s4.sonoma.edu

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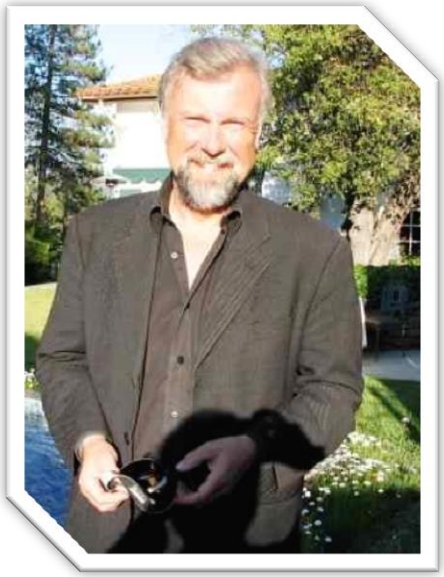
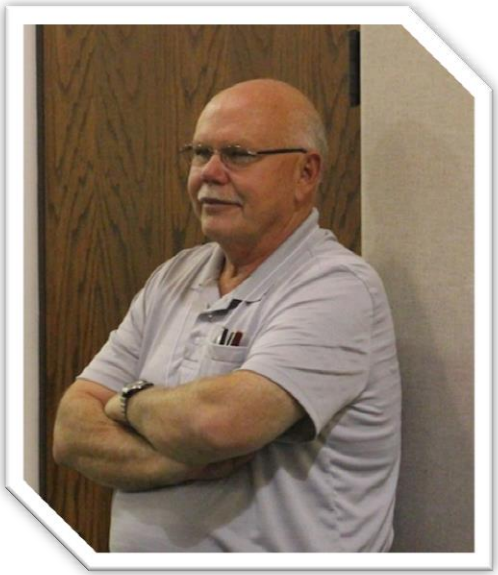
We support several different NASA Space Science missions, and are currently developing an online college curriculum in Cosmology. Our mission is to develop exciting formal and informal educational materials that use high-energy space science as a means to inspire students in grades 5-14 to pursue STEM careers, to train teachers nation-wide in the classroom use of these materials, and to enhance science literacy for the general public.

Collaborators



Ken Biba
AeroPac Education Director

Tony Alcocer
AeroPac President



Steve Kliewer
Endeavor Director

Rockets
&
Balloons

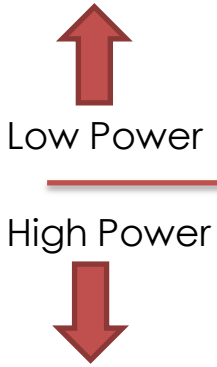
Payload
Electronics

Ground Systems

Education

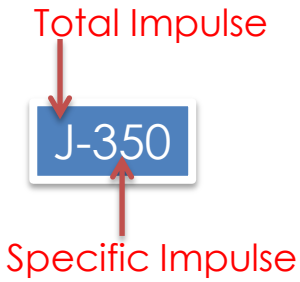
High Powered Rocketry

Motor Classifications



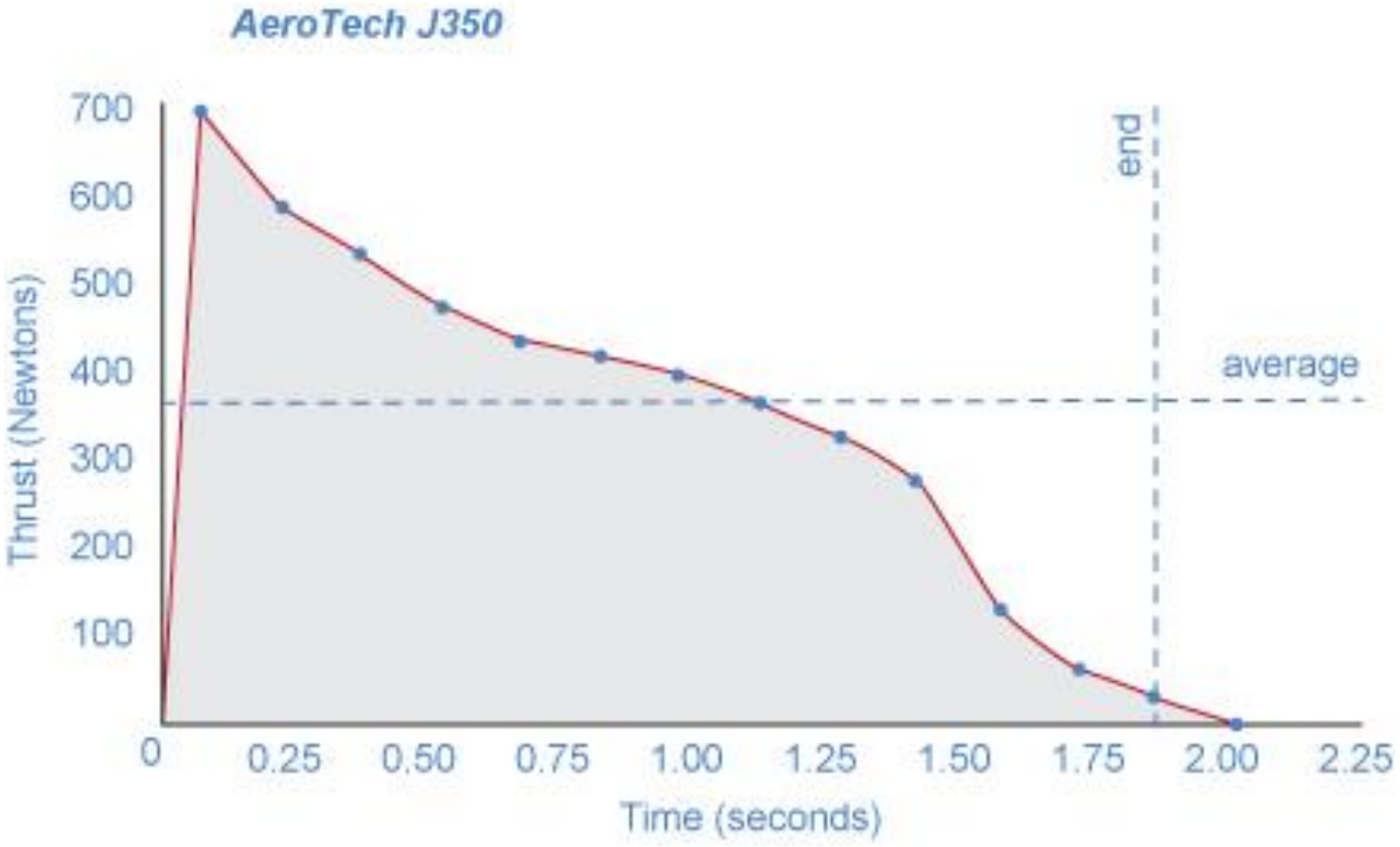
A	1.26-2.5 N·s
B	2.51-5.0 N·s
C	5.01-10.0 N·s
D	10.01-20.0 N·s
E	20.01-40.0 N·s
F	40.01-80.0 N·s
G	80.01-160.0 N·s
H	160.01-320 N·s
I	320.01-640 N·s
J	640.01-1,280 N·s
K	1,280.01-2,560 N·s
L	2,560.01-5,120 N·s
M	5,120.01-10,240 N·s
N	10,240.01-20,480 N·s
O	20,480.01-40,960 N·s

