Energy Management of a Sounding Rocket Using Cold-Gas Impulse Augmentation

Utah State University Chimaera Team

Contents

Nomenclature

δ_{max} Maximum diameter of the rocket body
$\Delta p_{(r,\theta)}$ Change of pressure in the wake
Δp_{edge} Change of pressure at the edge of the boundary layer
γ Flight path angle
A_{ref} Reference area of rocket
C_D Coefficient of drag
C_{D0} Drag coefficient at zero degree angle of attack
$C_{D compressible}$ Drag coefficient corrected for compressibility effects
$C_{D incompressible}$ Drag coefficient not corrected for compressibility effects
C_G Center of gravity
C_P Center of pressure
D_{ref} Reference diameter
h Altitude
h_{apogee} Altitude of apogee
h_{min} Altitude at which drag drops below available thrust
$h_{potential}$ Potential altitude estimate
h_{target} Target altitude
M Mach number
r Radius of the rocket body
t Time
t_{apogee} Time of apogee
$V_{horizontal}$ Horizontal velocity
$V_{vertical}$ Flight path angle
$\left(\frac{E}{M}\right)_{total}$ Mass-specific potential energy

I. Project Overview

I.A. Team Summary

The Chimaera Rocket Team is comprised of students from the Mechanical and Aerospace Engineering (MAE) and Electrical and Computer Engineering (ECE) departments at Utah State University (USU) in Logan, Utah. The rocket from Utah State is named the "Javelin" and will be referred to as such throughout the report. The team is led by Dr. Stephen Whitmore with the help of several graduate teaching and research assistants, who serve as subject matter experts for the project and assist the undergraduate design team with technical issues.

I.B. Launch Vehicle Summary

The Javelin has a total launch weight of 29.81 lbm (13.52 kg). The airframe has a 5.5 in diameter, and the total length of the rocket is 7.4 ft (2.26 m). The aft section of the rocket, or booster section, houses a Cesaroni L730 solid propellant motor and the payload, a Cold-gas Base-bleed Augmentation System (C-BAS). The C-BAS will be used to manage the total mass-specific energy of the vehicle to control the achievable apogee altitude. Both the solid motor and C-BAS have been tested extensively, verifying that their available impulse levels are capable of meeting mission objectives. The avionics section, located near the forward end of the rocket just behind the nosecone, houses flight instrumentation. The avionics suite includes an inertial measurement unit (IMU), two pressure-based altimeters, and a three-axis magnetometer. Navigation data is processed by a small on-board avionics computer to continuously estimate the total specific energy and potential altitude of the vehicle. Based on those estimates, the flight computer engages the energy management system. Additional flight instruments include the C-BAS plenum pressure sensor and expansion ramp surface pressures. The two pressure altimeters, PerfectFlite MAWD and R-DAS, are used in the recovery system for dual, redundant deployment of the parachutes. The PerfectFlite altimeter also provides the official measurement of the achieved altitude, for which the team is judged in the USLI competition. The rocket body is made from Blue Tube 2.0^{TM}[1] and EasyGlas Sock^{TM}. The Blue Tube has been tested and shown capable of withstanding the maximum loads encountered during flight. The recovery system is a dual, redundant deployment system that uses nylon parachutes with Kevlar harnesses sized to keep the descent rate within the specified ranges. The drogue and main parachutes are 2.5 ft (0.76 m) and 10 ft (3.05 m) in diameter, respectively. Ejection charges are made from black powder and electronic matches (e-matches) wired to the altimeters. The Javelin launches from the same rail used by the 2009 USU Rocket Team. The rail is made of aluminum and is 15 ft (4.5 m) in length. The launch rail is an integral part of the trailer used to transport the Javelin.

I.C. Payload Summary

The Javelin payload is the C-BAS, a cold-gas energy management system based on aerospike nozzle theory. While the aerospike nozzle[2] has long been known for its altitude compensation ability for endo-atmospheric flight, its unconstrained plume is ideal for integration into the Javelin airframe structure. Here the aerospike-derived isentropic expansion ramps are secured around the primary solid motor core and add negligible aerodynamic drag to the external configuration. The Javelin design uses a solid propellant rocket motor, which will carry the vehicle close to the one mile target altitude. During flight, however, the vehicle will lose energy due to aerodynamic drag. At different waypoints during flight, the on-board avionics will calculate the energy lost due to drag and initiate the C-BAS, raising the overall energy level of the rocket. Raising the overall energy level will augment the Javelin's projected apogee altitude. The ramp pressure measurements will be the first in-flight measurements of plume-induced compression for an over-expanded aerospike nozzle. These measurements will be analyzed post flight in order to increase accuracy in later flights and further understanding of the aerospike nozzle.

II. Changes Since CDR

The overall design of the Javelin has remained consistent, however the design of individual components have been significantly improved since the critical design review.

II.A. Vehicle Criteria

The overall design of the vehicle has not been significantly modified, although minor changes have been made during the manufacturing process to meet manufacturability requirements and ease of installation.

- The Javelin was first flown March 19, 2011. The test flight provided a complete systems test of the Javelins propulsion system, avionics suite, and recovery system. The rocket did not meet all flight requirements and will be flown again March 26, 2011 .
- Additional static testing has been performed allowing for three different motor tests to be compared to existing thrust curves, thus minimizing the effects of motor variability.
- Wind tunnel testing was performed to verify the drag coefficient calculated from Missile DATCOM and AeroCFD.
- Parachute ejection system was tested using both the R-DAS and PerfectFlite. The tests showed successful deployment of parachutes and successful shearing of shear pins used to hold rocket together. The black powder charges used were 2 grams for the drogue parachute and 3 grams for the main parachute.
- The team concluded trade studies on various system components and increased the fidelity of the Javelin's mass budget. This increased fidelity in the mass budget while simultaneously moved the center of gravity location.
- Global Reference Atmospheric Model 99 (GRAM 99) was used to predict atmospheric conditions for Huntsville, Alabama during the month of April.
- The Javelin body tube is reinforced with an EasyGlas Sock, which absorbs epoxy resin and adds to the structural strength of the airframe. Additionally, this will help prevent the Blue Tube from warping in the sun.
- Parachute ejection charges have been made using 2 and 3 grams of blackpowder for the drogue and main parachutes, respectively. Procedure for creating the ejection charges has also been made.
- The procedure for properly folding the parachutes has been remade.
- The carbon dioxide (CO_2) tank for the C-BAS was changed from a 24 oz to a 12 oz tank.

II.B. Payload Criteria

The overall C-BAS design has not been significantly modified, although minor changes have been made through the manufacturing process to meet manufacturability requirements of the various pieces.

- The isentropic expansion ramps manufactured by Space Dynamics Laboratory located in Logan, UT.
- C-BAS leak and efficiency tests were performed to verify overall performance.

II.C. Activity Plan

No major changes have been made by the team at this time regarding the proposed activity plan as outlined in the proposal. The team has been continuously fulfilling their activity plan objectives by performing outreach activities and maintaining the website throughout the rocket building process.

- Several more outreach activities will take place before the competition.
- The website has been updated to include all relevant rocket testing, calander items, and educational engagement activities.

- An “Upcoming Events” page was added to show all future events in sequential order and to demonstrate which current items are happening on the rocket.
- A “Testing Videos” page was added to demonstrate some of the testing being performed by the team.

III. Selection, Design, and Verification of Launch Vehicle

III.A. Vehicle Overview

III.A.1. Introduction and Mission Statement

The Chimaera Team's mission is to design and build a recoverable, reusable rocket that will carry an engineering payload to an altitude within feet of one mile. This objective will be achieved through careful design, manufacture and testing of the rocket. The C-BAS, composed of mechanical CO_2 base-bleed hardware, associated avionics, and energy management algorithms, serves as the engineering payload for this project. Valuable in-flight data will be collected from the C-BAS payload.

The CO_2-based system will vent the cold, inert gas through an isentropic expansion ramp, patterned after a linear aerospike nozzle. This sophisticated energy management system is able to increase the overall energy state of the rocket, regulating the apogee altitude and allowing the rocket to hone in on the one mile target altitude. Sensors mounted to the ramp assembly will obtain important first-time, in-flight pressure data on the linear aerospike expansion ramp.

III.A.2. Requirements and Mission Success Criteria

Design requirements for the Javelin come from three primary sources: competition specified conditions, safety codes, and team-specified design requirements. The top-level USLI rules mandated by the competition are strictly observed in the design and construction of the rocket, as are all NAR and NFPA codes regulating the launch of any and all high-power rockets. Beyond these outside design requirements, the team has determined additional requirements that will govern the specific design of the Javelin.

Success criteria for the Javelin is based on three factors: 1) Achieving an altitude within 30 ft (9.14 m) of a mile; 2) Successful deployment of the parachutes and recovery of the rocket; 3) Gathering in-flight pressure data along the isentropic expansion ramps. Fulfilling these criteria will constitute a successful launch of the Javelin.

III.A.3. Major Milestone Schedule

As the design progresses, the major milestones and critical path items become more apparent. For all design activities there was first a trade study performed to facilitate decisions, and then a high fidelity and verification phase to ensure the requirements are met. The major milestones are depicted in Figure 1. The milestones are grouped according to category, and displayed in-line with similar type milestones. They are then linked to their successors with an arrow. A detailed schedule is maintained and visible on the team's website.

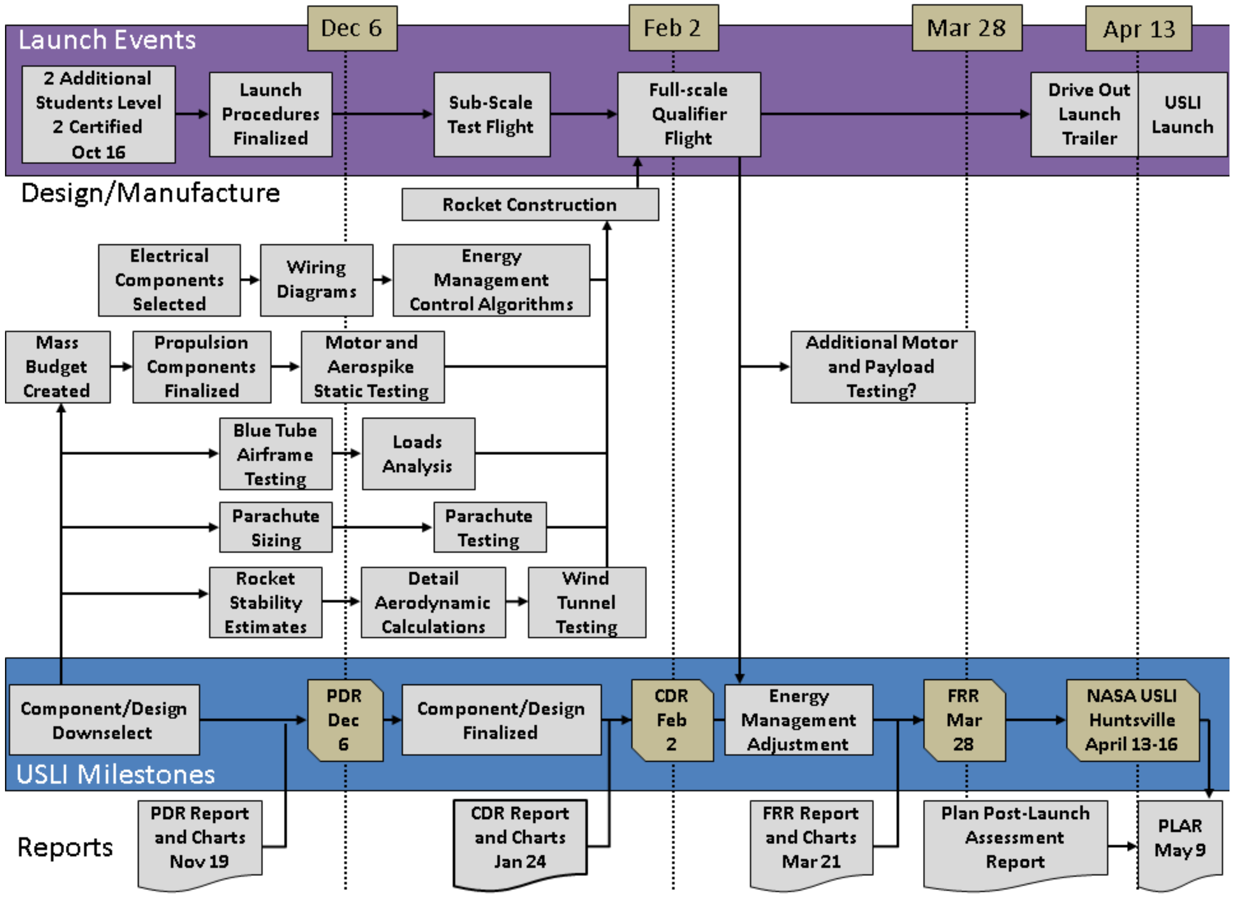

Figure 1: Milestone map.

