Table of Contents

Experiment I: Roll and Vibration 1
- **Research Question** 1
- **Background Information** 1
- **Experimental Design** 1
  - Variables to consider and measurement tools 2
- **Data** 3
- **Materials** 6
- **Procedure** 6
- **Results** 9
- **Conclusion** 9
- **Lessons Learned** 10

Appendix 1 – PBasic Program 11
Appendix 2 – Pre and Post Test Graphs 14
Appendix 3 – RDAS Tiny Flight Computer Results 15
Appendix 4 – On-Board Flight Videos 16

Experiment I: Roll and Vibration

Research Question:

What can be learned from measuring and analyzing roll and vibration during a rocket's flight?

Background Information:

Isaac Newton's first law says that an object at rest tends to stay at rest, and an object in **motion** tends to stay in motion, with the same direction and speed. Motion (or lack of motion) cannot change without an unbalanced force acting upon it. It is quite apparent that roll and vibration are unbalanced forces that may have significant impact on a rocket's flight characteristics.

Experimental Design:

We want to measure roll and vibration with two stock rocket kits and build them per instructions with the only modification being an upgrade to the recovery system so that it will withstand relatively high-speed deployment incase of a miss-timed deployment event.

We are going to monitor altitude, vibration and roll of two same-kit rockets built by two different students. If, after data analysis, there are significant differences, we will then examine the rockets to see if we can determine what caused the differences. Each rocket is a LOC Hi-Tech H45. The specifications are:

Length: 49.75 inches
Diameter: 2.625 inches
Weight: 20 ounces
Motors: H73J-10

Mariya Williams and Kyle Koos are building the rockets. Neither student has built a rocket before, nor have they any experience in building anything beyond plastic snap together kits. Construction is carefully monitored to ensure strength and durability.

Data measuring and logging will be done by the Basic Stamp microcontroller with a TSL230R Light-to-Frequency Converter from Texas Advanced Optoelectronic Solutions and a Piezo Film Sensor from Measurement Specialties Inc. We are using a memory stick data logger that will host a USB drive for holding the collected data. Everything will be mounted on a printed circuit board and securely fastened to the same board as the altimeter and video camera. This electronics board will be in the payload bays of the rockets. The TSL230R will turn on the data logging by having its viewing portal uncovered upon takeoff. The data logging will be terminated after eleven seconds via program control.

Here are the possible outcomes where R1= Mariya's, R2 = Kyle's, V= vibration, R=roll:

Compared Individually	
Roll	**Vibration**
R1R = R2R	R1V = R2V
R1R > R2R	R1V > R2V
R1R < R2R	R1V < R2V
data incomplete	data incomplete

We will consider each of the two forces separately and together

R1R = R2R and R1V = R2V
R1R = R2R and R1V > R2V
R1R = R2R and R1V < R2V
R1R > R2R and R1V = R2V
R1R < R2R and R1V = R2V
R1R > R2R and R1V > R2V
R1R > R2R and R1V < R2V
R1R < R2R and R2V > R2V
R1R < R2R and R1V < R2V

1. what are the forces data; maximum, mean, median, average?
2. what are the differences?
3. are the difference statistically significant?
4. what are the possible explanations for the differences

and if there are significant differences, applying what we've concluded to modifying our rocket construction techniques. We hope to continue this experiment afterwards to verify construction modifications have changed the data.

Variables to consider and measurement tools:

Since there will be two separate launches, this data needs to be logged:

1. Wind direction – portable weather station
2. Wind speed – portable weather station
3. Temperature – portable weather station
4. Barometric pressure – portable weather station

And for each rocket:

1. Weight - scale
2. Quality of finish - subjective

3. Straightness of fins – carpenter's level/subjective
4. Fin finish and shape - subjective
5. Straightness of launch lugs – carpenter's level/subjective
6. Length of flight – R-DAS Tiny flight computer
7. Altitude – R-DAS Tiny flight computer
8. Acceleration – R-DAS Tiny flight computer
9. Velocity – R-DAS Tiny flight computer
10. Deployment time – R-DAS Tiny flight computer
11. Deployment altitude – R-DAS Tiny flight computer
12. Motor variation - manufacturer's data
13. Roll - student built sensor
14. Vibration - student built sensor

Data:
Table 1 is the ambient conditions for the two flights.

May 1, 2010	Kyle	Mariya
Time	9:15	10:20
Wind Direction	Westerly	Westerly
Wind Speed	3-10 kts	8-10 kts
Temperature	71	72
Barometric Pressure	29.92	29.92

Table 1

Table 2 is the attribute comparisons between Mariya's and Kyle's rockets.