L1 L2 L3



Space Shuttle SRB	5Z	671,088,640.01-1,342,177,280 N·s

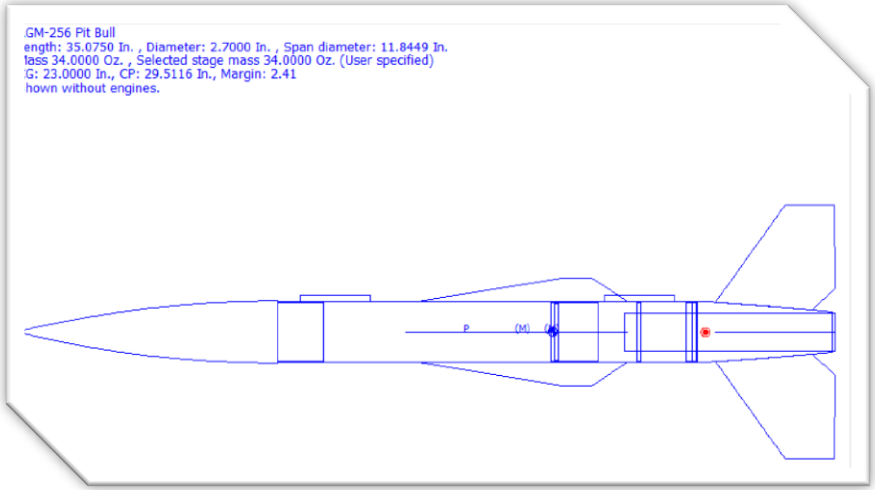
Thrust Curve



Show Motor Casings

Airframe Design

Manufactured Kit



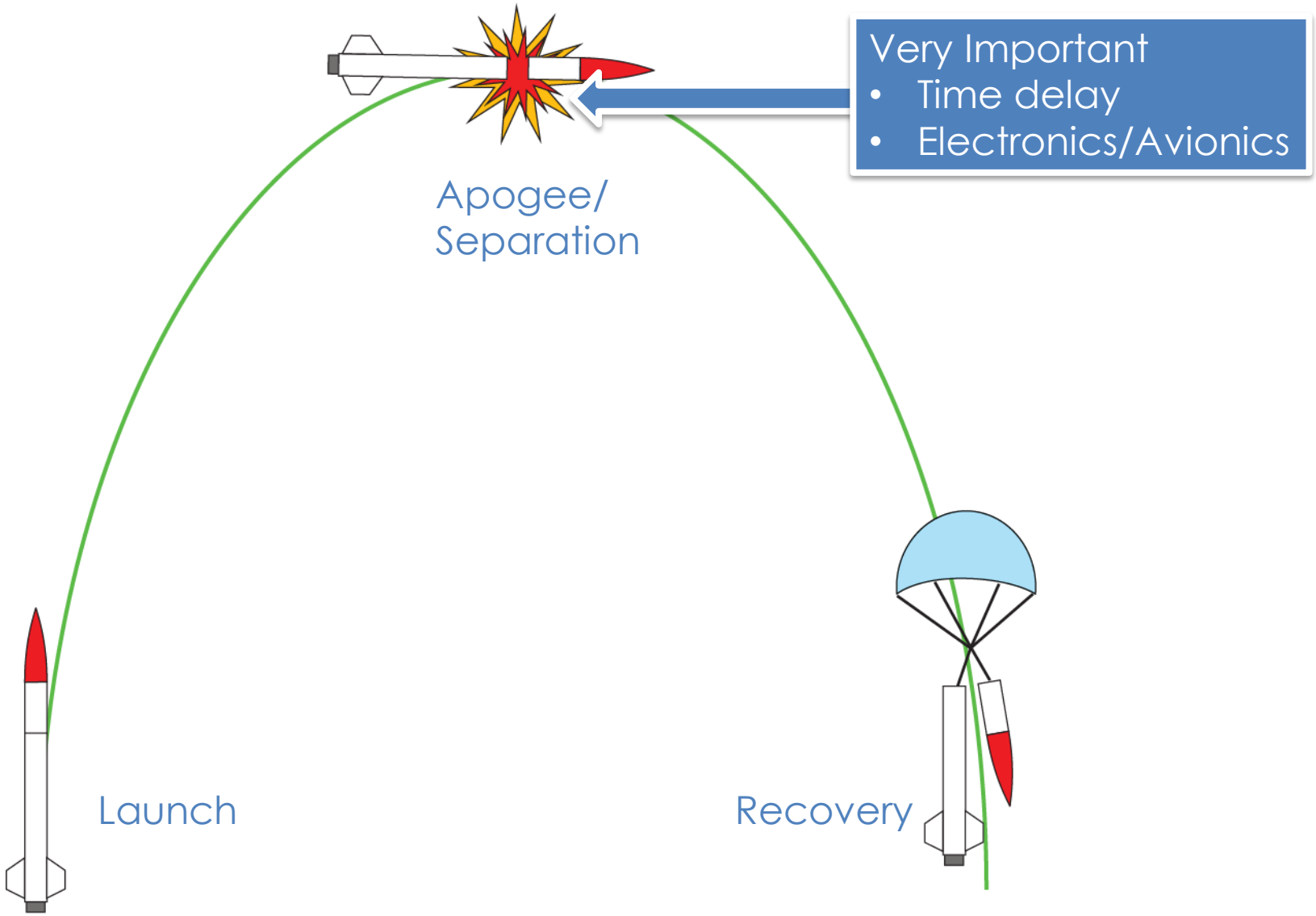
Scratch Built

Materials

- Fiberglass
- Cardboard
- Carbon Fiber
- Aluminum

Show Airframes

Ballistic Profile



Launch Sites

Snow Ranch (10,000 ft)

Launch Sites

Lucerne Lake Bed (15,000 ft)

Launch Sites

Black Rock Desert (200,000 ft)

High Powered Rocketry and YOU

Certification Process:

Level 1 – Build, fly and recover an airframe on an L1 motor

Level 2 – Build, fly and recover an airframe on an L2 motor and pass a written test

Level 3 - Build, fly and recover an airframe on an L3 motor using electronics

Upcoming Launches:

Saturday, October 26th
9:00am Low Power Launch, Moffett

Saturday, November 2nd
9:00am High Power Launch, Snow Ranch

November 9th-10th
RocStock, Lucerne Lake Bed

July 2014
Mudrock – Black Rock Desert

LUNAR http://lunar.org/
AeroPac http://aeropac.org/
ROC http://rocstock.org/

High Altitude Balloons

- Doesn't require certification or complicated FAA clearance
- Less expensive
- Doesn't require advanced equipment for telemetry
- Less constraints on payload size and weight
- Can be flown tethered to 1,000 feet or untethered
- Greater control over altitude
- Much longer time series for data

