Fuselage Design and Structure

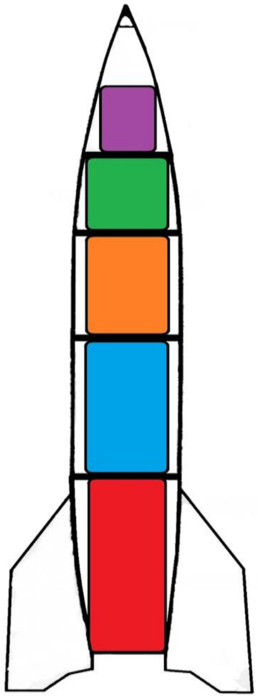
Solid Design Team

Scott, Nick, Esteban, Tarique, and Jack

Fuselage

Common Fuselage Material

- ➔ Cardboard
- ➔ Phenolic
- ➔ Fiberglass
- ➔ Fiberglassed Phenolic
- ➔ Carbon Fiber
- ➔ Quantum
- ➔ Blue Tube



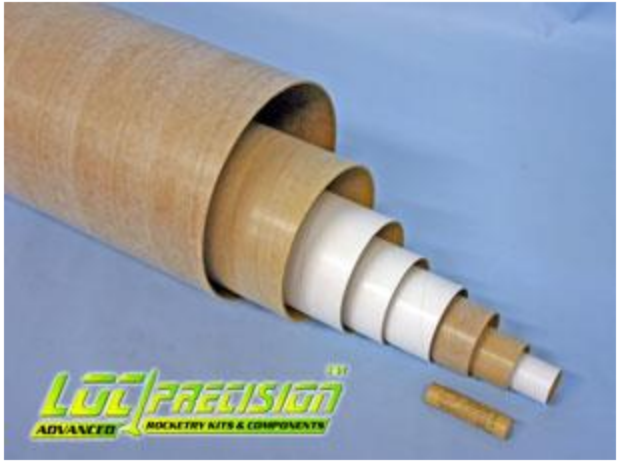
Cardboard

Positives

- ➔ Commonly used for low power rockets
- ➔ Cheap: $15.00
- ➔ Easy to obtain

Negatives

- ➔ Low durability
- ➔ Finishing needed



http://aksrockets.blogspot.com/2011/11/rocketry-materials.html

Based on 4” OD and 34” Length

Fuselage

Common Fuselage Material

- ➔ ~~Cardboard~~
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- ➔ Quantum
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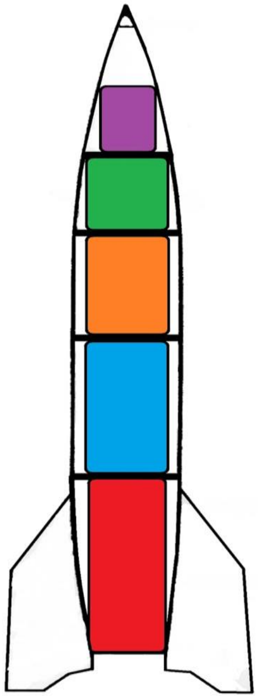

Phenolic

Positives

- ➔ Pretty good heat resistance
- ➔ Cheap: $44.99
- ➔ Easy to obtain

Negatives

- ➔ Brittle and tends to shatter
- ➔ Finishing needed

Based on 6” OD and 36” Length

http://www.gbrockets.co.uk/store/parts/tubes/phenolic-tubes.html

Fuselage

Common Fuselage Material

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- ➔ Fiberglass
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- ➔ Quantum
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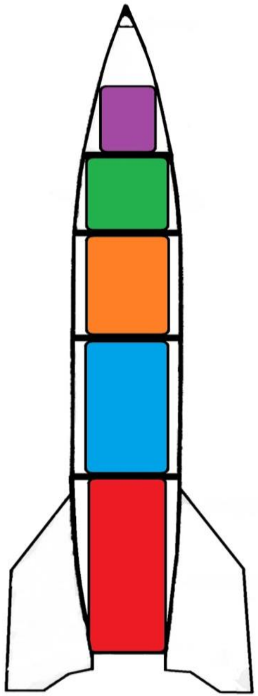

Fiberglass

Positives

➔ Good heat resistance
➔ Good durability
➔ No finish needed

Negatives

➔ Expensive: $170.00
➔ Heavy: 2.4 kg

Based on 5” OD and 60” Length

http://aksrockets.blogspot.com/2011/11/rocketry-materials.html

Fuselage

Common Fuselage Material

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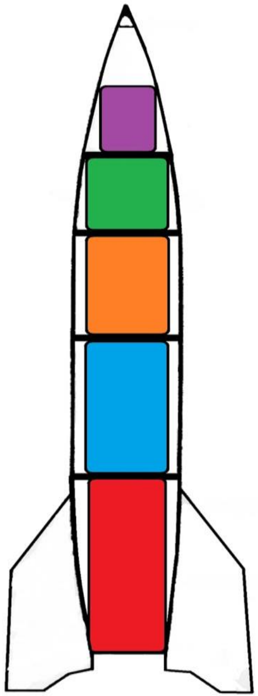
- ➔ Fiberglassed Phenolic
- ➔ Carbon Fiber
- ➔ Quantum
- ➔ Blue Tube



Fiberglass Phenolic

Positives

- Good heat resistance
- Good durability
- Cheaper than plain fiberglass
  if we wrap: $184.99

Negatives

- Finish is dependant on us
- Availability is low

Based on 6” OD and 48” Length

http://aksrockets.blogspot.com/2011/11/rocketry-materials.html

Fuselage

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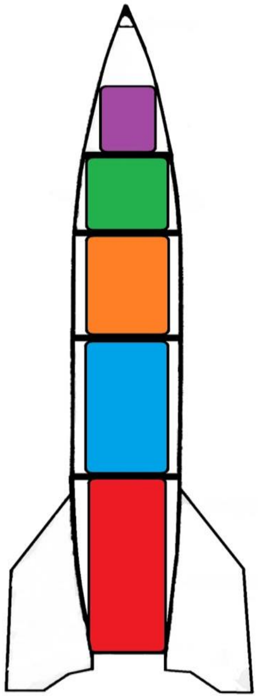