III.A.4. Mission Concept of Operations (CONOPS)

The Javelin is designed to reach, without exceeding, the mile altitude required by the USLI competition. The competition guidelines specify that launch teams must use a National Association of Rocketry (NAR) certified, commercially available hobby rocket motor for the main boost element of the vehicle. Hobby rocket motors are not as well characterized as professionally-certified motors, and total impulse among a particular type or class of motors can vary by as much as 20 percent. This variability results in an apogee altitude error in excess of 900 ft (274.3 m). Consequently, the team determined that the motors were not precise enough to achieve the desired apogee by ballasting the rocket.

Previous USU entries into the USLI competition solved this problem with a closed-loop energy management system that used air brakes to modulate the total energy of the rocket. The design philosophy was to aim high and then bleed off energy using four deployable and retractable airbrakes mounted circumferentially near the rocket boat tail. The brakes were deployed at prescribed waypoints, and the energy management system running on the onboard avionics flight computer determined the deployment times.

The previous energy management system consisted of airbrakes, an inertial navigation algorithm, and an asymptotic guidance algorithm. Navigation sensors included an inertial measurement unit (IMU), a pressure-based altimeter, and a single-axis magnetometer. Following the motor burnout, the navigation data was processed in a small onboard avionics computer using a Kalman filter to continuously estimate the total specific energy and drag coefficient of the vehicle (based on a ballistic trajectory). At each waypoint the airbrake deployment times depended on the estimated potential altitude. The target total energy state was approached from above.

Because of newly established launch-range safety restrictions, the USLI scoring rubric for the altitude prize has been significantly modified to severely penalize teams that exceed the one mile altitude limit. Furthermore, any rocket exceeding the target altitude by more than 300 ft (90 m) will be disqualified from the competition. Thus the previous "aim high" strategy is far too risky with regard to the competition rules, and has been replaced by an "aim low and boost" strategy. The airbrakes are to be replaced with small, aerospike-based expansion ramps, and energy is added instead of depleted, allowing the desired energy state to be approached from below. Figure 2 shows this concept of operations (CONOPS).

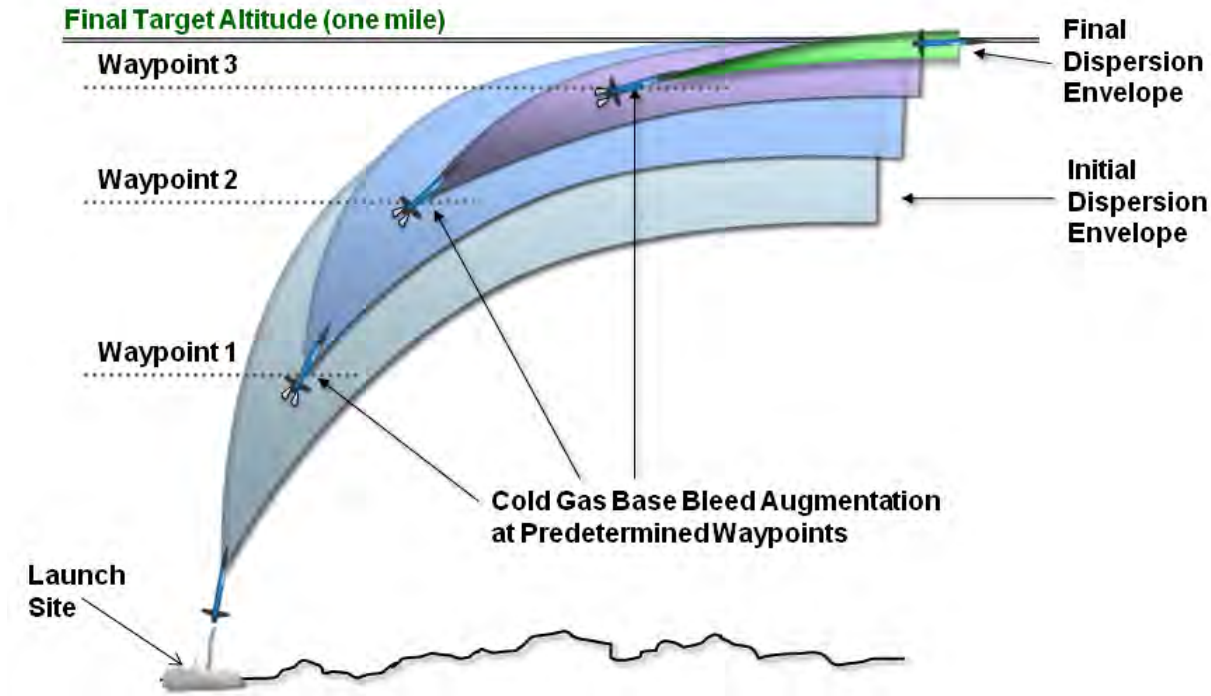

Figure 2: Concept of operations.

The Javelin uses an L-class impulse solid rocket motor to boost the launch vehicle to a projected altitude between 150-450 feet below the one mile altitude. At certain altitude ranges along the trajectory, the C-BAS will expel the inert ballast CO_2 through the isentropic expansion ramp and thereby increase the potential energy in the rocket, using principles of momentum flux. This increase in energy adds to the altitude potential of the rocket.

The system is governed by a robust, time-optimal control algorithm. This process has been carefully studied and refined to make it efficeincy. If the energy management system executes too early in the flight, the potential altitude gain will be absorbed by an increase in drag loss. If activated too late, there will not be enough angle and velocity to make up the distance to target apogee. High-fidelity analysis and testing has been performed to verify performance specifics. The following sections discuss the component designs that are needed to safely fly and recover the payload.

IV. Launch Vehicle Criteria

IV.A. Airframe and Structural Design

The structures team is responsible for providing an economical and durable rocket body and tracking the evolving mass properties, including center of gravity location and moments of inertia. Figure 3 shows the overall structure for the Javelin. The avionics are enclosed by a bulkhead on each side of the avionics section. The motor section is also capped with a bulkhead. The motor is held in place using a Slimline motor retainer. The Slimline does not create extra drag, is a simple design, and is low cost.[3] The parachutes are attached to the bulkheads in the nosecone and avionics section, which absorb the opening loads. Figure 3 also shows the C-BAS integrated into the boat tail. The boat tail design uses an innovative "nozzle in a nozzle" configuration that minimizes interference drag caused by external protuberances. The 2009 Chimaera team's work suggests that increased accessibility to the rocket's payload and avionics bays is necessary, so larger access doors have been designed along the rocket to ease accessibility.

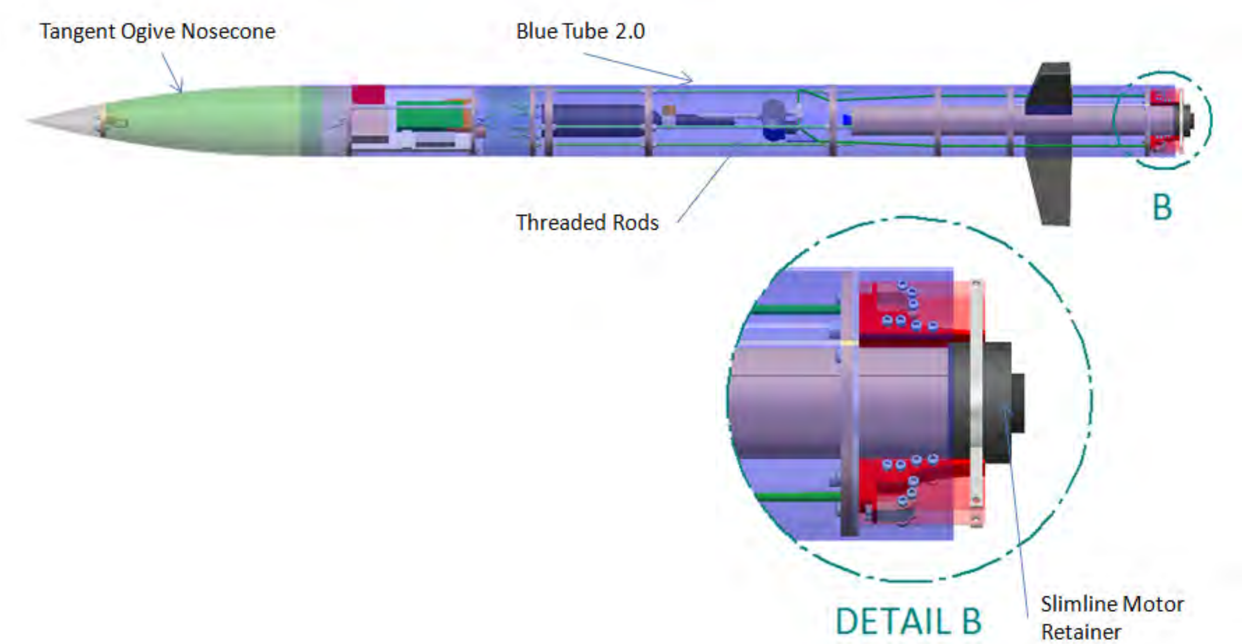

Figure 3: Vehicle structural layout.

The Javelin requires a high strength, light weight material for the airframe. Two options considered for the the airframe material were carbon fiber and Blue Tube 2.0™, a phenolic impregnated cardboard material specially designed for use in model rocketry. Table 1 shows a comparison between these two materials. The most important differences between these two materials are their strength and price. Due to the unfamiliarity with Blue Tube, a 48 in section of 5.5 in diameter tube was purchased prior to making a descision and tested under compression to verify that the Blue Tube could withstand the maximum compression load. After the design was verified, the Blue Tube was selected over carbon fiber. Always Ready Rocketry was chosen to be the supplier because of the availabilty of Blue Tube in standard sizes and at lower prices. Another reason Blue Tube was chosen is because of its low cost, which saved about $300 on flying hardware costs. This extra savings was reallocated to upgrade the avionics hardware. Some concerns have been raised that Blue Tube may warp when exposed to high temperatures. After some research, the team learned that Blue Tube warps only when it has been sitting in the sun with no internal supports for long periods of time.[?] An EasyGlas Sock was epoxied over the entire airframe to improve the overall strength and increase resistance to warping, and several bulkheads placed throughout the airframe eliminate the risk of warping.

Table 1: Airframe material comparison.

Tubing	Tensile Strength (ksi)	Density (lb/in^3)	Price ($/48in)
Carbon Fiber	580	0.063	312.00
Blue Tube 2.0	14.5	0.043	54.95

IV.B. Design for Hardware Access in the Avionics and Payload Section

One of the the team's self-imposed design requirements was to design doors to access the avionics and payload components. These doors facilitate the quick access of components without having to disassemble the rocket. Figure 4 shows the locations of the doors in the avionics and payload sections. The doors are designed such that the strength of the rocket body is not compromised, and the drag coefficient will not be significantly increased. The doors are removable sections of the Blue Tube body tube. The avionics section has two doors to allow for access to both sides of the avionics board. The doors are held in place using small screws, which was installed into nuts epoxied to the inside of the coupler tube that lines the inside of the section. The payload section door will be designed and attached similarly. The position of the payload section door was decided based on the C-BAS installation design. Easy access to this area is required in order to replace the CO_2 tank after each launch. Access to install the isentropic ramps was also needed, so two small doors were designed to access both ramps as shown in Figure 4. The access doors for the avionics section is shown in Figure 5.

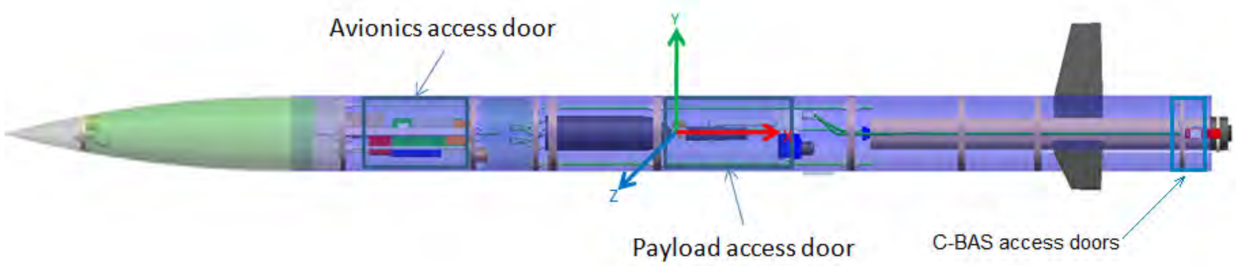

Figure 4: Access doors in the Javelin.