Balloonfest

Tobin James Cellars, Paso Robles, Ca

Rockets
&
Balloons

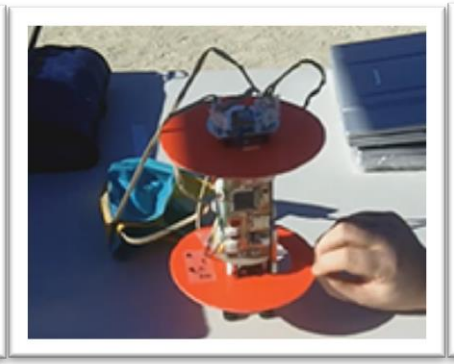
Payload
Electronics

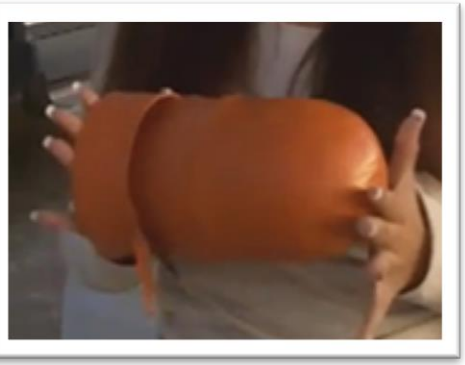
Ground Systems

Education

ARLISS

A Rocket Launch for International Student Satellites

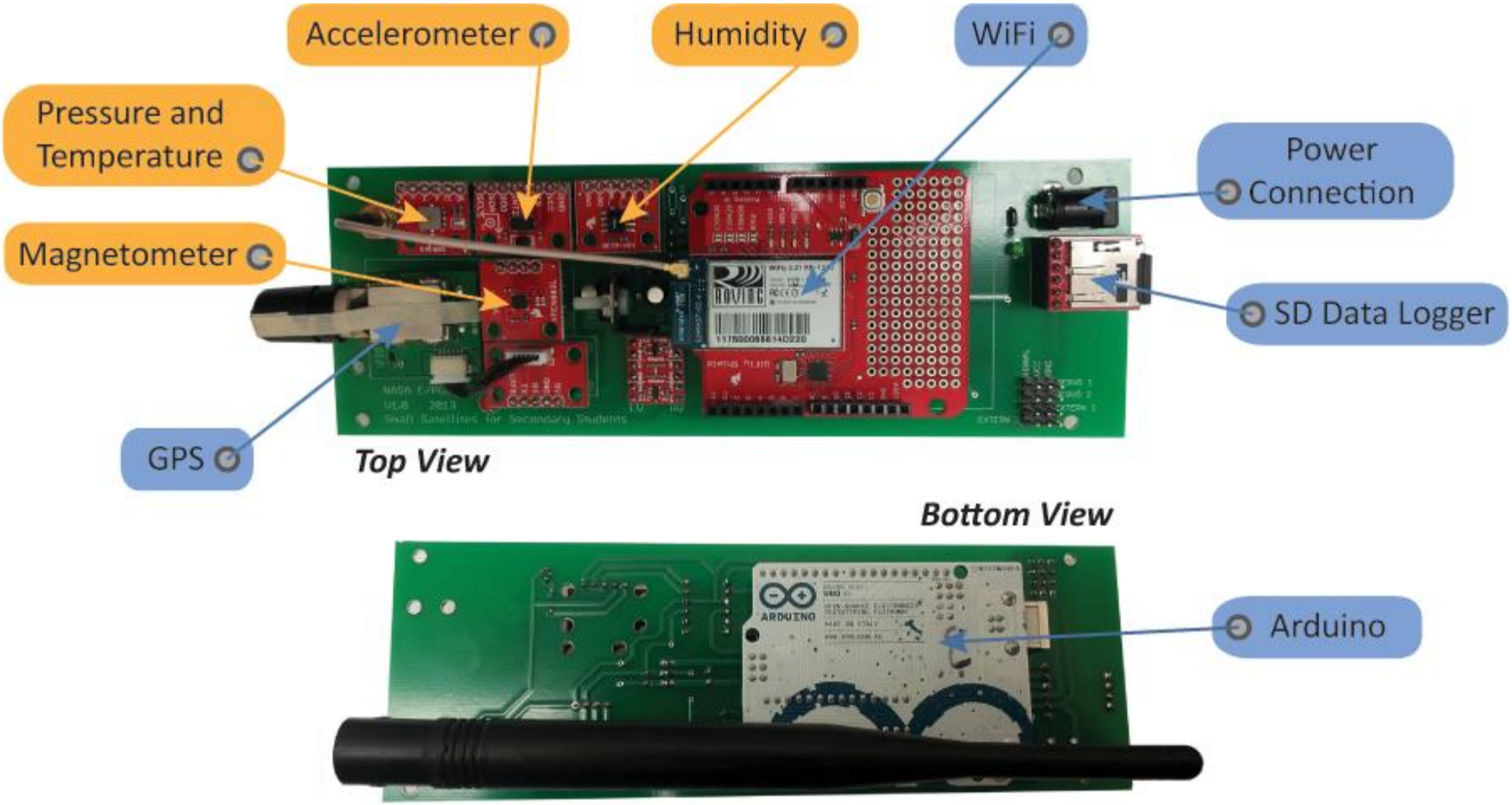





- Derivative of the CanSat concept developed by Prof. Bob Twiggs
- Collaboration between engineering students and amateur rocket flyers
- Various payload designs flown over the years include come-back rovers and scientific instruments
- Black Rock Desert simulates harsh alien environments

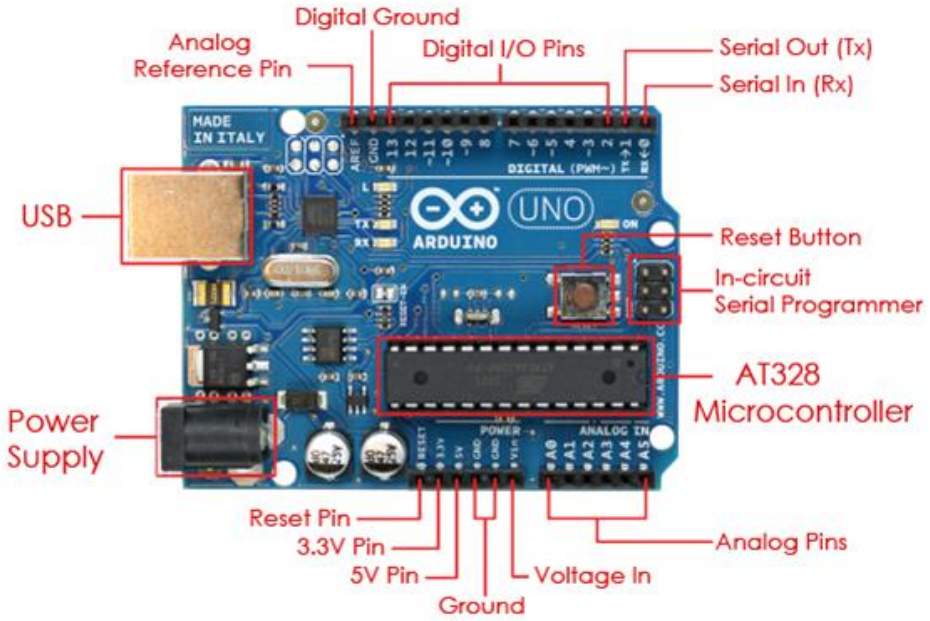
ARLISS

S4 Payload

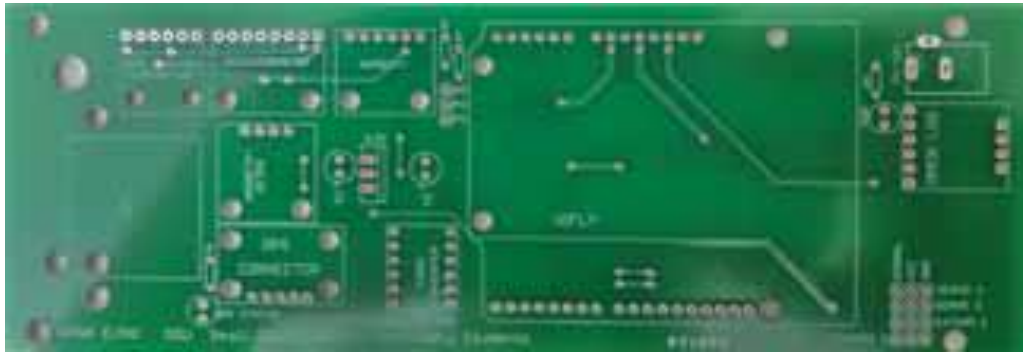

Accelerometer
Humidity
WiFi
Pressure and Temperature
Power Connection
Magnetometer
SD Data Logger
GPS
Top View
Bottom View
Arduino

Arduino

- Open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board.
- Inexpensive (~$30 board)
- Platform agnostic
- Easy to program (C/C++)
- Open source software – Software where the source code is made freely available
- Open source hardware – Hardware where the design specifications are made freely available
- Low Power



Flight Board



- Printed Circuit Board (PCB)
- NOT off the shelf (yet) provided by us
- Physical backbone of the payload
- Facilitates power and communication between payload components
- Requires soldering skill to assemble
- Does not require soldering skill to attach components once assembled
- Manufacturing partner for assembly?

Major Subcomponents

Logic Level Converter – Steps 5V source from Arduino down to 3.3V source for payload components

Voltage Regulator – protects payload components from over-voltage. Dissipates extra energy as heat.

