Drag on Tube Fins

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Summary

My objective was to predict if tube finned rockets have more drag than regular finned rockets. I also wanted to predict the drag of other tube finned rockets. I built one regular finned rocket with 2 x 2 inch fins. These were the other rockets I built: one with 2 inch long BT-60 fins; one with 2 inch long BT-70 fins; one with BT-20 fins that were 6 inches long, and scored at 5in, 4in, 3in, 2 in, 1in and 1/2 in. I scored these so when I did my tests it was easy to get the rocket ready for the next test. I did the same thing for the next rocket, except the tube fins were a BT-50. I did this so I could find out how much drag the tube and nose cone have. The last rocket I made was a rocket with no fins.

Through a special arrangement I was able to use the Air Force Academy's wind tunnel to do my project. The first time I went there I saw which wind tunnel I was going to use. The Air Force Academy had many wind tunnels. They decided to have me use the "Low Speed Wind Tunnel."

The next time I went back it was time to do my project. When I got there I put each rocket in the wind tunnel. I put in one at a time to test it. After I tested every rocket in the wind tunnel, I got the data on a CD and took it home to do data reduction. With the results I found that tube fins have about the same amount of drag as regular finned rockets with the same surface area. I made an equation to find out that drag of a BT-60 and BT-70 rocket. I also found out that as the tube length increases so does the drag.

The Objectives Of the Work

My objective was to find the drag coffecient of a tube fin rocket vs. a regular finned rocket, and try to predict drag of other tube-fin rockets.

The Approach Taken

Step 1: I built all the rockets the same exepct for the fins. I built one rocket with just a nose cone and a body tube. I did this so that I could find the drag of the nose cone and body tube, and subtract it from the overall drag of the rockets with tube fins. I wanted to get the drag of just the tube fins, and not the overall rocket itself. Next, I built a normal rocket with 2x2 squared fins. I did this to compare it to the tube finned rockets. The leading and trailing edges of the 1/16" fins were just rounded. The surface was finished with two coats of CyA glue, and sanded smooth.

Picture 1: Me building my rockets.

The next rocket was with 2in long BT-70 fins. Then I built one with 2in long BT-60 tube fins. Then I built a 6in long BT-50 tube fins. For this rocket I scored the 6in long tubes at 5in, 4in, 3in, 2in, 1in, and 1/2in. I did this so it would be easy to cut the tube for the next test when Igot to the Air Force Acedemy. I did the same thing for BT-20 rocket.

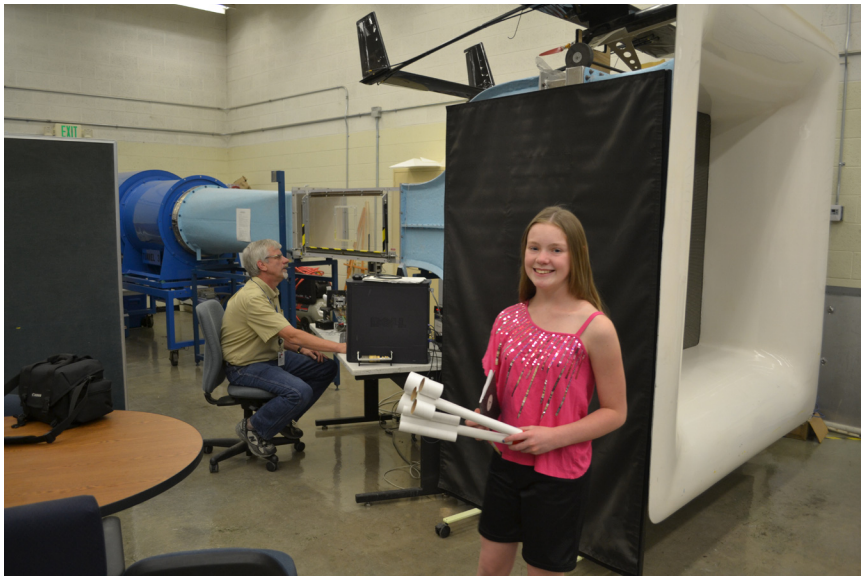
Picture 2: Scored Fins to make the test go faster.

Picture 3: The rockets I made prior to wind tunnel testing.

Step 2: The next thing I did was go to the Air Force Academy to do find out how we were going to mount the rocket in the wind tunnel, and which wind tunnel I was going to use. I would have loved to use the Subsonic wind tunnel, but it cost $10,000 per week to use it.

Picture 4: The Sub-Sonic Wind Tunnel that I wish I could have used.

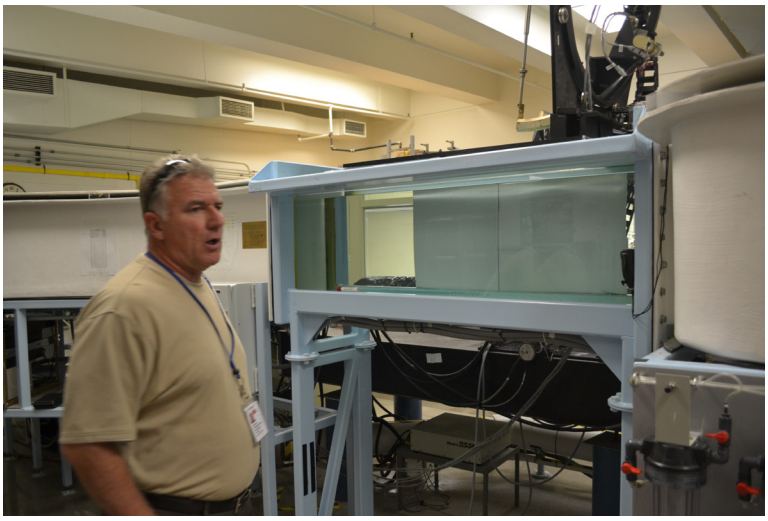
We ended up using 1ftx1ft classroom wind tunnel. The Air Force Academy calls



Picture 5: The Low Speed Wind Tunnel that I used.

this the "Low Speed Wind Tunnel."

While we were there, we got to take a tour of the Aeronautics Lab. That was really cool because I got to see things I had never even heard of, like "water tunnels."



Picture 6: Mr. Christopher A. Seaver, Deputy Director for Laboratory Operations, showed me the water tunnel and 7 other wind tunnels at the Air Force Academy.

Picture 7: Katarina McGuire helped me put my rocket in the wind tunnel.