Carbon Fiber

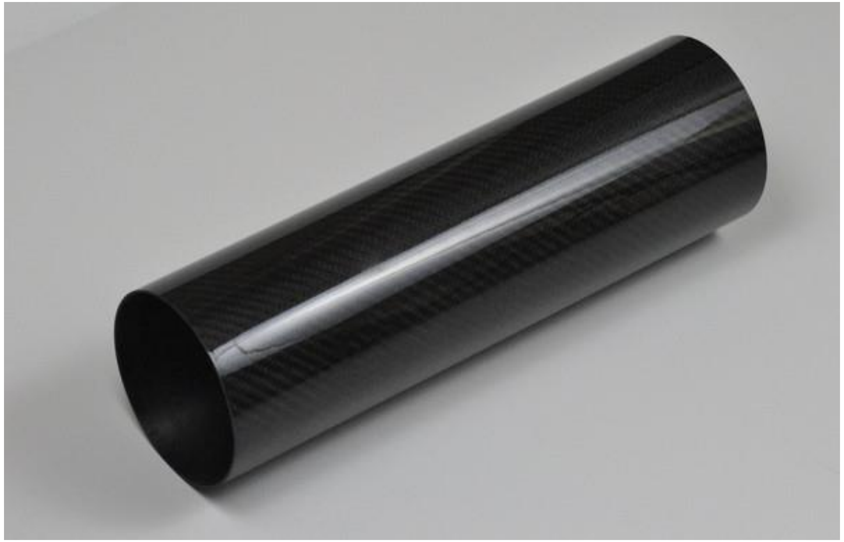
Positives

- ➔ Great Durability
- ➔ Great Heat Resistance
- ➔ Good Finish

Negatives

- ➔ Very Expensive: $350.00
- ➔ Used for rockets going Mach 2

Based on 5.5” OD and 48” Length



http://www.fwcarbon.com/products/4-carbon-fiber-tube-101mm-od-x-98mm-id

Fuselage

Common Fuselage Material

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- ~~Phenolic~~
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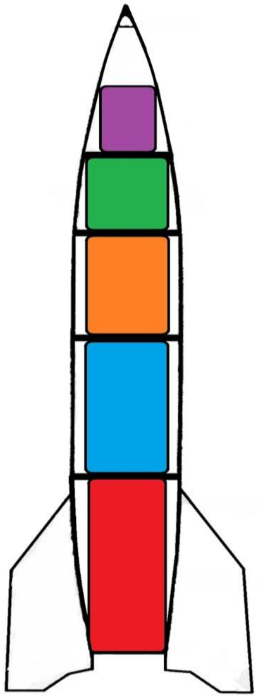
- ~~Fiberglassed Phenolic~~
- ~~Carbon Fiber~~
- Quantum
- Blue Tube



Quantum

Positives

- ➔ Good Finish
- ➔ Good Durability

Negatives

- ➔ Low heat resistance
- ➔ Availability is low

http://www.rebelrocketry.com/shop/product_info.php?info=p424_Quantum-Body-Tube-QT-3-9.html

Fuselage

Common Fuselage Material

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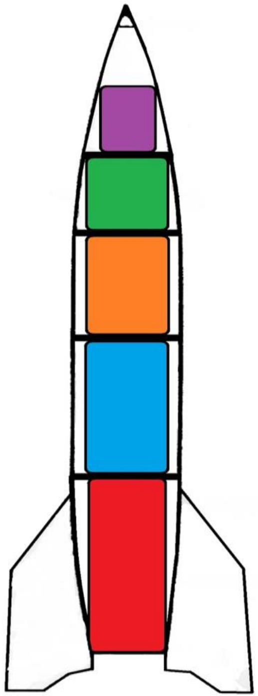
- Blue Tube



Blue Tube

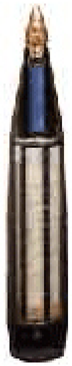
Positives

- ➔ Good Durability
- ➔ Good heat resistance
- ➔ Relatively Cheap: $89.95

Negatives

- ➔ Finishing needed
- ➔ Heavy: 1.89 kg

Based on 5.5" OD and 72" Length



http://www.alwaysreadyrocketry.com/product/1-15-29mm-x-062-wall-x-48-airframe-mmt/

Fuselage

Common Fuselage Material

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- ~~Carbon Fiber~~
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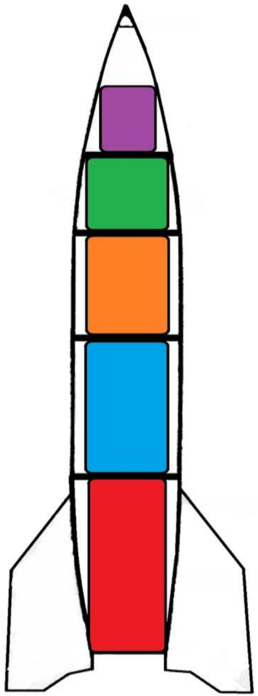


Fuselage

	Durability	Heat Resistance	Difficulty of Finish	Weight	Cost	Availability	Integration to System	Results
Fiberglass	+	+	+	-	-	+	0	2
Blue Tube	+	+	-	-	+	+	+	3

Fuselage

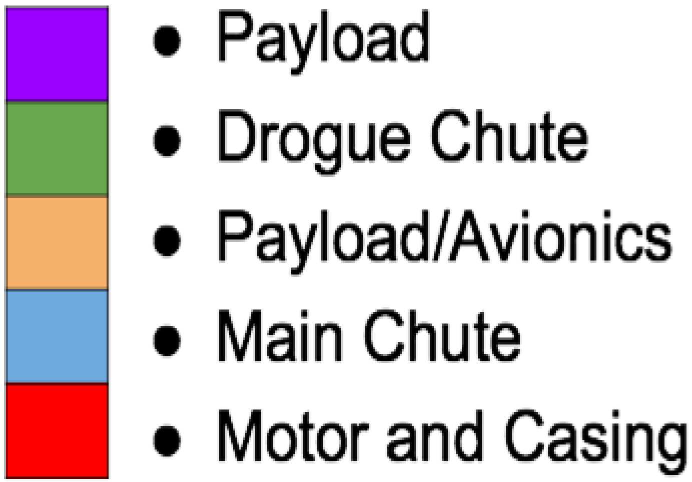
Blue Tube 2.0

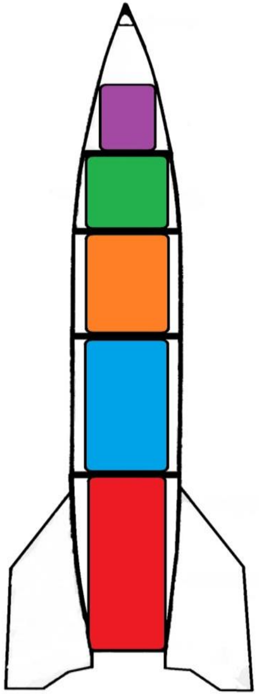
http://www.alwaysreadyrocketry.com/testimonials/

http://www.alwaysreadyrocketry.com/about-us/blue-tube-2-0/

Internal Structure

- How to connect all of this





Internal Structure

Motor

- Centering rings
- 9mm thick Birchwood
- Price $7.50 each
- Make it ourselves

http://www.alwaysreadyrocketry.com/product/centering-rings/

Internal Structure

Parachutes

- Parachute protector
- Flame Retardant material- Nomex
- Cost $10-$30-Fruity Chutes

http://fruitychutes.com/buyachute/nomex-blankets-c-2/11-nomex-blanket-3-75mm-airframe-p-19.html

Internal Structure

Avionics

- Electronics bay
- Blue Tube Cost $54.95
- Small tube that will fit in to 5.5in

http://www.alwaysreadyrocketry.com/product/blue-tube-electronic-bays/

Internal Structure

Payload

- Still in discussion
- Need to be easy access
- Depends on Payload
- Option another E-Bay