GPS

- Determine Latitude, Longitude, Altitude and Time for payload data points
- Same type of GPS as cell phones and Navigation
- Requires satellite signal to lock
- Lock can take up to two minutes

```
$GPGGA,210044.00,3820.39934,N,12240.61207,W,1,06,1.78,55.0,M,-29.2,M,,*5B
$GPGGA,210045.00,3820.39922,N,12240.61234,W,1,06,1.78,55.9,M,-29.2,M,,*54
$GPGGA,210046.00,3820.39839,N,12240.61260,W,1,06,1.78,56.4,M,-29.2,M,,*53
$GPGGA,210047.00,3820.39784,N,12240.61293,W,1,06,1.78,56.4,M,-29.2,M,,*57
$GPGGA,210048.00,3820.39738,N,12240.61346,W,1,06,1.78,56.4,M,-29.2,M,,*56
$GPGGA,210049.00,3820.39682,N,12240.61368,W,1,06,1.78,56.9,M,-29.2,M,,*56
$GPGGA,210050.00,3820.39660,N,12240.61340,W,1,06,1.78,57.1,M,-29.2,M,,*51
$GPGGA,210051.00,3820.39646,N,12240.61307,W,1,05,5.23,56.9,M,-29.2,M,,*57
```

WiFly

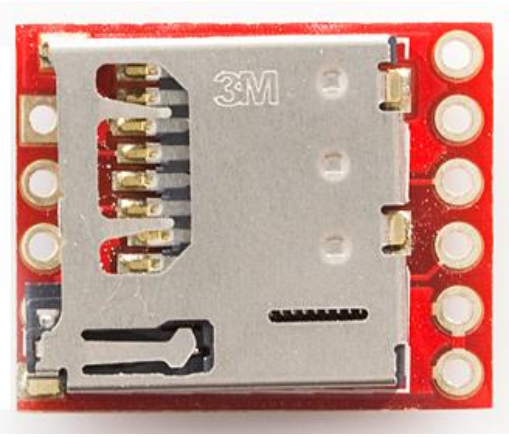
- Same type of Wi-Fi as computers and cell phones (802.11 b/g)
- Example of an Arduino Shield (shares pins with Arduino)
- Prototyping holes (unused)
- Maintain real-time telemetry throughout the flight
- Must be configured with network information

- Duck antenna improves signal
- Orientation not particularly important
- Not needed for classroom testing

Open Log (SD)

- Collect and store data without need for wireless networking
- Maintain data collection if and when wireless signal lost
- Same type of micro SD as cell phones
- Writes to a plain text file
- SD card reader and micro to standard adapter needed to recover data

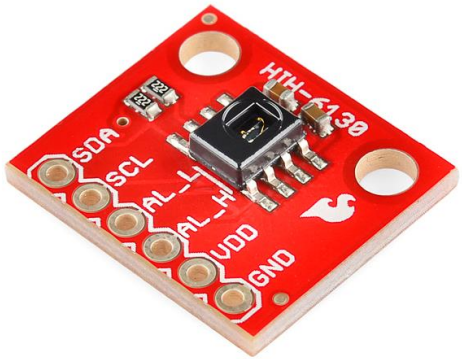
```
<sensor>PayloadName,data,1
<sensor>PayloadName,data,1
<sensor>PayloadName,data,1
<sensor>PayloadName,data,1
<sensor>PayloadName,data,1
<sensor>PayloadName,data,1
<sensor>PayloadName,data,1
<sensor>PayloadName,data,1
<sensor>PayloadName,data,1
```



Sensors

Accelerometer

Magnetometer

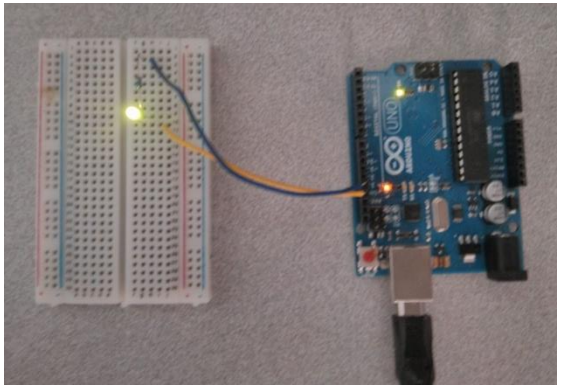


Humidity and Temperature

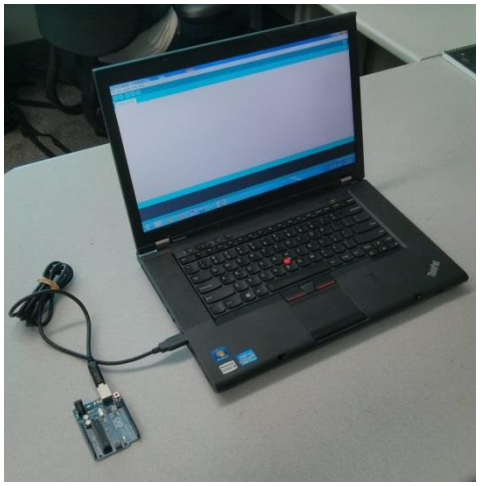
Barometric Pressure
And Temperature

Programming Arduino

Step 1: Configure Hardware

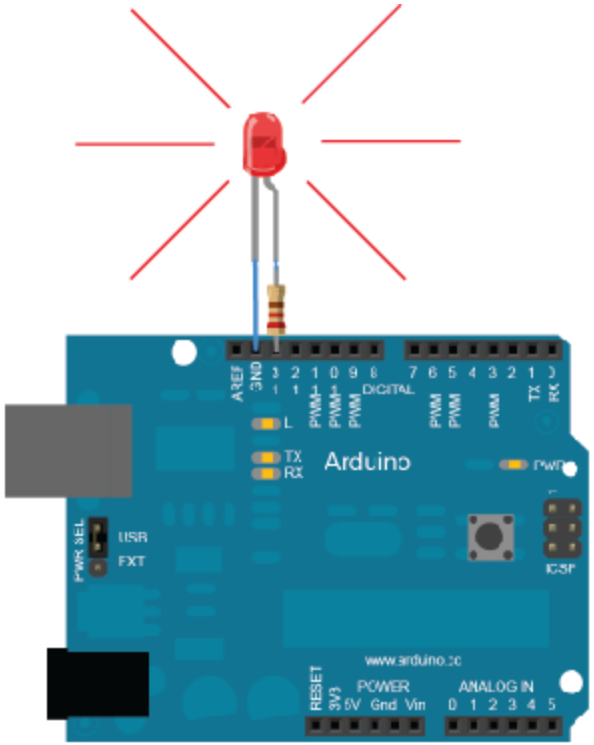


Step 3: Load Sketch to Device



Step 2: Write Code (Sketch)

Programming Arduino



Step 4:
Rejoice!

Anatomy of an Arduino Program

- Sketches always have at least two functions, setup and loop
- Setup gets run once and only once right after the device is started or restarted
- Loop is run continuously thereafter for as long as the device is active.