Step 3: The next thing I did when we went back to the Air Force Acadamy was do the tests. I put each of my models in the test section with help from Katarina McGuire,

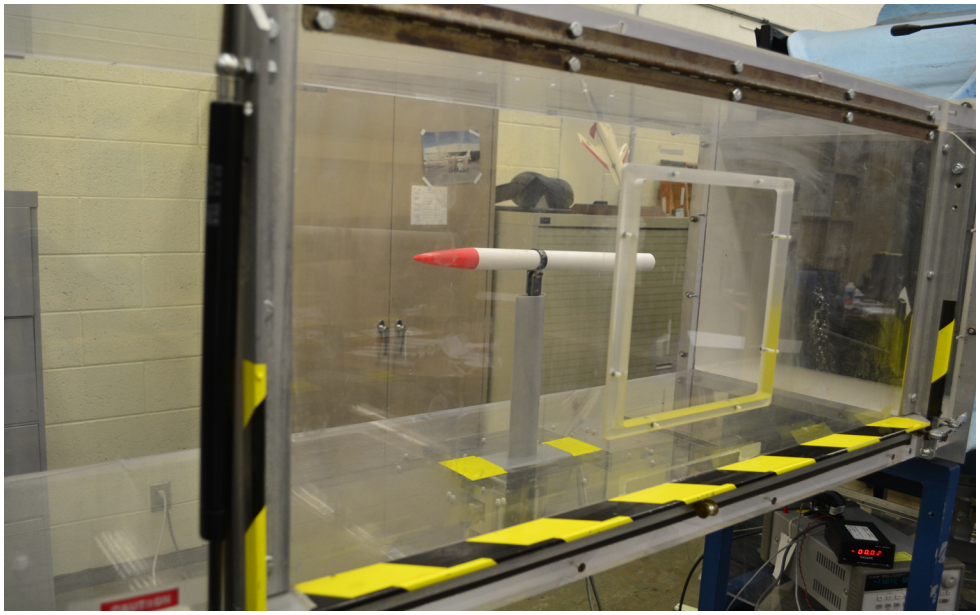
Picture 8: Katarina assisted me in leaveling my rocket.

who is an intern at the Academy in the summer.

We had to make sure the model was level. That way we knew that the model was pointed straight into the wind of the tunnel.

We started with an "air off" test to make sure the system was measuring data. Then we did a 10hz test, a 20hz, a 30hz, a 40hz, and a 50hz test. This was how the wind speed in the tunnel was adjusted. For example, 40 hz corresponded to a wind speed of approximately 32 mph, and 50 hz corresponded to almost 40 mph.

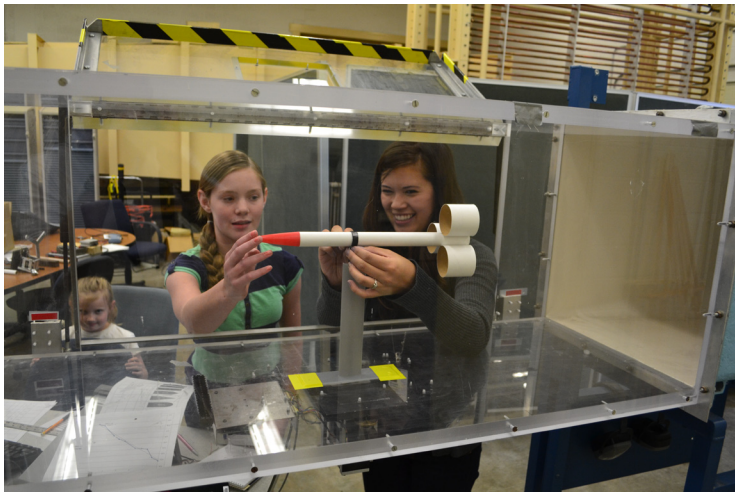
As a side note, the wind tunnel had a speed range of 20 - 150 ft/sec (13.6 mph - 102 mph). For my test, they only allowed it to go to around 40 mph, because they were afraid that some part would break off my model, and get stuck in the fan that sucked air through the tunnel. I wished I could have gone at a higher speed.



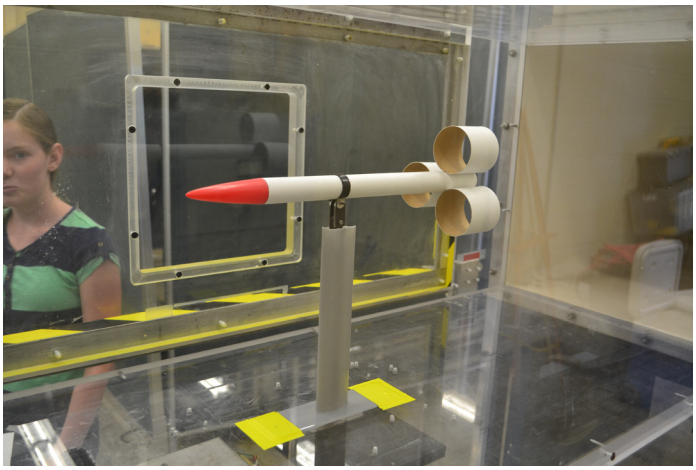
Picture 9: My "Base" model with no fins in the wind tunnel.

Picture 10: Marking the models at the same position. This is where they would be mounted in the holder of the wind tunnel.

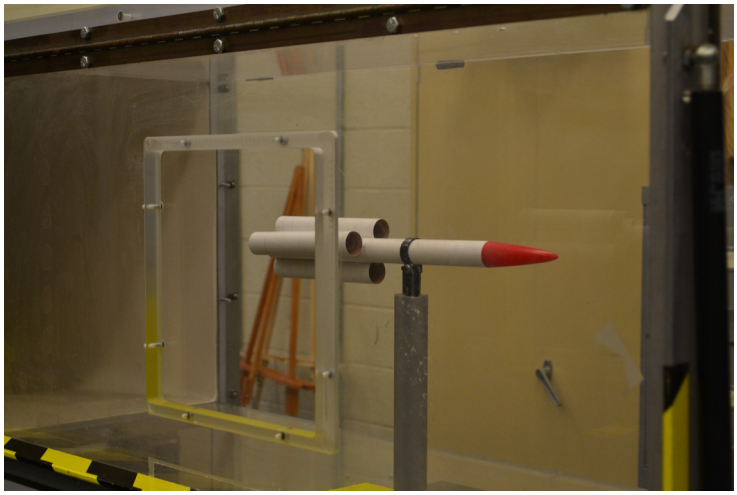
Picture 11: Katrina showed me how to save the data on the computer for each test run.



Picture 12: Katrina helped me secure the rockets into the holder of the wind tunnel.



Picture 13: All the models were tested in this orientation of the fins.



Picture 14: The BT-20 rocket with 6-inch long tube fins in the wind tunnel.

