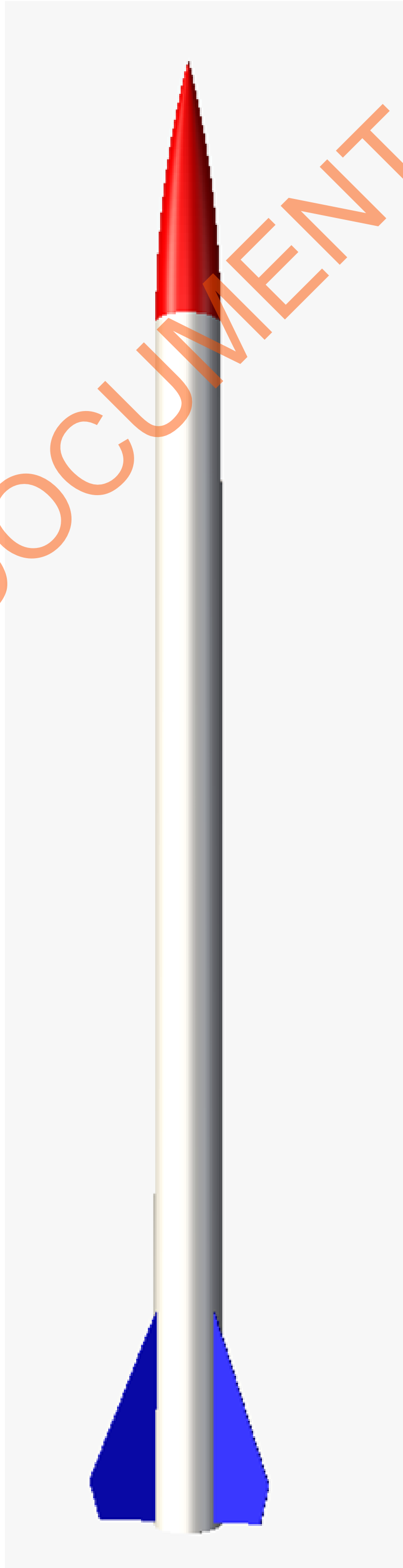
Level Three Certification

Required Documentation

Project: Aerobi 1



Prepared by:

My Name Sample
AMRS# 987654

Prepared for:

Australian Model Rocket Society Inc.
Advanced Certification Officers

Document Change Log

Revision Description	Date	Notes / Changes
First Draft	30 MAR 2011	Initial release to ACO
Second Draft	23 APR 2011	Second release to ACO. This version includes: 1. Assembly / configuration details 2. Ejection charge, shear pin, static vent sizing. 3. Avionics bay wiring plan and construction 4. Flight simulation data 5. Assembly photographs 6. Parts list 7. Pre-flight check list
Third Draft	TBD	Third release to ACO. This version to include: 1. Ejection charge, shear pin & avionics ground test results.

Table of Contents

1.0 Introduction

1.1 Purpose

The purpose of this document is to provide the technical advisory panel members of the Australian Model Rocket Society Inc. (AMRS) with the required technical details of the design, construction and preparation of a high powered rocket for flight on a level 3 class commercial motor. The main purpose of this project is for the applicant to attain level 3 certification within the AMRS.

Documents:	https://rocketry.org.au/
Images:	https://rocketry.org.au/pictures
Contact:	myname[at]rocketry.org.au

2.0 AMRS Required Content

As per the level three filing instructions on the AMRS website, the following required information has been included in this document (Table 1). In addition, supporting technical information related to the details of the analysis, simulation and testing performed is also organized into further sections of this document.

Requirement	Location
A completely filled out AMRS HPR Certification Application and Evaluation Form	Appendix A
Drawings of the rocket showing airframe components, fins, bulkheads, longerons, adhesive joints, recovery system components, payloads, etc.	Sections 4 & 6
A parts listing that includes material descriptions, adhesive types, screw sizes gauges, thickness', etc.	Sections 4 & 6, Appendix C
Schematics of recovery system electronics that show batteries, circuit designs, wiring diagrams, etc.	Section 4.3
Pre-flight checklist describing field assembly of the rocket, motor installation, recovery system preparation, launcher installation, system arming, etc	Appendix B

Table 1 - AMRS Required Content

3.0 Project Overview

3.1 Requirements

The main requirement driving the structural design of this level 3 certification rocket is the "M" impulse-class commercial rocket motors it will be propelled by. By definition an "M" motor has a total installed impulse of 5,120.01–10,240.00 N-sec (1,151.01-2,302.00 lb-sec). The average burn time for a M motor is approximately 3-5 seconds. The structure of the rocket will have to sustain a significant fraction of this force while rapidly accelerating through the atmosphere reaching speeds in excess of several hundreds of miles per hour.

3.2 Modeling & Analysis

The structural & physical aspects of this level 3 certification rocket are being designed and modeled in Open Rocket. Flight simulation and some analysis is also being accomplished in Open Rocket.

3.3 Testing

Where practical, tests are being conducted at various stages of development to verify specific areas of the design and minimize risk. Such tests are to include igniters, electric matches, ejection charge sizing, recovery harness strength, shear pin sizing, adhesives, propulsion, etc. Test results will be included in this document as results are obtained.

4.0 Design Details

Figure 1 – Aerobi 1 Open Rocket 3D View

Dry Weight	12.23 lbs / 5.55kg
Length	88.875 inches / 2.25 meters
Airframe Diameter	3.1 inches / 77 mm
Motor Mount	75 x 711 mm / 2.96 x 28 inches
Wingspan	12 inches / 304.8 mm
Configuration	"Zipper-less" - Booster / Upper Airframes
Recovery	Drogue (24") at apogee Main (84") at 1200 feet / 365 meters
Avionics	Primary/Back-up Flight Computers – (2x) Missile Works RRC2mini
Launch Platform	1515 Rail

Table 2 – Aerobi 1 Specifications

4.1 Booster Section

The booster section is comprised of the propulsion system mount, the primary stabilizing fins a section of airframe and a coupler section. Glass reinforced (2 layers of 5.8oz plane weave fiberglass cloth) phenolic convolute tubing (PML PT-3.9) was used for the airframe and motor mount tube (PML PT-3.0). Glass reinforced epoxy board (G-10/FR-4 0.093"T) was used for the fins. Aircraft grade ply-wood (0.75"T) was used for the centering rings. All structural components of the booster section were bonded using Hysol E-120 a high strength aerospace grade epoxy.

4.2 Upper Section

The upper section is comprised mainly of two glass reinforced (5.8oz plane weave) phenolic convolute tubes (PML PT-3.9) and plastic nosecone (PML PNC-3.9). The upper Section also provides the mounting location for the recovery section which includes the recovery harnesses and the avionics bay. The upper section airframe volume forward of the avionics bay is designated for the main recovery system and the area aft of the avionics bay is designated for the drogue recovery system.

4.3 Recovery Section

The recovery section is comprised of the avionics bay and the main/drogue recovery systems. The avionics bay is comprised mainly of a phenolic coupler tube (PML CT-3.9) with aircraft grade plywood and metal structural components. The avionics bay is mounted in the upper section of the rocket. It is positioned axially within the upper section to allow sufficient packing volume for the main and drogue recovery systems. The avionics bay will be secured in place within the upper section using through the way fasteners. The fasteners (Qty. 8, 10-32 x 1" SS flat head) will protrude through the outer wall of the upper airframe radially into threaded inserts in the avionics bay bulk-plates.

4.3.1 Avionics

Two dual-deployment Missile Works RRC2 flight computers will be employed to monitor the flight and control the recovery system of the Aerobi 1. Two flight computers are employed for full redundancy.