Open Source Hardware and YOU

http://arduino.cc/en/

http://www.sparkfun.com

http://www.adafruit.com/

http://www.makershed.com/Default.asp

Rockets
&
Balloons

Payload
Electronics

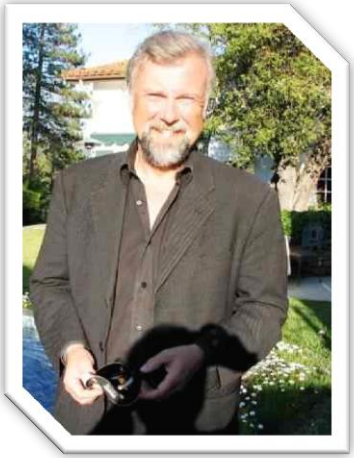
Ground Systems

Education

The Virtual Classroom

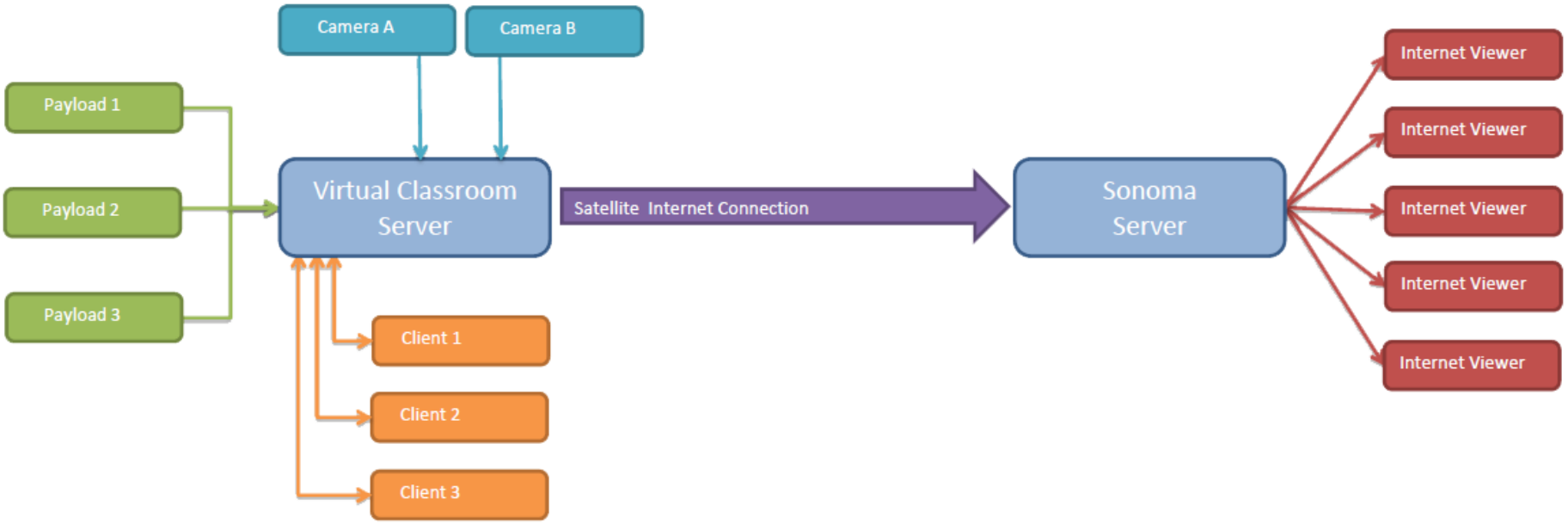
- Wi-Fi antennas and routers for supporting live telemetry from payloads
- Facilitate communication between payloads and local observers
- Satellite Internet for sending live telemetry and video to remote observers
- Administered by AeroPac and partially funded by our project

- Designed and built by AeroPac Education Director Ken Biba



Show Handheld Antenna

Systems Overview (With VC)



Server Side Software

```java
import java.awt.Image;

@SuppressWarnings("serial")
public class ServerFrame extends JFrame {

    public ServerFrame()
    {
        java.net.URL url = ClassLoader.getSystemResource("Graphics/S4.png");
        Toolkit kit = Toolkit.getDefaultToolkit();
        Image img = kit.createImage(url);
        this.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        this.setIconImage(img);
        this.setTitle("Server");

        JLabel lblCurrentPayloadConnections = new JLabel("Active Payload Connections");
        lblCurrentPayloadConnections.setFont(new Font("Tahoma", Font.PLAIN, 30));
        getContentPane().add(lblCurrentPayloadConnections, BorderLayout.NORTH);

        Connection connection1 = new Connection();
        connection1.ipAddress = "192.168.1.100";
        connection1.payloadName = "SSU-01";

        ConnectionsList connections = ConnectionsList.getInstance();
        getContentPane().add(connections);
```

Java based server software:

- Listens for data packets from payload from low level socket
- Processes and saves raw data to database
- Facilitates communication with local clients viewing live data
- Synchronizes data with remote server (wip)

Server Side Data Storage

+ Options

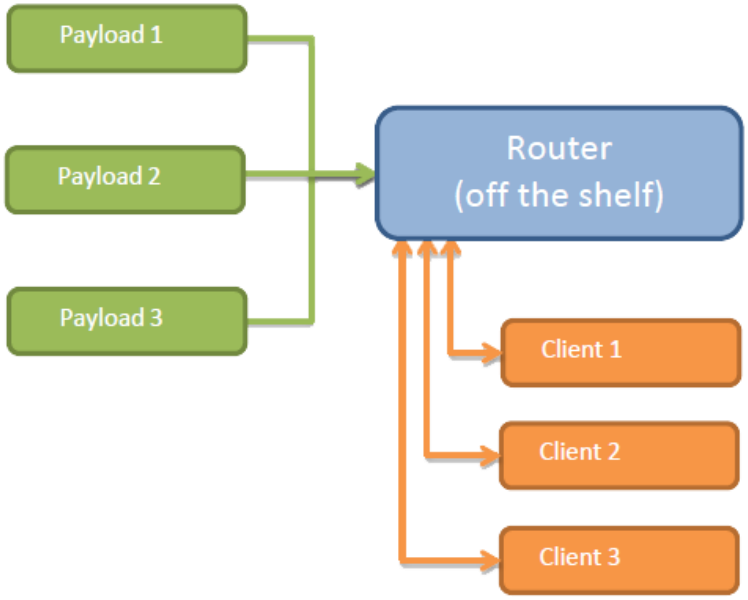
	id	Payload	TimeStamp	GPS_Lon	GPS_Lat	GPS_Alt	GPS_TimeStamp	GPS_Fix	GPS_Raw	Signal
Edit Copy Delete	1	SSU-02	2013-07-01 12:24:45	0	0	0			SSU-02,$È(è	0
Edit Copy Delete	2	SSU-02	2013-07-01 12:24:46	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	3	SSU-02	2013-07-01 12:24:47	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	4	SSU-02	2013-07-01 12:24:48	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	5	SSU-02	2013-07-01 12:24:49	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	6	SSU-02	2013-07-01 12:24:50	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	7	SSU-02	2013-07-01 12:24:51	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	8	SSU-02	2013-07-01 12:24:52	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	9	SSU-02	2013-07-01 12:24:53	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	10	SSU-02	2013-07-01 12:24:54	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	11	SSU-02	2013-07-01 12:24:55	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	12	SSU-02	2013-07-01 12:24:56	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	13	SSU-02	2013-07-01 12:24:57	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	14	SSU-02	2013-07-01 12:24:58	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	15	SSU-02	2013-07-01 12:24:59	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	16	SSU-02	2013-07-01 12:25:00	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	17	SSU-02	2013-07-01 12:25:01	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0
Edit Copy Delete	18	SSU-02	2013-07-01 12:25:02	0	0	0		0	SSU-02,$GPGGA,,,,,,0,00,99.99,,,,,,*48	0

+ Options

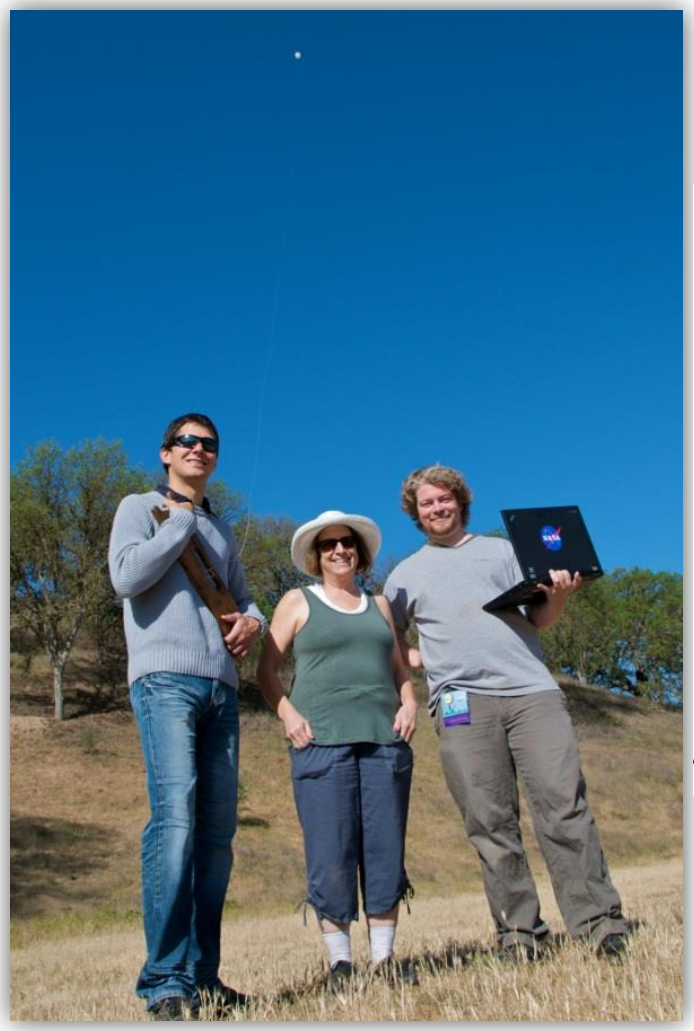
	ID	PayloadDataID	SensorKey	SensorValue
Edit Copy Delete	1	172		Baro
Edit Copy Delete	2	172	100196	Temp
Edit Copy Delete	3	172	26.70	Hum
Edit Copy Delete	4	172	50.22	Temp2
Edit Copy Delete	5	172	26.46	AccelX
Edit Copy Delete	6	172	0.0784	AccelY
Edit Copy Delete	7	172	-0.3843	AccelZ
Edit Copy Delete	8	172	0.8549	MagX
Edit Copy Delete	9	172	346	MagY
Edit Copy Delete	10	172	-169	MagZ
Edit Copy Delete	11	173	Baro	100194
Edit Copy Delete	12	173	Temp	26.70
Edit Copy Delete	13	173	Hum	50.14
Edit Copy Delete	14	173	Temp2	26.47
Edit Copy Delete	15	173	AccelX	0.0745
Edit Copy Delete	16	173	AccelY	-0.3882
Edit Copy Delete	17	173	AccelZ	0.8667
Edit Copy Delete	18	173	MagX	345