Internal Structure

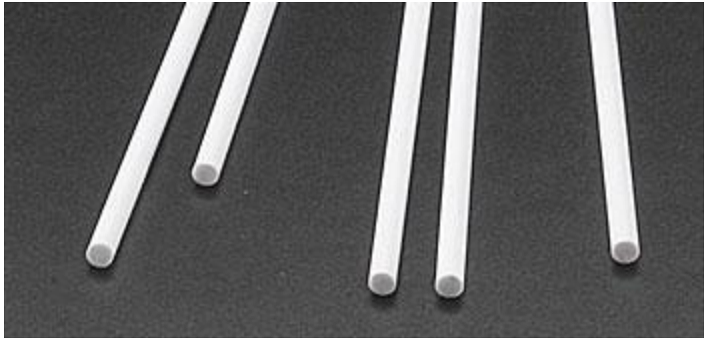
Fuselage Pins/Connectors Design Considerations

- Drag Separation
- Shifting Mass
- Apogee
- Oversized Ejection Charge
- Improper Ejection Timing

Internal Structure

Shear Pins

- Nylons Screws
- Nylon Rods
- Styrene Rods



Alternatives

- Neodymium Magnets

http://www.hobbylinc.com/htm/pls/pls90861.htm
http://www.amazon.com/Neodymium-Magnets-inch-Disc-N48/dp/B001KUWM3C

Internal Structure

Shear Pins

Advantages

- Very cheap ($0.60 - $0.80 per foot)
- Easily Available
- Repeatable

Disadvantages

- Requires drilling holes in the rockets
- Shear pins always need to be flush against fuselage exterior

Internal Structure

Neodymium Magnets

Advantages

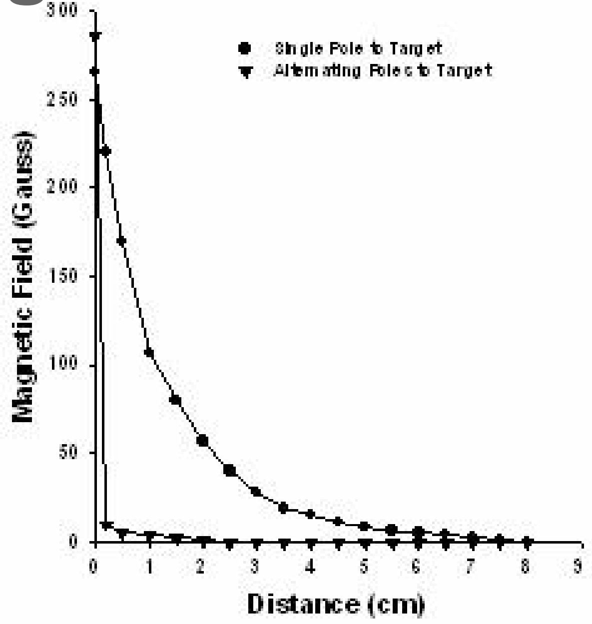
- Cheap ($5.99 for 30 1/4in x 1/16in disks)
- Easily Available
- Repeatable
- Doesn’t require any destructive hardware modifications

Disadvantages

- Requires little more testing than shear pins

Internal Structure

Magnetic “Pins” Expected Results



- Use spacers to vary magnetic field strength for more customizable alternative to shear pins

http://drpawluk.com/education/magnetic-science/

Internal Structure

Testing Procedure

Gutentite Testing Procedure

- Tests how effective a friction fit will hold up against rapid acceleration and deceleration
- Based on the results, test different shear pin and magnets configurations/sizes

http://rocketsnw.com/?page_id=1651

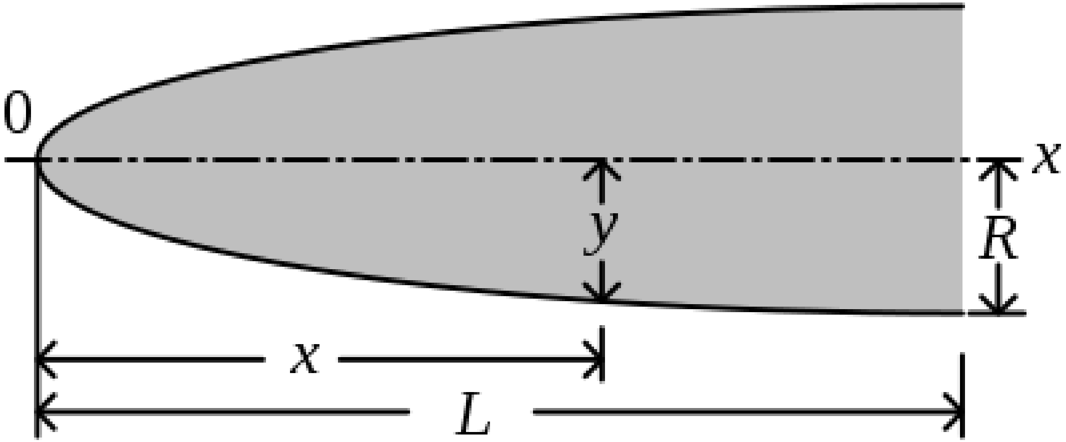
Internal Structure

Decision?

Test both shear pins and magnets and pick the best

Nose Cone

General Dimensions:

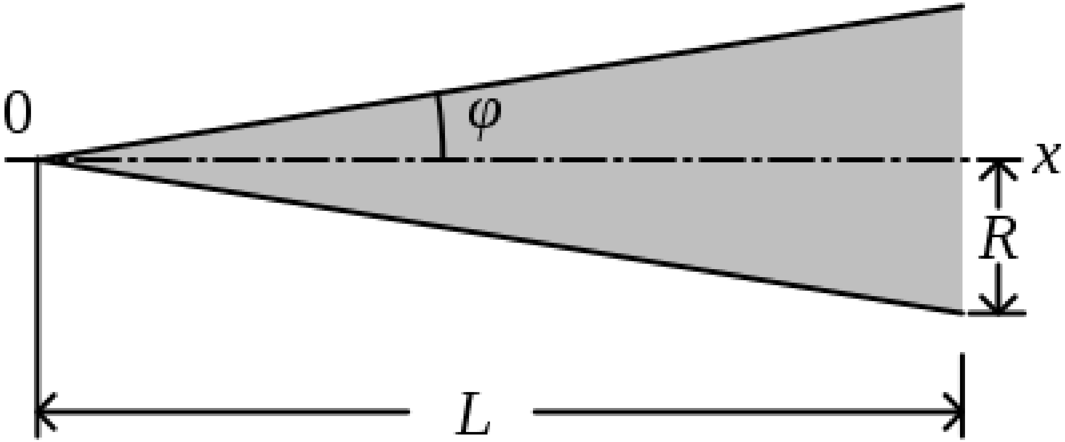


http://en.wikipedia.org/wiki/Nose_cone_design

Nose Cone Shapes

Conical:

- Diameter Equation: $y = \frac{xR}{L}$ $\phi = \arctan\left(\frac{R}{L}\right)$ and $y = x\tan(\phi)$



