



Development of a “Multi-cut” Payload for use in Stratospheric Ballooning Missions



Joey Habeck, Noah Biniek, Steve Smeaton, Austin Langford, Jordan Diers, Isaac Krieger, U of MN – Twin Cities

Faculty adviser: James Flaten, NASA’s MN Space Grant Consortium and U of MN – Twin Cities – Aerospace Engineering and Mechanics Department

Abstract

The ability to cut strings (AKA lines) during stratospheric ballooning missions has a wide variety of uses, including, but not limited to: (a) flight termination (i.e. cutting payloads away from the main balloon), (b) cutting away excess lift balloon(s) to slow ascent rate (and possibly achieve float), (c) cutting away ballast weights to slow descent rate or increase ascent rate, (d) cutting away burst balloon(s) on descent to avoid parachute entanglement, and (e) cutting away payloads which are intended to return to the ground independently for experimental purposes. We report on the development of a “multi-cut” payload box that uses an Arduino microcontroller that can control the cutting of multiple strings in arbitrary order at arbitrary points during a mission, expanding our options for stratospheric ballooning operations. For example, this device may be used during the solar eclipse of August 2017 to drop a timed-series of independently-recovered Geiger counter payloads from a stratospheric balloon stack to characterize changes to the Pfozter maximum as the Moon’s shadow passes.

System Overview

The “multi-cut” payload consists of (a) independent nichrome burner modules – currently 4, but this can be changed based on mission requirements, (b) a set of four 1-farad capacitors shared by the burner modules and recharged by a single 9-volt battery, (c) an Arduino Mega microprocessor with SD card logging, (d) sensors (gps and pressure) to allow the microprocessor to execute a mission profile autonomously, and (e) a short-range XBEE radio module through which commands can be sent to the Arduino from the ground via a communications relay payload. Each burner is attached to two pins on the Arduino, one to fire it and one to monitor the status of a pull-pin to give the Arduino feedback about whether or not a burn command has been successfully executed. The lines that run through the payload are 50-lb Dacron fishing line which can be easily cut by red-hot nichrome wire. Items to be released, either balloons to float away upward or weights to fall away downward, are attached to pull-pins so as to pull them out after a successful burn. Burners can be set to fire only if pull-pins are not pulled or forced to fire regardless of pull-pin status. Status updates, logged to an SD card, shown on a bank of LEDs, and sent out via XBEE transmission, include pull-pin status and “attempted to burn” (or not) status.