- Parity with on-board data storage
- Aggregation of data from multiple flights and payloads
- Real-time sharing with remote observers

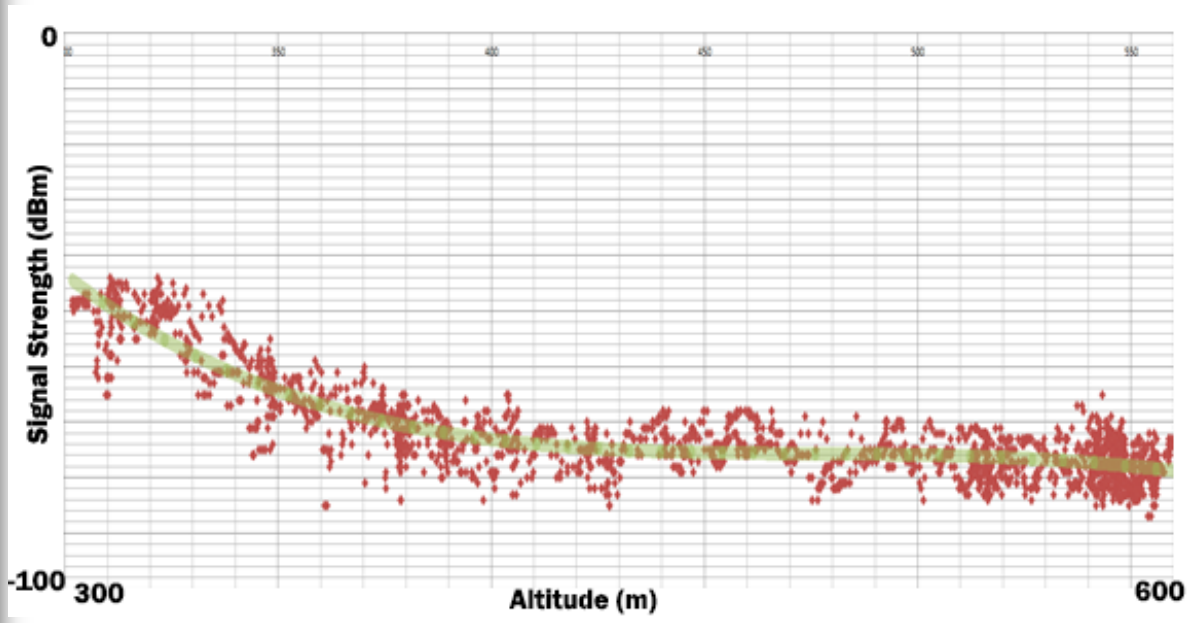
Systems Overview (Without VC)



Signal Strength vs. Altitude (off the shelf router)



