Recovery Systems

PRESENTED BY NASA Student Launch

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NASA STEM

Hardware: Parachutes

Parachutes:

The most used recovery device in high powered rocketry

A high drag device that slows down the high-speed descent of the rocket by producing a force that opposes the weight of the rocket

The effectiveness (or drag) of a parachute depends on:

- Velocity
- Air density
- Surface or “reference” area
- Drag coefficient

Typically have three major features:

- Canopy
- Support lines (shroud lines)
- Steel connector link (swivels, quick links, eyebolts)

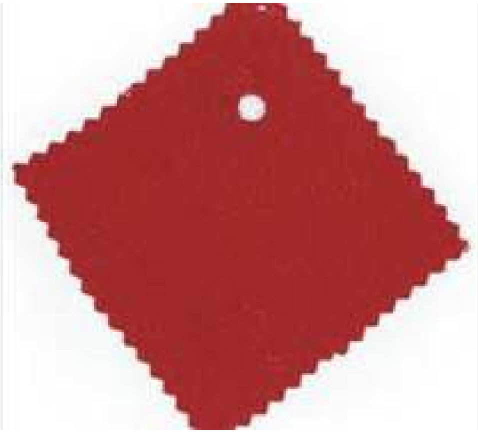
$$D = {}^{1}/_{2}\,\rho V^2 S C_d$$

Drag coefficient:
A dimensionless quantity that is used to quantify the drag of resistance of an object in a fluid environment such as air

Parachute Protectors:
A flameproof Aramid cloth or Kevlar cloth will protect the parachute from these hot gases and burning debris.


greenfiber
blow-in natural fiber insulation
R13-R60
no-itch
85% recycled
energy savings


MODEL ROCKET ACCESSORIES
Recovery wadding
Rembourrage de récupération
Isolierwatte



Hardware: Parachute Protectors

Parachute Protectors:

Nylon is susceptible to melting and charring

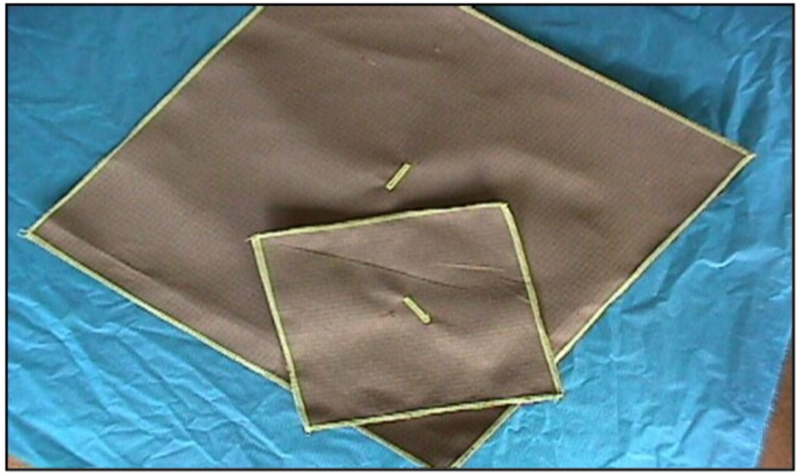
Necessary to protect parachutes

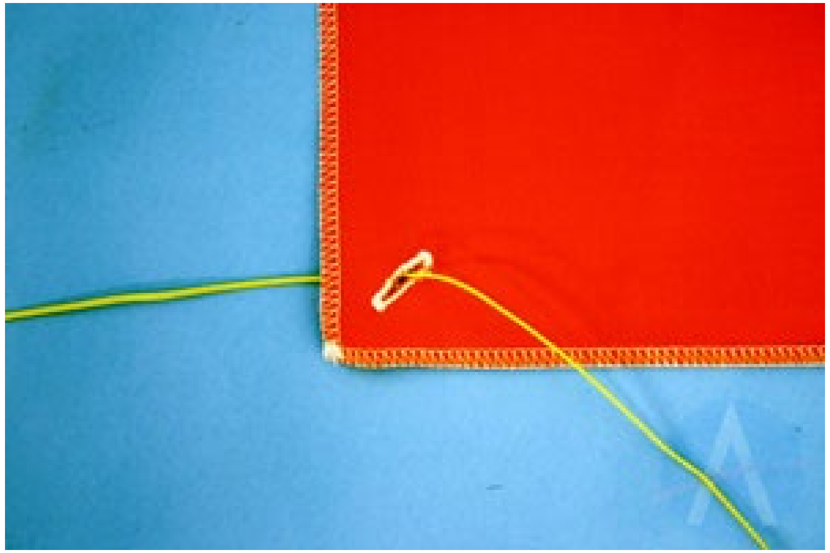
Typical materials for Parachute Protectors:

- Aramid/Kevlar
- Kevlar/Fiberglass

Other Options:

- Pistons
- Deployment Bags





Hardware: Recovery Harness

Recovery Harness:

A long length of cord that attaches structural components that separate as part of the recovery system

Each end is typically secured by quick-link to a *U-bolt* or *eye-bolt* that is rigidly mounted to a bulk plate on an avionics bay, nose cone, or booster

The length of shock cord required will be the subject or empirical testing and evaluation

Your workshop rocket has 12 feet of shock cord

An L3 type rocket may require more than 100 feet or shock cord

Rule of thumb is each section of shock cord should be 2-3 times the length of your rocket

Typical materials for shock cords:

- Aramid/Kevlar
- Kevlar/Fiberglass
- Nylon

Shock Cords

Nylon

Kevlar

Considerations:

Economics

Strength

Stretchiness

Durability

Preference

Hint: Be weary of manufacturer ratings, size is usually your best reference.