One of the flight computers will act as the primary system for initiating recovery events, while the second system will act as a fully redundant back-up. The back-up system will be a complete and fully redundant set of hardware. No electrical connections or other components will be shared with the primary system. All wiring conductors (except for the e-match's) will be rated to a minimum of 2x the maximum expected peak operating current (50% de-rated). Conductor insulation will be PTFE (or equivalent). Stranded conductors will be used throughout (except where it is not practical; i.e. e-match's). Splicing as a rule will not be allowed unless absolutely necessary. Insulated terminal ferrules will be used at all terminal blocks to ensure reliable mechanical and electrical connections. All conductors/bundles will be strain relieved and minimum bend radii will not be compromised.

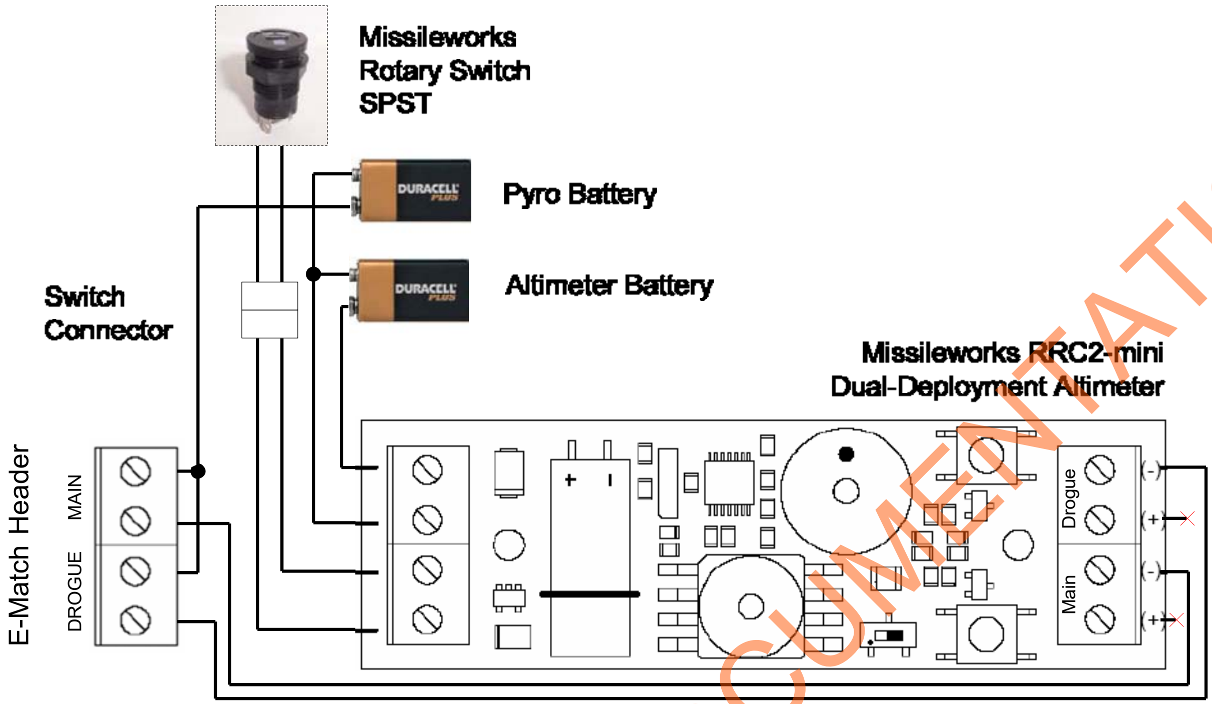


Figure 2 – Aerobi 1 Avionics Detail (single system shown)

As shown in Figure 9, the Missileworks RRC2-mini dual-deployment altimeters will be wired with the addition of an header to facilitate a centralized point for terminating e-matches. The arming switch was also made removable by employing a 4-pin Molex connector pair. Assembly images of the avionics bay and wiring configuration can be seen in the construction section of this document.

4.3.2 Parachute Deployment

At apogee or the highest point in flight, the avionics will initiate a pyrotechnic charge that will over-pressurize the lower portion of the upper airframe, causing the drogue recovery system and booster section to be ejected. The purpose of the drogue parachute is to control the initial descent phase of the rocket. The drogue will not allow the rocket to land safely, it will instead serve the purpose of controlling the rate of descent while minimizing the amount of drift the rocket might experience before the main parachute is deployed. At a pre-determined altitude a second pyrotechnic charge will over-pressurize the upper portion of the upper airframe causing the main recovery system and nose cone to be ejected. The main parachute is much larger and sized appropriately to allow the rocket to land safely.

Figure 3 - Kevlar parachute protector from Giant Leap Rocketry

Figure 4 - Kevlar shock-cord protector from Giant Leap Rocketry

The selection of the drogue parachute used for recovery (or lack thereof) will be determined at the field during launch preparations. Weather conditions will ultimately dictate the size (or need) of the drogue parachute. In the event of high wind conditions, the drogue parachute may not be employed at all.

The target descent rate for the rocket under the main parachute is 15±3 feet per second (10.x miles per hour). Simulations were run in Open Rocket, see Table 4 for an array of descent rates for different weights and parachute sizes.

4.3.3 Harness Design

The recovery harness can be broken down into two sections: main and drogue. Both harnesses will be manufactured essentially the same; only the length of the harnesses and location of where components attach will differ. Each harness is comprised mainly of 9/16" [14.3mm] width tubular nylon that has a working tensile strength 2000 pounds. Either end of the harness is terminated the airframe bulk-plates using 3/16" [5mm] quick-link removable links which are rated to 900lbf [4400N] of working-load. The tubular nylon is tied onto each removable link using a figure-eight knot with the loose end terminated by nylon stitching. The length of the tubular nylon harness closest to the hot gasses from the ejection charges will be protected with a Kevlar over-wrap (Figure 15). Flame-retardant blankets will also be employed to protect the rest of the recovery system (Figure 14).

The parachutes are strategically attached to the recovery harness to ensure the highest probability of a successful recovery. The drogue parachute (if used) will be attached approximately 3ft [0.91m] away from the end of the upper airframe. The main parachute and recovery harness will be attached to the nose-cone directly.

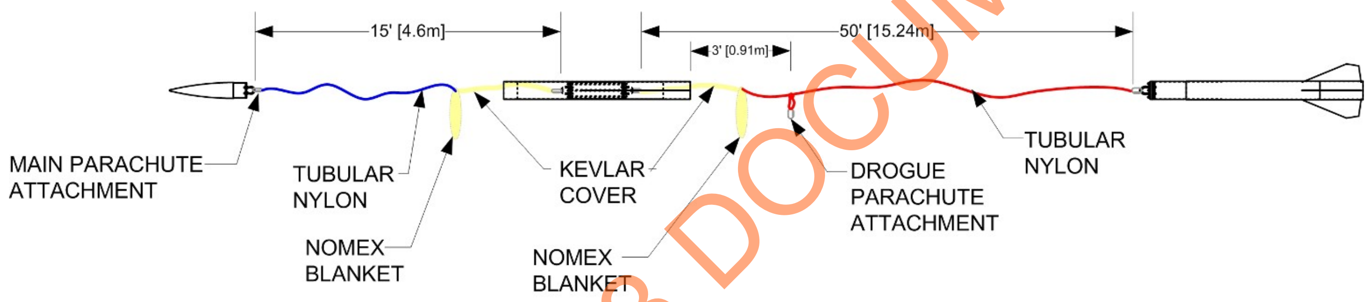


Figure 5 – Aerobi 1 Recovery System Overview

4.3.4 Ejection Charge Sizing

Black powder (Goex 4F) will be used for airframe separation at apogee and the main-deployment altitude. The respective compartments of the upper section that holds the main and drogue recovery systems differ in length (volume). The main recovery system compartment is 20 inches [508mm] long while the drogue recovery system compartment is 12 inches [304.8mm] in length. Chuck Pierce's calculator was used to determine the appropriate amount of black-powder. The results are shown below in Figure 17. Testing will be conducted on the fully assembled airframe sections to confirm these calculations.