Communications Vocab

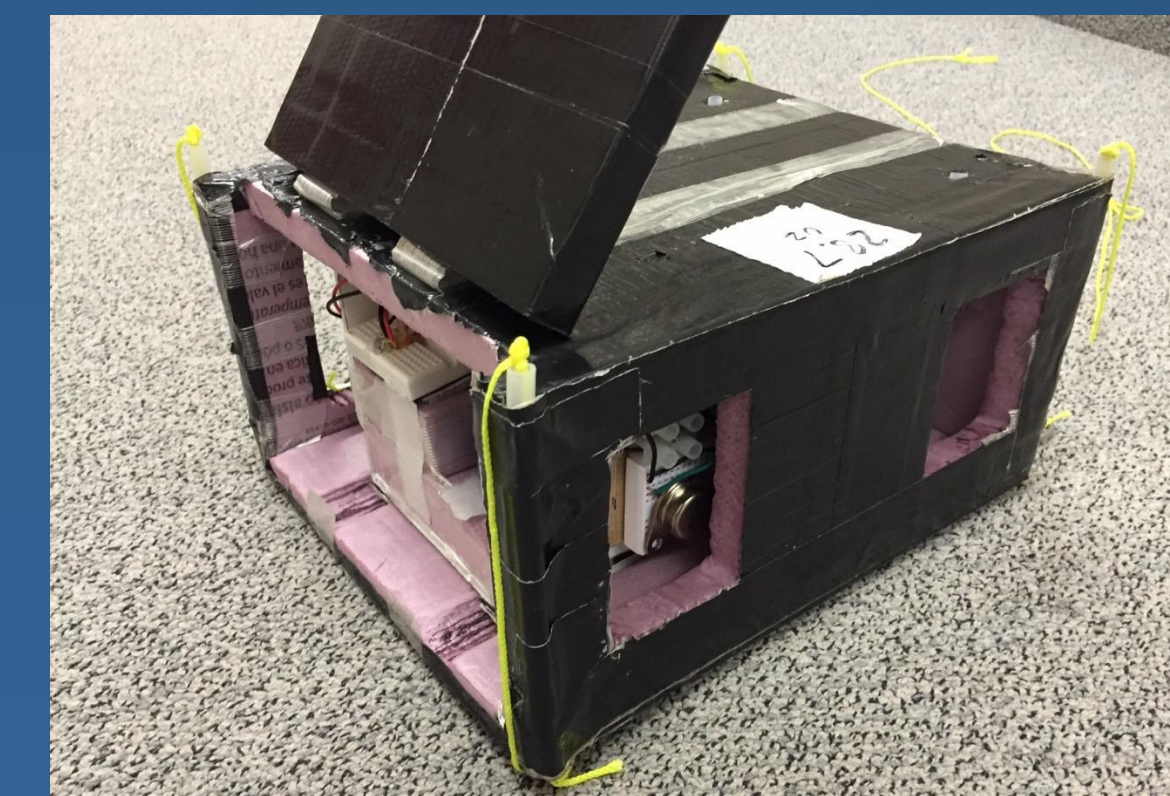
A series of commands were developed that could be relayed to the “multi-cut” payload from the ground via RFD 900 uplink then XBEE short-range radio. These commands included “Cut A if pull pin still in place” and “Cut A regardless of pull pin status” and “Transmit status of all pull pins” and “Transmit gps” and “Turn on (or off) automatic updates” and “Turn on (or off) automatic/autonomous burner operation” etc.

Proposed Flight Test

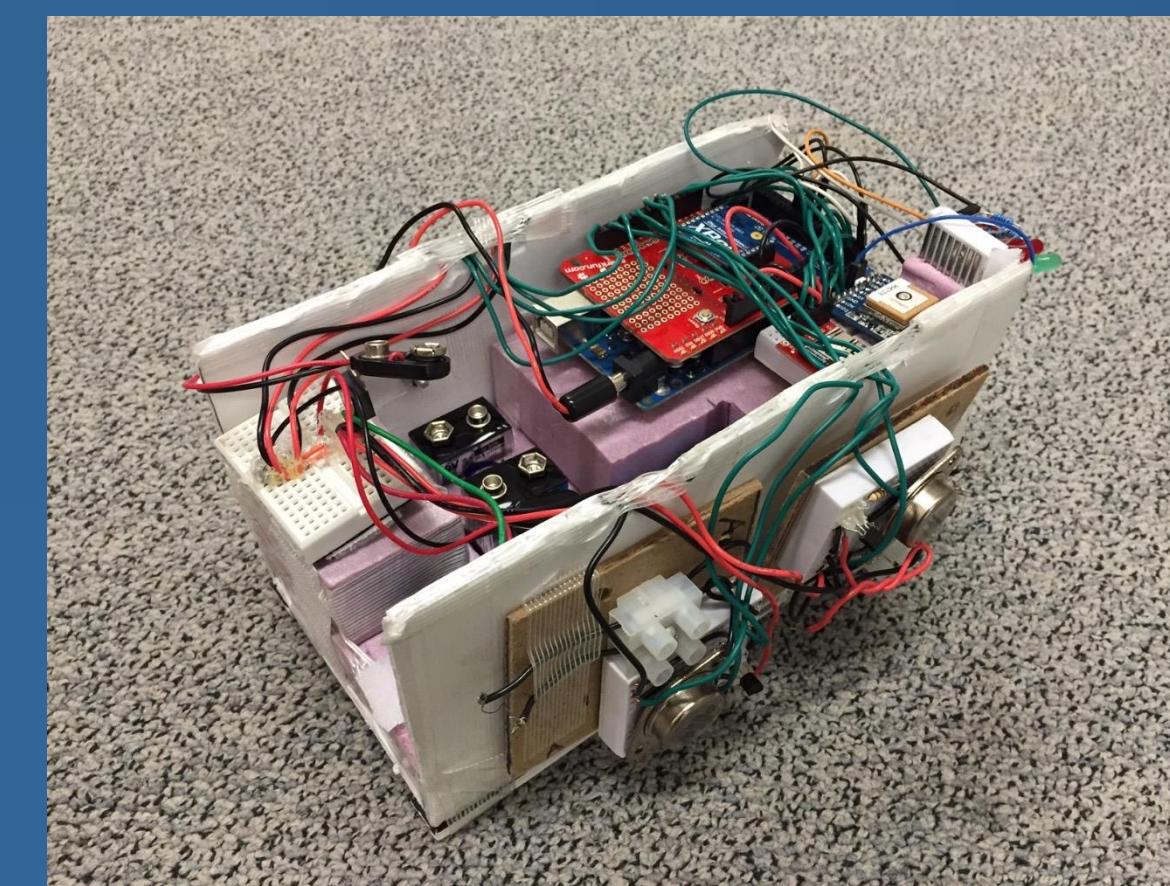
The planned first flight test of the “multi-cut” payload, which has been attempted but has not yet been entirely successful, included the following steps: Cut A (not attached to anything important) at 40,000 ft or at 50 minutes (cold!), Cut B (to release a pilot balloon providing extra lift) at 55,000 ft or 65 minutes, Cut C (not attached to anything important) at 80,000 ft (and plan to pre-empt that last step from the ground, as evidence of at-altitude communication capability), then Cut D autonomously on descent to get rid of the burst balloon.