Attribute	How Measured	Mariya	Kyle
Weight	scale	32 oz	32.5 oz
Quality of finish	subjective	average	slightly below average
Straightness of fins	carpenter's level/subjective	average	average
Fin finish and shape	subjective	average	slightly below average
Straightness of rail buttons	carpenter's level/subjective	excellent	excellent
Length of flight	R-DAS Tiny Flight Computer	11 sec	65 sec
Altitude	R-DAS Tiny Flight Computer	1253'	1240'
Acceleration	R-DAS Tiny Flight Computer	6.0 g	5.9 g
Velocity	R-DAS Tiny Flight Computer	318 fps	305 fps
Deployment time	R-DAS Tiny Flight Computer	11 sec	10 sec
Deployment altitude	R-DAS Tiny Flight Computer	1252'	1239'
Motor variation	manufacturer's data	Not available	Not available

Table 2

Tables 3 is Mariya's numerical roll data and Chart 1 is a graphical representation of that data.

Mariya's Roll Data							
Seconds	Light	Seconds	Light	Seconds	Light	Seconds	Light
0.3	83	4.2	216	8.1	220	12.0	330
0.6	83	4.5	220	8.4	217	12.3	528
0.9	89	4.8	222	8.7	214	12.6	590
1.2	95	5.1	224	9.0	208	12.9	555
1.5	105	5.4	227	9.3	178	13.2	221
1.8	113	5.7	229	9.6	156	13.5	413
2.1	120	6.0	230	9.9	149	13.8	501
2.4	127	6.3	229	10.2	145	14.1	290
2.7	134	6.6	228	10.5	511	14.4	258
3.0	141	6.9	226	10.8	395	14.7	550
3.3	151	7.2	224	11.1	255	15.0	512
3.6	183	7.5	223	11.4	475		
3.9	210	7.8	221	11.7	319		

Table 3

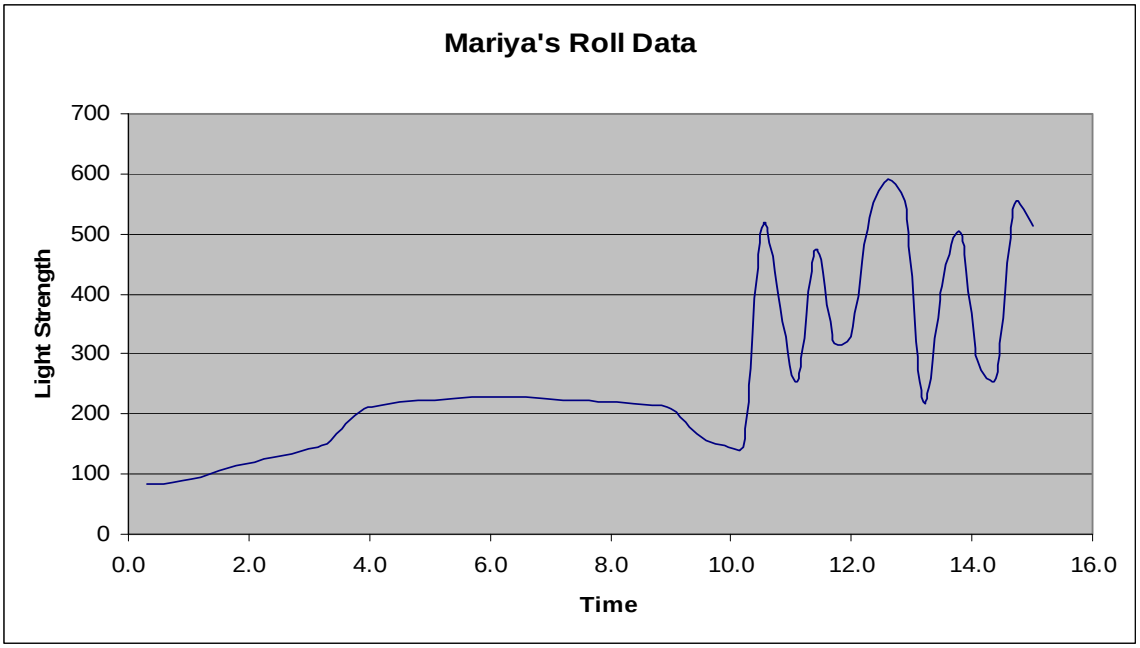
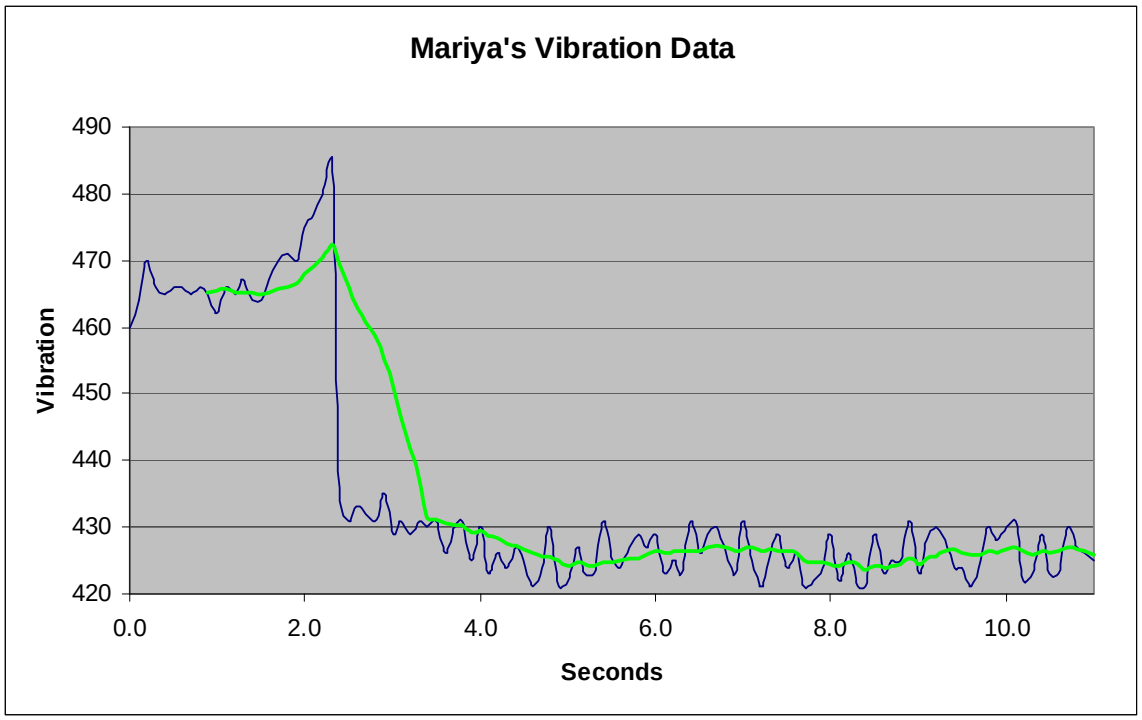