Black Powder Ejection Charge Calculator						
by Chuck Pierce						
© 2001 All Rights Reserved						
Volume =	238.9	in^3		4Fg Black Powder Gas Properties		
Dia =	3.9	inch		R =	22.16	ft*lbf/lbm/R
Lengh =	20	inch		Tc =	3307	R
				Conversions:	1 lbm = 454 grams	
					1 oz = 28.3 grams	
Calculation Mass of Black Powder for a desired Ejection Pressure						
Desired Pressure =	14	psi				
mass BP =	1.73	grams		m=PV/R/T		
Ejection F =	167.2	lbf		F=P*(pi/4)*d^2		

Black Powder Ejection Charge Calculator						
by Chuck Pierce						
© 2001 All Rights Reserved						
Volume =	143.4	in^3		4Fg Black Powder Gas Properties		
Dia =	3.9	inch		R =	22.16	ft*lbf/lbm/R
Lengh =	12	inch		Tc =	3307	R
				Conversions:	1 lbm = 454 grams	
					1 oz = 28.3 grams	
Calculation Mass of Black Powder for a desired Ejection Pressure						
Desired Pressure =	14	psi				
mass BP =	1.04	grams		m=PV/R/T		
Ejection F =	167.2	lbf		F=P*(pi/4)*d^2		

Figure 6 - Ejection Charge Calculations (Courtesy of Chuck Pierce)

4.3.5 Shear Pin Sizing

Shear pins are being employed to mitigate against inadvertent and untimely airframe separations. By design the nosecone is removable from the upper airframe and the upper airframe is removable from the booster airframe. Shear pins (sacrificial nylon screws) will be installed to securely fasten the nose cone and airframe sections together. The pins will be installed such that they protrude through the outer airframe radially and into the shoulder of the nose cone or booster bulk-plate. The shear pins are effectively fastening the respective sections of the rocket together to prevent them from coming apart. With proper design the pins will only see shear loads. The minimum load requirement is defined as the weight of the section(s) of the rocket below the pins if the rocket were suspended vertically from the nose tip. The maximum load is derived from the amount of force the ejection charges can safely exert to ensure shearing of the pins (air frame separation) without otherwise damaging the rocket. The size and selection of the pins was determined as per the method described by Bob Feretich (see reference 1).

Figure 7 – Example of Nylon machine screws to be used are shear pins

A total quantity of four (4) #2-56 x 0.75" long Nylon screws will be used as the shear pins. Each pin should provide a minimum of 31lbf and maximum of 46 lbf of shear resistance, for a total range of 61-92 lbf. The ejection charge should provide 14 psi or 167lbf of total force on the bulk-plates at separation (181% of maximum force to shear). Four (4) Nylon screws will be installed in the upper section of the Aerobi 1: two (2) to fasten the nose cone and two (2) to fasten the booster section. The screws will be spaced radially 180° apart. Only the airframe will be threaded and they will fit into blind minimum clearance holes in the bulk-plates or nose cone shoulder.

4.3.6 Altimeter Static Port Sizing

The flight computers will rely primarily on barometric pressure sensors for altitude determination. To ensure reliable pressure reading the volume surrounding the sensors must have a low resistance path to the atmosphere. Holes will be drilled through the outer airframe of the upper section and through the wall of the recovery section to create adequate pressure equilibrium. The sizes and location of the static ports were determined by two different methods and compared for verification as well as good practice. The first method used the flight computer manufacturer (Missile Works) guidelines, see Figure 19. The second method was done using a table provided by Vern Knowles (see reference 2). Four (4) 0.125” diameter holes were drilled through the airframe and into the avionics bay.

$$V_{AvionicsBay} = L_{AvionicsBay}\,\pi\left(\frac{ID_{AvionicsBay}}{2}\right)^2$$

$$D_{SingleVent} = 2\sqrt{\frac{V_{AvionicsBay}}{6739.71}}$$

$$A_{SingleVent} = \pi\left(\frac{D_{SingleVent}}{2}\right)^2$$

$$D_{VentHoles} = 2\sqrt{\left(\frac{A_{SingleVent}}{n_{VentHoles}}/\pi\right)}$$

$$ID_{AvionicsBay} = 3.9[inches]$$

$$L_{AvionicsBay} = 7.00[inches]$$

$$n_{VentHoles} = 4$$

$$D_{VentHoles} = 0.114[inches]$$

Figure 8 - Vent Hole Calculation (as per Missile Works RRC2-Mini_Rev1-2_manual_formad.pdf

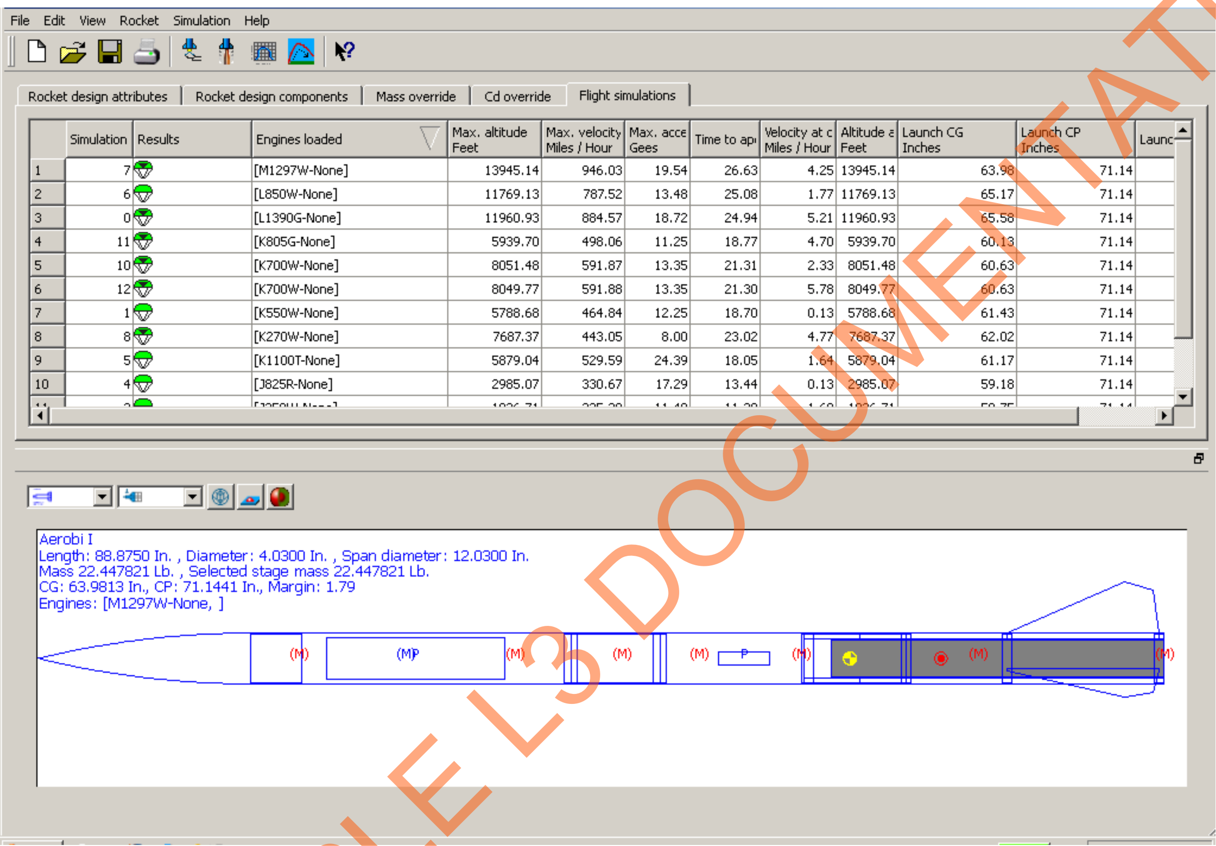
	Drill Size for 4 Pressure Port Holes					
Body Tube Inside Diameter	**3/32**	**1/8**	**5/32**	**3/16**	**7/32**	**1/4**
1.145	54.63	97.12	151.75	218.52	297.42	388.47
1.525	30.80	54.75	85.54	123.18	167.67	218.99
2.152	15.46	27.49	42.96	61.86	84.20	109.97
2.560	10.93	19.43	30.36	43.71	59.50	77.71
3.002	7.95	14.13	22.08	31.79	43.27	56.51
3.900	4.71	8.37	13.08	18.83	25.64	33.48
5.375	2.48	4.41	6.89	9.92	13.50	17.63
7.512	1.27	2.26	3.53	5.08	6.91	9.03
11.410	0.55	0.98	1.53	2.20	3.00	3.91
	Maximum compartment length in inches					

Figure 9 - Altimeter Static Port Sizing (Courtesy of Vern Knowles)

5.0 Simulation & Analysis

5.1 Flight Analysis

Open Rocket is being used to asses the stability and aid in the design of the Aerobi 1. Some preliminary results can be found in Figure 3 and on the following page.