Hardware: Quick Links

Quick Links:

Make connecting and rigging a recovery system very easy

Many different types of quick links available commercially

Always use quick-links with a locking gate

Take care in choosing a quick-link that will safely carry the maximum expected load

Too small of a quick-link may yield under heavy loading when the main parachute opens

Hardware: Eye Bolts and U-Bolts

Eye-Bolts & U-Bolts:

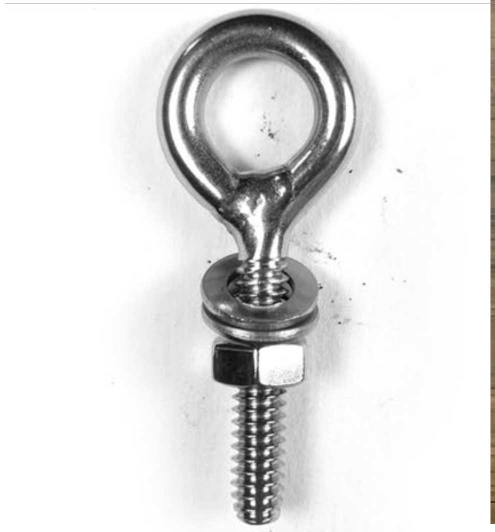
Hard points on rocket's structures for attaching recovery system

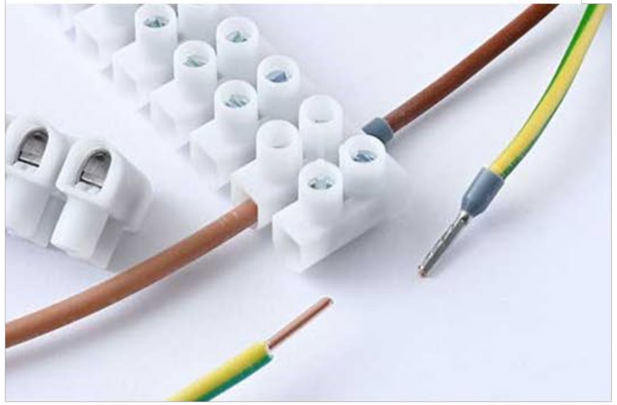
Typically mounted on bulk plates and/or centering rings

U-bolts are preferred on large rockets

Eye-bolts must be closed and/or welded closed, bent eyebolts are not permitted

Other Hardware





Single Event Recovery Systems (SERS)

A typical Single Event Recovery System ejects a parachute or streamer at apogee

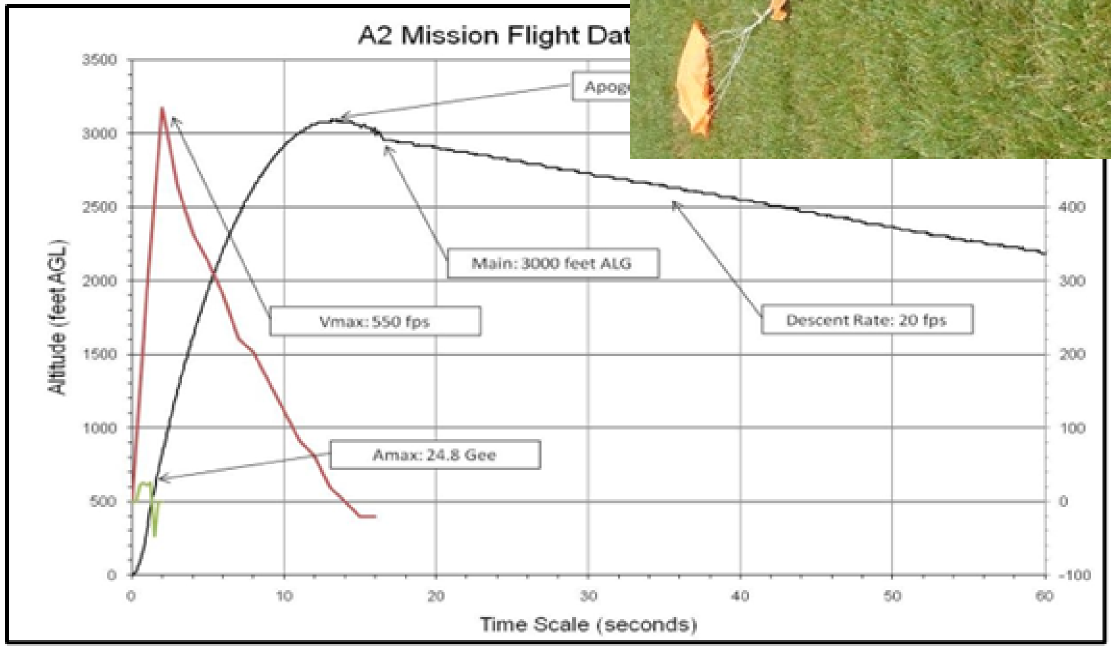
This can most commonly be achieved by using a motor ejection charge