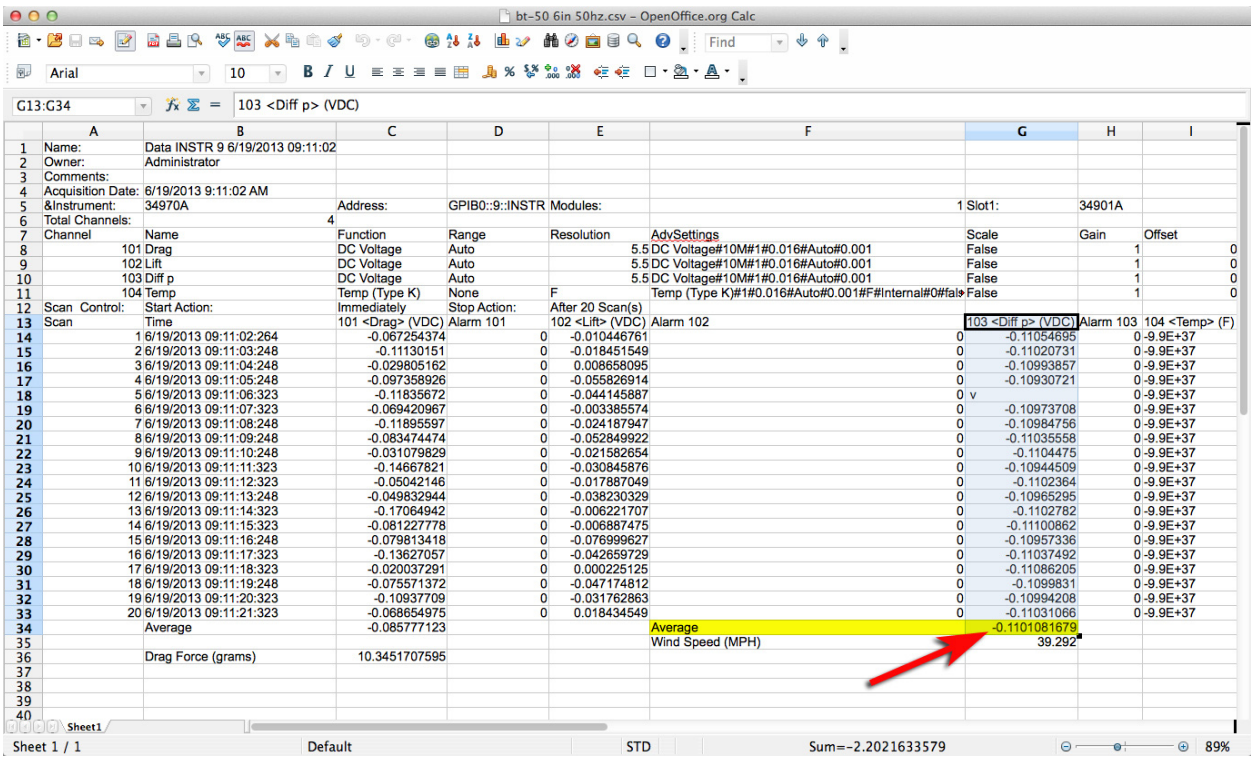
Picture 15: This is the close-up of the holder ring that held the rockets.

Each test lasted a couple of minutes. This happened because we had to wait for the air to stabilize, and to save the data file to the computer hard drive. I did this for every model.

Step 4: I collected and read all the data.

I didn't do any data reduction at the Air Force Academy. This was done when I got back home.

To find the wind speed: I opened the Excel files for each rocket configuration. It didn't give speed directly. It measured pressure difference in the tunnel. The wind

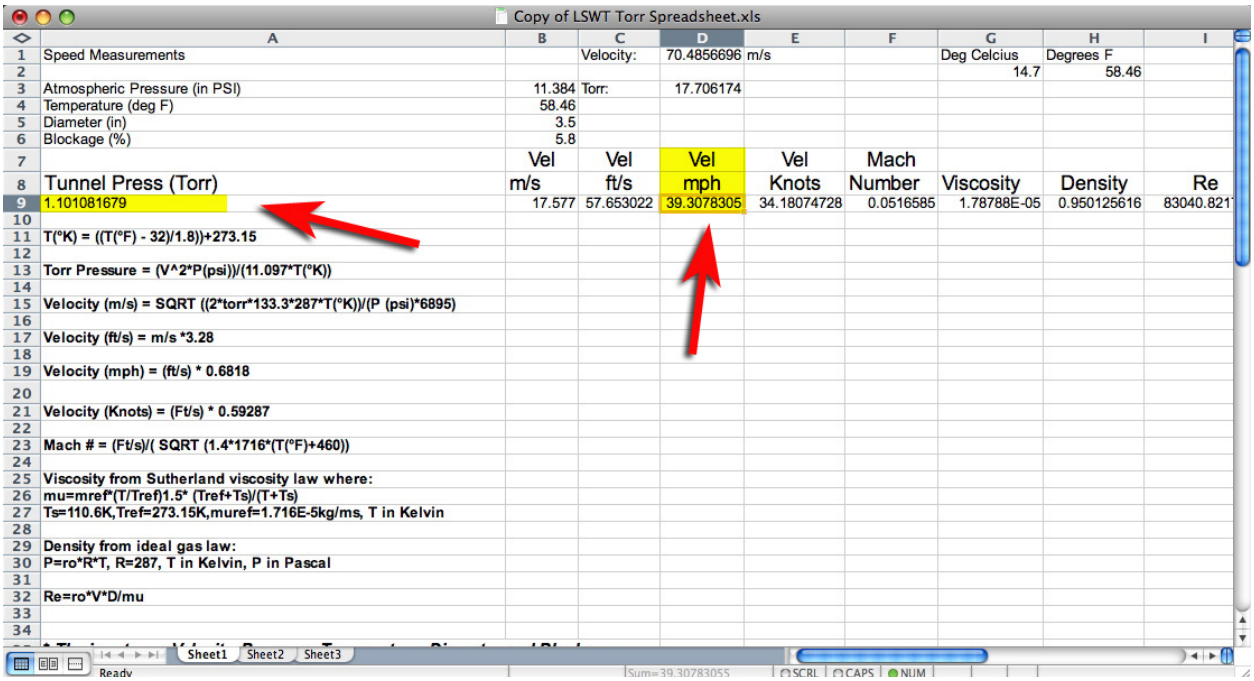


	A	B	C	D	E	F	G	H	I
1	Name:	Data INSTR 9 6/19/2013 09:11:02							
2	Owner:	Administrator							
3	Comments:								
4	Acquisition Date:	6/19/2013 9:11:02 AM							
5	&Instrument:	34970A	Address:	GPIB0::9::INSTR	Modules:	1	Slot1:	34901A	
6	Total Channels:	4							
7	Channel	Name	Function	Range	Resolution	AdvSettings	Scale	Gain	Offset
8	101	Drag	DC Voltage	Auto	5.5	DC Voltage#10M#1#0.016#Auto#0.001	False	1	0
9	102	Lift	DC Voltage	Auto	5.5	DC Voltage#10M#1#0.016#Auto#0.001	False	1	0
10	103	Diff p	DC Voltage	Auto	5.5	DC Voltage#10M#1#0.016#Auto#0.001	False	1	0
11	104	Temp	Temp (Type K)	None	F	Temp (Type K)#1#0.016#Auto#0.001#F#Internal#0#fal	False	1	0
12	Scan Control:	Start Action:	Immediately	Stop Action:	After 20 Scan(s)				
13	Scan	Time	101 <Drag> (VDC)	Alarm 101	102 <Lift> (VDC)	Alarm 102	103 <Diff p> (VDC)	Alarm 103	104 <Temp> (F)
14	1	6/19/2013 09:11:02:264	-0.067254374	0	-0.010446761	0	-0.11054695	0	-9.9E+37
15	2	6/19/2013 09:11:03:248	-0.11130151	0	-0.018451549	0	-0.11020731	0	-9.9E+37
16	3	6/19/2013 09:11:04:248	-0.029805162	0	0.008658095	0	-0.10993857	0	-9.9E+37
17	4	6/19/2013 09:11:05:248	-0.097358926	0	-0.055826914	0	-0.10930721	0	-9.9E+37
18	5	6/19/2013 09:11:06:323	-0.11835672	0	-0.044145887	0	v	0	-9.9E+37
19	6	6/19/2013 09:11:07:323	-0.069420967	0	-0.003385574	0	-0.10973708	0	-9.9E+37
20	7	6/19/2013 09:11:08:248	-0.11895597	0	-0.024187947	0	-0.10984756	0	-9.9E+37
21	8	6/19/2013 09:11:09:248	-0.083474474	0	-0.052849922	0	-0.11035558	0	-9.9E+37
22	9	6/19/2013 09:11:10:248	-0.031079829	0	-0.021582654	0	-0.1104475	0	-9.9E+37
23	10	6/19/2013 09:11:11:323	-0.14667821	0	-0.030845876	0	-0.10944509	0	-9.9E+37
24	11	6/19/2013 09:11:12:323	-0.05042146	0	-0.017887049	0	-0.1102364	0	-9.9E+37
25	12	6/19/2013 09:11:13:248	-0.049832944	0	-0.038230329	0	-0.10965295	0	-9.9E+37
26	13	6/19/2013 09:11:14:323	-0.17064942	0	-0.006221707	0	-0.1102782	0	-9.9E+37
27	14	6/19/2013 09:11:15:323	-0.081227778	0	-0.006887475	0	-0.11100862	0	-9.9E+37
28	15	6/19/2013 09:11:16:248	-0.079813418	0	-0.076999627	0	-0.10957336	0	-9.9E+37
29	16	6/19/2013 09:11:17:323	-0.13627057	0	-0.042659729	0	-0.11037492	0	-9.9E+37
30	17	6/19/2013 09:11:18:323	-0.020037291	0	0.000225125	0	-0.11086205	0	-9.9E+37
31	18	6/19/2013 09:11:19:248	-0.075571372	0	-0.047174812	0	-0.1099831	0	-9.9E+37
32	19	6/19/2013 09:11:20:323	-0.10937709	0	-0.031762863	0	-0.10994208	0	-9.9E+37
33	20	6/19/2013 09:11:21:323	-0.068654975	0	0.018434549	0	-0.11031066	0	-9.9E+37
34		Average	-0.085777123			Average	-0.1101081679		
35						Wind Speed (MPH)	39.292		
36		Drag Force (grams)	10.3451707595						