	Simulation	Results	Engines loaded	Max. altitude Feet	Max. velocity Miles / Hour	Max. acce Gees	Time to ap	Velocity at c Miles / Hour	Altitude a Feet	Launch CG Inches	Launch CP Inches	Launc
1	7		[M1297W-None]	13945.14	946.03	19.54	26.63	4.25	13945.14	63.98	71.14	
2	6		[L850W-None]	11769.13	787.52	13.48	25.08	1.77	11769.13	65.17	71.14	
3	0		[L1390G-None]	11960.93	884.57	18.72	24.94	5.21	11960.93	65.58	71.14	
4	11		[K805G-None]	5939.70	498.06	11.25	18.77	4.70	5939.70	60.13	71.14	
5	10		[K700W-None]	8051.48	591.87	13.35	21.31	2.33	8051.48	60.63	71.14	
6	12		[K700W-None]	8049.77	591.88	13.35	21.30	5.78	8049.77	60.63	71.14	
7	1		[K550W-None]	5788.68	464.84	12.25	18.70	0.13	5788.68	61.43	71.14	
8	8		[K270W-None]	7687.37	443.05	8.00	23.02	4.77	7687.37	62.02	71.14	
9	5		[K1100T-None]	5879.04	529.59	24.39	18.05	1.64	5879.04	61.17	71.14	
10	4		[J825R-None]	2985.07	330.67	17.29	13.44	0.13	2985.07	59.18	71.14	