Most low to mid power rocket motors have this capability

At motor ignition, the propellant and a delay grain begin to slowly burn

Once it burns through, the ejection charge is set off and the parachute is deployed

SERS is the simplest recovery system and is good for low altitude flights on small launch fields and high-altitude flight on very large launch fields



Dual Event Recovery System (DERS)

Your Student Launch Project rocket is required to use a Dual Event Recovery System

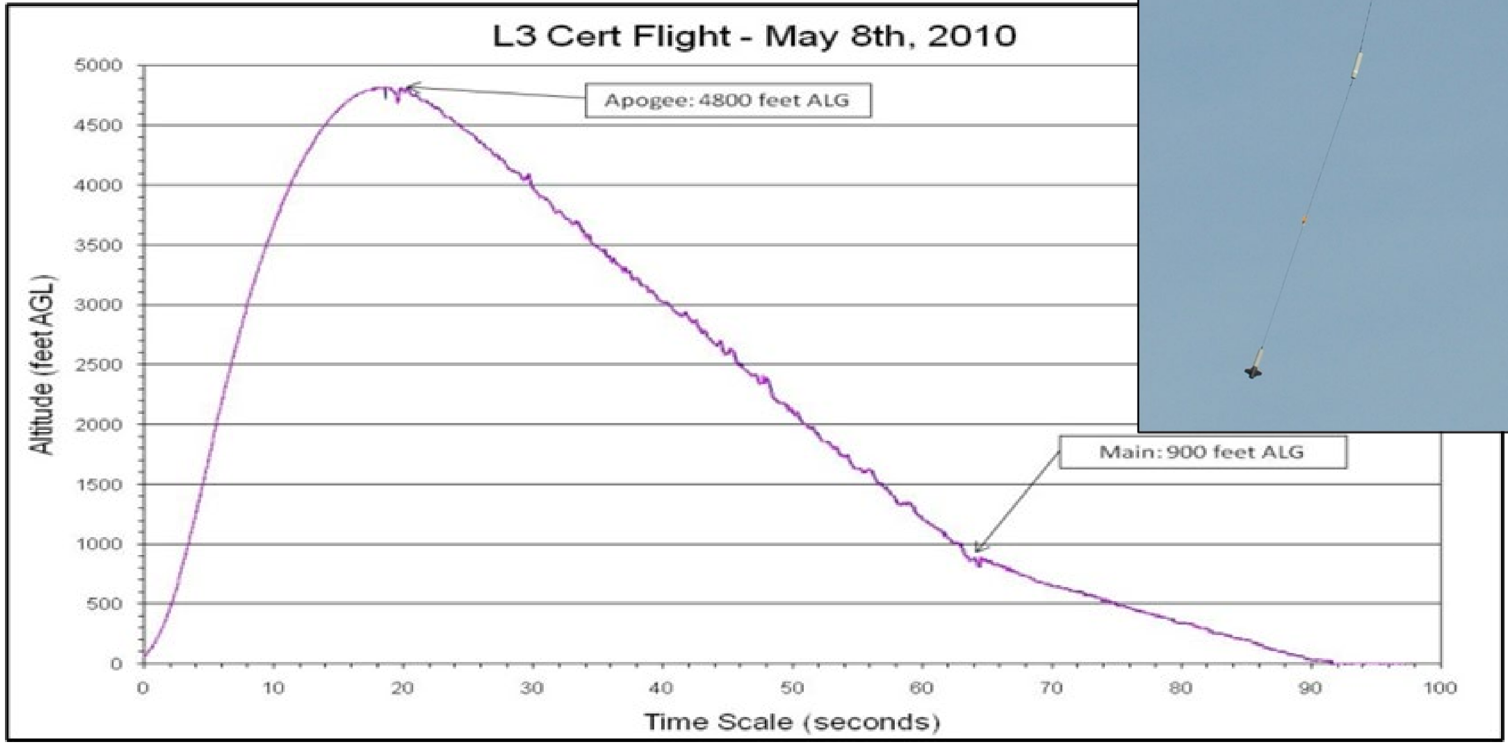
1st event at apogee

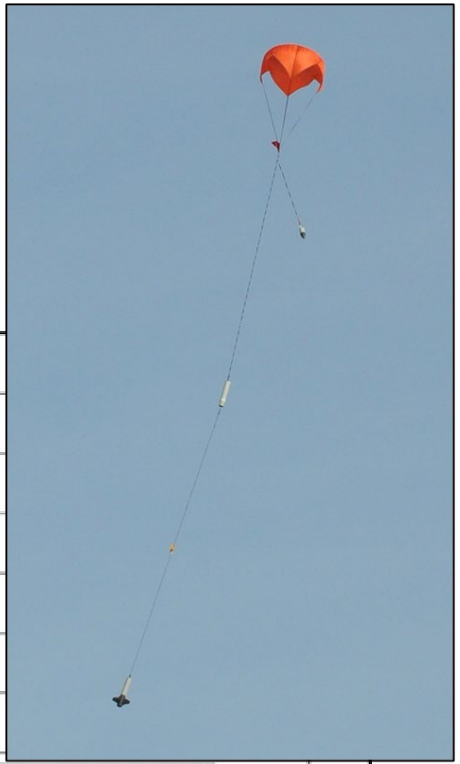
2nd event at much lower altitude

Typically, 500-1000 feet Above Ground Level (AGL)