Chart 1

Table 4 is Mariya's numerical vibration data and Chart 2 is a graphical representation of that data.

Mariya's Vibration Data							
Seconds	Vibration	Seconds	Vibration	Seconds	Vibration	Seconds	Vibration
0.0	460	3.0	429	6.0	429	9.0	423
0.1	464	3.1	431	6.1	423	9.1	428
0.2	470	3.2	429	6.2	425	9.2	430
0.3	466	3.3	431	6.3	423	9.3	428
0.4	465	3.4	430	6.4	431	9.4	424
0.5	466	3.5	431	6.5	426	9.5	424
0.6	466	3.6	426	6.6	429	9.6	421
0.7	465	3.7	430	6.7	430	9.7	425
0.8	466	3.8	431	6.8	426	9.8	430
0.9	465	3.9	425	6.9	423	9.9	428
1.0	462	4.0	430	7.0	431	10.0	430
1.1	466	4.1	423	7.1	425	10.1	431
1.2	465	4.2	426	7.2	421	10.2	422
1.3	467	4.3	424	7.3	425	10.3	423
1.4	464	4.4	427	7.4	429	10.4	429
1.5	464	4.5	425	7.5	424	10.5	423
1.6	467	4.6	421	7.6	426	10.6	423
1.7	470	4.7	424	7.7	421	10.7	430
1.8	471	4.8	430	7.8	422	10.8	427
1.9	470	4.9	421	7.9	424	10.9	426
2.0	475	5.0	422	8.0	429	11.0	425
2.1	477	5.1	427	8.1	422		
2.2	480	5.2	423	8.2	426		
2.3	485	5.3	423	8.3	421		
2.4	434	5.4	431	8.4	421		
2.5	431	5.5	425	8.5	429		
2.6	433	5.6	424	8.6	423		
2.7	432	5.7	427	8.7	425		
2.8	431	5.8	429	8.8	425		
2.9	435	5.9	427	8.9	431		

Table 4



Kyle has no data recorded for either vibration or roll data/

Kyle's Vibration Data – No Data	
Seconds	**Vibration**

Kyle's Roll Data							
Seconds	**Light**	**Seconds**	**Light**	**Seconds**	**Light**	**Seconds**	**Light**
0.3		4.2		8.1		12.0	

Materials:
2 LOC Hi Tech H45 rocket kits

Length :	49.75"
Diameter :	2.63"
Unfinished Kit Weight :	20 oz

Stamp Stack II Microcontroller
Stamp Stack II development board
TSL230R Light-to-Frequency Converter from Texas Advanced Optoelectronic Solutions
Piezo Film Sensor from Measurement Specialties Inc.
2 9v batteries
Mini Spy video camera
R-DAS Tiny flight computer
Parallax memory stick data logger
Ativa 4gb USB drive
2 Aerotech H73J motor
2-28" rip stop nylon parachutes
15' tubular nylon shock cord (Mariya)
20' tubular nylon shock cord (Kyle)
2-8"-square flame retardant protective blanket
Kestral 4000 Portable Weather Station

Procedure: First we built and tested the Stamp Stack II microcontroller and mounted it on the electronics board that would slide into the payload section of the Hi Tech 45s. We modified the connections to the Stamp so that micro-cable connectors could be directly connected to the I/O pins rather than through a breadboard. We then mounted the memory stick data logger on the opposite side of the electronics board and utilized the same micro-cable connector solution to connect the data logger to the Stamp Stack. The Piezo film sensor was securely fastened to the electronics board and wired to the I/O pins of the Stamp Stack.