Figure 10 - Flight Simulation Results

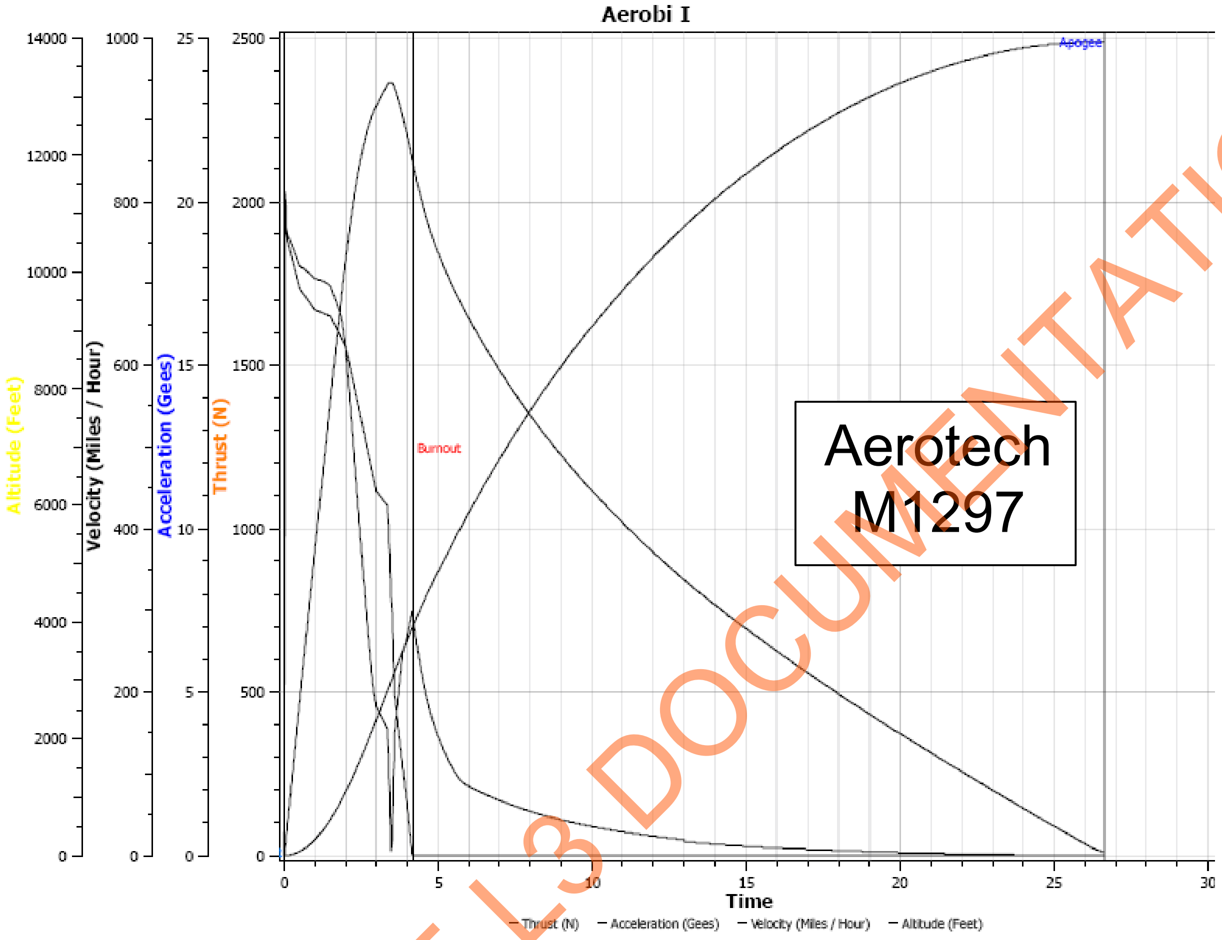


Figure 11 - Aerotech M1297 Flight Data

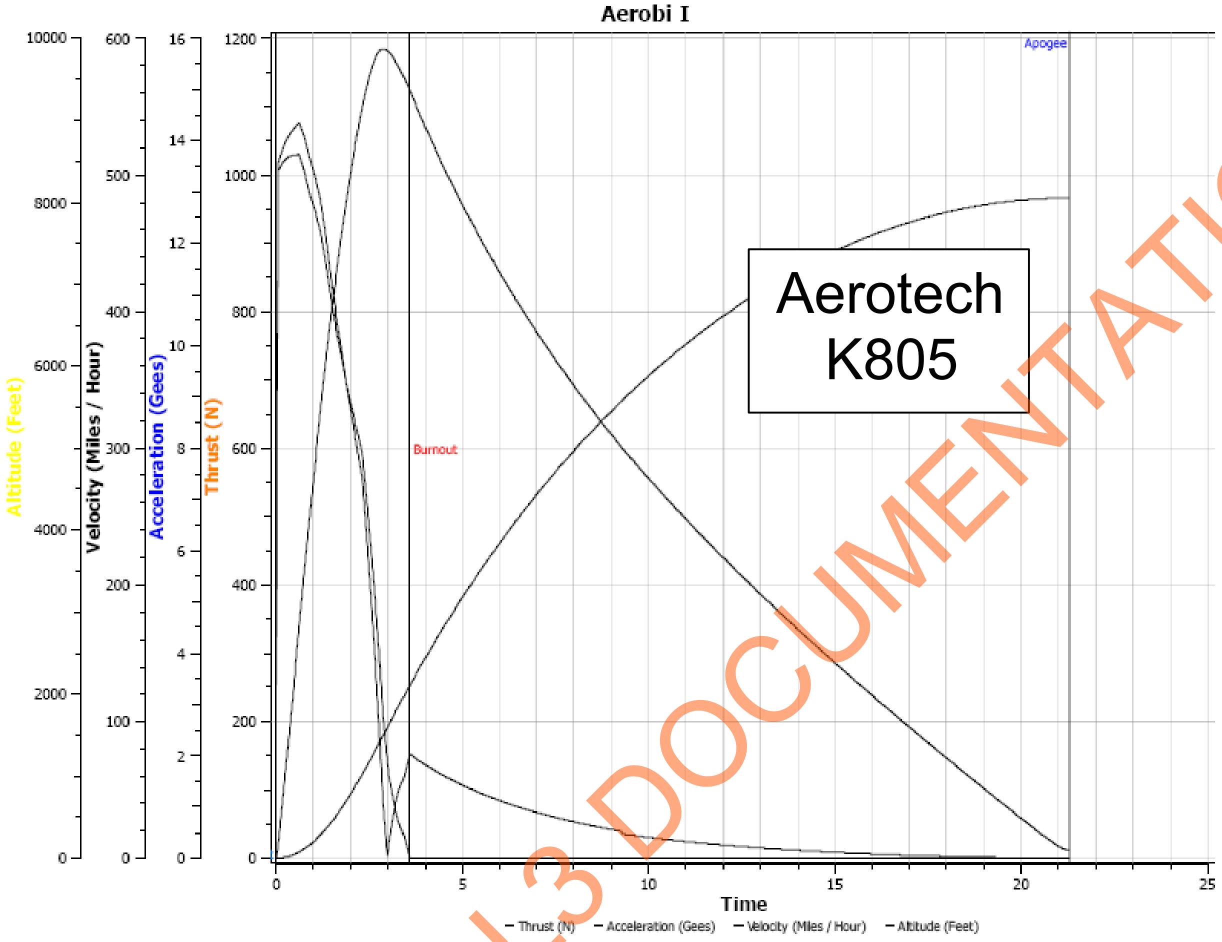


Figure 12 – Aerotech K805 Flight Data

6.0 Construction Details

6.1 Booster Section

Figure 13 - Booster Section Dry-Fit

Figure 14 - Booster Section Dry-Fit Complete

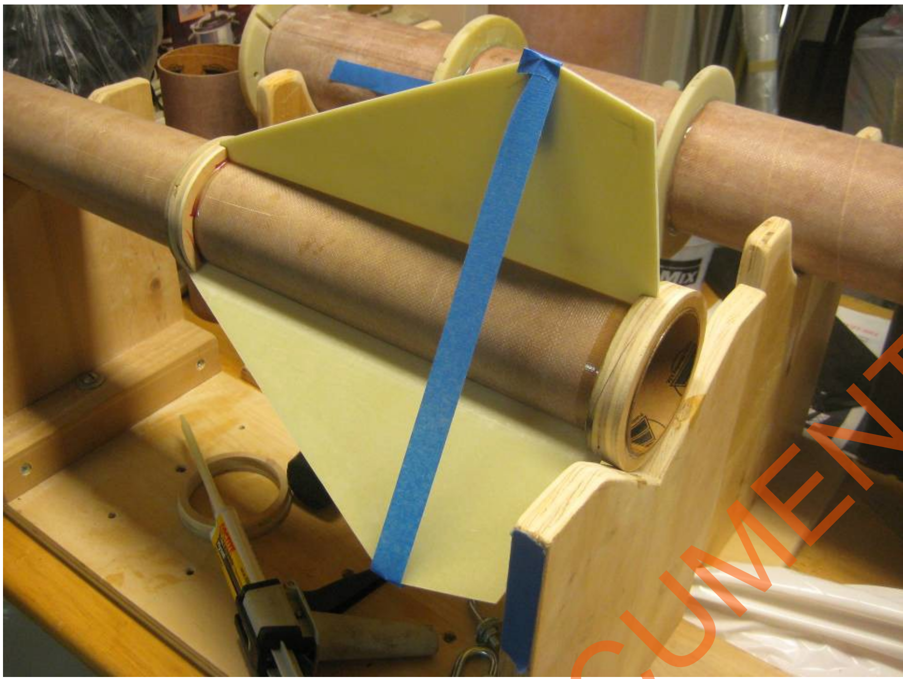


Figure 15 – Tacking the fins in place.

Figure 16 – Structural epoxy fillets.

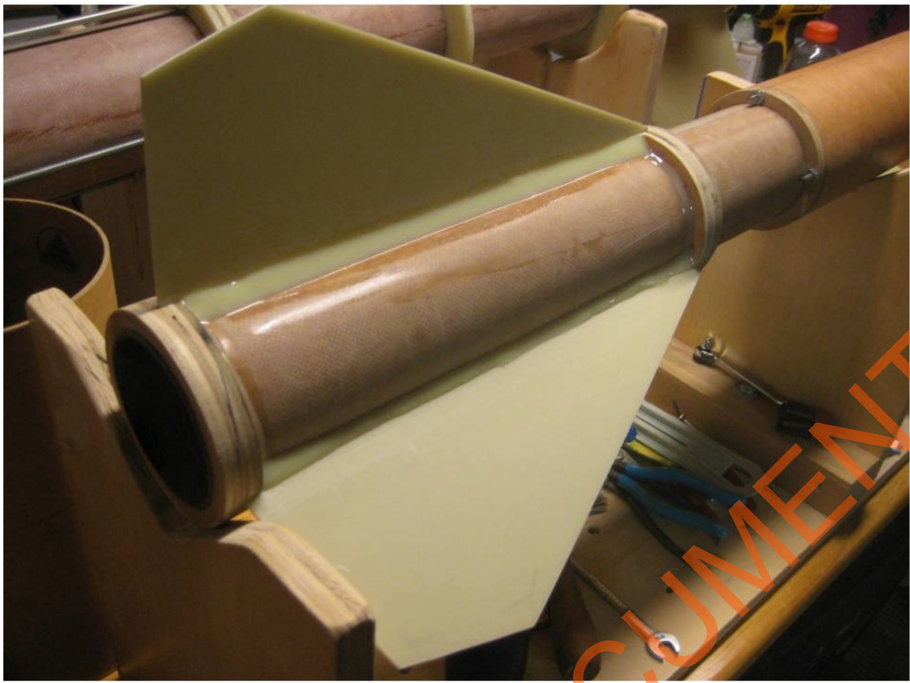


Figure 17- Structural epoxy fillets.

Figure 18- Fin-can forward centering ring epoxy fillet

Figure 19 – Booster airframe ready to be installed.

Figure 20 – Booster airframe installed and clamped.

Figure 21 – West System epoxy and colloidal silica used for external fillets.

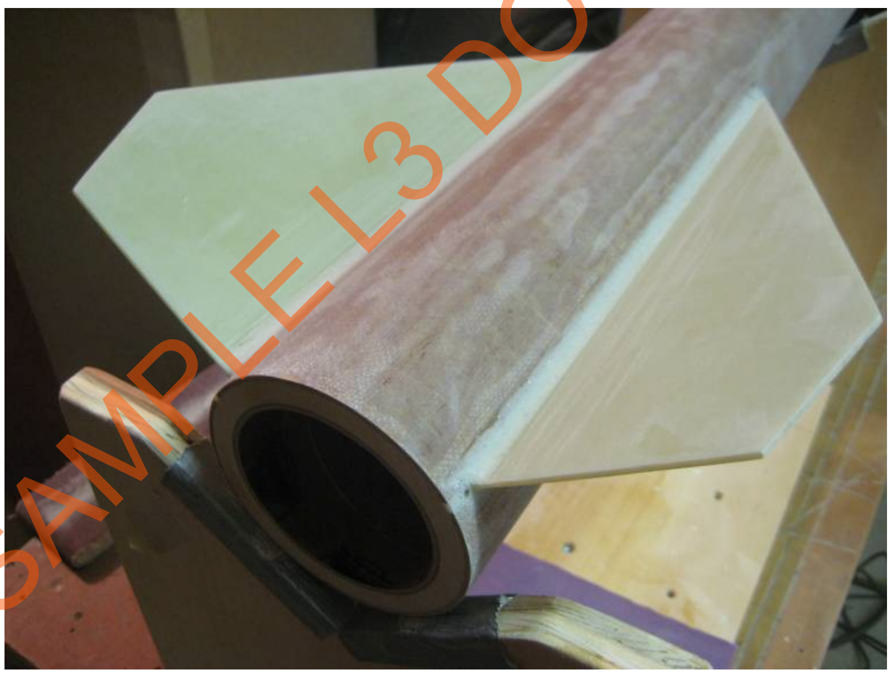


Figure 22 – Finished external fillets.