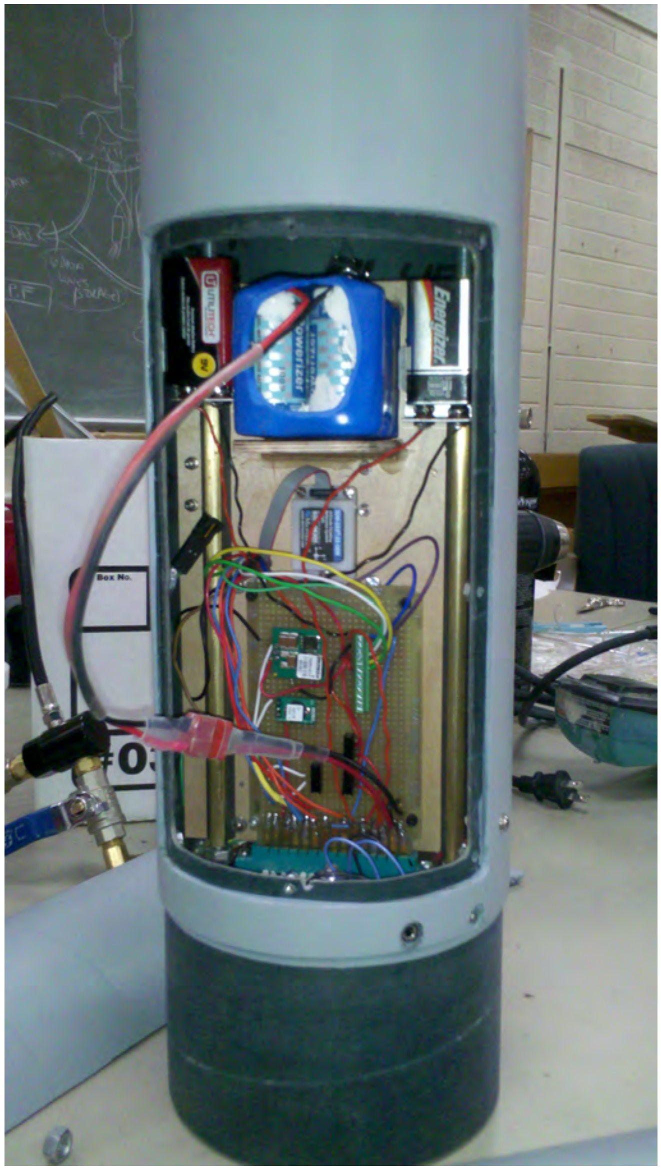

Figure 5: Access door in avionics suite.

IV.C. Load Bearing Structure

The primary compressive loads from the motor and C-BAS are transmitted along the airframe. Figure 6 shows the integration of the expansion ramps with the main motor nozzle and retainer. The isentropic expansion ramps will be attached to the wood bulkhead in the bottom of the Javelin. In addition, a thin aluminum plate and a small clamp will be used to ensure axial alignment of the ramps. When the cold-gas system is deployed, the expansion ramp will need to withstand a maximum pressure of 450 psi. Both static and finite element analysis was conducted on the ramps to see the deflections of the material. The opening loads of the parachutes are transmitted through the bulkheads of the avionics structure and the payload section. Figure 7 shows the threaded rods supporting the avionics bay. Stress concentrations on the bulkheads and the avionics support structure were of particular interest. The avionics support structure was analyzed to verify that it is capable of withstanding the loads generated as the recovery system is deployed, as well as the load produced by the motor. Most components were designed with a 2.5 factor of safety. Key components were proof tested at 1.25 times the calculated ultimate design load (UDL).

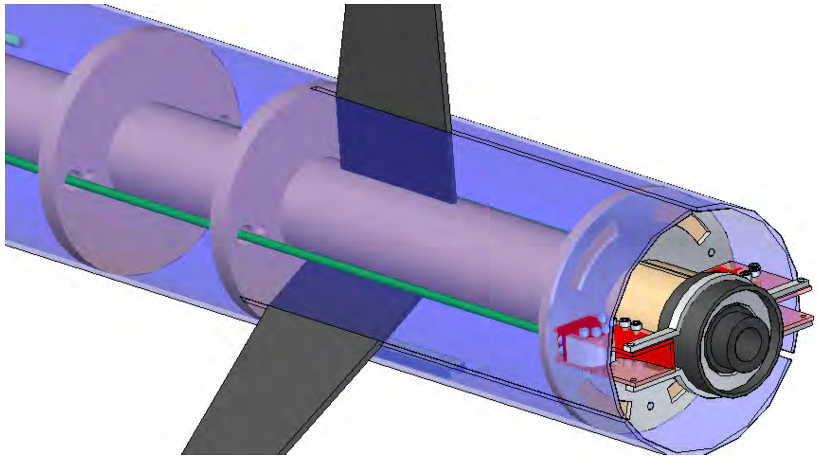

Figure 6: Integration of C-BAS expansion ramps into vehicle base area.

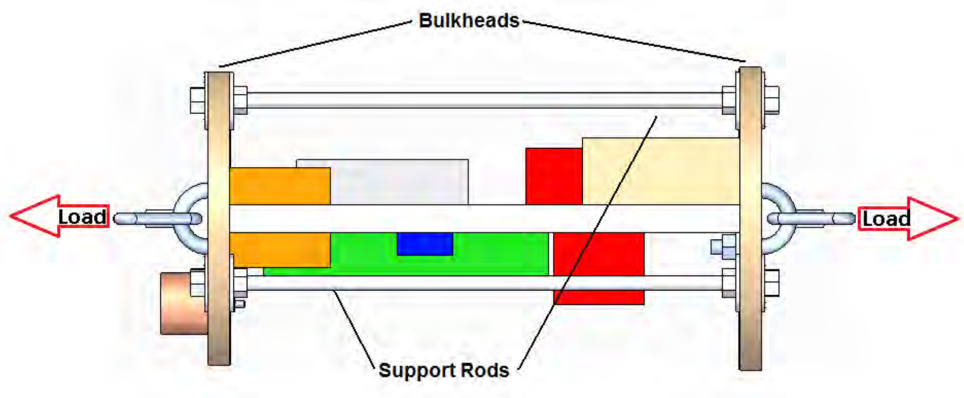

Figure 7: Avionics bay support rods.

IV.D. Structure Analysis and Testing

Finite element analysis was performed on the isentropic ramp using a commercial solid modeling program (SolidEdge™) in order to calculate the possible change in choking area from the thin part on the nozzle. Figure 8 shows the finite element analysis of the ramp. A safety factor of 33 was obtained. Thus, this part will not yield when the cold gas comes out at around 450 psi. However, the choking area will expand 0.3 micrometers.

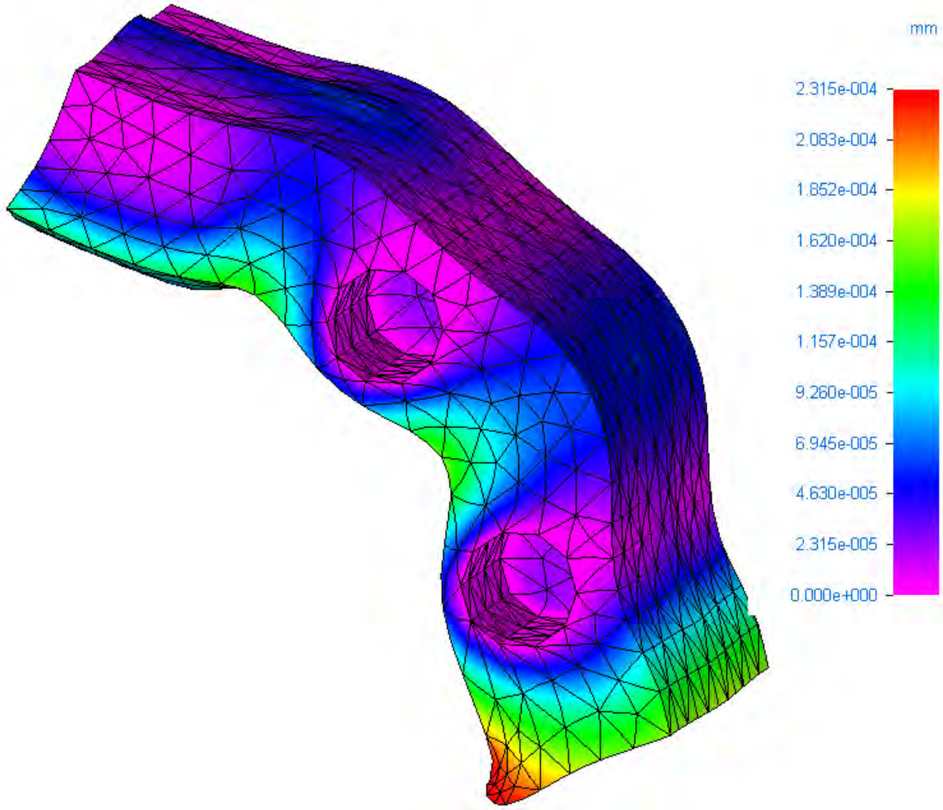

Figure 8: Finite element analysis on the isentropic ramp.

A compression test was performed on the Blue Tube. This test was intended to make sure that the tubing for the Javelin could resist the maximum force produced by the motor. Using the maximum g-load and the launch weight, the maximum load that the tube must withstand is approximately 360 lbs (164 kg). Figure 9 shows the body tube being tested under compression. The test stand was built to support the airframe material in an upright position, so the compression load could be more accurate. Sand bags were placed on the top board to approximate the ultimate load. The Blue Tube successfully withstood 415 lbs (188 kg), which is above the ultimate design load. After the test, there was no sign of buckling along the body, which confirmed the selection of Blue Tube 2.0 material as acceptable for the final airframe material. This test was done using a 1.25 proof-load factor of safety.

Figure 9: Body tube test stand.

The design of the avionics support structure is similar to the Pike's design. An avionics section was built and integrated into the Blue Tube. One bulkhead was epoxied permanently into the tube, while the other bulkhead was removable and connected with threaded rods. The top bulkhead was made to be removeable for easier assembly of and access to the avionics hardware. Stress concentrations due to the bottom bulkhead and the avionics structure were of particular interest. For this particular case, the compression test is the same as the tensile test because the only thing that is of main concern is the bulkhead, which will experience a shear force due to the opening load and the motor loads. The maximum opening load from operation of the recovery system is 127 lbf (563 N). The ultimate design load is approximately 237 lbf (1055 N). The motor load was considered as the maximum load that the bulkhead will experience. The compression test showed that the avionics section would be able to withstand about 300 lbf (1300 N). J-B Weld was used to epoxy the bulkhead to the tube. J-B Weld is a strong, two-part epoxy adhesive that can withstand high temperature environments. Figure 10 shows the bottom bulkhead of the avionics section attached to the airframe using J-B Weld.

For the final avionics structure, two threaded supporting rods were used instead of three. This helped the rocket decrease its weight and improve easy access to the avionics section. The structure of the avionics was analyzed and verified to make sure that it would not compromise the overall structure integrity of the rocket.

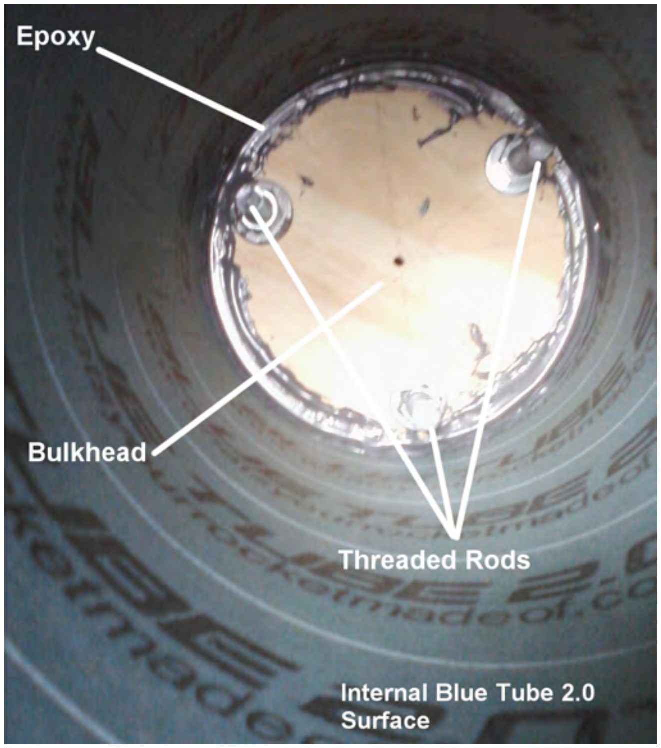

Figure 10: Bulkhead epoxied to the tube.

IV.D.1. Motor Integration

Motor Choice The team developed deterministic and Monte-Carlo simulations to predict the flight path of the rocket using simulation tools built in MATLAB/Simulink® and LabVIEW®. The simulations account for aerodynamic drag, variable thrust due to atmospheric back pressure, and launch rail characteristics. Prescribed time-varying or constant motor thrust profiles could be input into the model. The predictions of the MATLAB/Simulink and LabVIEW simulation models were compared to verify the trajectory predictions.

Preliminary analysis for an L-class motor was required for the Javelin design. L-class motors have total impulse between 576 lb-s (2560 N-s) and 1151 lb-s (5120 N-s). To simulate the rocket behavior using a variety of L-class motors, the team looked at motor profiles from the hobby rocket website, www.thrustcurves.org.[7] Following a preliminary analysis, the team selected a short list of candidate motors for high-fidelity design analysis. The high fidelity design analysis was completed for each selected motor using two different materials for tubing and three different types of energy augmentation. Figure 11 shows the motor and design selection procedure.