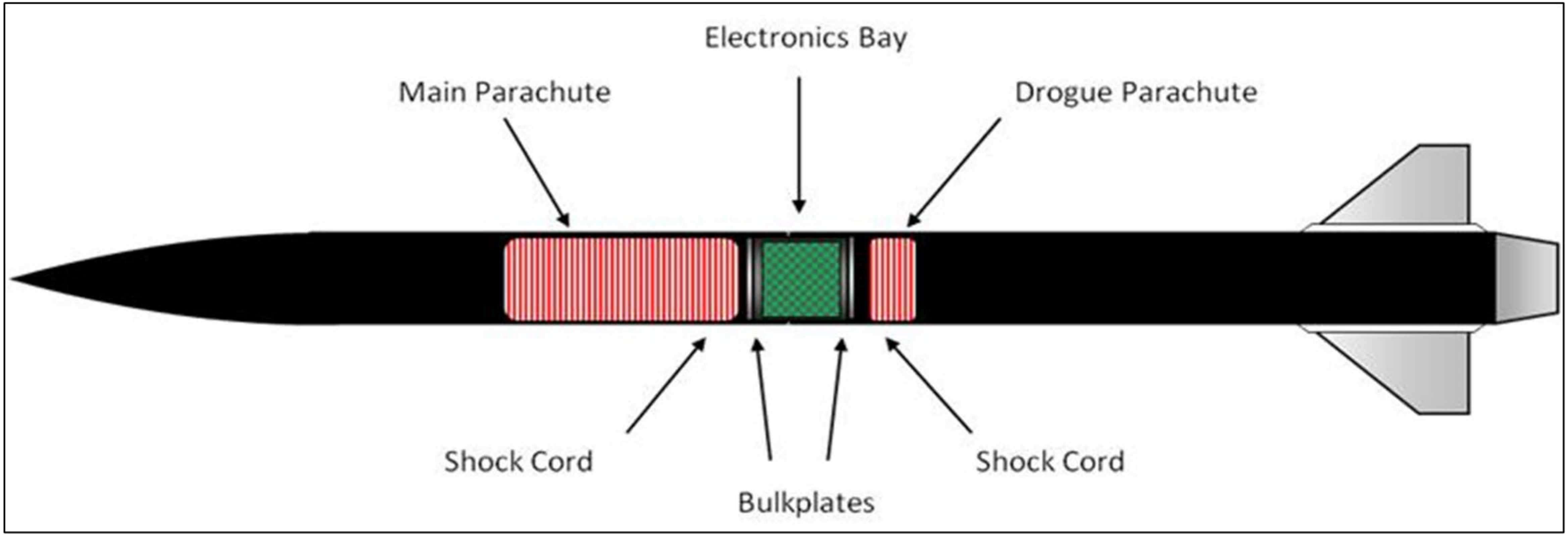
Requires electronics

Significantly reduces the recovery area





Dual Event Recovery System (DERS)

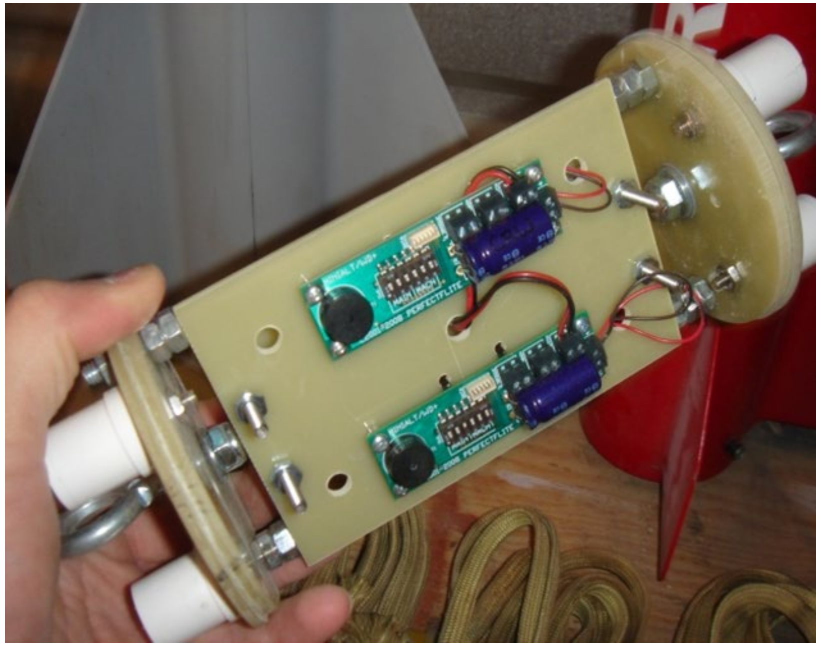


Dual Event Recovery System (DERS)

The Avionics Bay

Subsystem of a high-powered rocket that typically contains altimeters, batteries, and switches