Figure 23 – Bondo applied to fill and finish external fillets

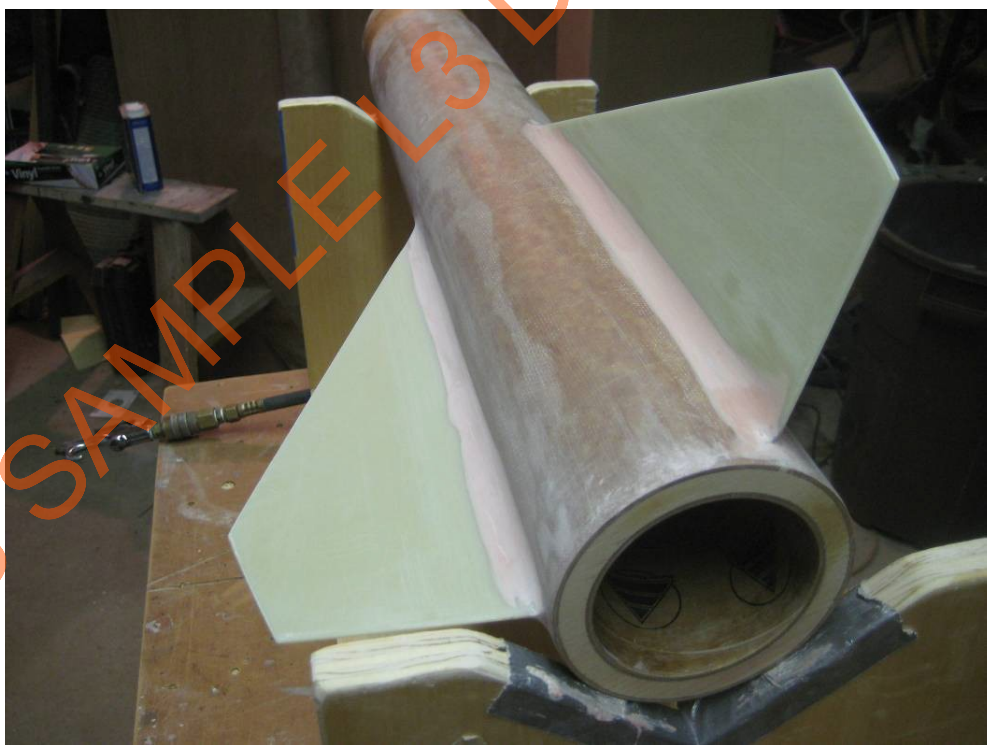


Figure 24 – Filled and sanded external fillets.

6.1.1 Centering Rings & Bulkhead Machining

All centering rings and bulkheads blanks were cut from ¾" thick 7-plywood. A drill press and adjusted circle cutting tool was used. Slots were added using a radial-arm circular saw.

Figure 25 - Centering ring fabrication

Figure 26 - Centering ring fin-slots

6.1.2 Fin Machining

The primary (booster airframe) and secondary (booster/upper airframe) fins are being machined out of stock 0.093” thick G-10/FR-4. Cardboard mock-ups were cut and attached to the airframe to asses aesthetics and aid in the final design.

The fins were machined using a carbide 0.125” diameter cutter router bit at a spindle speed of 30,000 RPM. After all the fins were rough-cut from the material, they were clamped together and ground down using a belt sander with a coarse 80-grit belt. Once ground alike, all surfaces were then sanded using an orbital palm sander with 150-grit paper.

Figure 27 - Fin machining preparation

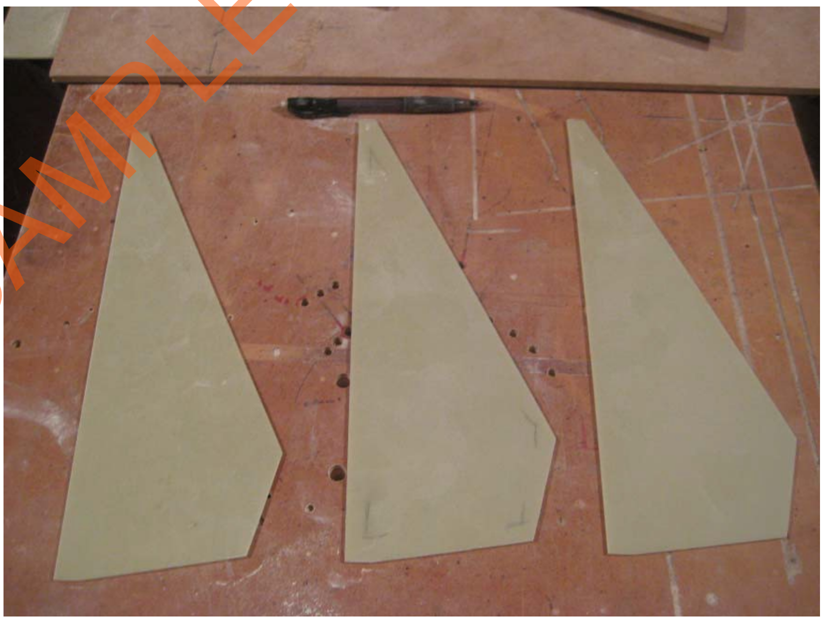


Figure 28 - Fins after routing and sanding

6.1.3 Airframe Preparation

Two 48" sections of PML-3.90 phenolic convolute airframe tubing have been reinforced with two layers of 5.8oz CST plain weave fiberglass cloth and West System 105/209 epoxy. The reinforced airframes were rough sanded using 150/220 grit aluminum oxide sand paper before a final coat of West System 105/209 w/ 407 low-density surface filling silica was applied for finishing. The booster airframe has been cut to length. Both airframes are ready further machined. Slots will be added for through-the-wall fin attachment, and several holes will be drilled for fasteners, venting, avionics access, etc.

Figure 29 - Airframe fiber-glass preparation.

Figure 30 - Completed components

6.1.4 Recovery System Anchor

Steel u-bolt's are being employed to form the recovery system anchor points. There are a total of four anchor points in the design: nose-cone, avionics bay forward, avionics bay aft and booster section. The steel u-bolts are rated to a working load of 1200lbs and will be each be fastened with four 1/4-20 nuts and Loctite thread locking adhesive.

6.1.5 Rail Guides

Standard 1515 rail buttons are being used. One is fastened into the aft most centering ring using a 1/4-20 threaded insert & fastener. The other is fastened into the upper airframe just forward of the CG using a ¼-20 fastener and backing plate.

6.1.6 Adhesives

Loctite® Hysol E-120 is being evaluated for the application of bonding the structural components of the booster section. Hysol E-120 is a high viscosity, non-sagging industrial grade epoxy with extended working life. Results are pending.

Figure 31 - Loctite Hysol E-120HP

6.2 *Upper Section*

6.2.1 Nose Cone

The PML PNC-3.9 plastic nose cone has been rough sanded using 220 grit aluminum oxide sandpaper and filled using West System 105/209 epoxy w/ 407 low-density surface filing silica. The very bottom of the nose cone shoulder was removed to install a bulk-plate with a u-bolt as a recovery anchor. The bulk-plate will also serve to mount future payloads in the empty nose cone volume.

6.2.2 Airframe

See Booster Airframe Section 6.1.3.