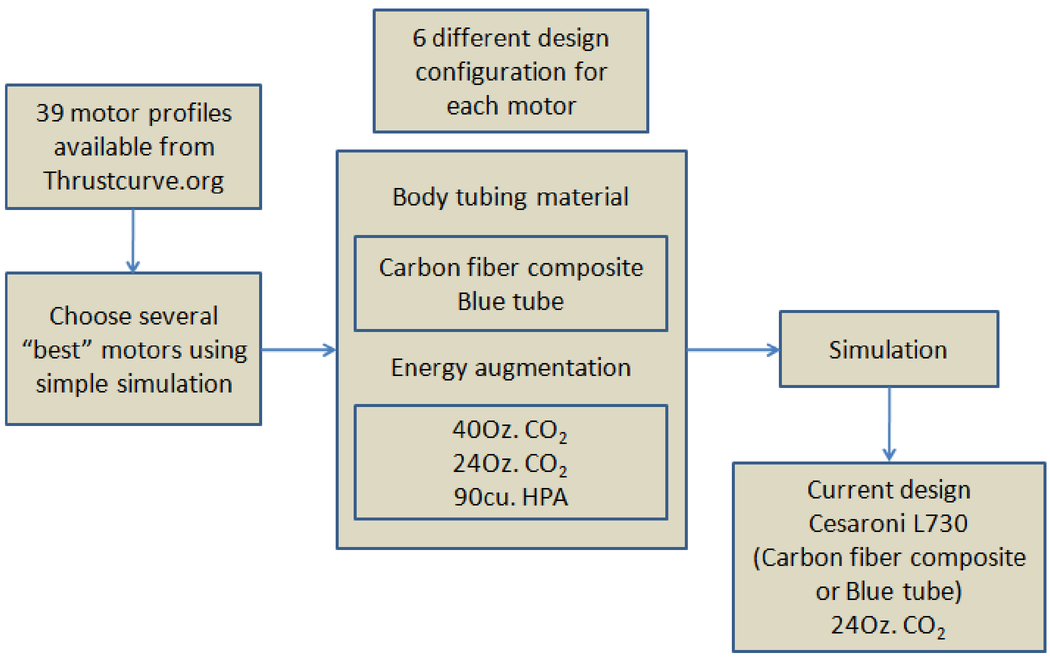

Figure 11: Motor and design selection procedure.

The motor trade study led to the selection of the Cesaroni L820 with Blue Tube as the optimal configuration. However, the team learned during the PDR that the L820 uses Skidmark propellant, which violates the USLI competition rules. Based on the procedure in Figure 11, the next best choice of for a solid motor was the Cesaroni L730. The Cesaroni L730 was chosen for its impulse and moderately long burn time, and consequently relatively low g-load. The motor's performance characteristics are summarized in Table 2.

Table 2: Cesaroni L730 characteristics.

	Value
Diameter	2.12in (54mm)
Length	25.55in (649mm)
Total Wt	4.95lbm (2.25kg)
Prop Wt	2.98lbm (1.35kg)
Avg Thrust	165lbf (733N)
Max Thrust	273lbf (1214N)
Total Impulse	621.6 lbf-s (2765 N-s)

Motor thrust characterization The motor thrust performance was characterized via three static burns, as well as using data from both Thrustcurve.org and the manufacturer's website. Figure 12 and Figure 13 show the results of the three tests and the online data.

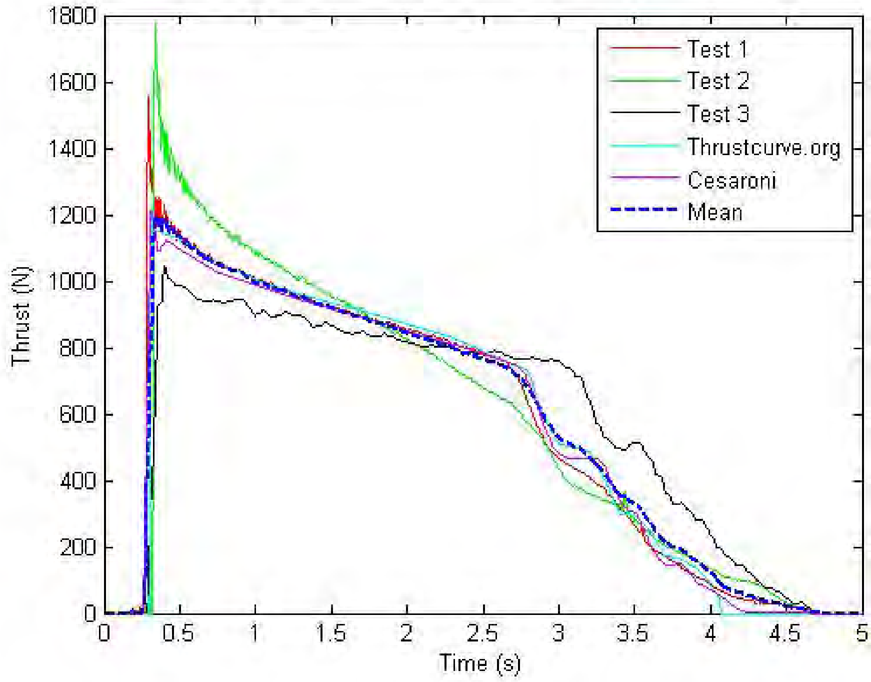

Figure 12: Cesaroni L730 test thrust data.

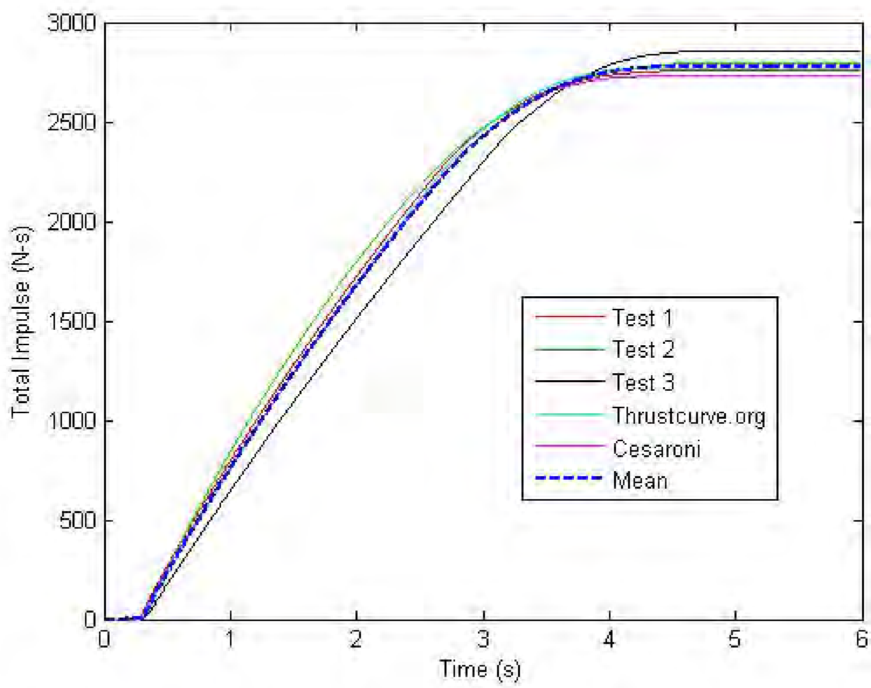

Figure 13: Cesaroni L730 test impulse data.

The mean total impulse is 624.90 lbf-s (2779 N-s), with a standard deviation of 10.62 lbf-s (47.25 N-s). The variation of total impulse is 1.7 percent. The 95 percent confidence uncertainty of the total impulse with five data points is 29.51 lbf-s (131.28 N-s) . This is approximately what is expected from a commercially available motor. These characteristics were used in the Monte-Carlo simulation to realistically model the variability of the Cesaroni L730.

Motor mounting and retention The motor is mounted into the Javelin using four wooden bulkheads which are securely fastened to the body tube. The bulkheads are linked together by three vertical support rods that run through the length of the booster section. Two threaded support rods link the avionics bay bulkheads. There is one bulkhead each on the fore and aft ends of the motor casing, and two bulkheads midway along the motor casing in order to prevent any bending of the motor tube. The motor is housed within the motor tube, which slides against the Slimline retainer. This allows the motor loads to be transmitted to the bulkheads through the phenolic liner which holds the retainer. The phenolic liner prevents any significant amount of heat transfer from occuring betweeen the motor and the surrounding rocket. Additionally, the C-BAS nozzles mount symmetrically about the motor and clamp around the motor cap. Since the nozzles are bolted into the bulkhead, this provides an additional attachment point for the motor. The motor grains are slid into the motor casing from the tail end of the Javelin. Figure 14 shows a model of the mounted motor.

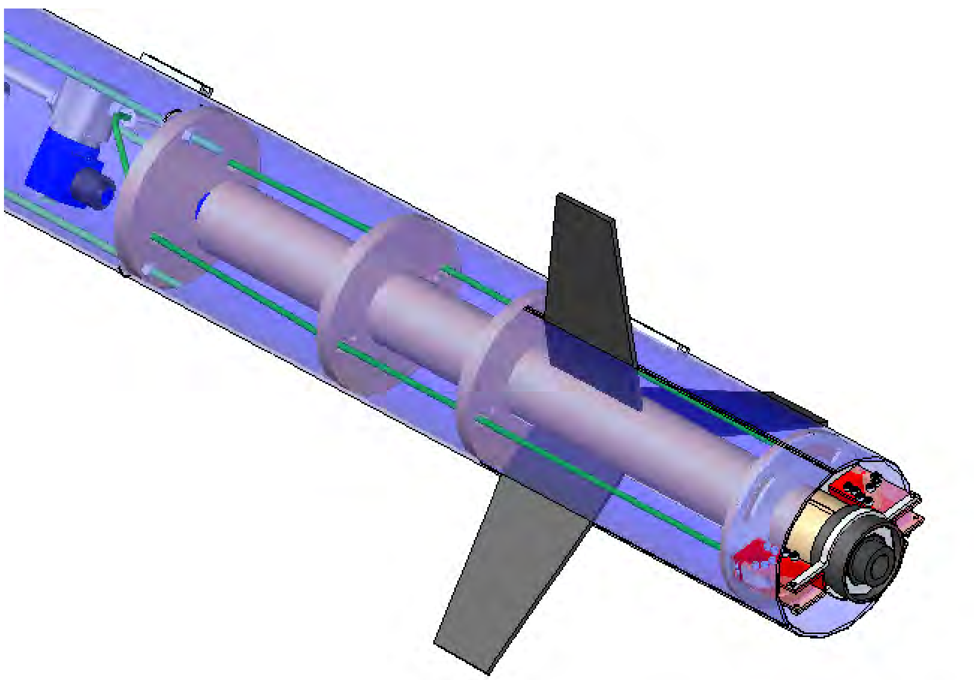

Figure 14: Motor mounting model.

IV.D.2. Fin Design and Manufacture

One of the design priorities for the Javelin was to reduce drag, so a three-fin configuration was chosen. The fin profile on the Javelin is patterned after previous Chimaera rockets. It features a trapezoidal shape with a 10 degree sweep angle and a 5.1 degree trailing angle. The span is 1.5 times the root chord. This radially-oriented and largely rectangular shape adds a good deal of strength to the fins, allowing them to remain intact after landing, as proven in the initial flight test. Given that profile, the fins were then scaled to provide a suitable C_P location. This was chosen to be slightly overstable, owing to C_G uncertainty and potential C-BAS assymmetry. The C_P location was first calculated for stability using Barrowman's equations. These values were then checked with Missile DATCOM and AeroCFD, the latter of which also used Barrowman's equations to calculate the C_P and C_G locations.

The fin manufacturing and installation process was quite intensive to ensure correct sizing and alignment of all fins connected to the rocket. The fins were manufactured from G10 Fiberglass and a rough cut was performed with a miter saw. Once the fins were cut they were mounted together and sanded smooth to the exact dimensions ensure all three fins were exactly the same size as it is a very important principle of stability to have the same surface area on each fin mounted on the rocket. Lastly the fins needed to have rounded edges on their forward and back edges as the rocket is traveling at subsonic speeds. Figure 15 shows the safety precautions taken to verify the fins were cut being very cautious of the dangers presented. Safety glasses and clamps were used to hold all parts together without allowing them to move.

Figure 15: Miter saw and clamps used to cut fins

The team chose to use three fins for their rocket which makes fin alignment the largest challenge for the fin manufacturing process. All three fins need to have exactly 120º separation between each of them. In order to make the alignment process easier, the fin alignment system consists of two separate alignment pieces. The interior fin alignment system is mounted directly onto the motor tube and shown in Figure 16.

Figure 16: Interior fin alignment.

The fin alignment system needs to also be removable after fin installation. To accomplish this task the two pieces of aluminum are offset from the wood and bolted together. When the bolts are removed after installation, all the pieces will come out of the rocket, decreasing the weight of the rocket. When the fins have been wedged and glued into the interior alignment system, the assembly is then placed inside the exterior alignment system pictured in Figure 17. The fins have very tight tolerances to fit in both alignment systems simultaneously and can then be maneuvered carefully until they are all perfectly level and aligned.

Figure 17: Exterior fin alignment.

Once the fins are perfectly vertical and aligned with the body tube, they can be verified for 120º separation and 10° sweep for the forward fin angle. The fins are then glued with J-B Weld. Figure 18 shows the completed mounted fin alignment system.

Figure 18: Mounted fin alignment system.