Chart 1: This is a sample of the raw data that was output by the computer at the Air Force Academy. Everything below line 33 is what I had to do. The first step: in the data spreadsheet for the test run, I had to average the 20 readings of pressure (shown by the arrow). This was to even out any turbulence in the wind tunnel. This data sheet was from the test of the rocket with the 6 inch long, BT-50 size tubes, and was run at the speed when the tunnel was turn on to the 50 hz setting.

tunnel measurement system took 20 air samples (once every two seconds) at each wind speed. I had to average out those to get the average pressure difference. By averaging the samples, any turbulence would be smoothed out in the results.

This pressure measurement (the average found above) was multiplied by 10. The reason was the Air Force Academy's data sheet had an error in it. They gave me a spreadsheet called the "LSWT Torr Spread Sheet," which finds the airspeed based on the pressure measurement system. The wind speed, this spreadsheet was calculating, was around 12 mph, instead of 40 mph. By talking with the Air Force, they finally fig-



Copy of LSWT Torr Spreadsheet.xls

	A	B	C	D	E	F	G	H	I
1	Speed Measurements		Velocity:	70.4856696	m/s		Deg Celcius	Degrees F	
2							14.7	58.46	
3	Atmospheric Pressure (in PSI)	11.384	Torr:	17.706174					
4	Temperature (deg F)	58.46							
5	Diameter (in)	3.5							
6	Blockage (%)	5.8							
7		Vel	Vel	Vel	Vel	Mach			
8	Tunnel Press (Torr)	m/s	ft/s	mph	Knots	Number	Viscosity	Density	Re
9	1.101081679	17.577	57.653022	39.3078305	34.18074728	0.0516585	1.78788E-05	0.950125616	83040.821
10									
11	T(°K) = ((T(°F) - 32)/1.8))+273.15								
12									
13	Torr Pressure = (V^2*P(psi))/(11.097*T(°K))								
14									
15	Velocity (m/s) = SQRT ((2*torr*133.3*287*T(°K))/(P (psi)*6895)								
16									
17	Velocity (ft/s) = m/s *3.28								
18									
19	Velocity (mph) = (ft/s) * 0.6818								
20									
21	Velocity (Knots) = (Ft/s) * 0.59287								
22									
23	Mach # = (Ft/s)/(SQRT (1.4*1716*(T(°F)+460))								
24									
25	Viscosity from Sutherland viscosity law where:								
26	mu=mref*(T/Tref)1.5* (Tref+Ts)/(T+Ts)								
27	Ts=110.6K,Tref=273.15K,muref=1.716E-5kg/ms, T in Kelvin								
28									
29	Density from ideal gas law:								
30	P=ro*R*T, R=287, T in Kelvin, P in Pascal								
31									
32	Re=ro*V*D/mu								
33									
34									

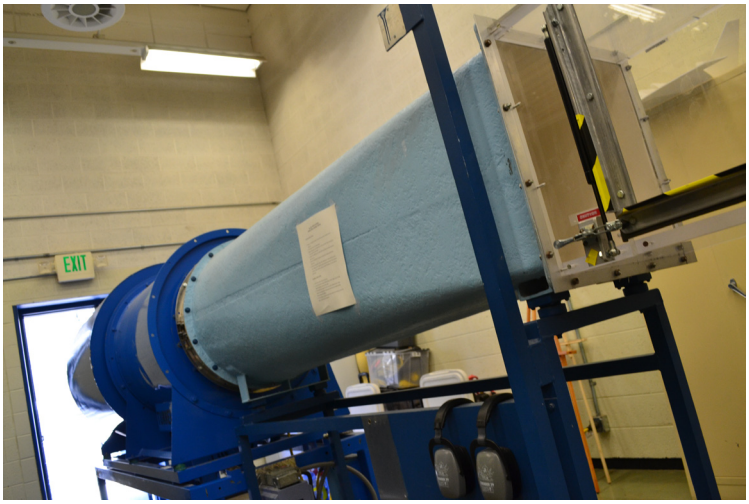
Sheet1 Sheet2 Sheet3

Ready Sum=39.30783055 SCRL CAPS NUM

Chart 2:The Air Force Academy gave my this spreadsheet that determines the wind speed in the tunnel based on the pressure reading. The pressure reading (from the chart on the previous page) had the decimal point in the wrong spot, so I had to multiply it by 10 before I typed it into cell A9 (left side). From that pressure, the spreadsheet calculated the velocity of the air in the tunnel.

ured that the decimal was in the wrong place. It was off by a factor of 10. They told us to multiply the pressure measurement by 10, and the spreadsheet would calculate the correct wind speed.

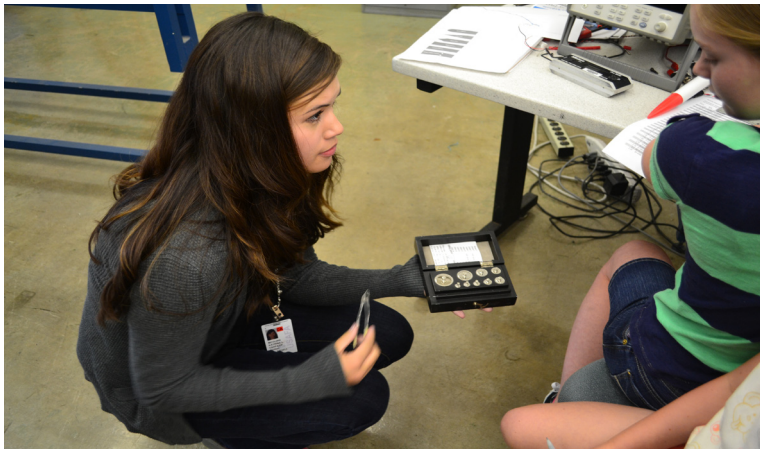
I took this speed and wrote it down in my data sheet (see the "Data Collected / Results Obtained" section of this report). The max wind speed was a little over 39mph.