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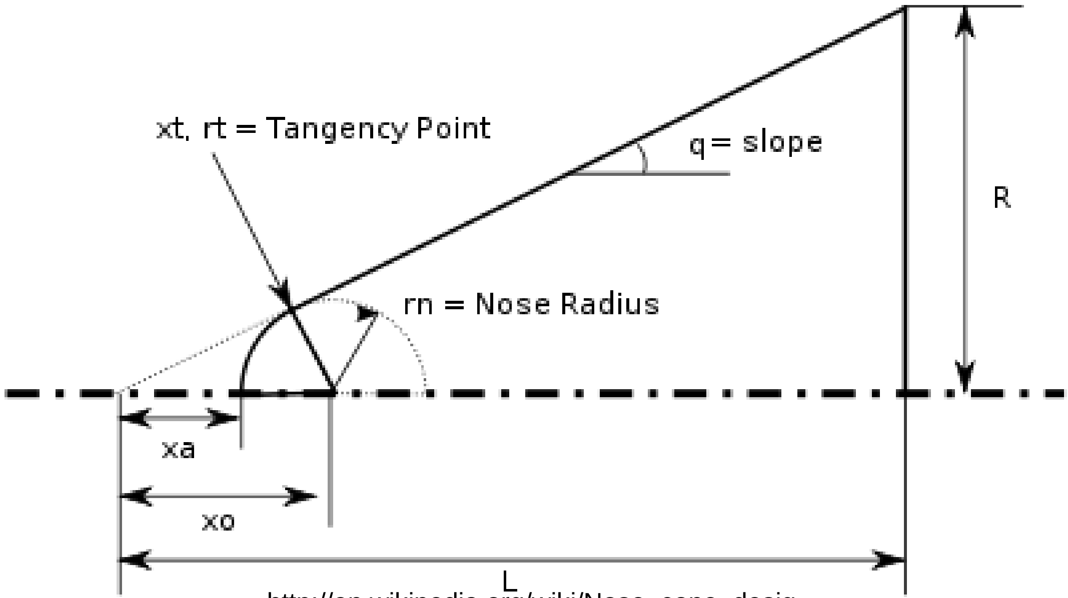
Nose Cone Shapes

Spherically Blunted Cone:



http://en.wikipedia.org/wiki/Nose_cone_design

Nose Cone Shapes

Bi-conic:

- for $0 \leq x \leq L_1 : y = \frac{xR_1}{L_1}$

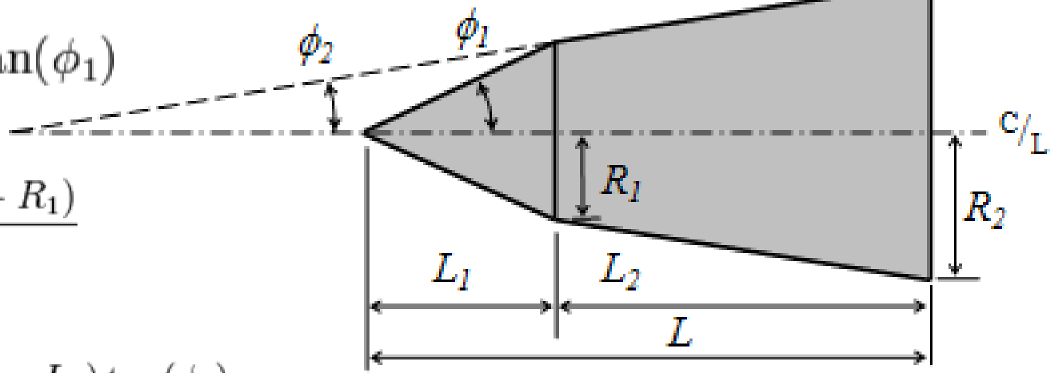
half angle :

$$\phi_1 = \arctan\left(\frac{R_1}{L_1}\right) \text{ and } y = x\tan(\phi_1)$$

- for $L_1 \leq x \leq L : y = R_1 + \frac{(x - L_1)(R_2 - R_1)}{L_2}$

half angle :

$$\phi_2 = \arctan\left(\frac{R_2 - R_1}{L_2}\right) \text{ and } y = R_1 + (x - L_1)\tan(\phi_2)$$



http://en.wikipedia.org/wiki/Nose_cone_design

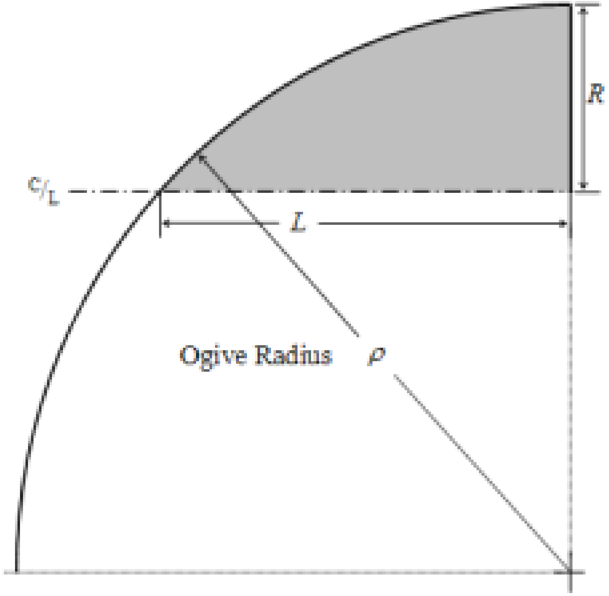
Nose Cone Shapes

Tangent Ogive:

- Ogive Radius: $\rho = \dfrac{R^2 + L^2}{2R}$
- Radius (y) at any x:

$$y = \sqrt{\rho^2 - (L - x)^2} + R - \rho$$

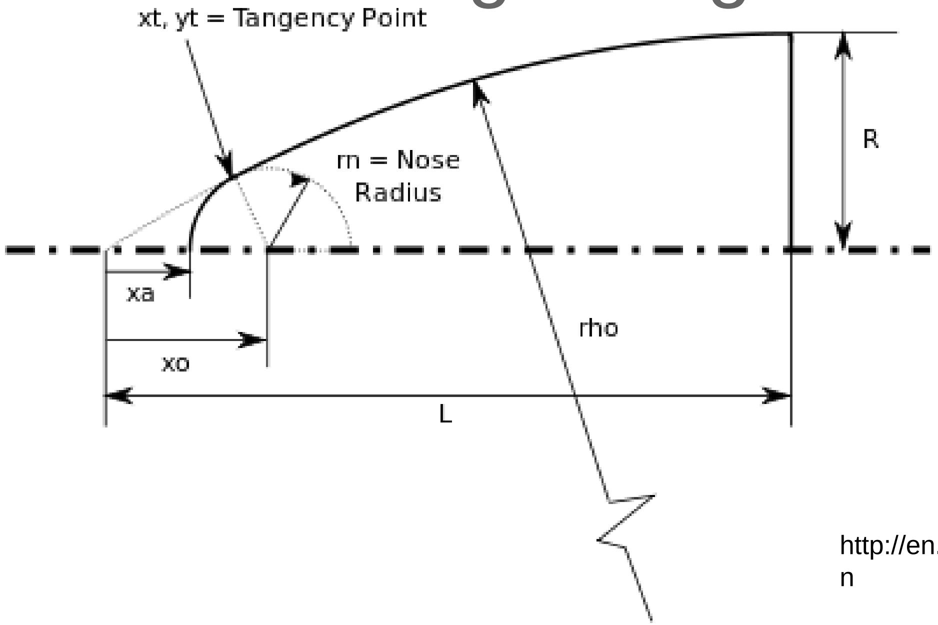
- L ≤ ρ
  - If equal, hemisphere



http://en.wikipedia.org/wiki/Nose_cone_design

Nose Cone Shapes

Spherically Blunted Tangent Ogive:



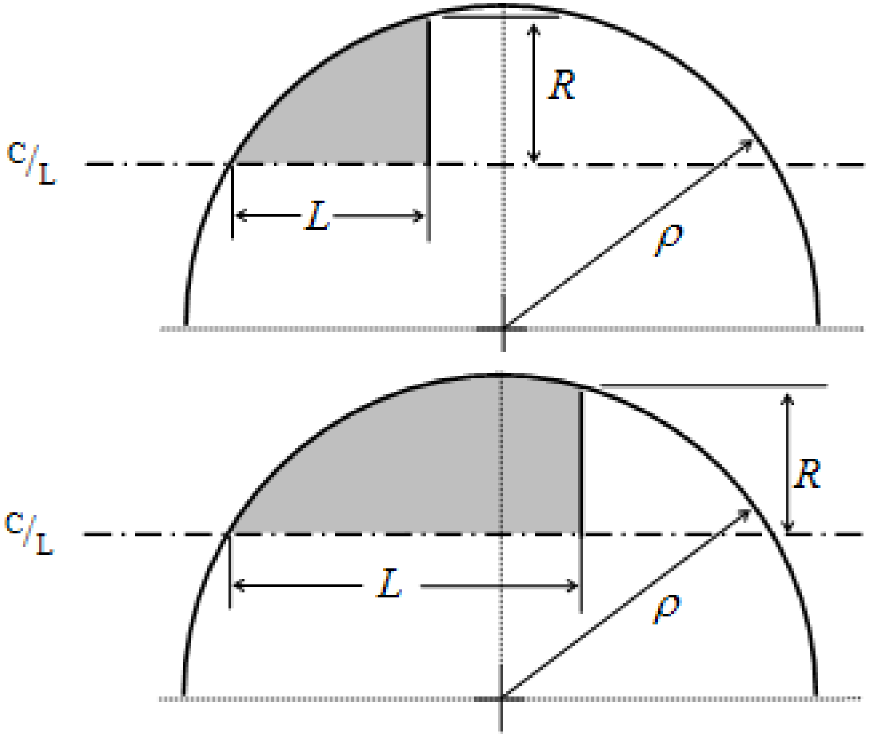
http://en.wikipedia.org/wiki/Nose_cone_design

Nose Cone Shapes

Secant Ogive:

- Case 1: $\rho > \frac{R^2 + L^2}{2R}$

- Case 2: $L/2 < \rho < \frac{R^2 + L}{2R}$



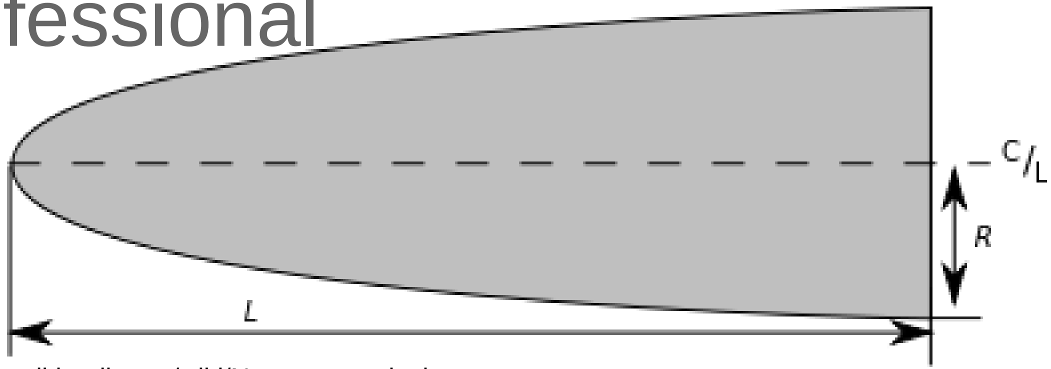
http://en.wikipedia.org/wiki/Nose_cone_design

Nose Cone Shapes

Elliptical:

- Major axis: Centerline
- Minor axis: Base
- Not found in professional rocketry

$$y = R\sqrt{1 - \frac{x^2}{L^2}}$$



http://en.wikipedia.org/wiki/Nose_cone_design

Nose Cone Shapes

Parabolic:

For $0 \leq K' \leq 1 : y = R\left(\frac{2\left(\frac{x}{L}\right) - K'\left(\frac{x}{L}\right)^2}{2 - K'}\right)$

- K' can vary between 0 and 1
  - K' = 0 for a cone
  - K' = 0.5 for a ½ parabola
  - K' = 0.75 for a ¾ parabola
  - K' = 1 for a full parabola
- If K' = 1, then nose cone is tangent to body at base
- Commonly confused with elliptical shape

http://en.wikipedia.org/wiki/Nose_cone_design

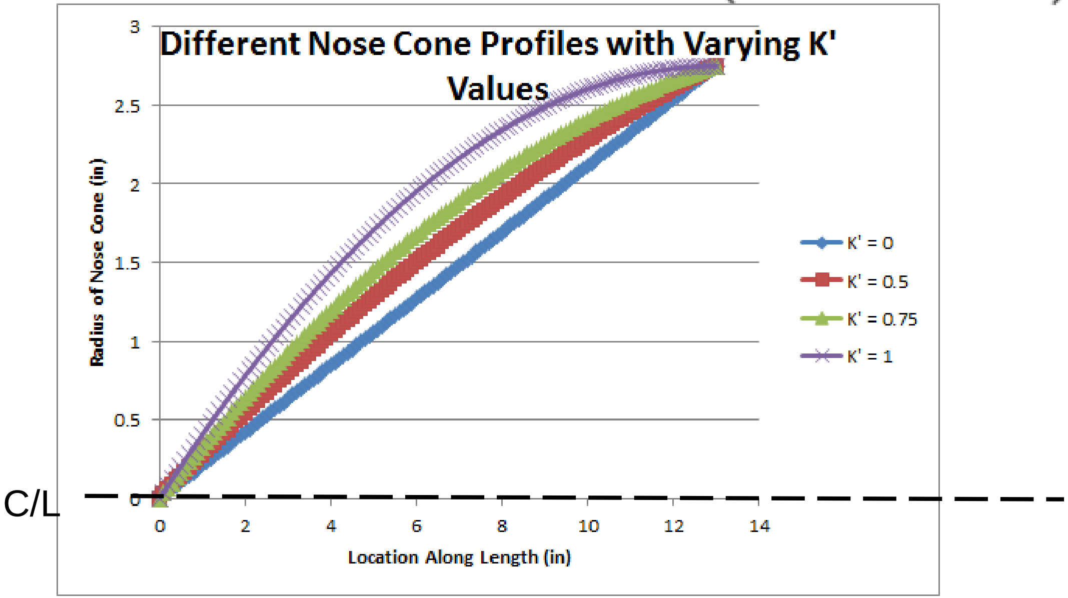
Nose Cone Shapes

Parabolic:

For $0 \leq K' \leq 1 : y = R\left(\frac{2(\frac{x}{L}) - K'(\frac{x}{L})^2}{2 - K'}\right)$

L = 13 in

R = 2.75 in



Nose Cone Shapes

Power Series

- Usually blunt tip
- Always discontinuity at joint

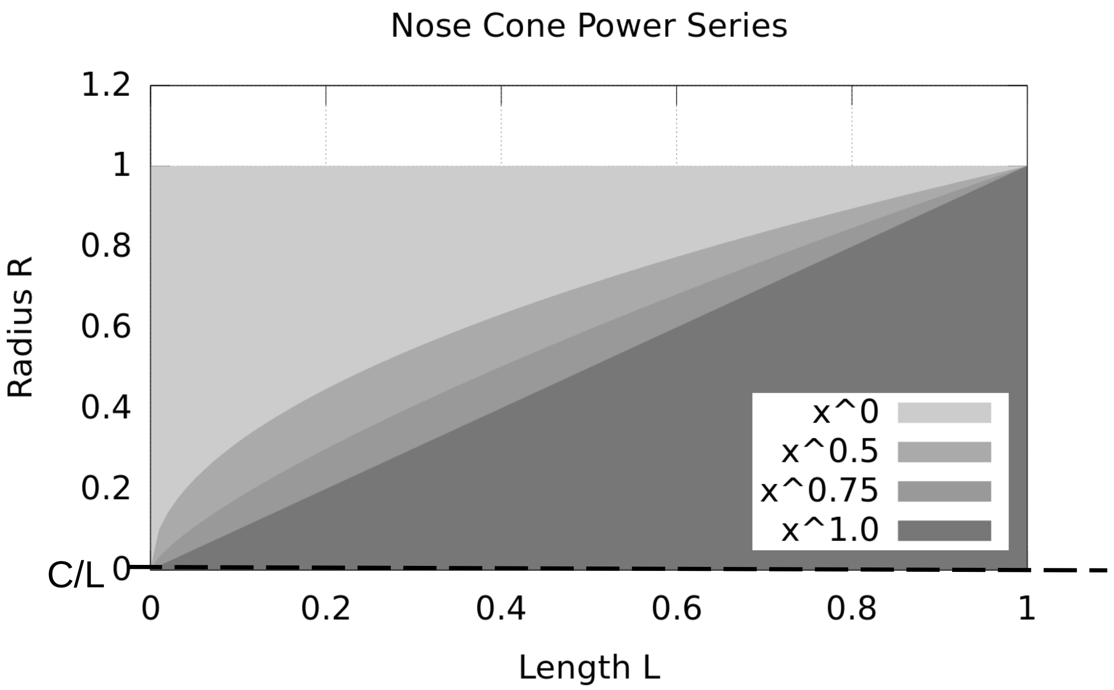
For $0 \leq n \leq 1 : y = R\left(\frac{x}{L}\right)^n$

n = 1 for a cone

n = 0.75 for a 3/4 power

n = 0.5 for a 1/2 power (parabola)

n = 0 for a cylinder



http://en.wikipedia.org/wiki/Nose_cone_design

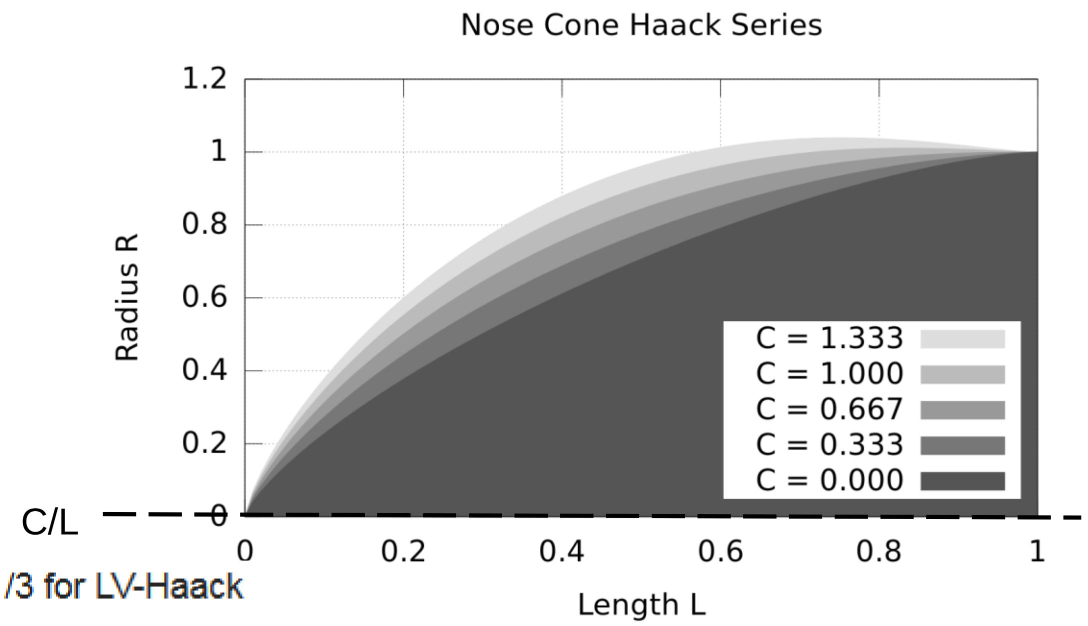
Nose Cone Shapes

Haack Series

- Mathematically derived
- Minimize drag
- Two Cases:
  - Given L,D
  - Given L,V

$$\theta = \arccos\left(1 - \frac{2x}{L}\right)$$

$$y = \frac{R}{\sqrt{\pi}}\sqrt{\theta - \frac{\sin(2\theta)}{2} + C\sin^3\theta}$$



C = 1/3 for LV-Haack

C = 0 for LD-Haack

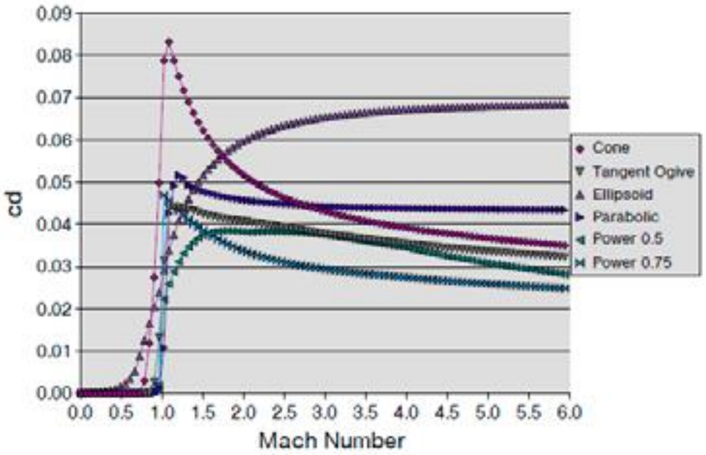
http://en.wikipedia.org/wiki/Nose_cone_design