The assembly was mounted on the same 1/8” plywood electronics board that held the RDAS-Tiny altimeter and the video camera. This board slid into the payload bay and was held in place by fitting snugly between the nose cone and the payload bay’s aft bulkhead. Lateral movement was confined by wooden rails mounted on the interior walls of the payload bay.

We had to fashion an 8-pin DIP socket at the end of an 8” cable to hold the TSL230R light to frequency IC. Photos 1 and 2 show the electronics details. The sensor was designed to be placed in an opening in the payload bay wall so that it would have an unobstructed view to the exterior.

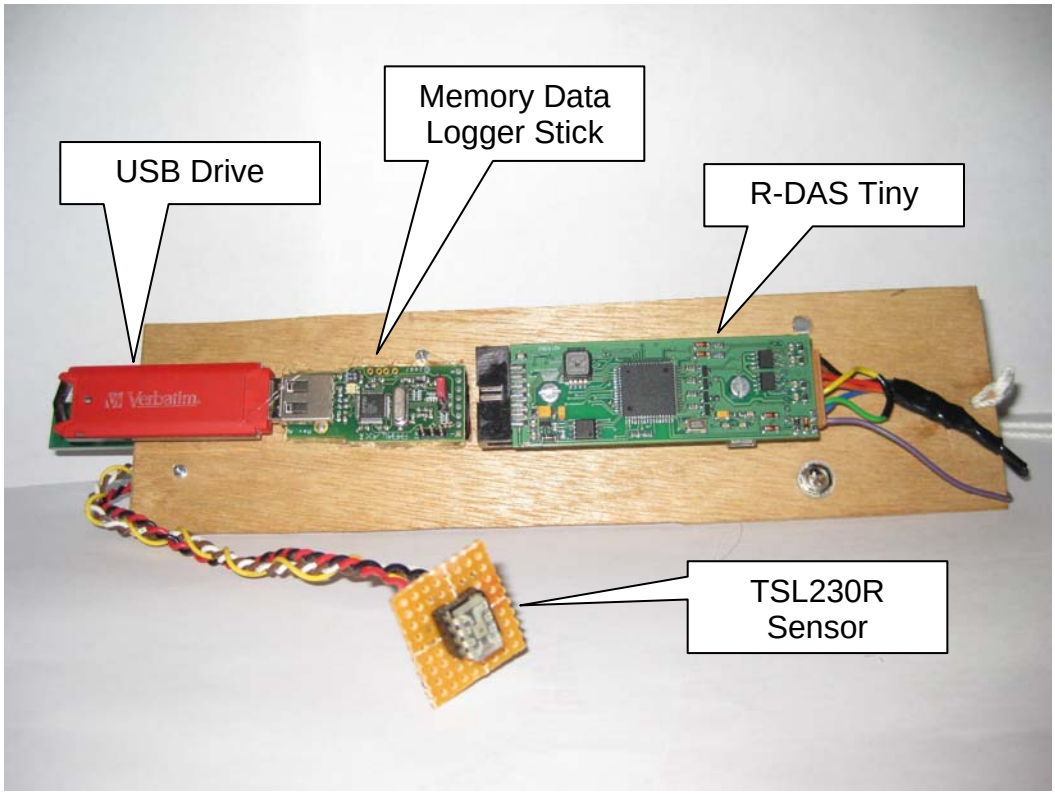


Photo 1

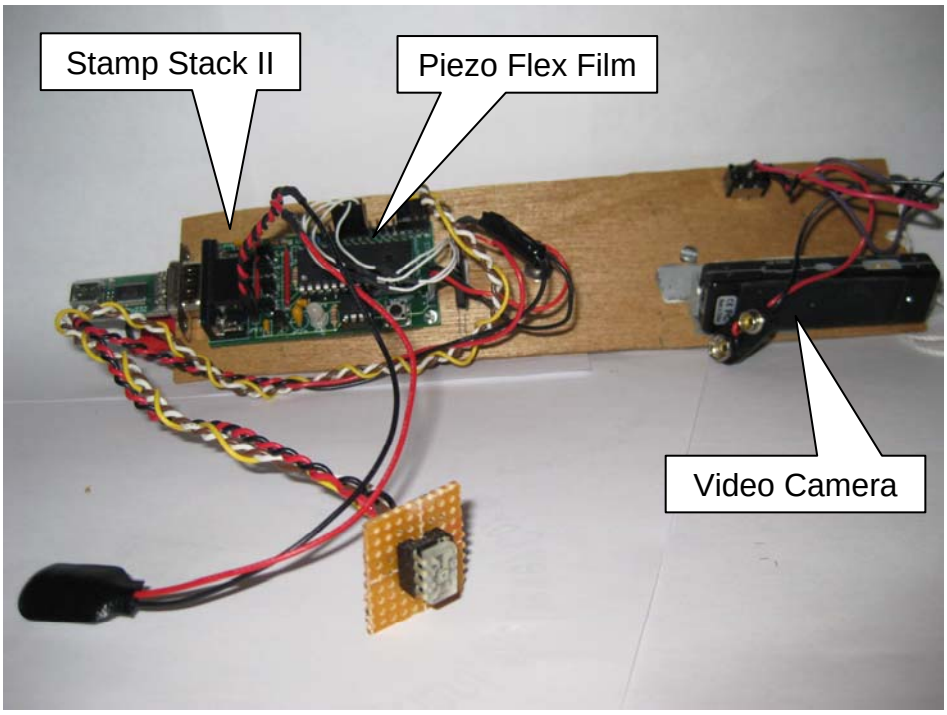


Photo 2

The program to control the Stamp Stack and to log the data from the two sensors is written in PBasic. The program code is Appendix 1. The program includes a subroutine to write the data to a USB drive mounted in the memory stick data logger. The data is written as a comma delimited text file, which can be read by Microsoft Excel.

The program monitors the amount of light registered by the TSL230R and performs a loop until the light is greater than 100, which is a very dim light. When it is greater than 100, the data logger starts storing information from the TSL30R and the Piezo flex film for a period of 15 seconds. At the expiration of 15 seconds, the program stops the data logging. Data is retrieved from the USB drive mounted in the data logger via a USB cable and stored on our laptop until analysis could take place.

An opaque screen was fitted over the opening that the TSL230R was mounted in and the screen removed itself upon liftoff by having a length of line fastened to it and the launch pad.

The roll (TSL230R) sensor was tested both prior to its flight and after the flight for data collection and to learn what the data might look like. The pre and post tests consisted of periodically covering and uncovering the sensor in a lighted room. The tests lasted for 15 seconds. We chose 15 seconds because that appeared to be somewhat beyond the maximum HPR liftoff-to-recovery deployment time. This assured us that we could capture the powered flight portion and not record too much chaotic movement while the rocket descended. The pre and post test data

are Appendix 2.

We didn't do a pre or post test of the Piezo film sensor beyond making certain that it did record miniscule amounts of movement.