Proposed Actual Expt.

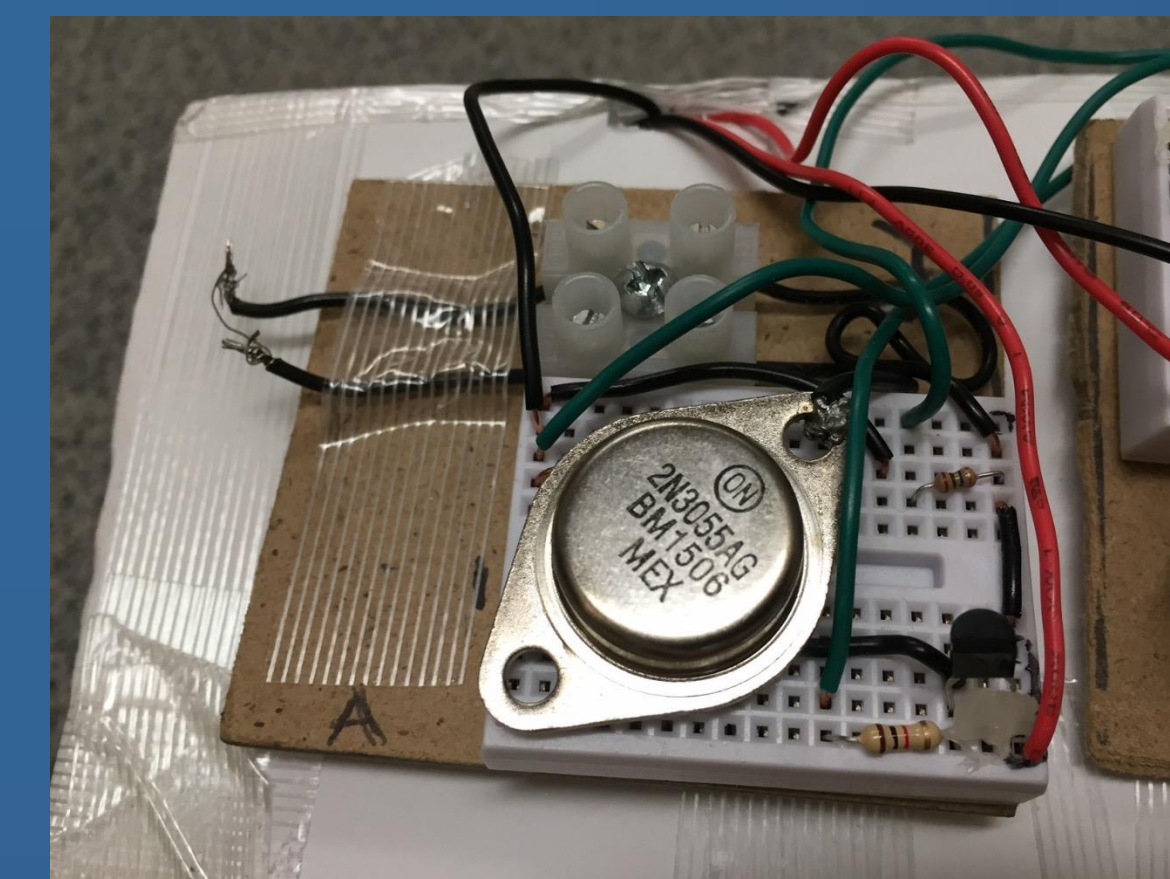
One solar eclipse ballooning mission that would benefit from a multi-cut capability would be to drop a series of cosmic radiation detectors (Geiger counters) down through the Pfozter maximum before, during, and just after an eclipse. Such a mission might have the following approximate steps. Use two main balloons to lift the stack above the Pfozter maximum then park it there by cutting away one balloon. Drop Geiger counter payloads at specific times as the eclipse passes, each with its own parachute or perhaps its own small balloon. If doing so upsets the float-balance, cut away more items (extra lift balloons, if ascending – general ballast, if descending) to maintain station above the Pfozter maximum and keep the final main balloon from bursting prematurely. Finally, cut away the main balloon to terminate the mission and to bring the stack remnants, possibly just the “multi-cut” payload itself, back down. This implementation would require more than 4 burner modules, but should be a relatively easy expansion of the current design. We are already in the process of practicing using extra balloons for extra lift that can be cut away in flight – that idea presents its own challenges, we have already discovered.