Nose Cone Shapes

Our Rocket: Mach 1.4 (1600 ft/s) - Rocksim

Drag Coefficients of Different Shapes:

- At Mach 1.4, power series and tangent ogive are optimal
- Study done for Sugar Shot to Space



https://www.apogeerockets.com/education/downloads/Newsletter376.pdf

Nose Cone Shapes

Metrics:

	Drag Coefficient	Requires Machining	Tangent at Base?	Used in Amateur Rocketry?	Used in Supersonic Flight?	Integration into System	Results
Power Series	+ (GREAT)	- (YES)	- (NO)	+ (YES)	+ (YES)	+ (EASY)	+2
Tangent Ogive	0 (MID)	+ (NO)	+ (YES)	+ (YES)	+ (YES)	+ (EASY)	+5

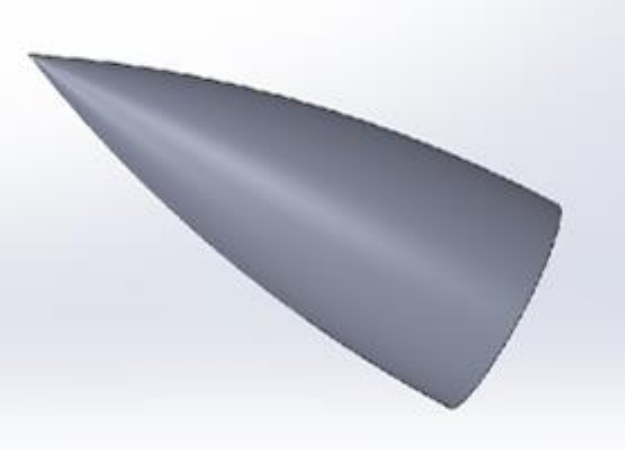
Nose Cone

Decision: Tangent Ogive

Solidworks Model:

L = 13 in

D = 5.5 in



Nose Cone

Decision: Tangent Ogive

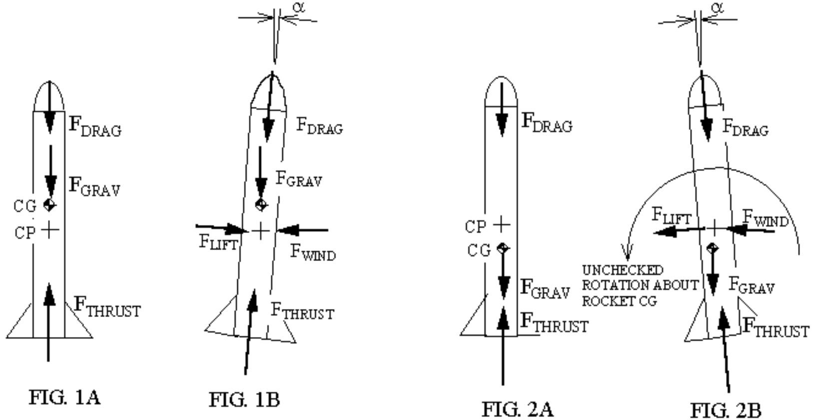
Solution: Always Ready Rocketry

- Precision-molded plastic nose cones
- Length = 13 inches
- Diameter = 5.5 inches
- Price = $54.95

http://www.alwaysreadyrocketry.com/product/nosecones/

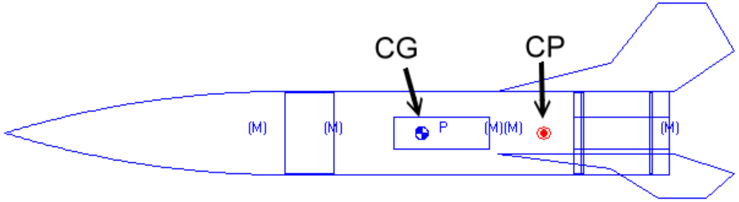
Fins

- Purpose: Provide stability during flight
  - CG: the mass balance point of the rocket
  - CP: the aerodynamic balance point
- Why CP after CG?



STABLE ROCKET -- CP AFT OF CG   UNSTABLE ROCKET -- CP AHEAD OF CG

http://www.nakka-rocketry.net/fins.html



http://www.rocketreviews.com/images/cp_cg_image.gif

Fins

- How far behind the CG should the CP be?
  - Model rockets: 1 body diameter
  - Amateur rockets: 1.5-2 body diameters
- Best shape of fins?
  - For amateur rockets, not highly important as long as
    - CP-CG relationship is maintained
    - Span is sufficient to generate a good lift force

Fins

Most common fin shapes

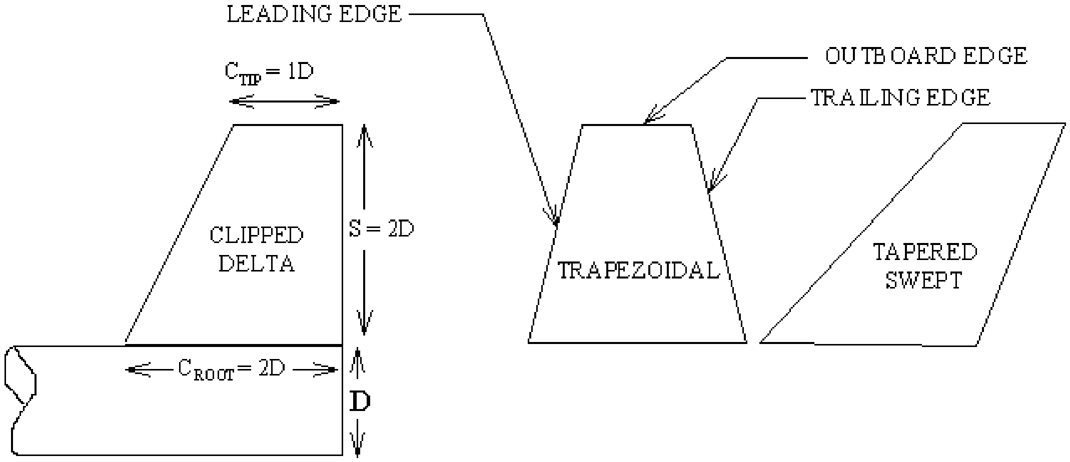
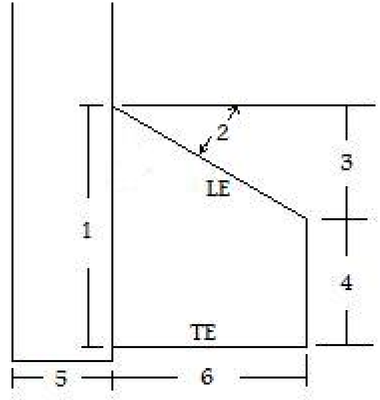