On launch day we mounted the electronics package in Kyle's payload bay along with fresh batteries for both the altimeter and the sensors. The camera was turned on and set to video record mode and the nose cone fastened with three self-tapping screws.

Once his rocket was on the launch rail and the light screen was in place, the altimeter and the electronics package were turned on.

The rocket launched, the parachute deployed, and the rocket descended safely. Upon recovery we discovered that the g forces on take-off had dislodged the USB drive and as a result, no sensor data was recorded.

The steps were repeated for Mariya's rocket with additional care taken to ensure that the USB drive was more firmly attached. Her flight was also successful and we recovered data for analysis.

Results: We were able to gather data from one of the two rockets and therefore are not able to do a comparison between the two rockets.

There is some roll, almost 360 degrees prior to parachute deployment after which the rocket's movement becomes chaotic.

The vibration data suggest that there is a significant amount of vibration upon launch while during the coast phase, the degree of vibration decreases to a lower level and settles into a somewhat cyclical pattern as shown by the green trend line.

Conclusion: The data suggests that the roll is smooth throughout the ascent. After deployment, the rocket appears to gyrate quite wildly (to be expected) until the data recording stopped. We speculate that the extreme motion data values increased because the sensor was aimed more in the direction of the sun during the few recorded seconds of the descent. The RDAS Tiny flight computer data for both rockets is Appendix 3.

The amount of roll is supported by two video recordings of other rocket launches. The PML Ariel and the Mad Cow Patriot both have short videos that show a smooth and almost 360 degree roll prior to parachute deployment. Unfortunately, the video camera on board both Mariya's and Kyle's rockets turned off just seconds before launch. Weblinks to these videos are in Appendix 4.

The vibration data is consistent with what one could reasonably expect during HPR flight. Lots of vibration during the thrust phase and less during the coast phase. We will have to be satisfied with this data being baseline information because the other rocket failed to produce data to do a comparison with.

We plotted a trend lines by calculating the least squares fit through points using the formula:

$$Y=b+p_1x + p_2x^2 + \dots +p_nx^n$$

Microsoft Excel applies this formula when adding a trend line to a chart.