Picture 16: The wind tunnel and the open door where the air shot out through.

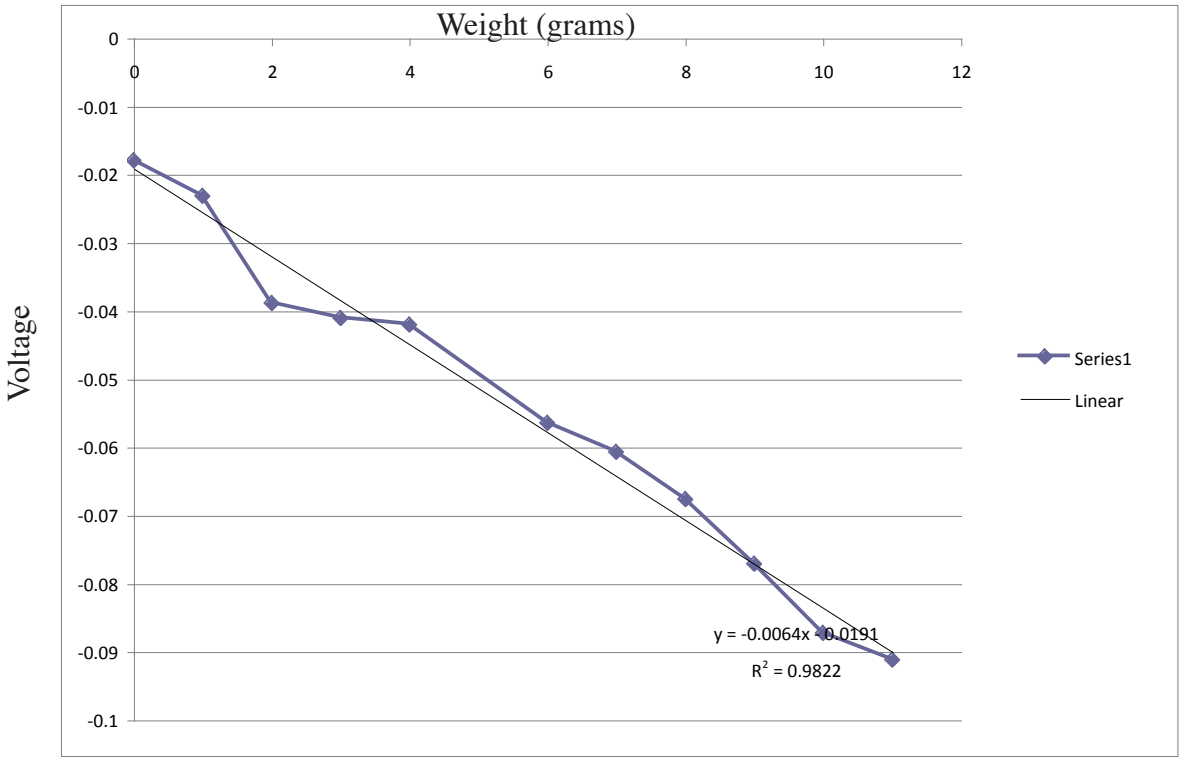
It varied slightly from test to test because pressure outside the room changed (the door to outside was open, to prevent turbulence inside the room from the air hitting the wall behind the wind tunnel)

To find the drag:



Picture 17: Katarina showing me the wieghts I couldn't touch.

Prior to my arrival at the Air Force Academy Katrina McGuire and Ken Ostasiewski calibrated the measurement system with precise gram weights that I couldn't



Graph 1:This is the calibration chart that Katrina and Ken made prior to my test.

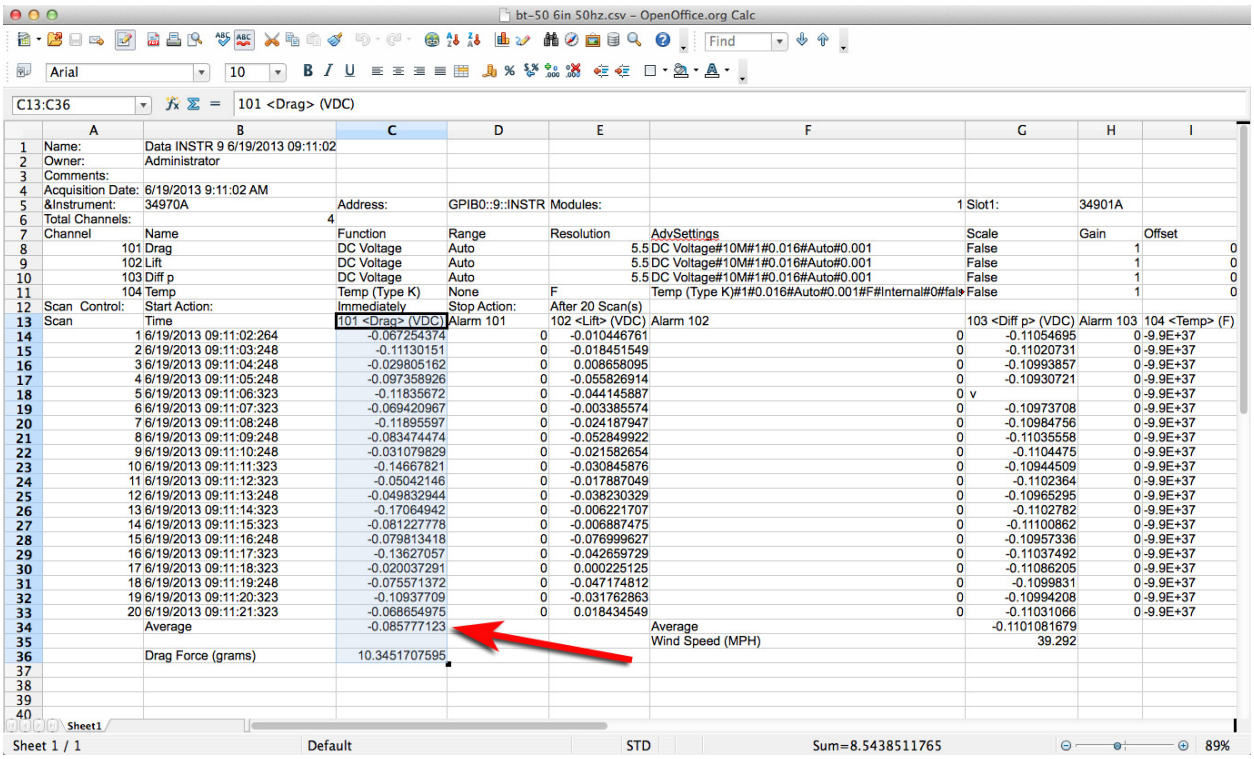
touch, because the oil on your skin can change the mass of the weights.

They created a graph and equation that calculates the force at each voltage value. I would use this equation to find the drag of each configuration.