Balloonfest 2013



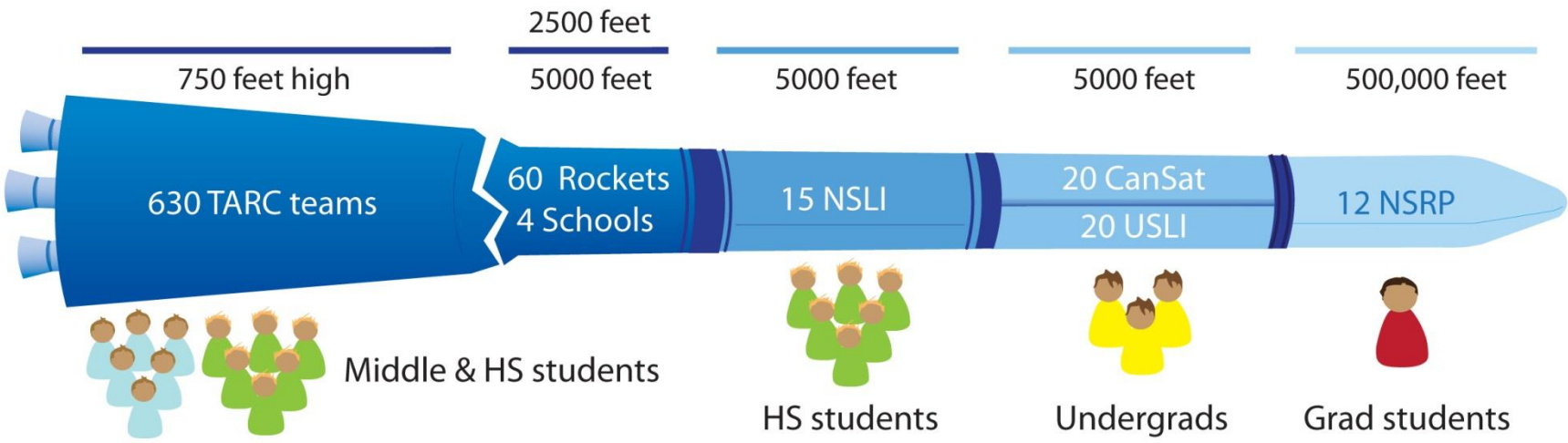
Rockets
&
Balloons

Payload
Electronics

Ground Systems

Education

Original Impetus for S4 Project

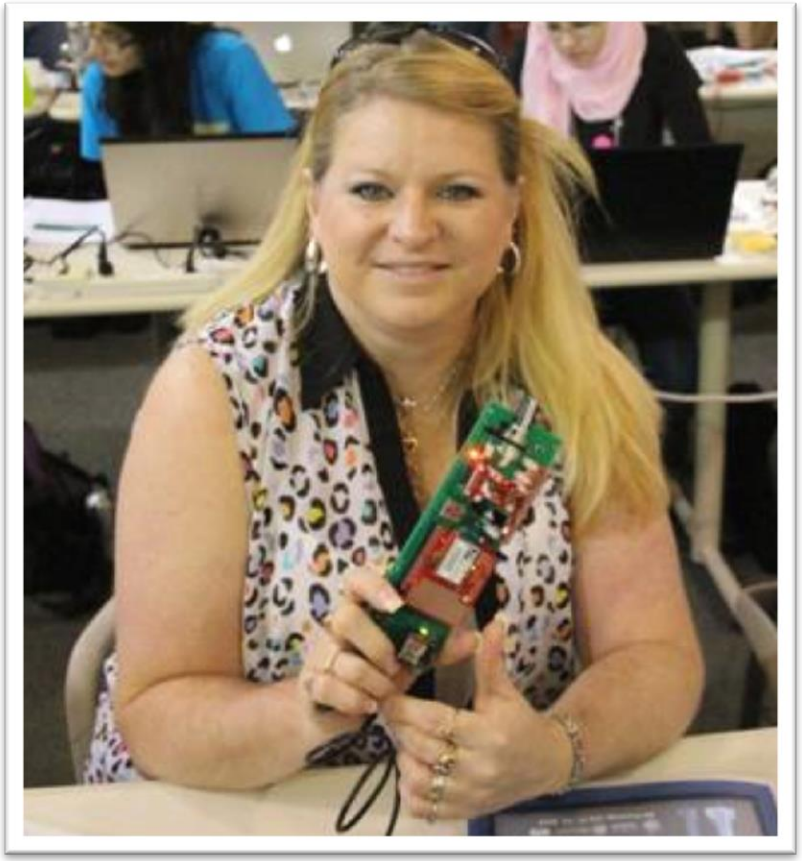


Addressing disconnect in pipeline for rocket based education

S4 Teacher Training – July 2013 Aero Institute, Palmdale Ca

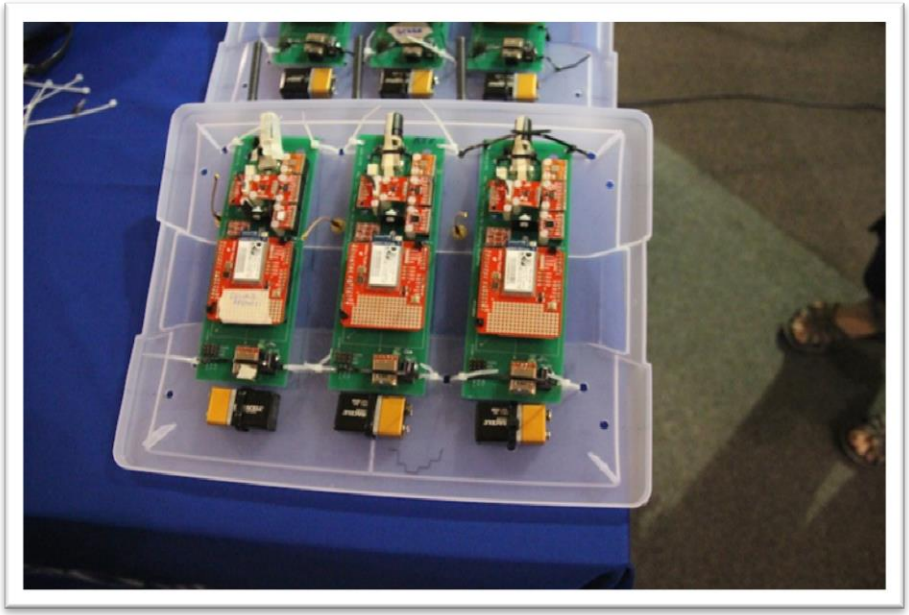
- 18 educators from a diverse set of schools and other teaching organizations
- Week long course
- Built, tested and flew a prototype payload
- Helped us refine our educational materials and the payload itself
- Included talks from our partners and mentors

The first two days were spent learning the basics of electronics and soldering which were then put to use in constructing the flight board.



Beth Hill, Lawrence Jones Middle School

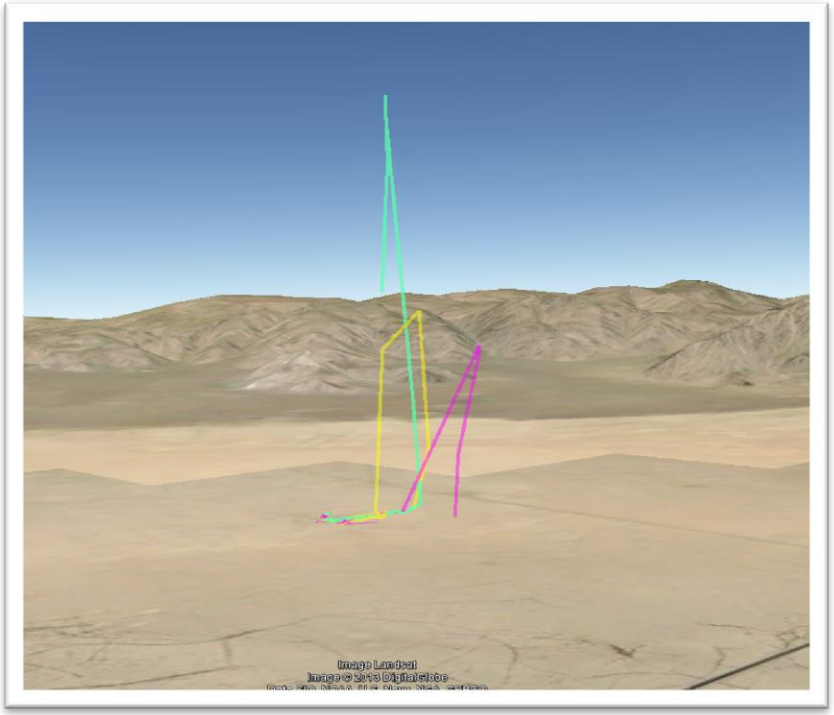
Once the flight board was finished the educators were introduced to programming in Arduino's Processing language. They were then able to upload the programs to the payload after which they installed the sensors onto the flight board and finalized the payload.



On Thursday the educators took their payloads out to a local high school's fields. They readied their payloads for tethered helium balloon flights, three-to-a-gondola, as dark storm clouds were approaching.

Once a helium balloon was filled and tethered the winds really kicked up and it began to rain. With the weather too chaotic to fly helium balloons, the educators took their payloads around the high school on foot in order to get data.

Donald Repucci, Morrow Bay



On Saturday the training was shifted to the Lucerne dry lake bed about 70 miles east of Palmdale. There, the payloads were flown on 3 and 4 inch diameter rockets to altitudes as high as 1828.1m (6000 feet) with on-site routers taking live data of each launch.