A typical E-Bay is comprised of three structural components: the *housing,* a forward and aft *end-cap* and an *avionics sled*



Dual Event Recovery System (DERS)

Avionics Bay Housing:

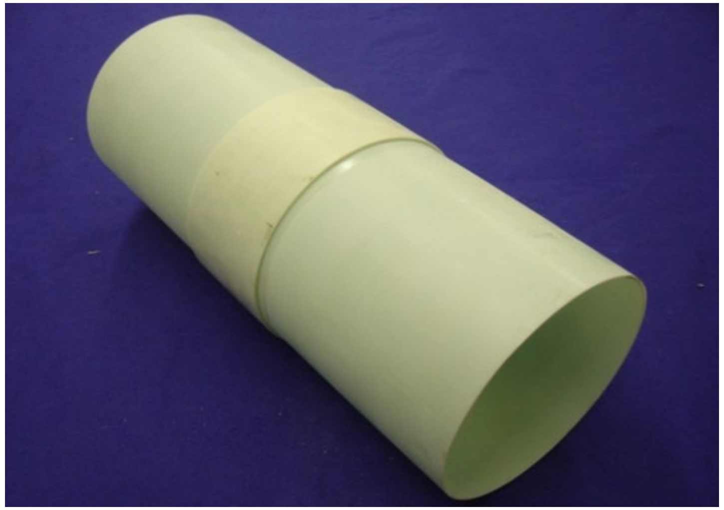
Typically built from a coupler tube

Can have a collar (switch band) made from a segment of airframe epoxied to the middle of the couple

Allows direct access to the switches that power on the altimeters

Supports static pressure ports that equalize the housing's interior pressure with the exterior atmosphere

Generally, when joining airframes with a coupler, the coupler should extend at least one airframe diameter into each joined segment



Dual Event Recovery System (DERS)

End Caps (i.e., removable bulkheads):

Close out the housing separating the rocket's volumes

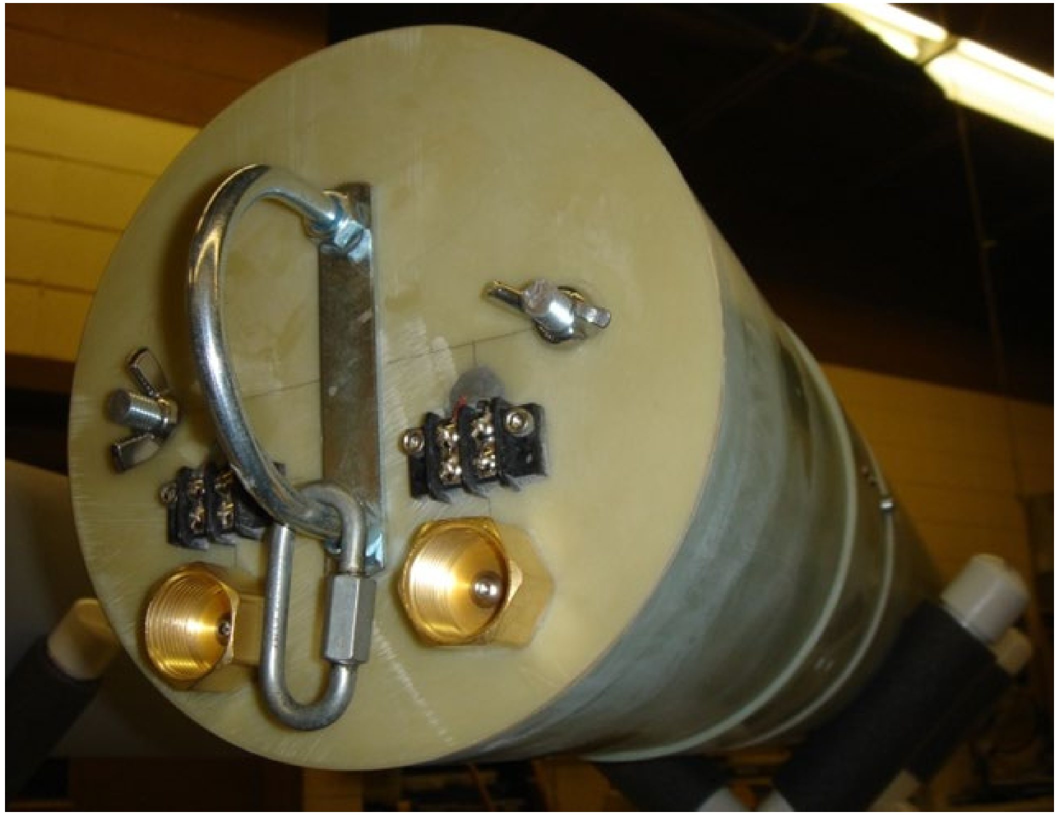
Support the recovery harness hard mounts, charge cups, and all-threads

The all-threads act as a two-force member that connect both end-caps and carry the recovery harness load through the E-Bay

End-caps should create a good seal around the end of the housing to prevent hot gas seepage from the ejection charges

Typical Materials:

- G-10 fiberglass
- Plywood



Dual Event Recovery System (DERS)