6.3 *Recovery Section*

6.3.1 Avionics Bay

Figure 32 - Avionics bay forward/aft bulk-plates

Figure 33 - Avionics bay bulk-plate installed

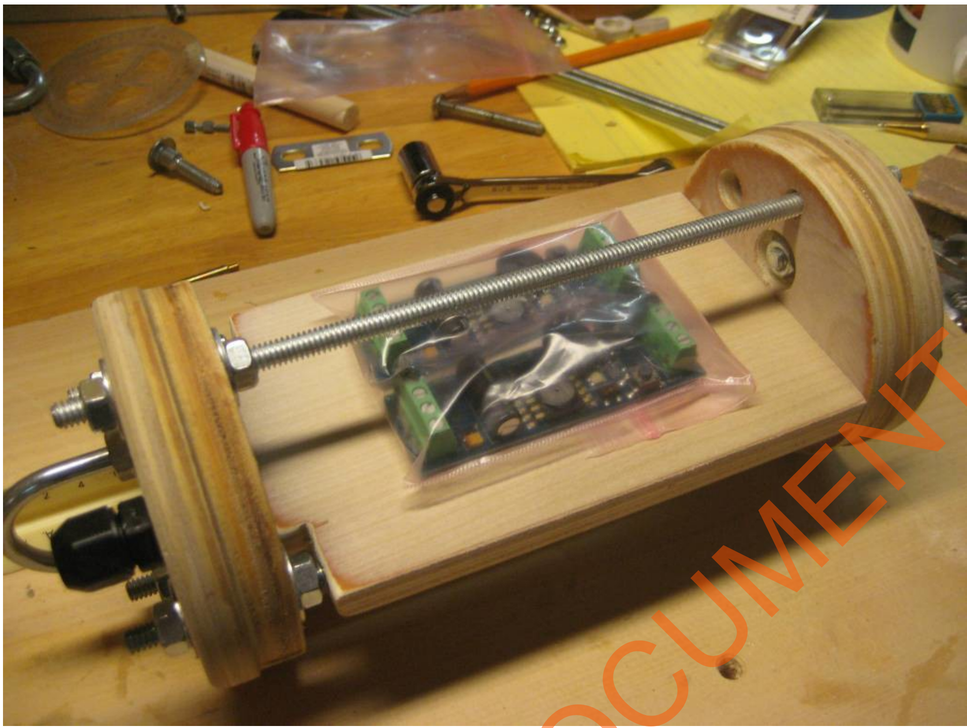


Figure 34 – Initial layout of Missileworks altimeters

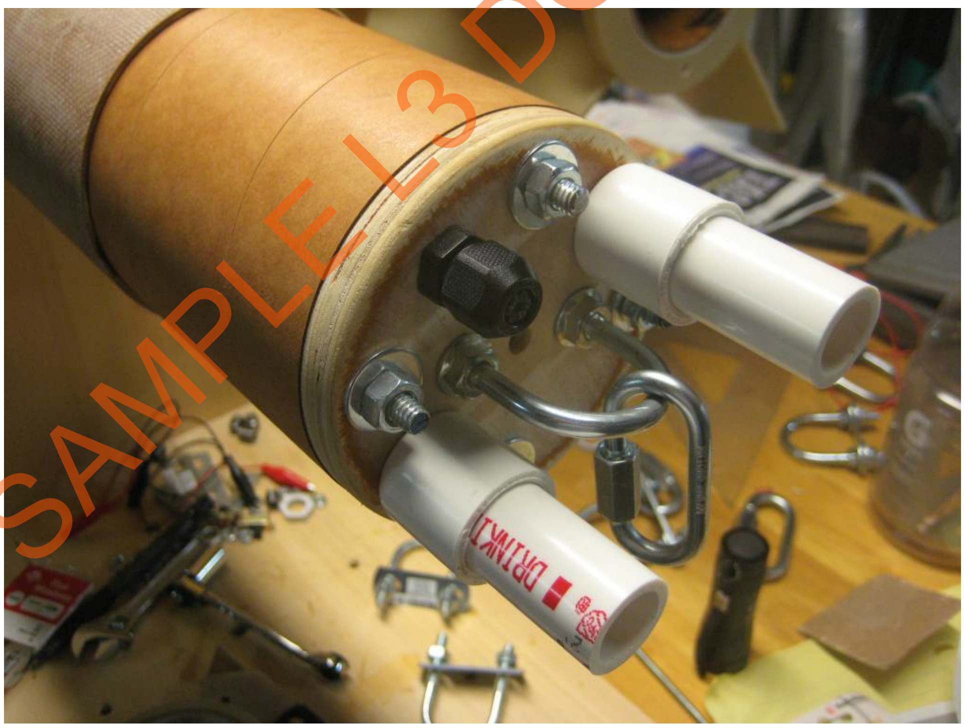


Figure 35 - Avionics bay bulk-plate fully populated.

7.0 Final Assembly

Figure 36 – Ready to check aboard flight to Western Australia

Figure 37 – 54/1706 casing shown for scale.

8.0 Testing

8.1 Ejection Charge & Shear Pin Tests

As of the date of the release of this document, this test has not yet been conducted.

8.2 Avionics

The avionics were powered up and software verified using e-matches. The wiring was verified to be correct. Full-functional tests will be conducted using black-powder charges for the ejection sizing & shear pin verification.

9.0 Ground Support Equipment

9.1 Launch Rail

A rail system will be used to support and guide the Aerobi 1 during the initial portion of it's flight. The lift-off weight of the rocket will be approximately 23lbs. The rail will either be of the uni-strut or structural extrusion type. In either case the rail will be approximately 11 ft long. Matching "rail buttons" will be fastened to the booster section of the airframe.

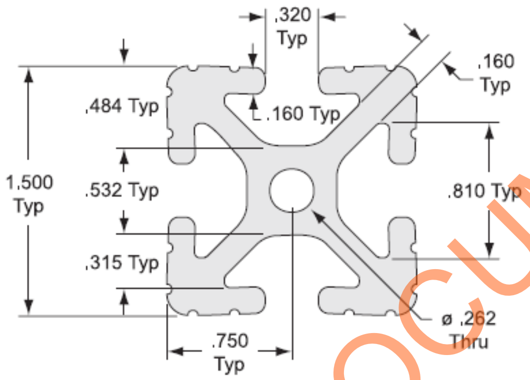


Figure 38 - Standard 1.5" Extruded Aluminum Channel

10.0 References

1. http://www.aeroconsystems.com/tips/Ejection_ChargeCalc.xls
2. http://www.feretich.com/Rocketry/Resources/shearPins.html
3. http://www.vernk.com/AltimeterPortSizing.htm

Appendix

Appendix A. AMRS HPR Certification Application and Evaluation Form (requirement)

Australian Model Rocket Society Inc.
PO Box 1233, Browns Plains, QLD 4118
www.rocketry.org.au
ARBN 165 666 357

AMRS HPR Certification Application and Evaluation Form

Flyer name: ______________________ Club name: ______________

Contact Email: ______________________ Contact Phone: ____________

Rocket name: ______________ AMRS/Club #: ________ Cert attempt: 1☐ 2☐ 3☐

Length: ________ Diameter: ________ GLOW: ________ CP: ________

Motor (Manufacturer/designation): __________ Altitude: ________ CG: ________

Electronics (If applicable): ______________________________________

Recovery: ____

Other Comments: ____

Please confirm each item below, sign and date

☐ I built this rocket myself (either from a kit or from parts)

☐ I prepared this rocket for flight myself

☐ I assembled the motors myself

☐ (For L3 only) I have flown a J/K/L motor with successful electronic deployment for recovery

☐ I am a current member of the AMRS

Flyer's signature: ______________________ Date: _____/____/________

The following is to be completed by an AMRS CO/ACO ONLY

For L2 Certification:
L2 exam score: ____/50 Examiners signature: ______________ Online: Y / N Date:___/___/______

For L3 Certification: Design and documentation for this L3 project has been reviewed and found satisfactory
ACO #1 Signature: ______________________ AMRS#:________ Date:___/___/______
ACO #2 Signature: ______________________ AMRS#:________ Date:___/___/______

For ALL Certifications: Flight result: Successful ☐ Unsuccessful ☐
Launch location: ____
Comments (if flight was unsuccessful, give the reason(s): ____________________________
____

Witnessing CO/ACO Signature: __________________ AMRS#:________ Date:___/___/______

AFOR-001 HPR Certification Application Form (Rev 1.1) 26 August 2015 Page 1 of 1

Appendix B. Pre-Flight Checklist (requirement)

Pre-Flight Check List (abbreviated version)

Avionics Bay Preparation & Installation

STEP 1. Test batteries & install into avionics bay.