The equation used to find the force was found by rearranging the equation on the calibration chart and solving for the variable "x". The equation was:

Weight = (voltage reading + 0.0190667343) / 0.006448457

When the data system took measurements, it actually takes voltage readings. Like for wind speed, it took 20 measurements (once every two seconds) that had to be



bt-50 6in 50hz.csv - OpenOffice.org Calc

C13:C36 | 101 <Drag> (VDC)

	A	B	C	D	E	F	G	H	I
1	Name:	Data INSTR 9 6/19/2013 09:11:02							
2	Owner:	Administrator							
3	Comments:								
4	Acquisition Date:	6/19/2013 9:11:02 AM							
5	&Instrument:	34970A	Address:	GPIB0::9::INSTR	Modules:	1	Slot1:	34901A	
6	Total Channels:	4							
7	Channel	Name	Function	Range	Resolution	AdvSettings	Scale	Gain	Offset
8	101	Drag	DC Voltage	Auto	5.5	DC Voltage#10M#1#0.016#Auto#0.001	False	1	0
9	102	Lift	DC Voltage	Auto	5.5	DC Voltage#10M#1#0.016#Auto#0.001	False	1	0
10	103	Diff p	DC Voltage	Auto	5.5	DC Voltage#10M#1#0.016#Auto#0.001	False	1	0
11	104	Temp	Temp (Type K)	None	F	Temp (Type K)#1#0.016#Auto#0.001#F#Internal#0#fal»	False	1	0
12	Scan Control:	Start Action:	Immediately	Stop Action:	After 20 Scan(s)				
13	Scan	Time	101 <Drag> (VDC)	Alarm 101	102 <Lift> (VDC)	Alarm 102	103 <Diff p> (VDC)	Alarm 103	104 <Temp> (F)
14	1	6/19/2013 09:11:02:264	-0.067254374	0	-0.010446761	0	-0.11054695	0	-9.9E+37
15	2	6/19/2013 09:11:03:248	-0.11130151	0	-0.018451549	0	-0.11020731	0	-9.9E+37
16	3	6/19/2013 09:11:04:248	-0.029805162	0	0.008658095	0	-0.10993857	0	-9.9E+37
17	4	6/19/2013 09:11:05:248	-0.097358926	0	-0.055826914	0	-0.10930721	0	-9.9E+37
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19	6	6/19/2013 09:11:07:323	-0.069420967	0	-0.003385574	0	-0.10973708	0	-9.9E+37
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22	9	6/19/2013 09:11:10:248	-0.031079829	0	-0.021582654	0	-0.1104475	0	-9.9E+37
23	10	6/19/2013 09:11:11:323	-0.14667821	0	-0.030845876	0	-0.10944509	0	-9.9E+37
24	11	6/19/2013 09:11:12:323	-0.05042146	0	-0.017887049	0	-0.1102364	0	-9.9E+37
25	12	6/19/2013 09:11:13:248	-0.049832944	0	-0.038230329	0	-0.10965295	0	-9.9E+37
26	13	6/19/2013 09:11:14:323	-0.17064942	0	-0.006221707	0	-0.1102782	0	-9.9E+37
27	14	6/19/2013 09:11:15:323	-0.081227778	0	-0.006887475	0	-0.11100862	0	-9.9E+37
28	15	6/19/2013 09:11:16:248	-0.079813418	0	-0.076999627	0	-0.10957336	0	-9.9E+37
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32	19	6/19/2013 09:11:20:323	-0.10937709	0	-0.031762863	0	-0.10994208	0	-9.9E+37
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34		Average	-0.085777123			Average	-0.1101081679		
35						Wind Speed (MPH)	39.292		
36		Drag Force (grams)	10.3451707595						
37									
38									
39									
40									

Sheet1

Sheet 1 / 1 | Default | STD | Sum=8.5438511765 | 89%

Chart 3: To find the drag force, I first had to average the 20 voltage readings that were gathered during the test. This number was then plugged into the calibration equation (listed above). This gave the drag force on the rocket being tested (shown in cell C34). I had to do this every time for the different rockets I tested.

averaged.

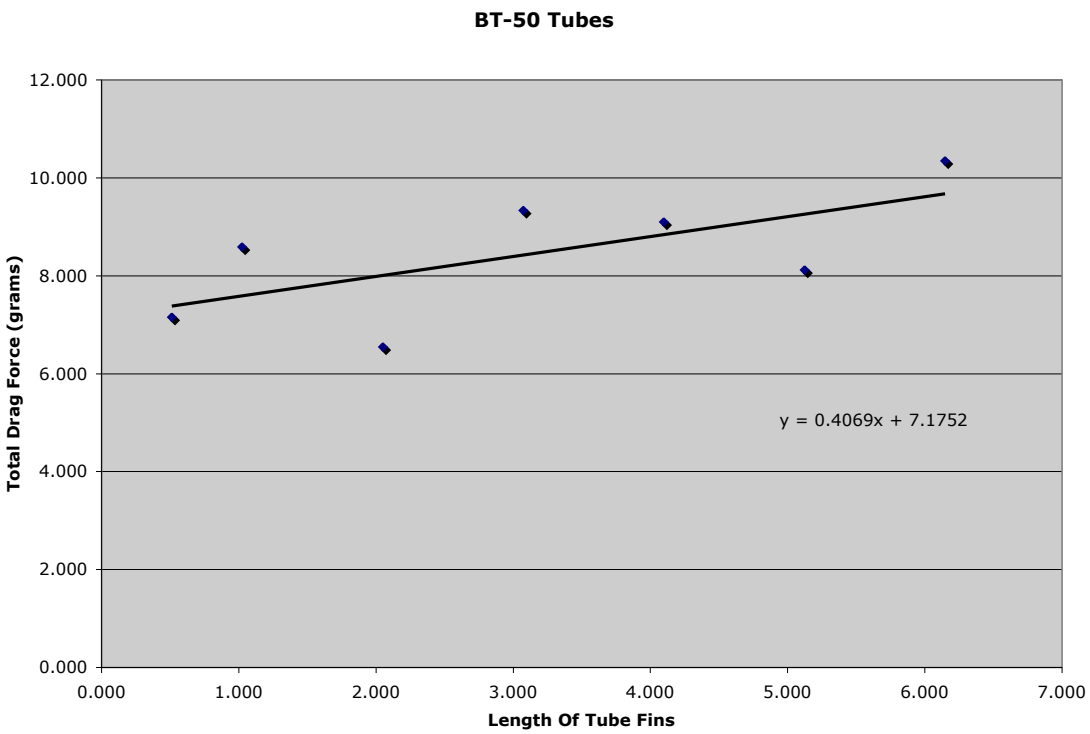
I took the average voltage measurement and put that number into the calibration formula. That formula gave me the force in grams that created the voltage.

Once I had the drag I put it into my chart. I had to do this for 17 rocket configurations and three tests; one for the stand and two without fins.