The slots on the external body tube were cut one at a time with a miter saw. The slot was then widened using a Dremel tool to fit the fin assembly inside the external rocket body casing. The motor tube assembly was dry-fit into the rocket body to ensure it fit successfully without turning the fins at all. This bottom assembly was plumbed with the C-BAS tubing and epoxied into the external rocket body. The fins were glued and filleted with epoxy on the external body tube to ensure strength when landing and appropriate angles when the rocket is flying. Figure 19 shows the configuration of the rocket before the fillet was placed on the fins.

Figure 19: Finished fin assembly.

IV.D.3. Approach to Workmanship

Manufacturing and Assembly In order to achieve competition objectives, careful, precise assembly of the Javelin was critical. Every subsystem of the rocket was fully modeled using SolidEdge software. From these models, dimensioned drawings of all critical components were produced. These drawings, as well as those for the major assemblies, can be found in Appendix H. The 3D solid model also included correct masses for each of the components. These masses were recorded and updated regularly in a mass tracker to ensure that the Javelin would fall within the mass range necessary to perform as predicted.

Body Tube Blue Tube was chosen for the airframe material because of its strength, durability, low cost and availability. The team performed stress tests to verify that the Blue Tube would be able to handle the loads incurred during flight. An EasyGlas Sock with fiberglass coating was epoxied over the entire airframe to improve the overall strength and increase resistance to warping. The final result was a very light and durable structure, able to withstand the rigors of flight. The Blue Tube was purchased in two sizes: a body tube, and a coupler tube. The coupler tube was used to join individual sections of body tube to provide a long enough structure for the rocket and to facilitate manufacturing of the access doors. Tubing was cut with a band saw, and the team learned that placing a coupler tube inside the main body tube while cutting made cleaner lines. The cutting process required two individuals; one to monitor the cutting rate and another to hold and stabilize the tube. Phenolic tubing was used as a motor tube because it was readily available and cost-effective. The bulkheads were fabricated from various thicknesses of birch plywood because the material was easy to machine and available at local stores. The bulkheads were manufactured with a wood lathe, and wiring and plumbing holes were drilled with a drill press.

Fins The Javelin's fins were fabricated out of G10 fiberglass because of its strength and rigidity. They were cut to size using a band saw and their leading edges were profiled with a belt sander and hand sanding. Using a mounting jig, the fins were carefully aligned and attached with epoxy to the motor mount tube. Fillets were epoxied on either side to reinforce the fins. Also, the maximum sweep that maintains stability was used on the fins to help reduce the impact load on the fins when the Javelin touches down.

Isentropic Expansion Ramps The isentropic expansion ramps, derived from aerospike nozzle theory, had to be incredibly precise and able to withstand large amounts of pressure. To ensure precision the team had the ramps manufactured professionally at the Space Dynamics Laboratory. The assembled aerospikes were aligned using an aluminum plate and alignment jig manufactured using the CNC machine on Utah State University's campus. High pressure plumbing for the expansion ramps was directed along the motor tube, forward to the payload section, where it was integrated with the rest of the C-BAS.

Adhesives Various adhesives were used in the construction of the Javelin. Where strength was the primary consideration, a two-part epoxy was used. For areas susceptible to heat, J-B Weld epoxy was used. For non-structural applications, such as securing bolts and wiring attachments, cyanoacrylate was used. A silicone-based adhesive was used to seal fittings around the isentropic expansion ramps.

Rocket Assembly The first step in assembling the Javelin was to glue the lower bulkheads and fins to the phenolic tube motor case. After all the C-BAS plumbing was installed and tested, the outer body tube was slid over the fin assembly and glued in place. Access doors were cut into the exterior of the frame prior to sliding in internal coupler tubing. After coupler tube was installed, access holes were then cut into the coupler tube using the external tube as a guide. Next, the payload bulkheads were assembled using threaded aluminum rods. Components were temporarily installed and tested, then removed while the bulkhead assembly was installed into the upper end of the lower body tube.

Avionics are housed in the foreward section of the Javelin. In order to facilitate easy removal, the avionics board was attached to brass tubing, which could then be slid over steel threaded rods and secured in place by the upper avionics bulkhead. This enabled the Javelin bulkhead section to be assembled in the rocket while the avionics team attached the required components to the avionics board. Once all glue dried, the avionics board was slid into the avionics bay and secured with the upper bulkhead. The lower body segment, avionics segment, and nosecone, were all assembled together and holes for the shear pins were then drilled and tapped.

Finally, three coats of gray primer were applied to the rocket to seal the airframe and provide a smooth, durable finish. After successfully test flying the airframe, MonoKote will be applied to the rocket to provide a smooth, aerodynamic finish. The rail guides were the final step in assembling the Javelin. They were aligned using the launch rail. The lower rail guide was attached using J-B Weld and pop rivets, while the upper rail was attached using countersunk bolts because the thickness of the tube in this portion prevented the use of pop rivets.

IV.D.4. Manufacturing Safety

Precautions were taken in order to ensure that a safe environment was maintained throughout the assembly of the Javelin. Two people were present at all times while using power tools or machines in the shop. Personal protective equipment was used to prevent eye and respiratory injury. Protective gloves were worn when working with solvents or adhesives. MSDS sheets for all hazardous materials were made available in the construction areas and are posted on the Chimaera website. Protective masks were worn when sanding the fiber glass portions to avoid inhaling glass and epoxy particles. Respiratory protective equipment also had to be implemented when spraying and sanding the primer coats. Additionally, all spraying was done in a well ventilated room. When applying MonoKote to the Blue Tube, there is a mild fire risk due to the use of heat guns and hot irons. In order to mitigate these risks before any surfaces were covered, all flammable materials were removed from the area surrounding the workspace. All work was done on a nonflammable surface and heat resistant gloves were worn to reduce the risk of burns.

IV.D.5. *Safety and Failure Analysis*

The main challenge of the structural design of the isentropic expansion ramps was the limited space in which the ramps had to fit. Because of the very tight tolerances under which they were built, the ramps consitute one of the most expensive parts of the rocket. The ramps can withstand the pressure of CO_2 coming in at 450 psi.

During an iterative design process of the critical components of the ramps (see Figure 20), such as the thin part which had a yielding safety factor of 33, the team concluded that should the ramps fail, it would be because of the forces and bending moments acting on the screws labeled as “Failing Screws” in the figure.

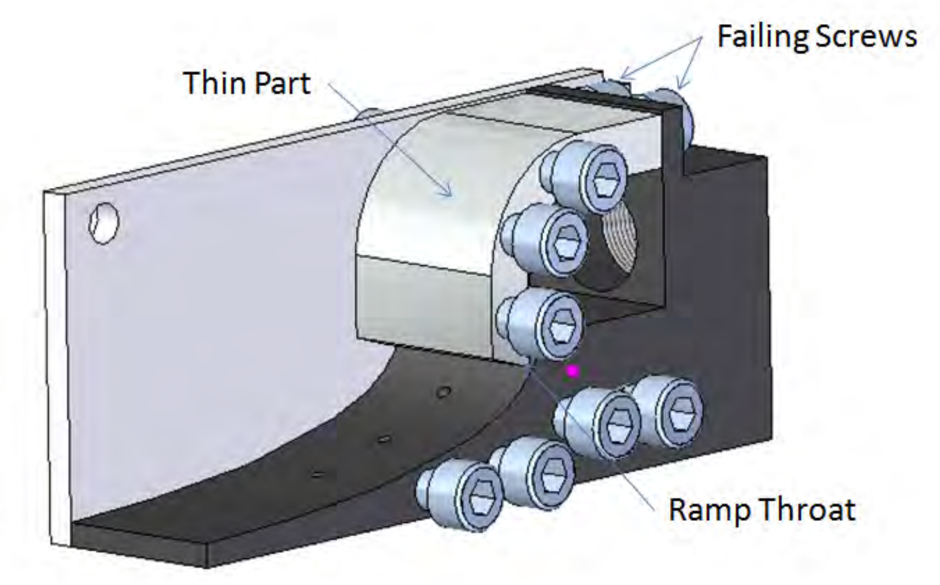

Figure 20: Ramps assembly with side plate removed.

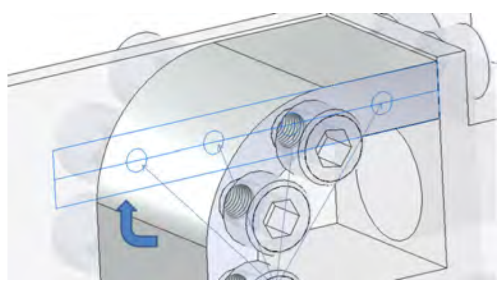

Figure 21: Location of screws if part was a beam.

To calculate the forces acting on the screw, the team simplified the shape of the narrowest section to an equivalent straight, statically indeterminate beam. Using SolidEdge beam calculator, the team found out that the maximum load acting on any of the screws would be 19 lbf (85 N). Analyzing Steel 6-32 screws through finite element analysis, the team determined that the screws had a safety factor of 2.1, which does not comply with the established 2.5 minimum design safety factor. However, the ramps were proof tested at a safety factor of 1.25, and the team is satisfied that the system will withstand the forces it will experience. Figure 22 shows a finite element analysis on the screw based on the force it experienced. This analysis was performed using Femap 10.1.1™ and NX Nastran 7 Solver™. The mesh type was tetrahedral, and a very fine grid of 379,139 nodes was used.

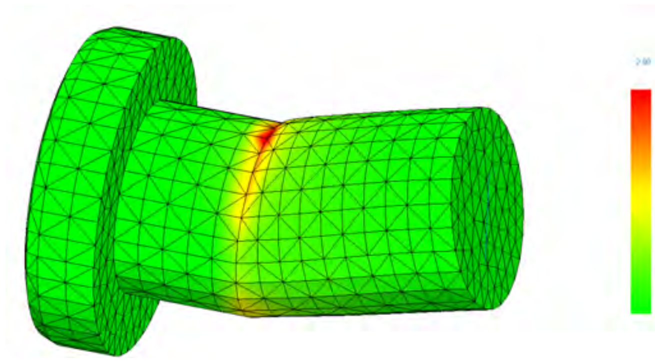

Figure 22: Finite element analysis on the screw

IV.D.6. Full Scale Test Flight Results

On March 19, 2011 the Utah State University Chimaera Team went to the Pony Express Range outside of Lehi, Utah, to do a preparatory launch of the Javelin, per to USLI requirements. Conditions at the site were less than ideal. Sustained winds of 20 mph and gusts exceeding 30 mph made launch preparations a challenge. This provided a good test to ensure that the Javelin was more than capable of handling whatever launch conditions it would experience at the USLI competition launch.

The team had several objectives for the test: 1) Evaluate the stability of the Javelin while in flight, 2) Ensure the CO_2 tank would survive flight conditions, 3) Verify packing procedures for the recovery system, 4) Achieve the target altitude of one mile through use of C-BAS, and 5) Proper deployment of the parachutes that would bring the rocket down within 2500 ft of the launch site. Three of the five test objectives were met during this flight.

In-flight Stability According to the various tests and analyses done by the team, the Javelin has a static margin of at least 1.10 at all times. This means that the rocket should trim properly during flight without wobble or weather-cocking. The Javelin experienced two wobbles right off the rail due to wind gusts, but then instantly corrected itself for a picture-perfect flight to apogee. Despite the wind, the Javelin was stable throughout the flight. Figure 23 shows the Javelin right after launch.

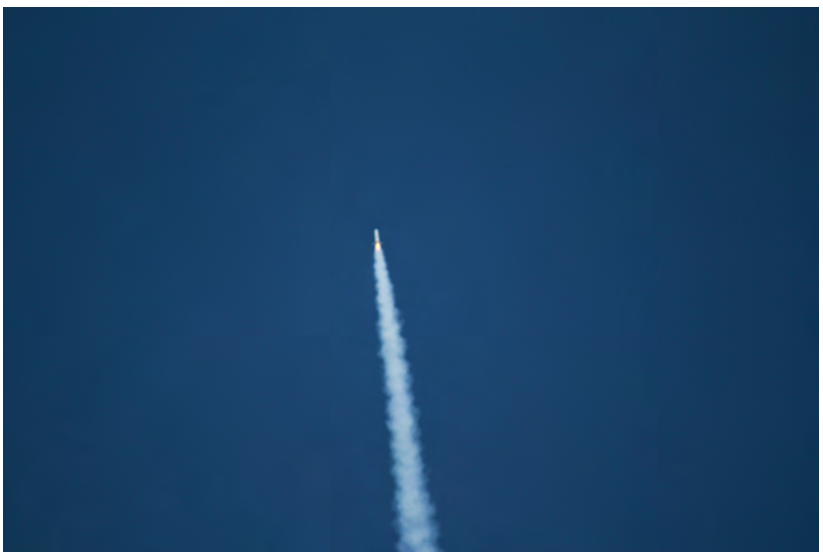

Figure 23: Javelin in midflight.

Verify CO_2 Tank Survivability A main concern of the Team was that the CO_2 tank would survive the launch with no damage to it or the Javelin. The team had to make sure that the tank would be able to withstand the heat from the motor case. Post-flight analysis of the tank showed no damage was sustained. All of the CO_2 gas was safely vented, demonstrating that despite rough landing conditions (as discussed below), the tank will not rupture during any point of the flight.