Avionics Sled

Sliding onto the all threads that connect the end plates - like a sled

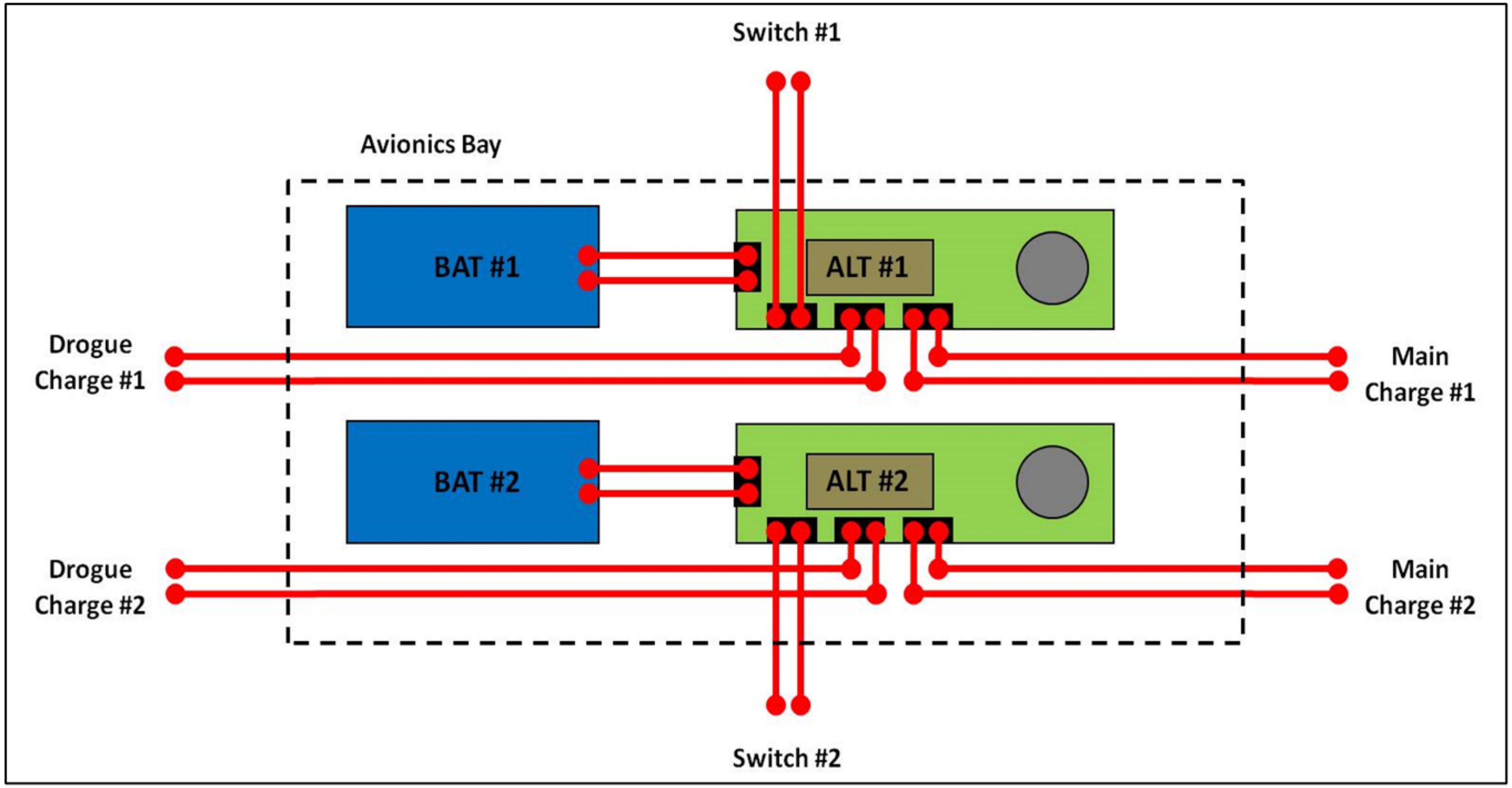
The avionics electronics, batteries, and switches are mounted to the sled and wired together to form systems

Typical Materials:

- G-10 fiberglass
- Plywood

DERS Recovery Wiring Schematic

Recovery Electronics Diagram (Required for Each milestone):



Recovery Electronics: Altimeters

Altimeters:

Dual Event Recovery Systems require the use of electronic devices called Altimeters

Determine altitude and initiate recovery events

Your Student Launch Project rocket shall have no less than two commercially available, independent, redundant altimeters

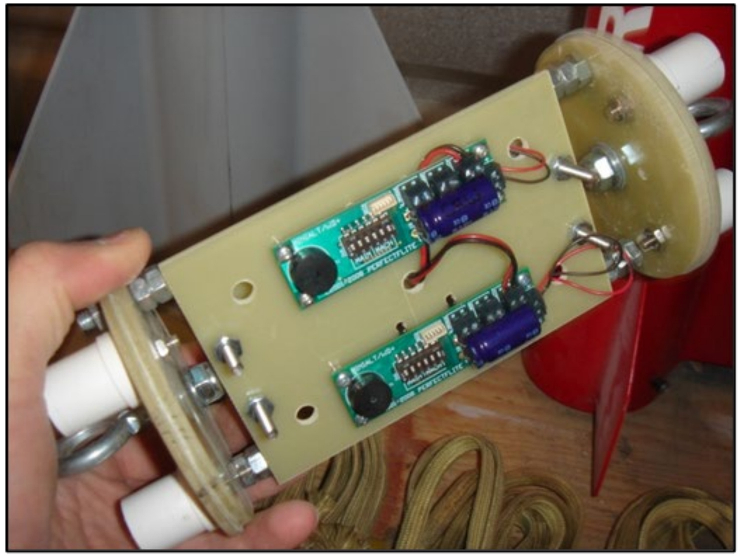
It is recommended that each altimeter have a dedicated battery and on-off switch.