FIGURE 3 -- FIN PLANFORMS



1. Root Chord
2. Sweep Angle
3. Sweep Length
4. Tip Chord
5. Body Tube Diameter
6. Semi Span

LE Leading edge
TE Trailing Edge

http://www.nakka-rocketry.net/fins.html

Fins

Rocksim Tests

Root Chord (in.)	8	8	8	8	8	8
Tip Chord (in.)	5	5	5	5	5	5
Sweep Length (in.)	3	3	3	3	3	3
Sweep Angle (deg.)	20.6	20.6	20.6	20.6	20.6	20.6
Semi Span (in.)	5	6	7	8	9	10
Altitude (ft.)	**10205**	**10104**	**10005**	**9910**	**9819**	**9729**

Root Chord (in.)	8	8	8	8	8	8
Tip Chord (in.)	5	5	5	5	5	5
Sweep Length (in.)	1.6	2.8	4.2	6	8.6	12.87
Sweep Angle (deg.)	15	25	35	45	55	65
Semi Span (in.)	6	6	6	6	6	6
Altitude (ft.)	**10103.8**	**10103.5**	**10104.1**	**10103.7**	**10104.1**	**10104.1**

Root Chord (in.)	8	8	8	8	8	8
Tip Chord (in.)	1	2	3	4	5	5
Sweep Length (in.)	3	3	3	3	3	3
Sweep Angle (deg.)	20.6	20.6	20.6	20.6	20.6	20.6
Semi Span (in.)	6	6	6	6	6	6
Altitude (ft.)	**10177**	**10165**	**10146**	**10126**	**10104**	**10081**

Root Chord (in.)	5	6	7	8	9	10
Tip Chord (in.)	5	5	5	5	5	5
Sweep Length (in.)	3	3	3	3	3	3
Sweep Angle (deg.)	20.6	20.6	20.6	20.6	20.6	20.6
Semi Span (in.)	6	6	6	6	6	6
Altitude (ft.)	**10327**	**10252**	**10177**	**10104**	**10033**	**9963**

Fins

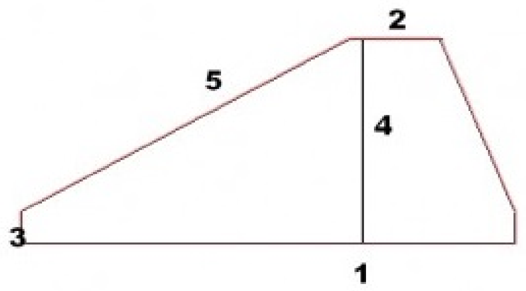
- Selecting Fins
  - Finalize Rocksim model
  - Implement Blue Tube 2.0
  - Optimize fin design
- Options
  - Manufacture
    - $10-15 for materials
    - Attachment
      - Slot
      - Mounting bracket
  - Custom Purchase

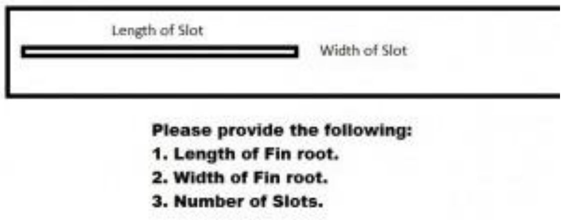
Fins

Solution:

Always Ready Rocketry

- Custom CNC Services
- $1 per fin
- $4 per slot





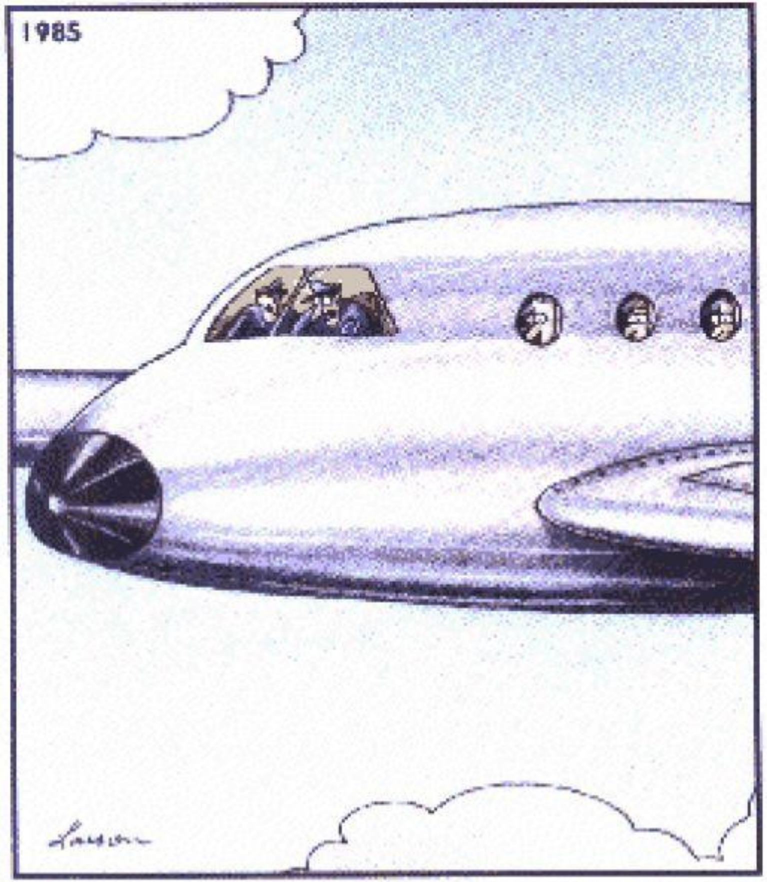
http://www.alwaysreadyrocketry.com/product/cnc-services-2/

Summary

- Fuselage
  - Blue Tube 2.0 from www.alwaysreadyrockery.com
  - 72”($89.95) + 48”($56.95) = $146.90
- Internal structures
  - Electronics Bay $54.95 from www.alwaysreadyrockery.com
  - Centering rings $7.50 from www.alwaysreadyrockery.com
  - Parachute Protector $10-$30 from www.fruitychutes.com
  - Shear Pins/Magnets $10- $15
- Nose Cone
  - Tangent ogive precision molded plastic from www.alwaysreadyrocketry.com
  - $54.95
- Fins
  - Custom made from www.alwaysreadyrocketry.com
  - 3 fins ($1) + 3 slots ($4) = $15

Next Steps

- Finalize Rocksim, Solidworks designs/simulations
- Order parts from www.alwaysreadyrocketry.com
  - (2-5 business days shipping)
- Order parts from www.fruitychutes.com
- Assemble rocket
- Test motor and recovery system
- Launch!



"The fuel light's on, Frank! We're all going to die! ... We're all going to die! ... Wait, wait ... Oh, my mistake—that's the intercom light."

Questions?

Thank You