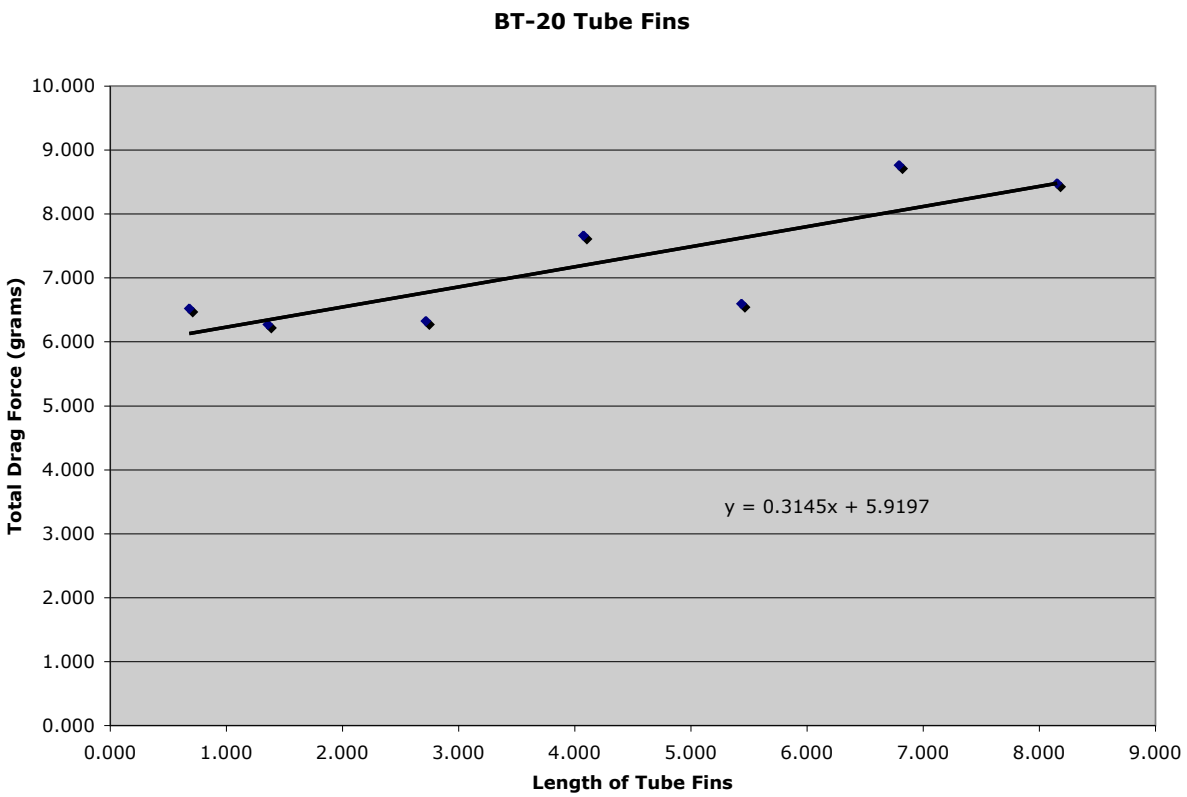
After the chart was made I organized it by putting it into graphs. I used a feature in Microsoft Excel to put trend lines on the graph, and calculate the equation of the trend line.

Rocket Configuration	Tube Size	Tube Diameter	Tube Length	Length/Dia. Ratio	Wind Speed (mph)	Total Drag Force	Tube Fin Drag (g)	Temp
Base	No fins	No Fins	No Fins	No Fins	31.81	2.150		72°F
Base	No fins	No Fins	No Fins	No Fins	39.29	6.958	0.000	72°F
1	BT-20	0.736	6	8.152	39.34	8.479	1.521	72°F
2	BT-20	0.736	5	6.793	39.21	8.765	1.807	72°F
3	BT-20	0.736	4	5.435	39.21	6.598	-0.360	72°F
4	BT-20	0.736	3	4.076	39.23	7.663	0.705	72°F
5	BT-20	0.736	2	2.717	39.26	6.326	-0.632	72°F
6	BT-20	0.736	1	1.359	39.31	6.272	-0.686	72°F
7	BT-20	0.736	0.5	0.679	39.20	6.522	-0.436	72°F
8	BT-50	0.976	6	6.148	39.31	10.345	3.387	72°F
9	BT-50	0.976	5	5.123	39.34	8.116	1.158	72°F
10	BT-50	0.976	4	4.098	39.05	9.096	2.138	72°F
11	BT-50	0.976	3	3.074	38.97	9.338	2.380	72°F
12	BT-50	0.976	2	2.049	39.28	6.550	-0.408	72°F
13	BT-50	0.976	1	1.025	39.47	8.592	1.634	72°F
14	BT-50	0.976	0.5	0.512	39.18	7.155	0.197	72°F
15	BT-60	1.637	2	1.222	39.23	11.862	4.904	72°F
16	BT-70	2.217	2	0.902	39.25	12.275	5.317	72°F
17	2x2	N/A	2x2	N/A	39.32	7.597	0.639	72°F
18	Stand	N/A	N/A	N/A	39.28	3.805	N/A	72°F

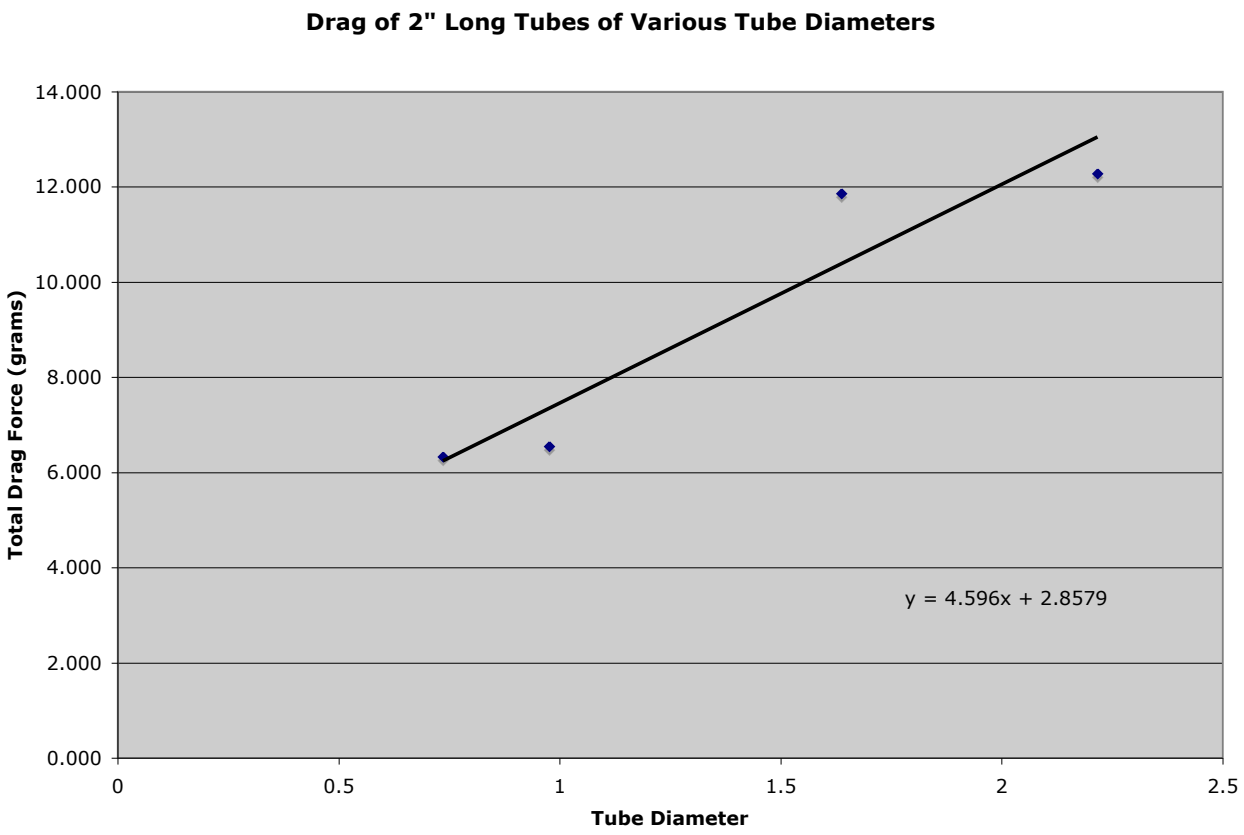
Chart 4: This is a chart of all the rockets I tested at the Air Force Academy.