Validate Packing Procedures No one from the 2009 Chimaera Team is on this year's team, so several members had to re-learn how to fold parachutes correctly out in the field. The high winds made this task even more difficult than normal. It took nine members to hold the main parachute down on the back of a trailer, but both parachutes were successfully packaged for the rocket flight. Now the team has members who have prepared parachutes for the Javelin, which will be critical for the competition flight in April.

Achieve One Mile Altitude with C-BAS Operational Avionics suffered a malfunction during the test flight. The R-DAS was accidentally left in external voltage mode from earlier tests, so it did not properly activate the C-BAS when it needed to. The C-BAS did not turn on during the entire flight. Altitude data was also incorrectly logged by the PerfectFlite, so apogee altitude for the Javelin was not obtained. Both sensors were in good operating condition post-flight, so the team is confident that correct programming procedures at the next flight will fix this anomaly.

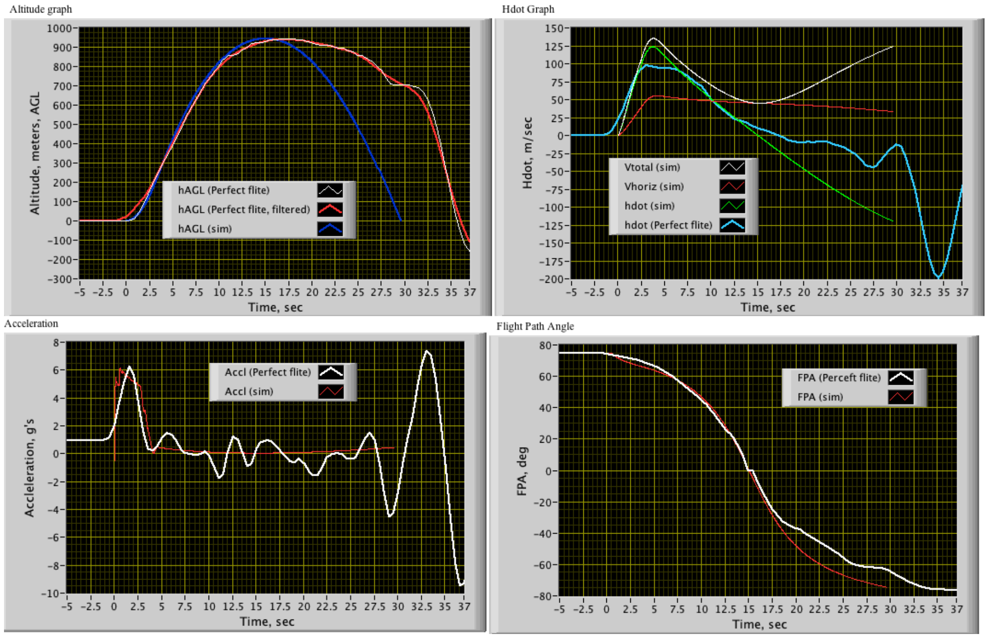

Figure 24: Flight data from the PerfectFlite altimeter.

Parachute Recovery Anomalies in the PerfectFlite and R-DAS led to ultimate failure of the recovery system. The Javelin crashed into the ground without the parachutes being deployed. The rocket landed on its side, which destroyed the body tube but saved the critical avionics and C-BAS components. In addition, the fins, nosecone, and parachutes were recovered intact. All the key systems of the Javelin were successfully salvaged from the wreckage. Recovery charges were still unlit, so the team ignited the black powder to ensure personnel safety during the accident review. The team is reviewing the data, but is confident that the changes to the flight computers will allow the Javelin to be safely recovered via parachutes at its next flight on March 26, 2011.


Figure 25: The Javelin after its test flight.

Future Flights The Utah Rocket Club (UROC) has obtained a flight waiver for March 26, 2011. The Chimaera Team will complete a second Javelin without C-BAS installed to fly on this date. This will allow the team to satisfy USLI flight requirements in a timely manner. The necessary changes to the R-DAS and PerfectFlite will be made to ensure that this flight anomaly will never occur again.

IV.E. Recovery Subsystem

IV.E.1. Recovery Subsystem Overview

A dual, redundant recovery system is being used on the Javelin. The primary controller is a PerfectFlite altimeter, which will be backed up by an R-DAS altimeter. When either altimeter senses apogee it sends a signal to the e-matches, which separate the avionics bay from the main airframe, deploying the drogue parachute. In order to reduce drift, but slow the rocket enough for a safe landing, the main parachute will be deployed at approximately 1000 ft (300 m) AGL. Figure 26 shows the functional block diagram of the parachute deployment system. The sections of the Javelin are connected with 2-56 nylon shear pins, and black powder and Quickburst ematches will be used for ejection charges.

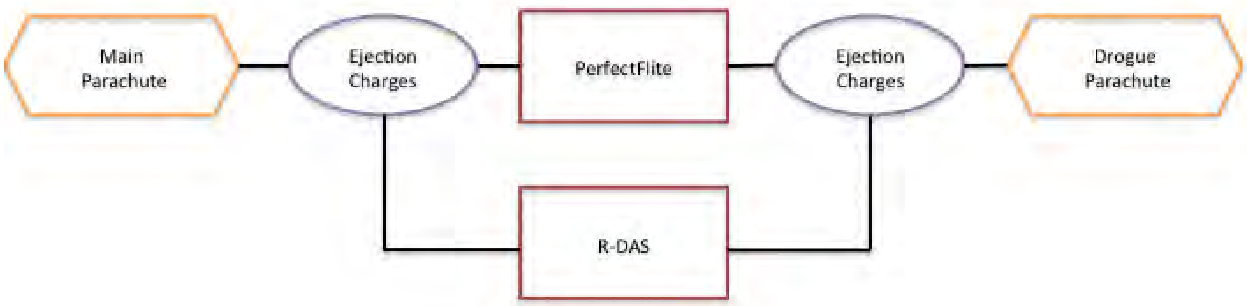

Figure 26: Functional block diagram of recovery system.

IV.E.2. Recovery Subsystem Design

A milestone map detailing the steps of the recovery system design process is shown in Figure 27.

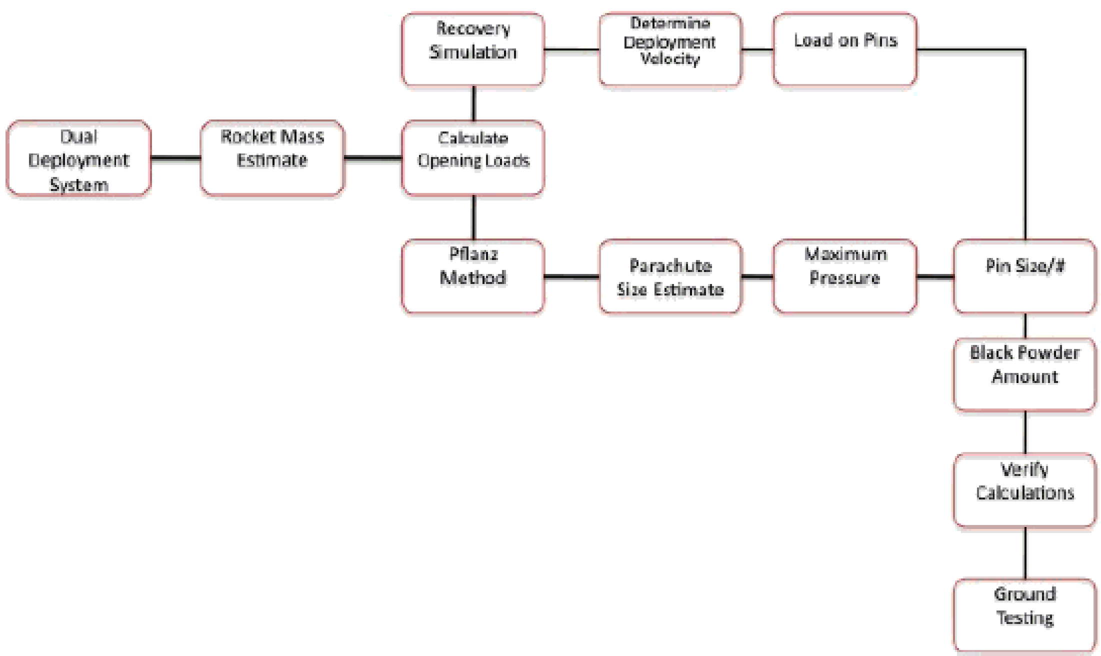

Figure 27: Recovery subsystem design milestone chart.

The first step in the recovery subsystem design process was to determine the sizes of the parachutes using the terminal velocity method, as outlined in Figure 28. Under the drogue parachute, the rocket will descend at a design rate of 77.6 ft/s (23.7 m/s). The main parachute design rate is 18.5 ft/s (5.64 m/s).

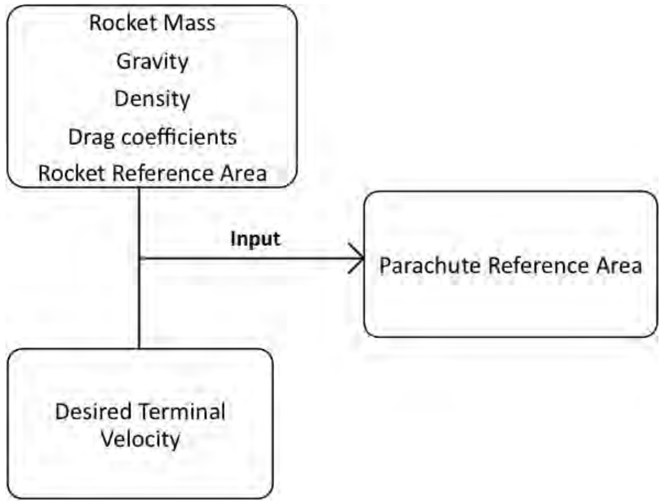

Figure 28: Summary of terminal velocity method.

All other input parameters for this calculation were taken from the *Parachute Recovery Systems Design Manual* by T.W. Knacke.[5] A mid-valued drag coefficient of 0.8 for conical parachutes was used. The reference area of the Javelin is .015 $m^2$and wind tunnel testing proved that a coefficient of drag of .35 is still accurate. The area is multiplied by two for the first sizing calculation because the rocket will be in two pieces under the drogue parachute. It is multiplied by three when calculating the area of the main parachute. The mass used for this analysis was 24.3 lbm (11.02 kg), which was the estimated launch mass of the rocket at the time of calculation, minus the mass of the motor propellant and the mass of the used cold gas, assuming 63 percent consumption.

Pflanz's Method[5] was used to determine opening loads of the parachutes. Figure 29 is a flow chart demonstrating Pflanz's Method.

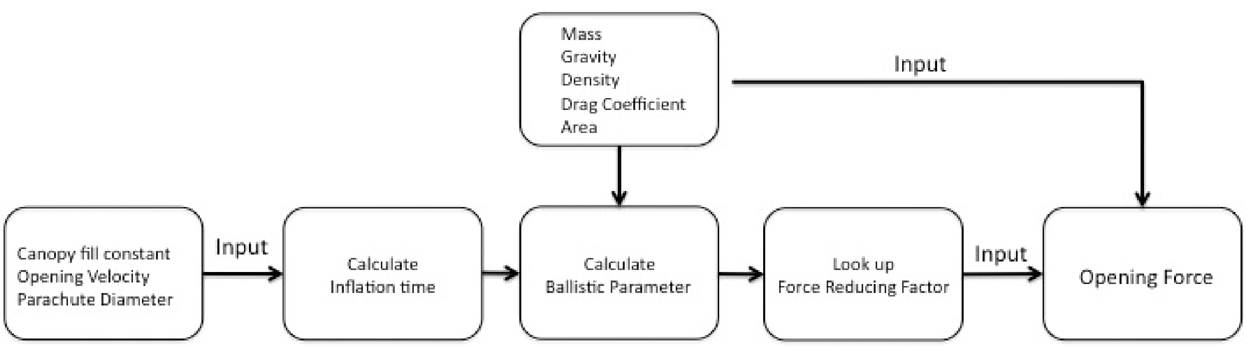

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Figure 29: Summary of Pflanz's Method.

The canopy fill constant for elliptical parachutes is four. The opening velocity for the drogue parachute was estimated to be no more than 139.8 ft/s (42.6 m/s) according to direct simulation. This estimate is based on the velocity that the rocket will reach after four seconds of free fall. It was decided that, should the drogue parachute fail to deploy at apogee as planned, it would take no more than than four seconds for the responsible team member to recognize this fact and deploy the drogue parachute remotely. At the time of the test flight, this remote-deployment capability was not available, but it will be for the USLI launch. The Javelin's descent will slow due to drag between parachute deployments, so the opening velocity for the main parachute is estimated to be 73.0 ft/s (22.26 m/s), slightly less than the terminal velocity of the drogue parachute. This effect has been accounted for in Pflanz's Method and in the simulation verification. After finding the ballistic parameter, (Ab), graphs found in the Knacke manual were used to determine (X1), the force reducing factor, for conical parachutes, assuming a parachute fill constant of n=2.

