Update 01 Jan 2020:

This is an updated README file from the public repository:

<https://github.com/parkerswanson/RocketKinematics>

This repository contains documentation which can be downloaded by anyone. It includes the Arduino code, ExpressPCB .pcb file, etc.

As part of handing-off this project to my valued (former) colleagues, I’ll put here a few notes to constitute a “Mini-HowTo”. Please feel free to contact me with any questions. My main regret is that I didn’t have time to build a prototype of the latest electronics, check out the program with the latest Arduino development environment and libraries, and especially build and fly a complete up-to-date rocket! Someone else can have the pleasure of those steps!!

Things to do, more or less in chronological order:

1. Get some of the custom PH131 PC boards: From the ExpressPCB website, download and install the current design software (free, for Windows). Since the board is only 2 layers, their simpler current version (“Classic”?) should do. Open the file PH131Dec2019.pcb file. From within the program, “Order Boards”... The correct choice is “Mini-Board Pro” or something like that. That should get you 3 boards, each of which has 3 PH131 boards on it. That should cost about $85, for a cost of < $10 per rocket. ExpressPCB is in Molalla OR so “air ship” is irrelevant. :-) You should get your boards in just a few days.
   1. Bandsaw each Mini-Board into 3 PH131 boards (Use a bandsaw not a recip saw, and wear a mask since you’ll be sawing fiberglass.)
2. Inventory the parts needed and fill in your inventory from Adafruit and Digikey (my preference) or wherever. You’ll need to order reed switches, solid-state relays, 4-pin sockets for the SSR’s, LED’s, etc.
3. Build the electronics. You can use an existing sample of a 2018 assembled unit (there are several Dead ones to look at) as a partial guide.
   1. A main point is to choose and install the correct combination of headers so the 2 boards (Feather Adalogger and custom PH131 board) will plug together nicely. You can assemble the stack “dry” to help keep the header pins aligned during soldering.
   2. Solder the parts onto the board, considering accessibility as you do it.
   3. You may want to mount the LED with long leads and bend it over to make sure the assembled payload will fit nicely into its compartment in the rocket.
   4. If desired, check the SSR docs (linked from Digikey) to verify which way to plug the SSR into its 4-pin socket. (As I recall, the dot on the SSR goes toward the middle of the board…)
   5. Charge each battery by plugging it into an Arduino Feather, and connecting the Feather to a source of USB voltage. It takes a while to charge.
4. Look over the Arduino .ino program. Note that a line in the header can be edited to turn on/off DEBUG mode. In DEBUG mode the data isn’t written to the SD chip, but is sent to the Arduino monitor. When you’re satisfied, you can re-edit, re-compile, and upload the “Flight” code which will write to SD. Each run creates a new file numbered up to 99 (I think). The files are very small so you will never fill up a SD chip. A high-class (such as class 10) SD (from Adafruit?) should handle the default datapoint interval of 10 ms.
   1. New for 2020 is the use of a magnetic switch to turn on the electronics. :-) It worked on my bench, so I hope it works for you and in the rocket! Physics teachers always have lots of good magnets; the unit should turn on with the magnet an inch or so from the switch. One LED lights at turn-on and the other when the system starts taking data. If the program fails to start, the data LED should flash slowly.
5. Build the rocket!
   1. Bandsaw each of the 18-inch body tubes from Apogee into 3 6-inch lengths, to make 3 payload compartments.
   2. Look at an assembled rocket to estimate how far the coupler and the aft end of the nose cone extend into the payload compartment. In each payload compartment, drill a ¼” hole near the forward and aft ends to allow external air to have free access to the compartment - so the pressure sensor can sense pressure.
   3. The Estes instructions for the Top Shot rocket have you build the motor compartment first. Note that there are 2 different spacers available to glue in there. We will be using an E size motor, so we DON’T want the spacer for a smaller motor. You can assemble the motor compartment and a motor “dry” to check.
   4. A note on adhesives: For gluing paper to paper or paper to wood, yellow carpenter’s glue works fine and allows for positioning parts after glue is applied. For everything else, our experience is that you want cyano-acrylate. A good thick type is preferred. You can get a spray-on accelerator which helps. (The accelerator smells attractive, but try to discourage students from putting a dab behind their ears. :-) ) Cover the work tables with paper, and wear gloves. One fault of the Top Shot is that its fins tend to fall off, so fins should be glued with generous fillets of cyano.
   5. Look at an assembled rocket to see how to build it including our added payload compartment. The rocket break-apart is between the main body (orange tube) and the payload compartment. The elastic is tied to the eyelet screwed into the bulkhead (from Apogee) which is glued into the coupler. The coupler is glued to the payload compartment and, of course, not to the main body.
   6. For flight, the electronics are loaded into the payload compartment and padded nicely so they won’t jiggle around. Crumpled paper towel etc. works OK; try to avoid plastic, which can generate static electricity. Then the nose cone can be inserted into the payload compartment and secured with painters’ tape.
6. Fly!
   1. Load a motor (E12-6) into the rocket, secured with its bayonet ring. Insert an igniter into the motor and secure it with a yellow plug. (And, if needed, a little Scotch tape. Just about the most annoying thing about these rockets is that the igniters fall out easily! :-( )
   2. Follow the Top Shot instructions for use of the fire-resistant wadding.
   3. Notify our good LBCC Security people that you are going to do some launches. They want to know what to say to neighbors who might call with concerns about North Korea...
   4. Follow the safety guidelines from the National Association of Rocketry.
   5. Connect the electric launcher to the igniter. At present there’s just one modified-Estes launcher, in pretty sad shape. You can order another one (for E-motor rockets) from Estes, or: I included parts to build a better one - a great project for some maker-inclined student!! The launcher wires get looped once around a launch-pad foot.
   6. Pass a magnet near the payload of the rocket on its launch pad, to turn on the electronics and start taking data.
   7. LAUNCH!
7. After flight, you can take out the electronics, retrieve the SD chip, and analyze the data using any spreadsheet program.