Lessons Learned: Since this was our team's second and third rocket launch, we entered this process with very little prior knowledge and experience. We are now much more aware of and appreciative of the extreme forces that a high powered rocket undergoes. Duct tape, regardless of what the manufacturer claims, cannot withstand g forces that these rockets experience!

We need to determine why the video camera turned it self off for four of the five flights that took place on this day. We have used this camera in many bottle rocket flights and have not experienced this phenomena previously. First speculation is that even though the camera is capable of storing an hour's worth of video, perhaps the charge time between flights wasn't' sufficient.

Our electronics payload needs to be more robust in its construction. Again, the g forces and landing exerted considerable strain on some of the components, their attachment, and the wiring. Careful post flight examination found two loose components and one broken connection.

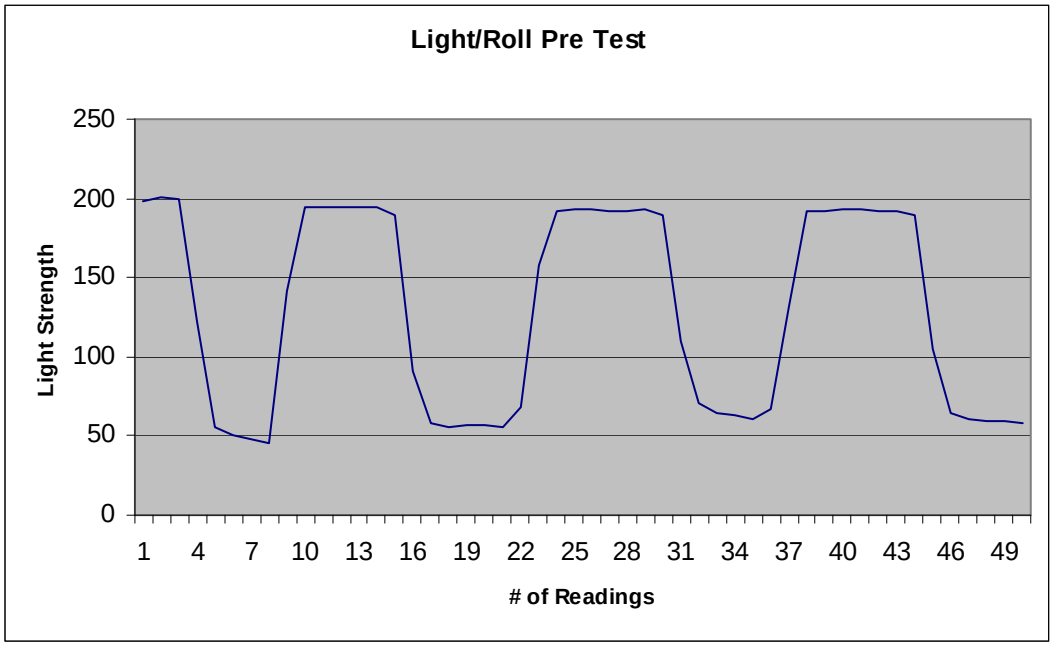
Appendix 1 – PBasic Program

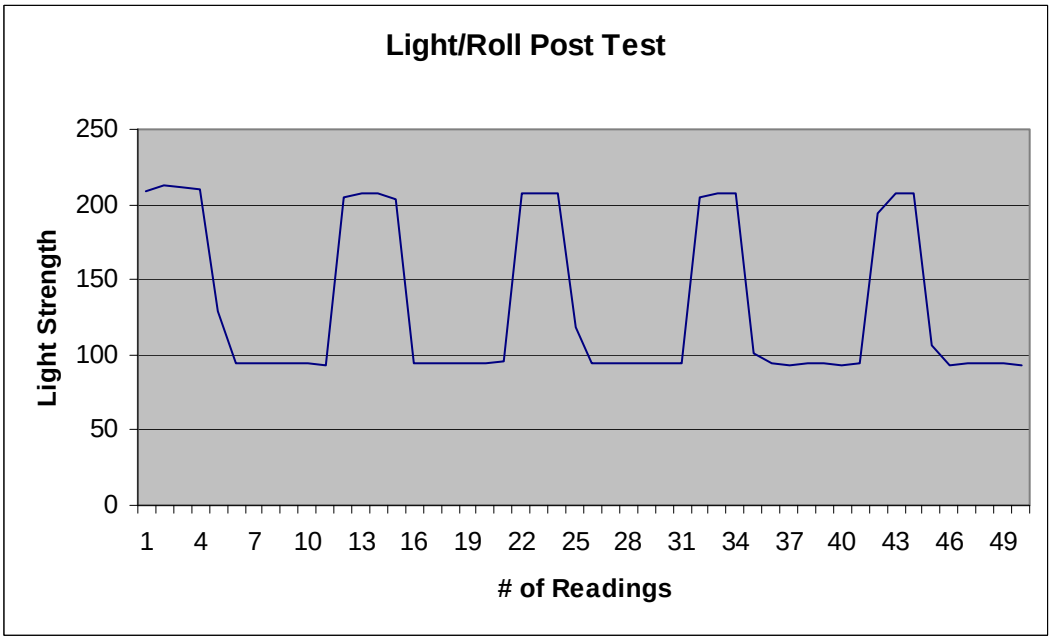
```
'   File...... FNL Dattalogger & Light.bs2
'   Author.... GLB
'   Started... 4/15/10
'   Updated... 4/20/10
'
'   {$STAMP BS2}
'   {$PBASIC 2.5}
'
' =========================================================================


' -----[ Program Description ]---------------------------------------------

' This program collects data from a TSL23OR light to analog converter and
' save it to a comma-delimited file. .
'

' -----[ I/O Definitions ]-------------------------------------------------

Sensor          PIN     2               ' TSL230R
TX              PIN     8               ' Transmit Data   --> 27937.4 (RXD)
RTS             PIN     9               ' Request To Send --> 27937.6 (CTS)
RX              PIN     10              ' Receive Data    <-- 27937.5 (TXD)
CTS             PIN     11              ' Clear To Send   <-- 27937.2 (RTS)


' -----[ Constants ]-------------------------------------------------------

Baud            CON     84              ' Serial Baud Rate 9600 bps (BS2)
NumSamples      CON     50              ' Number Of Samples To Log
'light -----------------------------------
S0 PIN 0 '0 'Sensitivity selection pins
S1 PIN 1
In PIN 2 'TSL230R output pin

' -----[ Variables ]-------------------------------------------------------

buffer          VAR     Byte(15)        ' Input Buffer
index           VAR     Byte            ' Index Variable
ioByte          VAR     Byte            ' Input/Output Storage
counter         VAR     Word            ' Counter Variable
flag            VAR     Bit             ' Event Status Flag

'light ------------------------
cnt VAR Word
HIGH S0 'Set sensitivity pins (S0,S1) to x10
HIGH S1
' -----[ Initialization ]--------------------------------------------------

DEBUG CLS, "Memory Stick Datalogger Demo V1.0", CR, CR, "Initializing..."
PAUSE 200                               ' Allow Time To Settle