Graph 2: This is my graph of all the tests I did on the rocket with the BT-50 size tube fins.



Graph 3: This is my graph of all the tests I did on the rocket with the BT-20 size tube fins.

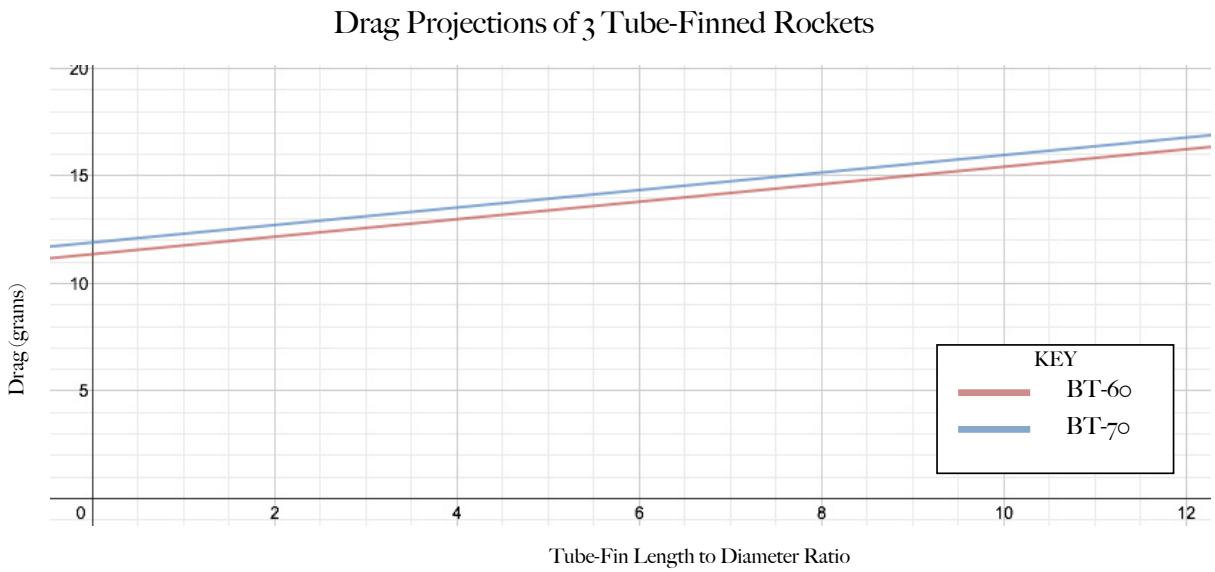


Graph 4: This is the graph I made for all the 2-inch long tubes I tested.

Data Collected/ Results Obtained

Conclusions Drawn

The Results that I obtained are as follows:



Graph 5: My BT-60 and BT-70 prediction.

1. As the tube length increases the drag goes up.

2. Also the slope in the BT-50 and BT-20 slopes are very close. This says that a person can predict the drag will be about the same slope for a BT-60 and BT-70.

Here is the graph I made to predict the drag:

3. I also realized that when I tested the base rocket the drag was too high. See the chart for the second "Base" configuration at 39.29 mph wind speed. That configuration had a force of 6.958 grams, where the same configuration at 31.81 mph had a much lower drag force of 2.150 grams. I don't know why it was too high, except that maybe it wasn't aligned in the wind tunnel perfectly straight. That is why some of the numbers for "Tube Fin Drag" are negative. Other than that, I believe that all my numbers are accurate because I had the help of the Air Force Academy to make these measurements.

4. Tube-Finned rockets have about the same amount of drag as regualar finned rockets. If you had a tube finned rocket with the same surface as a regular finned rocket you would find that the drag is about the same.

Here's how I figured this out. If the surface area of the regular finned rocket is 2x2in, that is equivelent to a tube fin rocket having a 2 inch long X 0.6366 inch diameter. To figure this out, refer to graph 3 on page 15. When you extend a line up from .63 inches diameter, you'll find the drag to be a little over 7 grams. That is real close to the drag of a 2" X 2" fin which had a drag of 7.597 grams. But tube fin rockets are less stable

than regular flat fin rockets, (see reference #1) so you'd need bigger tubes to make up the difference. That would mean rockets of equal stability, the tube fin rocket would have more drag, because it needs larger tubes.

Further work that would clarify or extend the results obtained:

I could test my projection graphs (graph #4) and see if they were accurate. I could also do larger numbers of tube fins. I could also test the drag of swept tube fins, where the leading edge and trailing edge are not perpendicular to the sides.

Related R&D Reports: Previous Work Done On Subject

I have never done work on this subject.

References on Subject

1. Stability of tube fins by Seth Avecilla
2. The Effect of Model Rocket Tube Fin Characteristics on the location of the center on pressure by Andrew Polashenski 11th grade science fair project
3. Larry Brand, "Tube Fin Rocket Aerodynamics Revisited", Sport Rocketry, January-February 2008
4. Larry Brand, "Tube Fin Rocket Aerodynamics Revisited Part 2", Sport Rocketry, March-April 2008
5. Larry Brand, "Tube Fin Rockets - Seven Beats Six Part 3", Sport Rocketry, March-April 2010
6. Larry Brand's Simulator: http://webalt.markworld.com/webalt.html
7. Larry Brands Tube Fin Construction Articles: http://www.rocketreviews.com/larry-brand-page.html
8. United States Air Force Academy Department of Aeronautics - Laboratory Facilities Handbook.

Equipment Used

Modeling equipment to build the rockets
12" Open Circuit Wind Tunnel at the Air Force Academy
Level - to make sure the rockets were pointed straight in the wind tunnel.
Computer
Microsoft Excel Spread Sheet

Facilities Used

Air Force Academy Aeronautics Lab: Low Speed Wind Tunnel.

Money Spent

What	Where	Packs Bought	Cost per Pack	Total Cost
PNC-24A	Apogee Compents	2	$6.00	$12.00
BT-50	Apogee Compents	2	$8.62	$17.24
BT-60	Apogee Compents	1	$12.91	$12.91
BT-70	Apogee Compents	1	$11.52	$11.52
BT-20	Apogee Compents	1	$8.35	$8.35
Balsa Sheet-1/8inx6in	Apogee Compents	1	$0.75	$0.75
CR 18-24	Apogee Compents	1	$2.51	$2.51
Total Cost				$65.28

Chart 5 : The money I spent.

Credits:

I would like to thank the following individuals for assisting in the use of the wind tunnel at the United States Air Force Academy

Christopher A. Seaver, Lt Col (ret), USAF
Deputy Director for Laboratory Operations
Department of Aeronautics
United States Air Force Academy

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