Raw Data


```
<gps>Jadkins,$GPGGA,164839.00,3429.81825,N,11657.47729,W,1,07,1.87,864.4,M,-30.8,M,,*6F</gps>
<sensor>Jadkins,,Baro,91705,Temp,35.00,Hum,16.70,Temp2,34.52,AcelX,0.8549,AcelY,0.6118,AcelZ,0.1098,MagX,-189,MagY,-633,MagZ,-77</sensor>
<gps>Jadkins,$GPGGA,164840.00,3429.81803,N,11657.47803,W,1,07,1.87,865.9,M,-30.8,M,,*6E</gps>
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<gps>Jadkins,$GPGGA,164841.00,3429.81739,N,11657.47909,W,1,07,1.87,868.8,M,-30.8,M,,*6E</gps>
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<gps>Jadkins,$GPGGA,164842.00,3429.81715,N,11657.47944,W,1,07,1.87,869.9,M,-30.8,M,,*6A</gps>
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<gps>Jadkins,$GPGGA,164843.00,3429.81713,N,11657.47962,W,1,07,1.87,870.0,M,-30.8,M,,*68</gps>
<sensor>Jadkins,Baro,91715,Temp,35.00,Hum,22.06,Temp2,34.00,AcelX,0.7490,AcelY,0.3255,AcelZ,0.5725,MagX,-245,MagY,-538,MagZ,-229</sensor>
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<gps>Jadkins,$GPGGA,164847.00,3429.81694,N,11657.48024,W,1,07,1.87,870.9,M,-30.8,M,,*6F</gps>
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<gps>Jadkins,$GPGGA,164849.00,3429.81691,N,11657.48090,W,1,07,1.87,871.6,M,-30.8,M,,*65</gps>
<sensor>Jadkins,Baro,91712,Temp,35.00,Hum,22.19,Temp2,34.10,AcelX,0.7529,AcelY,0.2078,AcelZ,0.5529,MagX,-275,MagY,-520,MagZ,-228</sensor>
<gps>Jadkins,$GPGGA,164850.00,3429.81682,N,11657.48118,W,1,07,1.87,872.0,M,-30.8,M,,*6B</gps>
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<gps>Jadkins,$GPGGA,164851.00,3429.81685,N,11657.48148,W,1,07,1.87,872.7,M,-30.8,M,,*6F</gps>
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<gps>Jadkins,$GPGGA,164852.00,3429.81682,N,11657.48171,W,1,07,1.87,873.1,M,-30.8,M,,*66</gps>
<sensor>Jadkins,Baro,91709,Temp,35.00,Hum,20.21,Temp2,34.07,AcelX,0.7529,AcelY,0.2471,AcelZ,0.5490,MagX,-271,MagY,-525,MagZ,-224</sensor>
<gps>Jadkins,$GPGGA,164853.00,3429.81671,N,11657.48195,W,1,07,1.87,873.6,M,-30.8,M,,*66</gps>
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<gps>Jadkins,$GPGGA,164854.00,3429.81655,N,11657.48204,W,1,07,1.87,874.1,M,-30.8,M,,*6C</gps>
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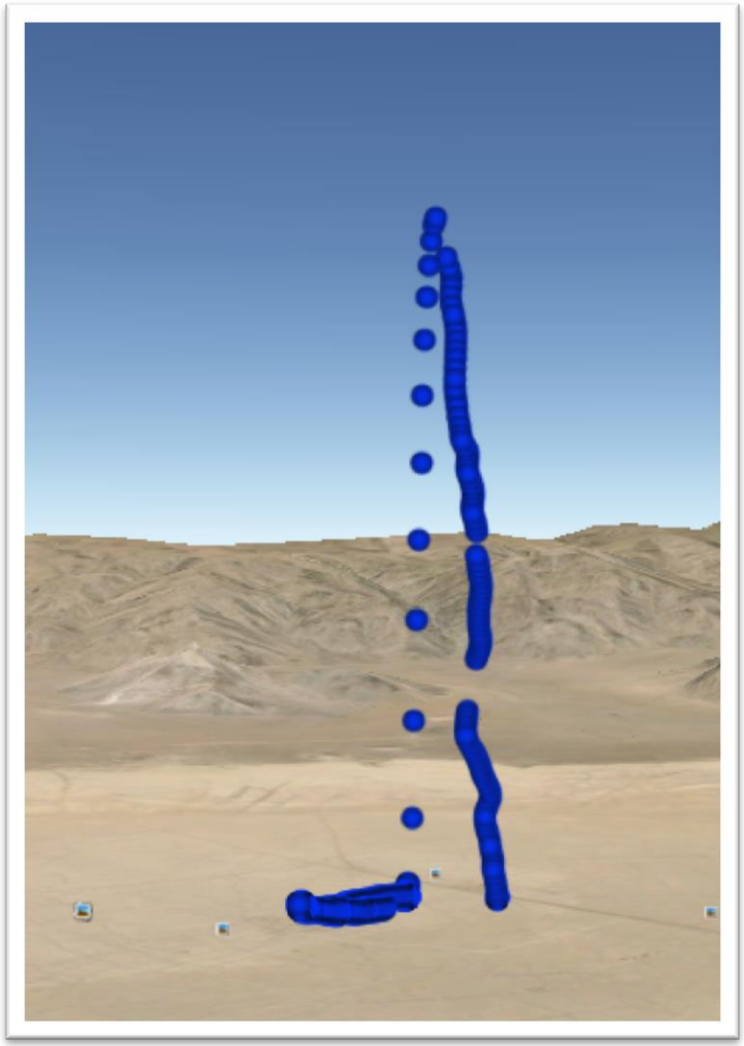
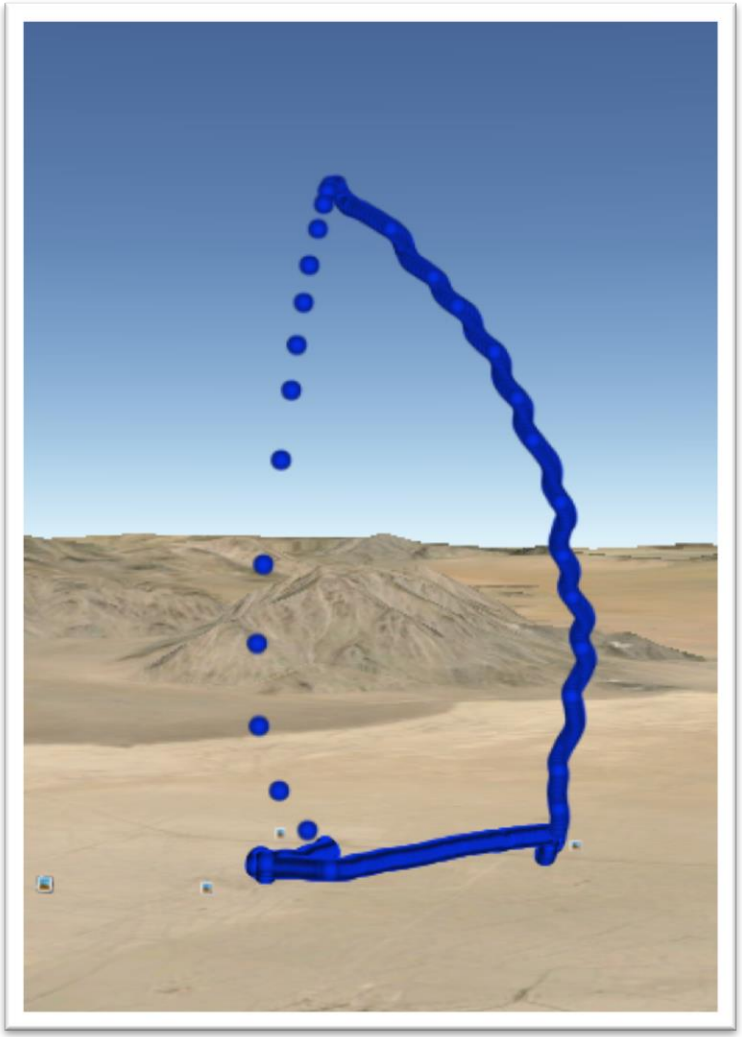
Time	Lon	Lat	Alt	Baro	Temp	Hum	Temp2	AcelX	AcelY	AcelZ	MagX	MagY	MagZ
60519	-116.958	34.49697	864.4	91705	35	16.7	34.52	0.8549	0.6118	0.1098	-189	-633	-77
60520	-116.958	34.49697	865.9	91702	34.9	25.08	33.99	0.7804	0.4667	0.4039	-236	-595	-128
60521	-116.958	34.49696	868.8	91714	35	24.42	33.99	0.4941	0.1804	0.7882	-202	-485	-323
60522	-116.958	34.49695	869.9	91707	35	23.06	33.99	0.6431	0.2392	0.6745	-243	-513	-265
60523	-116.958	34.49695	870	91715	35	22.06	34	0.749	0.3255	0.5725	-245	-538	-229
60524	-116.958	34.49695	870.4	91713	35	22.13	34.02	0.7216	0.2314	0.6235	-278	-522	-215
60525	-116.958	34.49695	870.6	91708	35	21.52	34.03	0.8157	0.2588	0.5216	-306	-527	-180
60526	-116.958	34.49695	870.8	91708	35	21.55	34.04	0.7569	0.2392	0.5608	-273	-522	-227
60527	-116.958	34.49695	870.9	91706	35	21.28	34.04	0.7569	0.251	0.5765	-276	-519	-223
60528	-116.958	34.49695	871.2	91708	35	21.67	34.07	0.7529	0.2196	0.5725	-279	-521	-222
60529	-116.958	34.49695	871.6	91712	35	22.19	34.1	0.7529	0.2078	0.5529	-275	-520	-228
60530	-116.958	34.49695	872	91705	35	21.52	34.1	0.7569	0.2353	0.5608	-274	-521	-228
60531	-116.958	34.49695	872.7	91696	35	20.73	34.07	0.749	0.2353	0.5725	-272	-520	-228
60532	-116.958	34.49695	873.1	91709	35	20.21	34.07	0.7529	0.2471	0.549	-271	-525	-224
60533	-116.958	34.49695	873.6	91709	35	19.73	34.07	0.8078	0.2	0.3725	-264	-549	-191
60534	-116.958	34.49694	874.1	91698	35	19.35	34.07	0.8078	0.2	0.3725	-321	-337	-338

Flight Paths





Everything thing went *perfectly…*

Nose cone from
“lawn dart” rocket

…right up until the last flight

What's Next?

- Over the next year, students of the teachers from our training will be building and flying payloads of their own (around 55 teams total)
- Working with suppliers and manufacturers to try and make the parts needed to build the S4 payload more readily and easily available
- Address some supply chain concerns
- Publish revisions to our educational materials
- Publish remainder of our source code through GitHub

For more information visit:

s4.sonoma.edu

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