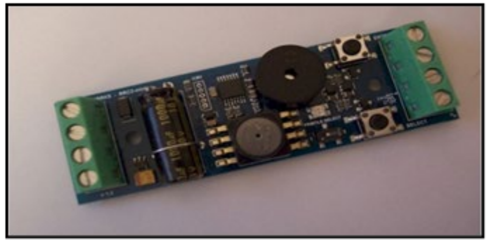
- This setup will greatly reduce the likelihood of a recovery system failure

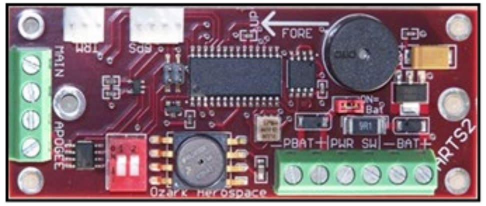
Typically, altimeters require 9V-12V of electricity

Altimeters, generally inside of the rocket's avionics bay, need to sample the outside air pressure

Your rocket will need static pressure port along the outside to allow the inside pressure to equalize to the outside pressure







Recovery Electronics: Batteries

Batteries:

The NASA Student Launch Projects official handbook requires that your rocket have a *minimum* pad stay time of three hours

That means that your electronics should be able to remain switched on and reliably operate if the rocket remains on the pad for up to one hour on the pad before launch

Two main types of batteries:

Primary - designed to be used once and discarded when they are exhausted

- Cost less than secondary batteries
- Don’t require sophisticated chargers to recharge them
- Lower *“self discharge”* rates than secondary batteries

Secondary - designed to be rechargeable and used multiple times

- Weigh less than primary batteries
- Manufacturers can shape them however they please
- Greatly increased run time

Improper use or charging of some secondary batteries can result in fire or explosion

Recovery Electronics: Switches

Switches:

Each altimeter will be armed by a dedicated mechanical arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.

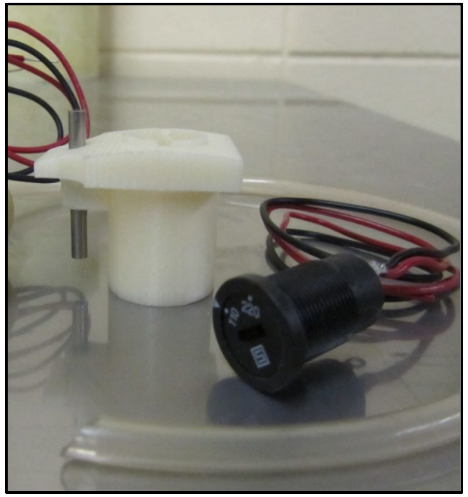
Safety feature for pressure & g-switch activated recovery systems

Maximizes battery life

Surface mounted to airframe or mounted inside rocket with access hole or panel

Two categories of switches typically used on high powered rockets:

- *Single Pole Single Throw (SPST),* is a simple of-off switch where the two terminals are either connected or disconnected from each other
- *Dual Pole Single Throw (DPST)* is equivalent to two SPST switches controlled by a single mechanism.



In these two categories, there are toggle switches, push button switches, and selector switches

Note: We do not allow magnetic switches

Ejection Charge Sizing

A black powder charge is the most common and reliable method of ejecting a parachute from your rocket

Hot gases that pressurize the rocket's airframe and exert a net force on the bulk plate of the nose cone

This net force will eject the nose cone, shock cord, and parachute out of the rocket airframe

This all happens because the rocket is obeying the *Idea Gas Law*

- *P* is the absolute pressure of the gas
- *V* is the volume occupied by the gas
- *N* is the amount of substance (black powder)
- *R* is the gas constant
- T is the absolute temperature

$$PV = NRT$$

Ejection Charge Sizing

The equation can be reordered to solve for N directly and known values substituted

Online calculators can help calculate amount of black powder to start with for testing purposes

The design pressure is determined by the desired net force on a surface divided by the area of that surface

Typical net force values for a 4-inch diameter rocket range from 100 lbf - 200 lbf

- This translates to a typical pressure range of 8psi – 16psi

$$Pressure: P = F/A = \frac{200\ lbf}{\pi\ (2in)^2} = 16\ psi \qquad Volume: V = \pi R^2 L = 12.5 in^2 L$$

Black Powder charge amounts are typically reported in the unit grams

- Recall that there are 454 grams in 1 pound

$$Black\ Powder: N = \frac{PV}{RT} = \frac{16psi * 12.5in^2 L}{266\ \frac{in\ lbf}{lbm} * 3307°R}\left(\frac{454\ grams}{1\ lbf}\right) = 0.1L$$