IV.E.3. Recovery Subsystem Sizing

Originally, the team aimed to have both parachutes descend at the lower limits of the allowable descent rates, but such an approach led to high, unbalanced opening loads and an oversized landing footprint. In order to eliminate extraneous forces on the Javelin, the goal was to minimize and equalize opening loads of the two parachutes. Top Flight Rocketry, the team's parachute supplier, supplies standard sized parachutes, so the sizing calculations were revisited. The team adjusted the design terminal velocities until the parachute diameters were 2.5 ft and 10 ft for the drogue and main parachutes, respectively. This brought the opening loads down, as well as narrowed the landing footprint to an acceptable radius. Final parachute design parameters are shown in Table 3. These results are based on the most likely descent mass at the time of the calculation, 24.3 lbm (11.02 kg), assuming 63 percent CO_2 consumption. In the case that less than 63 percent of the CO_2 is used, the opening forces will increase slightly and terminal velocities will decrease, but remain within acceptable parameters. In the case that more CO_2 is used than anticipated, the opening loads will decrease and terminal velocities will increase, but still remain within acceptable ranges.

Table 3: Recovery subystem parameters for 63 precent CO_2 consumption.

Parameter	Drogue Parachute	Main Parachute
Parachute Type	Conical	Conical
Deployment Altitude (ft AGL)	5025	984
Deployment Density (lb/ft^3)	0.064288	0.072587
Deployment Velocity (ft/s)	139.7	73.03
Nominal Terminal Velocity (ft/s)	77.60	18.50
Drag Coefficient	0.8	0.8
Reference Area (ft^2)	4.91	78.50
Peak Opening Load (lbf)	131.2	118.3

All recovery system analyses have been verified by direct simulation. Pflanz's Method tends to be conservative in predicting opening loads, but the test results show that the method is sufficiently accurate for the team's purposes. Figure 30 shows the forces exerted on the rocket over the duration of the launch, according to the team's simulation. The greatest load occurs at launch, so the airframe was tested to 1.25 times the motor load. It can be concluded that the airframe will also withstand the deployment forces.

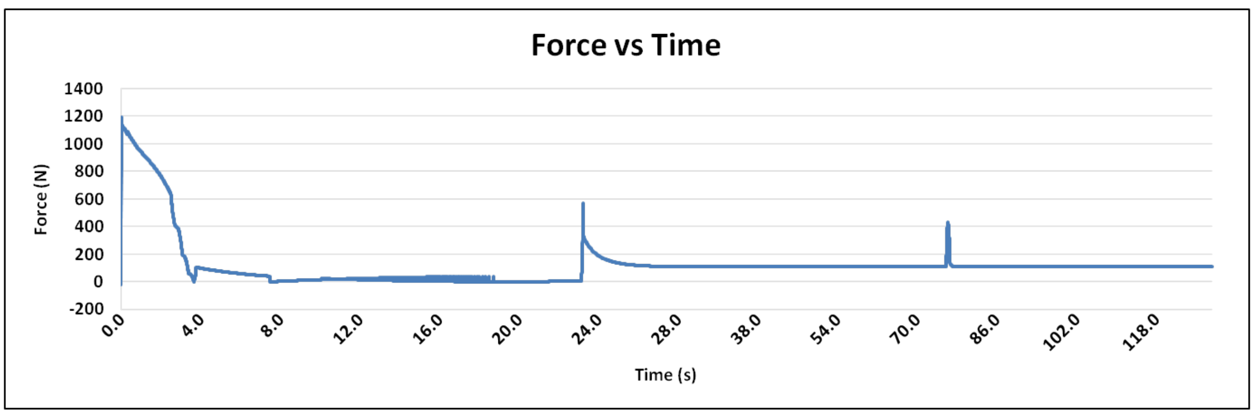


Figure 30: Force distribution throughout launch.

IV.E.4. Parachute Deployment Analysis

The nosecone and avionics bay are secured to each other and the booster section with 2-56 nylon shear pins, each rated to withstand a minimum force of 31 lbf (138 N) and a maximum force of 46 lbf (205 N). The shear pins must withstand all forces on the Javelin prior to deployment, but still be able to separate smoothly when the black powder charges are triggered. The shear load, multiplied by a 2.5 factor of safety and divided by the minimum shear strength of the shear pins, gives the number of pins required. Table 31 shows the shear pin analysis results. Ground tests of the deployment system confirm that four pins for initial separation and five pins for secondary separation are sufficient.

Figure 31: Shear pin analysis for dual deployment.

Pin data	Drogue deployment	Main deployment
Shear load (lbf)	47.95	54.25
Number of pins	4	5

Black powder is being used for ejection charges. The black powder amounts were determined using the ideal gas law. The shear load was multiplied by the chamber volume of either section, then divided by the cross-sectional area of the bulkhead, gas constant and temperature of the gas produced upon ignition. Black powder calculation results are shown in Table 4. It was reported in the CDR that the ejection charges would be packaged according to a procedure developed by previous Chimaera teams. The team determined that the black powder packing scheme was too unreliable, so a new procedure has been written. The new ejection charge preparation procedure can be viewed in Appendix B.

Table 4: Black powder needed for ejection charges.

Parameters	Drogue deployment	Main deployment
Gas constant ($\frac{J}{kg*K}$)	11.92 (71.28 $\frac{ft^2}{R*s^2}$)	11.92 (71.28 $\frac{ft^2}{R*s^2}$)
Cross-sectional area (in^2)	23.76	23.76
Chamber volume (in^3)	103.8	110.65
Shear Load (lbf)	47.95	54.25
Calculated black powder mass (g)	1.08 (0.038 oz)	1.30 (0.046 oz)
Required black powder mass (g)	2.0 (0.071 oz)	3.0 (0.106 oz)

Static ground tests were performed to confirm the shear pin and black powder calculations. Figure 32 shows the set up for this test. A rocket section was strapped to the table to simulate the mass of the booster section and to hold the setup in place. Appropriate masses and volumes were placed in the avionics section and nosecone. Initially, the ejection charges were wired to a battery and manually ignited without incident. While the black powder calculations resulted in 1.08 g and 1.3 grams for the drogue and main parachute deployments, respectively, in practice those amounts were inadequate. Two grams will be used for the drouge parachute, and three grams will be used to deploy the main parachute, in order to compensate for friction forces between airframe sections.

Figure 32: Pin test.

The system was also tested with the R-DAS and PerfectFlite altimeters separately. The PerfectFlite was placed into a jar that could be pressurized. When the PerfectFlite sensed pressure that correspondes to the appropriate altitudes, it sent a signal to the e-matches. The team discovered that the e-matches they were using had too high of an impedence for the R-DAS to function properly, so they were replaced with Quickburst e-matches and the R-DAS test was later performed with nominal results.

The parachutes are secured to bulkheads on either side of their compartments with 35 ft (10.7 m) Kevlar harnesses. The harnesses were donated by Total Impulse Rocketry, and the company helped the team determine an appropriate construction for the harnesses. Each harness hooks to a U-bolt on either end, and the parachute is attached to a loop 15 ft from one end of the harness. The 20 ft end of the harness is connected to the section that will be heavier after deployment. The long harnesses allow for the opening forces to be distributed, rather than absorbed entirely by the shroud lines, or any one bulkhead.

IV.E.5. Landing Footprint

The Javelin must be recovered within 2500 ft (760 m) of the launch pad. For approximate landing footprint calculations, the team estimated drift distance for constant wind speeds. The competition rules state that the rocket will not be launched in wind any higher than 10 mph, but Figure 33 shows that the Javelin could be launched in constant winds up to 22 mph, and still be within the acceptable recovery range.

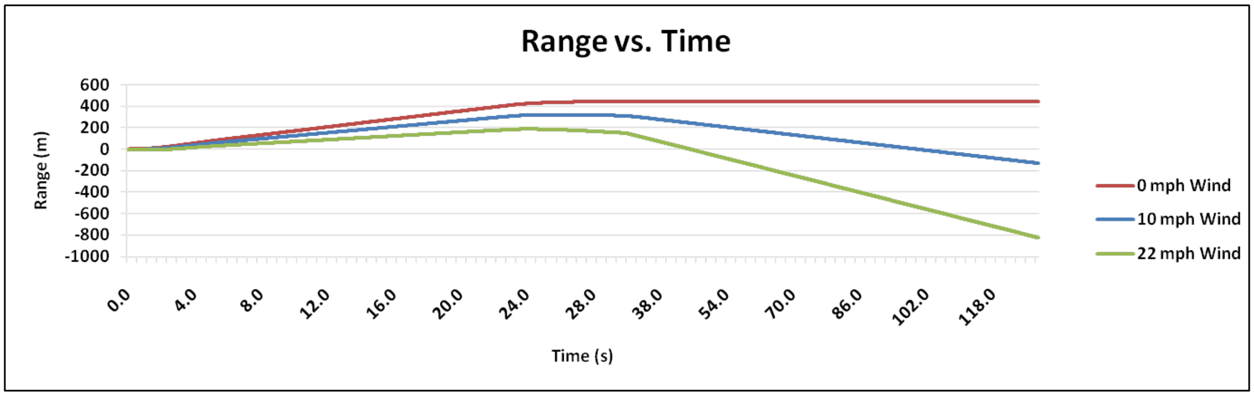


Figure 33: Landing footprint approximation for fixed wind speed.

However, this is a very crude approximation, and it does not account for differing wind speeds as the altitude increases. To get a more accurate prediction of wind effects on drift of the Javelin, the team pulled the GRAM 99 profile for the launch site on April 16. The data points were added to the Monte Carlo simulation, along with all other parameters for the Javelin's subsystems, which simulated the flight from launch to landing. Figure 34 shows the projection of the resulting data from 1001 simulation runs onto the local surface. The rocket landed within the 2500 ft radius 89.1 percent of the time, which corresponds to a 1.6 sigma confidence level. Upon closer examination, the team found that the simulations that drifted outside the allowable area were being run with predicted winds above 10 mph, at which point the rocket would not be launched in reality. The team has therefore concluded that the Javelin will be well within the boundary at the competition launch.

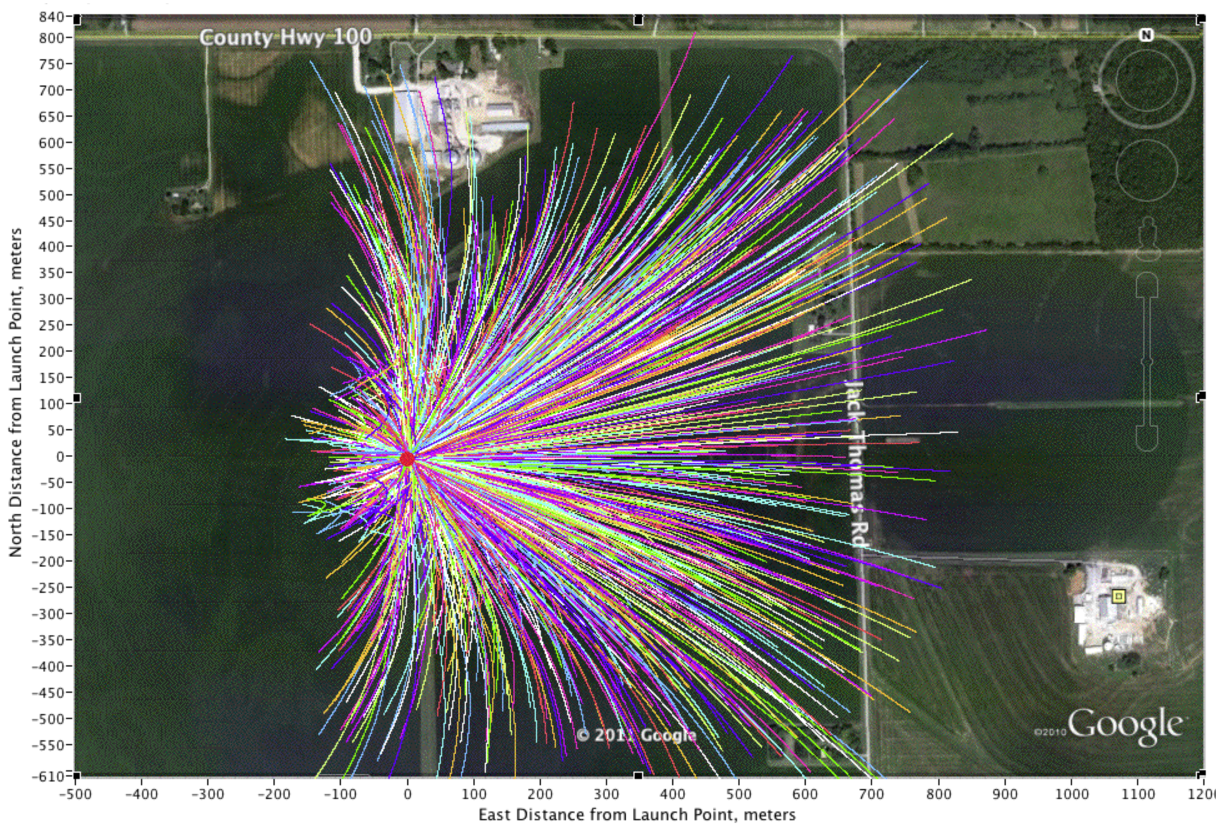


Figure 34: Landing footprint prediction for launch at Huntsville, AL on April 16.