HIGH TX                                 ' Initialize Transmit Line
LOW RTS                                 ' Take Vinculum Out Of Reset

PAUSE 600                               ' Allow Time To Settle
DEBUG "Done!", CR, "Synchronizing..."

DO
  SEROUT TX\CTS, Baud, ["E", CR]        ' Sync Command Character
  GOSUB Get_Data                        ' Get Response
  PAUSE 250
LOOP UNTIL ioByte = $0D                 ' Wait For Carriage Return

DO
```

```
  SEROUT TX\CTS, Baud, ["e", CR]        ' Sync Command Character
  GOSUB Get_Data                        ' Get Response
  PAUSE 250
LOOP UNTIL ioByte = $0D                 ' Wait For Carriage Return


' -----[ Program Code ]----------------------------------------------------

Main:
  DEBUG "Done", CR, "Switching to Short Command Mode..."
  SEROUT TX\CTS, Baud, ["SCS", CR]      ' Switch To Short Command Mode
  GOSUB Get_Data                        ' Purge Receive Buffer
  DEBUG "Done!", CR, "Waiting for Memory Stick..."

Check_Drive:
  DO
    SEROUT TX\CTS, Baud, [CR]           ' Prompt Device For Status
    GOSUB Get_Data                      ' Purge Receive Buffer
    IF buffer(0) = ">" THEN             ' Check For Ready Prompt
      EXIT                              ' If Ready Then Exit Loop
    ELSEIF buffer(0) = "N" AND buffer(1) = "D" THEN
      DEBUG "."                         ' Device Ready But No Memory Stick
    ELSEIF buffer(0) = "D" AND buffer(1) = "D" AND flag = 0 THEN
      DEBUG "Connected!", CR, "Accessing..."
      flag = 1                          ' Memory Stick Ready
    ELSE
      DEBUG "."
    ENDIF
    PAUSE 250                           ' Command Retry Delay
  LOOP
  DEBUG "Ready!", CR

  DEBUG "Delete Data File..." ,CR       ' First Delete File
  SEROUT TX\CTS, Baud, [$07, $20, "datafile.txt", CR]
  GOSUB Get_Data                        ' Purge Receive Buffer
  DEBUG "Create & Open Data File..."    ' Then Create File
  SEROUT TX\CTS, Baud, [$09, $20, "datafile.txt", CR]
  GOSUB Get_Data                        ' Purge Receive Buffer
  'GOTO works
  'Wait for lift off ------------------------
  cnt=0
  DO WHILE cnt < 100
    DEBUG HOME, CLRDN, "waiting for lift off"
    COUNT In, 50, cnt 'COUNT on P2 FOR 100 ms, store value in cnt
  LOOP
  'Liftoff ----------------------------------
   DEBUG HOME,CLRDN, "LIFTOFF" ,CR

 works:
  DEBUG "Open!", CR, CR, "Writing Data...", CR
  FOR counter = 1 TO NumSamples         ' Number Of Samples To Log
    COUNT In, 50, cnt 'COUNT on P2 FOR 100 ms, store value in cnt

    SEROUT TX\CTS, Baud, [$08, $20, $00, $00, $00, $0D, CR,
          DEC5 counter, ",", DEC4 cnt, CR, LF, CR]

    PAUSE 50                            ' Write Results/Delay
    GOSUB Get_Data                      ' Purge Receive Buffer
  NEXT

  DEBUG "Closing Data File..." ,CR      ' Close File (MUST CLOSE!)
  SEROUT TX\CTS, Baud, [$0A, $20, "datafile.txt", CR]
  DEBUG "Done"
  STOP


' -----[ Subroutines ]-----------------------------------------------------

Get_Data:
  index = 0                             ' Reset Index Pointer
```