The reduced equation for this case, states that 0.1 grams of Black Powder is needed for every 1 inch of airframe containing the recovery system

- If L = 20 inches, then 2.0 grams of black powder is needed to eject the recovery system

E-Matches

Universal initiator of many rocketry pyrotechnics and motors

Typically made from a thin nichrome (nickel-chromium) wire laminated to a small nonconductive flake of fiberglass

Each end is soldered to one wire of a two-conductor solid core copper shooter wire

The nichrome bridge is dipped into a pyrogen formula that dries hard and looks like a match, hence the name

Typically, high current or low current

Kits for making your own e-matches can be purchased on the internet – NOT TO BE USED IN NASA STUDENT LAUNCH

Note: Some distributors use other names.

Shear Pins

Generally used on mid to high powered rockets to prevent *dynamic separation* or premature/incomplete deployment of the recovery system

Dynamic separation occurs when a rockets separates in the coasting phase because the different sections are decelerating at different speeds

An example would be when a rocket's booster section separates from the forward airframe or nose cone because the fin drag, or the base drag effects creates a significant enough force to overcome the frictional force keeping the sections together

Rocket builders generally use small nylon machine screws as shear pins

- #2-56 nylon machine screw has an average shear strength of 25 lbs.
- #4-40 nylon machine screw has an average shear strength of 40 lbs.

Recovery System Testing

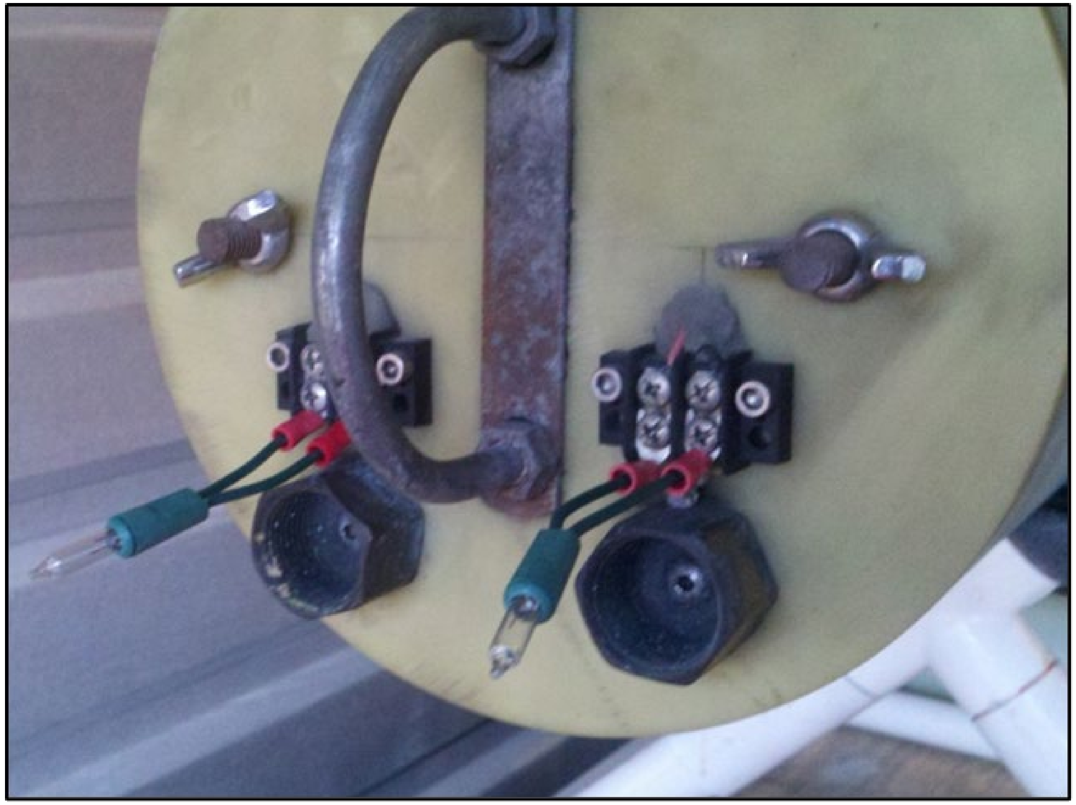
Vacuum Chamber Testing:

Proves pressure-based rocket altimeters are functional

Can be as simple as a single altimeter in a mason jar using a marinade syringe to pull the air out

Or as complex as a full systems test of the entire rocket recovery system

A simple visual indicator of an altimeter's health can be a Christmas tree light wired into the ejection charge terminal blocks



Recovery System Testing

Ejection Charge Testing:

Conduct several ejection charge tests before flight

Best way to assess:

- Ejection charges are of sufficient size
- Assess the configuration effectiveness

Success criteria:

- Both main and drogue systems deploy as expected
- The parachutes extract from the airframe
- The parachutes and shock cords are suitably protected from the ejection charge

The tests prove the design is ready for flight

Note: Successful ground ejection test does not ensure successful in-flight separation

- Strong ejection on the ground will help ensure successful deployment in-flight

Questions?

NASA