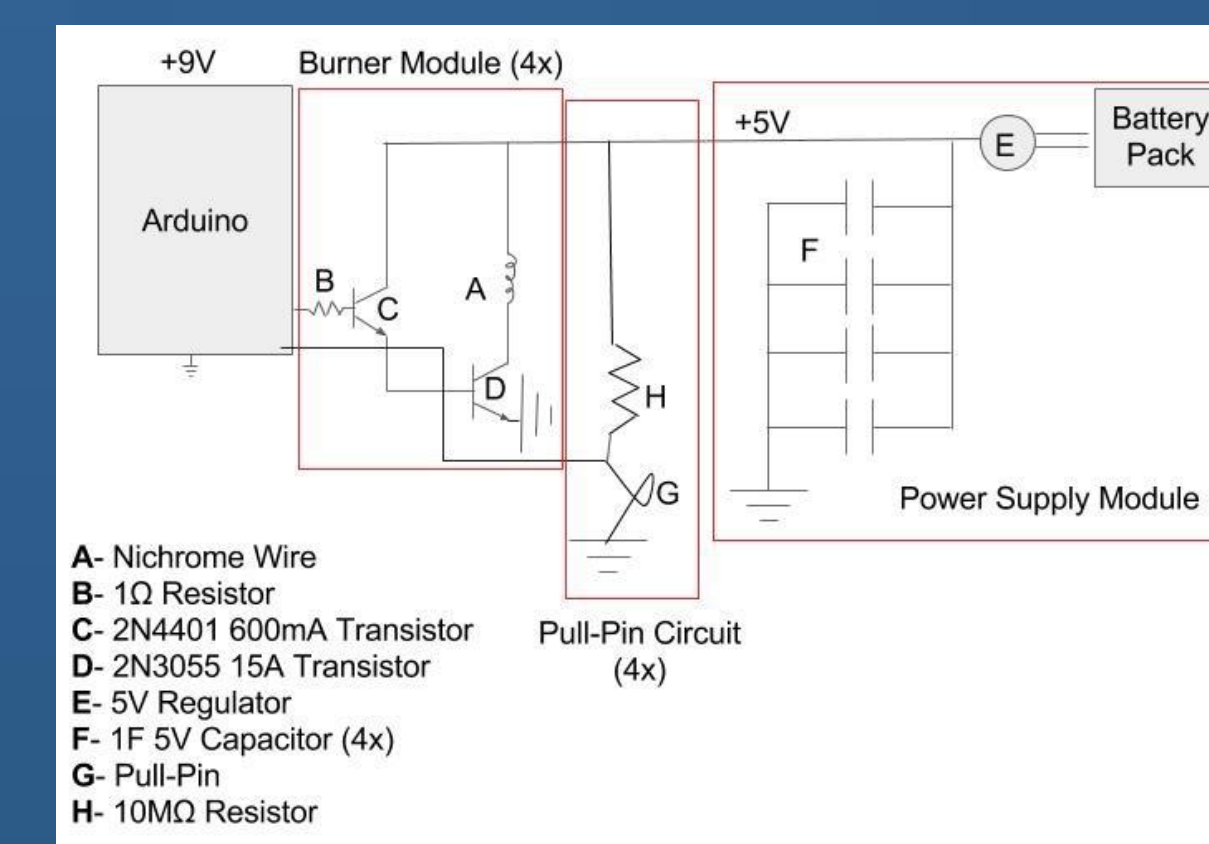
“Multi-cut” - windows uncovered



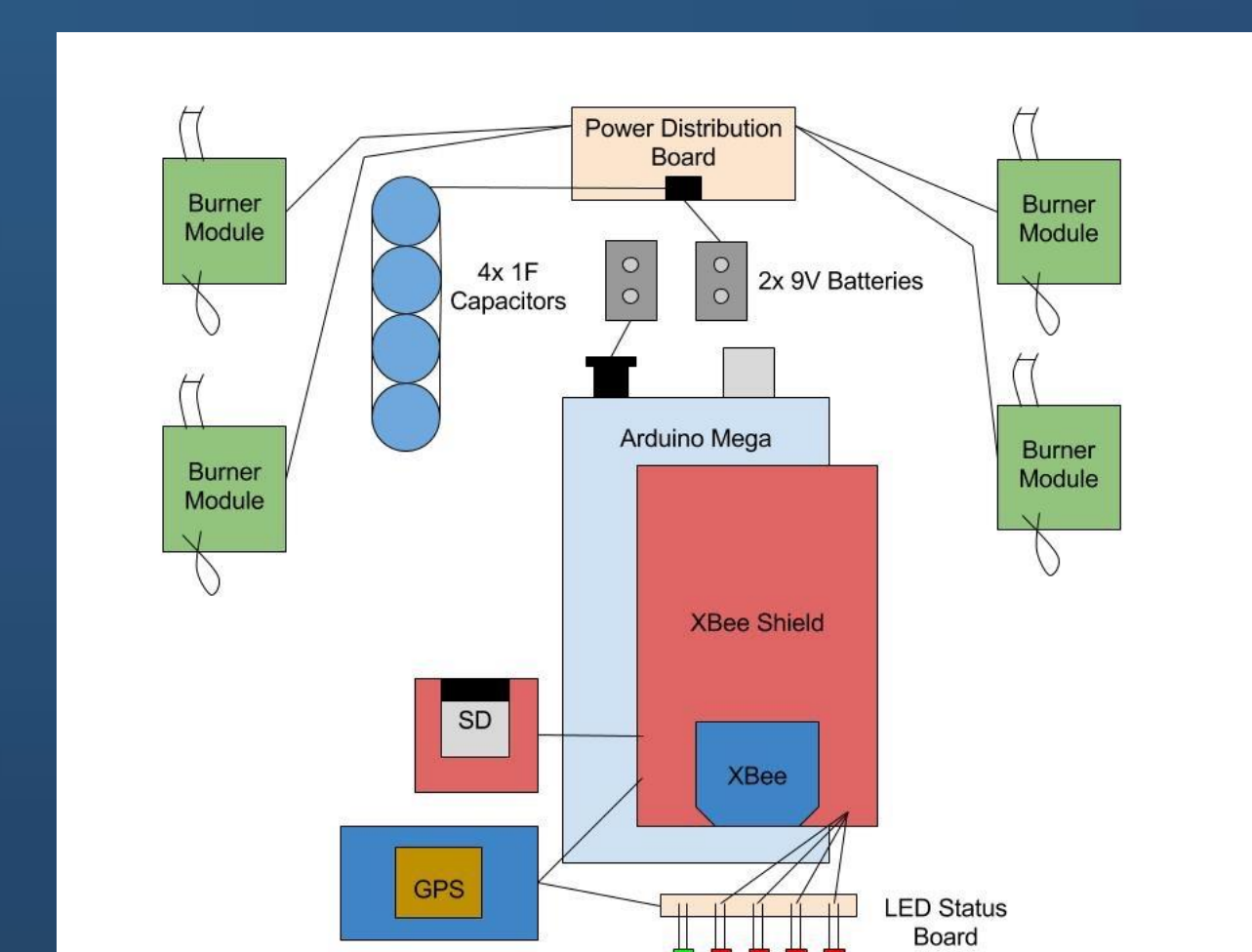
Extractable electronics sled



One nichrome burner module



Nichrome burner wiring



Block diagram of the overall system

Hardware Listing

Burner Module (4x)

- 30 gauge nichrome wire
- Terminal block
- "Tiny" breadboard
- 2N3055-AG 15 amp transistor
- 2N4401-AP 600 milliamp transistor
- 1.0 kΩ resistor
- 10.0 MΩ resistor
- Shorting wires (AKA pull-pins)

Power Supply

- 9V lithium battery for Arduino
- 9V lithium battery for nichrome burners
- LM7805-CT 5V regulator
- 4x FS0H105-ZF 1.0 Farad 5V capacitors (wired in parallel to increase capacitance)

Microprocessor, Sensors, Communication

- Arduino Mega 2560
- AdaFruit Ultimate GPS Breakout Board v3
- SparkFun microSD Transflash breakout
- SparkFun XBee shield w/ XBee S1 Module, 1mW

Miscellaneous

- 5x LED w/ 562 Ω safety resistors (used as status indicators)
- 16 GB Micro SD Card (for data logging)

Status of Development

The “multi-cut” payload is still under development. It has been flown 3 times so far, with varying amounts of functionality and varying degrees of success. During the first flight, a class flight for the CSE 1012 freshman seminar, it did not yet have the communication capability and thus ran in full-autonomous mode. Unfortunately that flight got waterlogged in a rainstorm, striking the ground and knocking off a glider that was to be released by the multi-cut early in the flight, and ultimately failing to reach altitude. Hence the altitude-based triggers did not fire, though the timer-based triggers did. Due to the “user-unfriendly” nature of the design, a major overhaul was undertaken after that first flight.

On the second flight the communication functionality had been added but a coding error (not converting from meters to feet before testing for altitude triggers) again resulted in a failure of the autonomous altitude-based triggers. Uplink of commands from the ground was ineffective because the payload was already too far downrange from the ground station before commands were needed during the flight.

Just prior to the third flight the nichrome cutter circuitry malfunctioned but the payload was flown anyway, in order to test the communication capabilities. During this flight the payload was able to relay status updates and GPS updates to the ground, but the on-board data log became corrupted and uplink by 900 MHz radio channels was unsuccessful for unknown reasons.

Despite these setbacks, and the potential for more in the future, we continue to believe this payload will add valuable capability to our ballooning program so we intend to keep working on this project. The payload is again slated for an overhaul, this time to make the internal wiring neater, lighter, more modular, and more robust. We will then continue to flight-test this payload until it works reliably and can potentially be shared with other ballooning teams.

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This poster was presented at the 7th annual Academic High-Altitude (ballooning) Conference (AHAC 2016) at St. Catherine University in St. Paul, MN, in June of 2016.