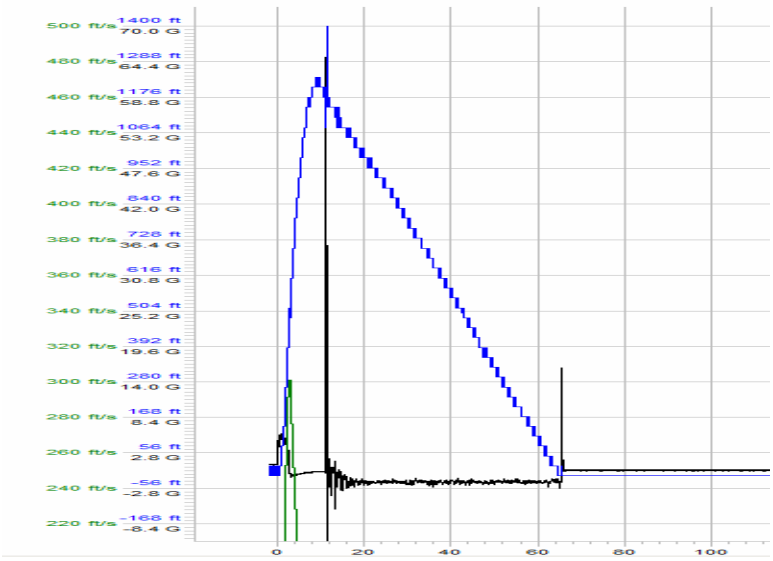
```
  DO                                  ' Receive Data
    SERIN RX\RTS, Baud, 100, Timeout, [ioByte]
    buffer(index) = ioByte              ' Add Received Byte To Buffer
    index = index + 1                   ' Increment Index Pointer
    IF index > 14 THEN Timeout          ' Check For Overflow
  LOOP

Timeout:
  RETURN
```

Appendix 2 – Pre and Post Test Graphs

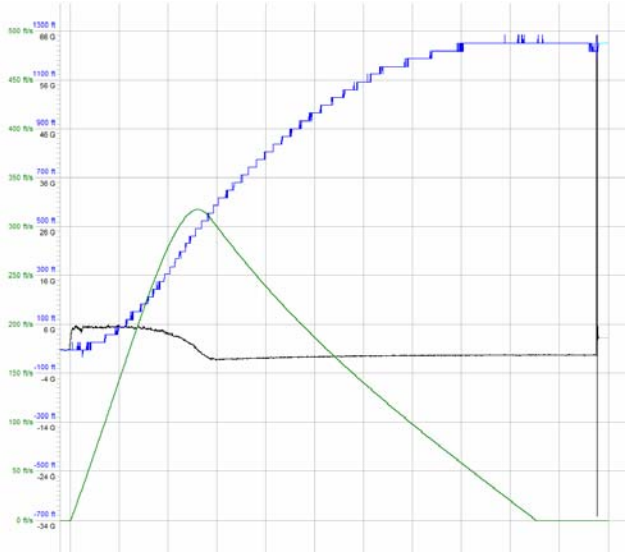




Appendix 3 – RDAS Tiny Flight Computer Results



Plot 1 - Kyle's LOC Hi-Tech 45, "T-100"



Plot 2 – Mariya's LOC Hi-Tech 45, "Mortimer"

Appendix 4 – On-Board Videos

On board flight videos

Ariel at Mansfield, April 24, 2010
http://www.youtube.com/watch?v=0xVIO0N_pI0

“High Caliber” at FNL, May 12, 2010
http://www.youtube.com/watch?v=Ok7B9I5BeEA