THANKS!!

Parker Swanson, KO7Q [parkerwswanson@gmail.com](mailto:parkerwswanson@gmail.com) 541-760-5473

Notes from earlier versions of this file:

We will use Estes "E" class one-time-use black powder rocket motors. These require extra-cost HazMat shipping, so it's advisable to minimize the number of orders.

Electronics:

Parts will be ordered from: <https://www.adafruit.com/> and <http://www.digikey.com/>

The PC boards will be made by <https://www.expresspcb.com/>

using the .pcb file (proprietary format) downloadable from github, as above. They come in a batch of 3 "Mini-Pro" boards, each of which will be bandsawed into 3 boards for the rockets, resulting in a cost of less than $10 per board per rocket.

A number of workshop tools will be required, including *good* soldering stations (about $50 each), electronics assembly tools, etc. I will write out a suggested list. I like to buy such tools from:

<http://www.mcmelectronics.com/>

Considering the time required to incorporate this project into a class:

I think the students can assemble the rocket in about 3 hours.

I think, with intensive coaching and plenty of available tools, they can assemble the electronics in another 3-5 hours. The time will depend on their experience and skill. Students who are already "makers" on their own will be prized role-models! Unfortunately, our experience has been that students rarely acquire "maker" skills during their usual college or university courses.

A cheerful, competent Teaching Assistant will be invaluable!

The rocket flights can occupy a pleasant weekend morning. Expected apogee will be about 300m, so a calm day and a big space (at least 500 ft radius) without threatening trees or obstacles will be needed!

Data analysis can be done as homework.

Many students will want to do additional flights and data analysis. This is habit-forming!

Thanks for your interest in "Microcontrollers in Research & Design: Kinematics of Model Rockets".

This repository includes a graph of data collected and plotted by PH131 student James Sinnett, on the flight of his rocket. The blue line, right axis, shows vertical acceleration; the red line, left axis shows altitude. The x axis is in milliseconds. The acceleration events show the motor firing, then the specified delay of about 6 seconds, then high-amplitude shaking caused by the firing of the parachute-ejection charge and the parachute deployment. You can note the few seconds of near-zero-g near apogee. Peak acceleration during motor firing was approximately 8 g, so our 16-g range accelerometer was an appropriate choice.

Rather satisfying is to compare the plot of acceleration during motor firing with the thrust curve of an Estes E-12 motor as measured by the Natl Assoc of Rocketry, in the second attached graphic.

A report from PH131, "Microcontrollers in R & D": Students in this 1-unit "workshop" course build model rockets and equip them with microcontroller-based instrumentation to measure acceleration (in 3 axes), pressure, and temperature (thus altitude) during flight.

The electronics uses an Arduino Feather "Adalogger" from Adafruit, a 3-axis digital accelerometer, and a pressure/temperature sensor. The little system can write 100 data points per second to a micro-SD card (3 axis accel, plus temp, pressure, calculated altitude).

Of course all those functions are available Off The Shelf, but it's more fun if the students put some "skin in the game" by assembling electronics and loading up (and modifying if they want) the Arduino code. It would be possible, but somewhat frustrating, to assemble the electronics on a solderable kludge-board, but I laid out a little custom PCB for them (now on its 3rd rev.). All the supplies for the course, including a rocket kit, cost about $130. The rocket uses an Estes E12-6 motor (12 N average thrust, 6 secs delay between motor cutoff & parachute ejection), so the rockets fly to a satisfying 300m+ apogee.

Any questions, please ask.

Parker Swanson, MSEE; amateur radio KO7Q

parkerwswanson@gmail.com