STEP 2. Program or verify that the Missile Works RRC2-mini altimeters are set to the following (actual program values shown in brackets [ ]).

Parameter	Primary Altimeter	Back-up Altimeter
Main AGL	1200 feet [12]	1000 feet [10]
Mach Inhibit Delay	7 seconds [7]	7 seconds [7]
Drogue Delay	0 seconds [16]	1 seconds [1]
Main Delay	0 seconds [16]	0 seconds [16]
Deployment Mode	Mode 1 [1]	Mode 1 [1]
Operations Mode	See Manual [14]	See Manual [15]

STEP 3. Prepare ejection charges.

STEP 4. Install the forward end of avionics bay in the upper section of the upper-airframe (main parachute bay).

Main Recovery System Preparation & Installation

STEP 5. Attach one end of the main recovery harness to the u-bolt on the forward end of the avionics bay.

STEP 6. Install the main recovery harness into the airframe.

STEP 7. Attach the deployment bag to the top of the main parachute and pack the main parachute into the deployment bag.

STEP 8. Install the packed deployment bag into the airframe. The parachute swivel should go in last.

STEP 9. Attach the main parachute swivel and the remaining end of the main recovery harness directly to the nose cone.

STEP 10. Attach the pilot parachute to the top of the deployment bag, wrap in a protective Kevlar blanket and insert it in the airframe.

STEP 11. Install the nosecone into the airframe, aligning the shear pins holes. Install two (2) 2-56 Nylon screws (shear pins).

Drogue Recovery System Preparation & Installation

STEP 12. Attach one end of the drogue recovery harness to aft of the avionics bay.

STEP 13. If used, attach the drogue parachute to the recovery harness approximately three (3) feet from the end of the drogue bay. Pack the parachute and recovery harness into the Kevlar protective blanket and install into the airframe.

Motor Preparation & Installation

STEP 14. Assemble the motor as per the manufactures instructions.

STEP 15. Insert motor into booster section using 3/8" threaded rod for motor retention.

Fastening the Booster Section to the Upper Airframe

STEP 16. Attach the remaining end of the drogue recovery harness to the booster section.

STEP 17. Slide the upper airframe assembly (main / avionics / drogue bay) onto the booster section coupler. Align and install two (2) 2-56 Nylon screws (shear pins).

Preparing for Launch

STEP 18. Install assembled rocket onto the launch rail.

STEP 19. Arm the avionics and verify they are ready for flight.

STEP 20. Install the igniter into the motor.

STEP 21. Attach the launch pad alligator clips to the igniter leads.

STEP 22. Return to the flight line and wait for launch.

Appendix C. Parts List (requirement)

Section	Component	Description	Vendor	Part Number	Specifications	Qty
Booster	Primary Fins	Reinforced Epoxy Board Fins		Custom	G-10/FR4, 0.1875" T x	4
	Secondary Fins (lower)	Reinforced Epoxy Board Fins		Custom	G-10/FR4, 0.1875" T x	4
	Airframe	Glass Reinforced Phenolic Tubing		PT-6.0	6.007" ID x 0.074" WT x 48" L	1
	Motor Tube	Glass Reinforced Phenolic Tubing		PT-3.0	3.002" ID x 0.062" WT x 36" L	1
	Centering Ring	Motor Tube Centering Ring		CR-01	G-10/FR4, 0.25" T x 6 " OD x 3.126" BORE	1
	Centering Ring & Fin Mount	Motor Tube Centering Ring & Fin Mount		CR-02	G-10/FR4, 0.375" T x 6 " OD x 3.126" BORE	2
	Centering Ring - Coupler	Motor Tube Centering Ring (Coupler)		CR-04	G-10/FR4, 0.25" T x 5.86 " OD x 3.126" BORE	2
	Booster Bulkhead	Glass Reinforced Epoxy Board		BH-01	0.375" T x 6 " OD	1
	Booster Coupler	Glass Reinforced Phenolic Tubing		CT - 6.0	5.86" OD x 0.074" WT x 12" L	1
	Motor Retention	Constrains Motor Aft		Custom	Al 6061	1
	Bulkplate Fasteners	Hex Head Fastener		91257A420	1/4-20 x 12" Partially Threaded Zinc Plated	4
	U-Bolt	Drogue Recovery System Anchor				1
	Removable Link	Drogue Recovery System Attachment				1
Upper	Secondary Fins (upper)	Reinforced Epoxy Board Fins Glass		Custom	G-10/FR4, 0.1875" T x	4
	Upper Airframe	Reinforced Phenolic Tubing Anti-		PT-6.0	6.007" ID x 0.074" WT x 24" L	1
	Upper Zipper Band Lower	zipper airframe edge protector Anti-		Custom		
	Upper Zipper Band Upper	zipper airframe edge protector		Custom		
	Shear Pins	Nose Cone / Booster Fasteners		93135A081	Nylon Pan Head Slotted 2-56 1/2"	8
	Nose Cone	Fiberglass Nose Cone		FNC-6.0	6.007" x 24.00"	1
	U-Bolt	Main Recovery System Anchor				1
	Removable Link	Main Recovery System Attachment				1
	Launch Rail Guides	TBD		TBD	TBD	2
	Rail Guide Fastener Insert	Threaded Inserts		90192A114	10-24 IT x 15/32" L x 19/64" OD	2
Recovery	Avionics Bay Bulkhead Upper	Aft bulkhead		Custom	0.25" T x 6 " OD	1
	Avionics Bay Bulkhead Lower	Fore bulkhead		Custom	0.25" T x 6 " OD	1
	Avionics Bay Housing	Phenolic Convolute Tube Coupler		CT - 6.0	5.86" OD x 0.074" WT x 12" L	1
	Avionics Housing Fasteners	Hex Head Fastener		91257A418	1/4-20 x 10" Partially Threaded Zink Plated	4
	Pilot Parachute	Rip-Stop Nylon Parachute		TAC-Drogue	24" 1.9oz Rip-stop Nylon parachute	1
	Drogue Parachute	Rip-Stop Nylon Parachute		TBD	TBD	1
	Main Parachute	Rip-Stop Nylon Parachute		TAC-9B		1
	Deployment Bag	Main Parachute Deployment Control		TAC-9B BAG	20" L x 5.8" D bag	1
	Parachute Protector	Non-flammable Parachute Protector		FCP-18x18"	18x18" Nomex	2
	Main Recovery Harness	Tubular Nylon		Custom	1" x 25' Nylon	1
	Drogue Recovery Harness	Tubular Nylon		Custom	1" x 50' Nylon	1
	Recovery Harness Protector	Kevlar Wrap			30" Kevlar Wrap	2
	U-Bolt	Main/Drogue Recovery System Anchors				2
	Primary Flight Computer	Dual Deployment Flight Computer		RRC2 mini		1
	Back-up Flight Computer	Dual Deployment Flight Computer		RRC2 mini		1
	Avionics Backpanel	G-10/FR4		Custom		1
	Avionics Backpanel Mounts	G-10/FR4		Custom		4
	Ejection Cannisters	Aluminum casings		Custom		6
	Ejection Cannister Fasteners	Secures ejection charge cannisters		TBD		8