IV.E.6. Recovery System Failure Modes

Black powder involves a high risk of heat damage to other system components, but this is prevented through careful packing procedures. The harnesses are made from Kevlar, a heat resistant material, and no heat-sensitive components will be touching the charges. The nylon parachutes will be wrapped in a Nomex bag, and a Nomex layer will be placed between the bundle and the ejection charge. Appendix C contains the parachute folding procedure, which has been adapted from previous teams' procedures. A summary of other possible failure modes and the team's proposed solutions are outlined in Table 5.

Table 5: Possible risks and solutions of recovery system.

Failure Mode	Design Location	Likelihood	Proposed Solution
Tangled Parachute Lines	Packing Procedures	High	Properly fold parachutes so lines will not cross on deployment
Torn Parachute	Opening Load	Low	Minimize opening loads, inspect housing to avoid snag points
Burned Parachute	Charges, Packing Procedures	Moderate	Surround heat-sensitive parachute components in protective material and ensure charges are placed such that they do not touch unprotected areas.
Charge Failure	Charges	Moderate	Use redundancy in avionics. Store black powder in a dry environment. Check e-match wires for continuity.
Rocket Separation Failure	Shear Pins, Charges	Moderate	Use redundancy in avionics. Apply appropriate charge sizes.
Parachute Separation Failure	Opening Load	High	Use harness materials capable of withstanding opening loads.
Excessive Drift	Parachute Size, Descent Rate	Low	Correctly size parachute, accurately predict descent rates.
Airframe Damage	Charges, Opening Loads, Descent Rate	Moderate	Accurately predict opening loads and charge sizes.

IV.F. Vehicle Mass Properties

The external dimensions and mass breakdown of the Javelin were derived using the 2009 Chimaera rocket design as a reference point. These initial mass estimates were subsequently modified to account for components unique to the current design. Since the CDR, the team has significantly increased the fidelity of the mass budget by measuring the weight of each individual component before and after each test launch. Furthermore, the mass budget has been broken into several categories. Table 6 shows this mass breakdown along with the most current general dimensions for the Javelin. Figure 35 presents the mass budget data in graphical chart.

Table 6: General dimensions for the Javelin.

Grand Launch Mass	29.81 lbm	13.52 kg
Motor Length	25.55 in	0.649 m
Total Length	7.40 ft	2.26 m
Payload Mass	24.11 lbm	10.94 kg
Structural Mass	23.37 lbm	10.60 kg
Clean Mass	21.26 lbm	9.64 kg

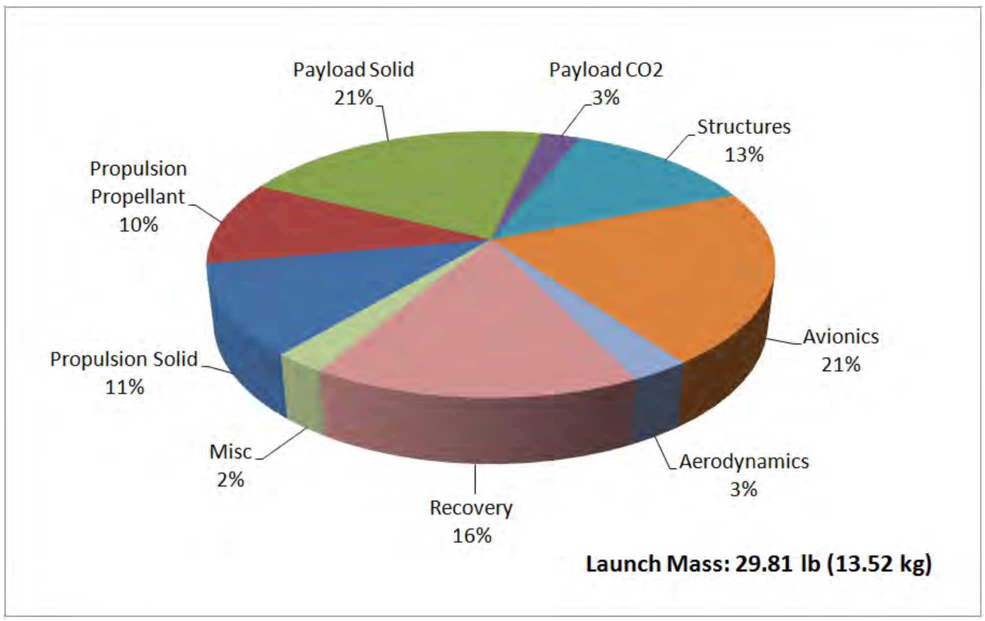


Figure 35: Projected vehicle mass breakdown.

Mass and positioning of the payload, avionics, and structural components directly affects the stability of the Javelin. Consequently, an accurate estimate of the mass properties that are necessary to effectively simulate the Javelin's altitude and rotational dynamics during fight. The data in Table 8 shows the center of mass, and the moments of inertia at launch, at motor burnout, and at apogee with all CO_2 exhausted. These values will change as the mass of the Javelin changes during flight.

Table 8: Mass and moments of inertia of the Javelin.

	Launch		Motor Burnout		Apogee	
Center of Mass, in the x direction (ft, m)	4.2365	1.291	3.977	1.2123	3.9868	1.2154
Center of Mass, in the y direction (ft, m)	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000
Center of Mass, in the z direction (ft, m)	-0.0009	-0.0003	-0.0001	-0.0003	-0.0009	-0.0003
Moments of Inertia, I_{xx} (lbm-f, kg-m^2)	2510.362	105.787	2510.362	105.787	2510.362	105.787
Moments of Inertia, I_{yy} (lbm-f, kg-m^2)	2070.818	87.265	2070.818	87.265	2070.818	87.265
Moments of Inertia, I_{zz} (lbm-f, kg-m^2)	4327.466	182.360	4327.466	182.360	4327.466	182.360
Moments of Inertia, I_{xy} (lbm-f, kg-m^2)	-1405.682	-0.0234	-1405.682	-0.0234	-1405.682	-0.0234
Moments of Inertia, I_{xz} (lbm-f, kg-m^2)	136.114	0.0938	136.114	0.0938	136.114	0.0938
Moments of Inertia, I_{yz} (lbm-f, kg-m^2)	-181.227	-0.0061	-181.227	-0.0061	-181.227	-0.0061

IV.G. Mission Performance Predictions

The team used a number of different methods in order to accurately predict mission performance. Each method is explained in detail in the sections below.

IV.G.1. Simulation Procedure

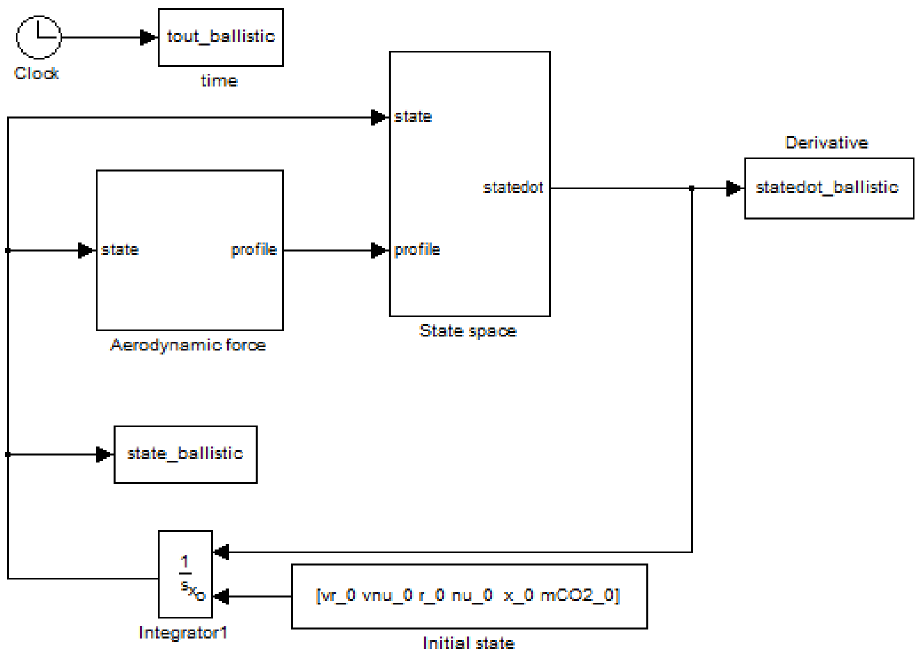
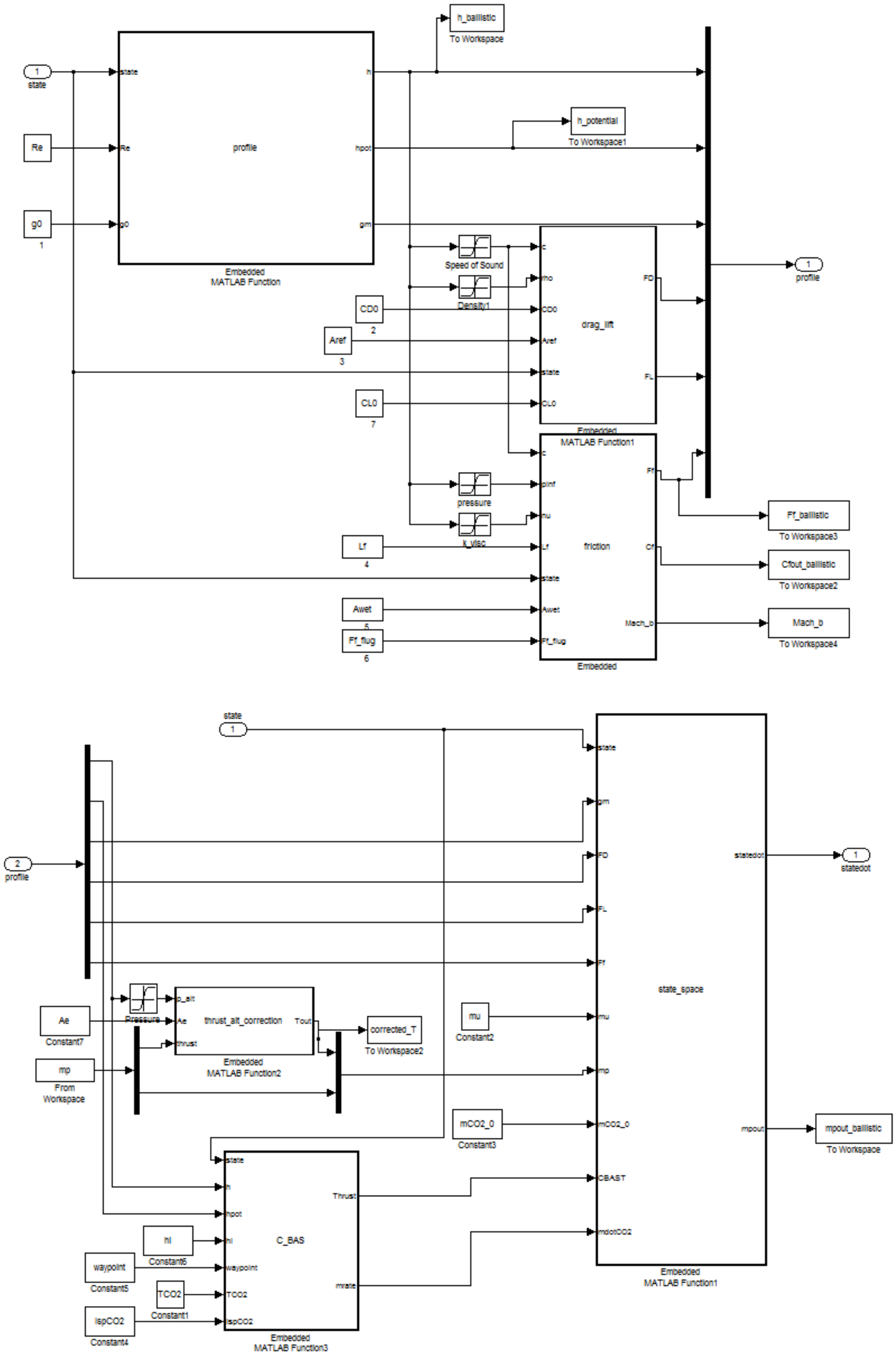


Figure 36: Rocket simulation model from MATLAB/Simulink.

Figure 36 shows the overview of the simulation model that was used to predict rocket trajectory. The simulation starts with initial conditions and calculates states for each time step period using a numerical integrator. Figure 37 (a) and (b) shows the subsystems of the simulation. The current simulation program accounts for aerodynamic forces such as drag, lift and friction, pressure correction of the solid motor thrust, and C-BAS activation based on rocket altitude and potential altitude.



(a)

(b)

Figure 37: Rocket simulation subsystem: (a) Calculate aerodynamic forces (b) Find derivative of the state vector.

IV.G.2. Motor Performance Analysis

Figures 38 and 39 plot the predicted altitude, velocity, and acceleration profiles, with C-BAS inactive and active, respectively.

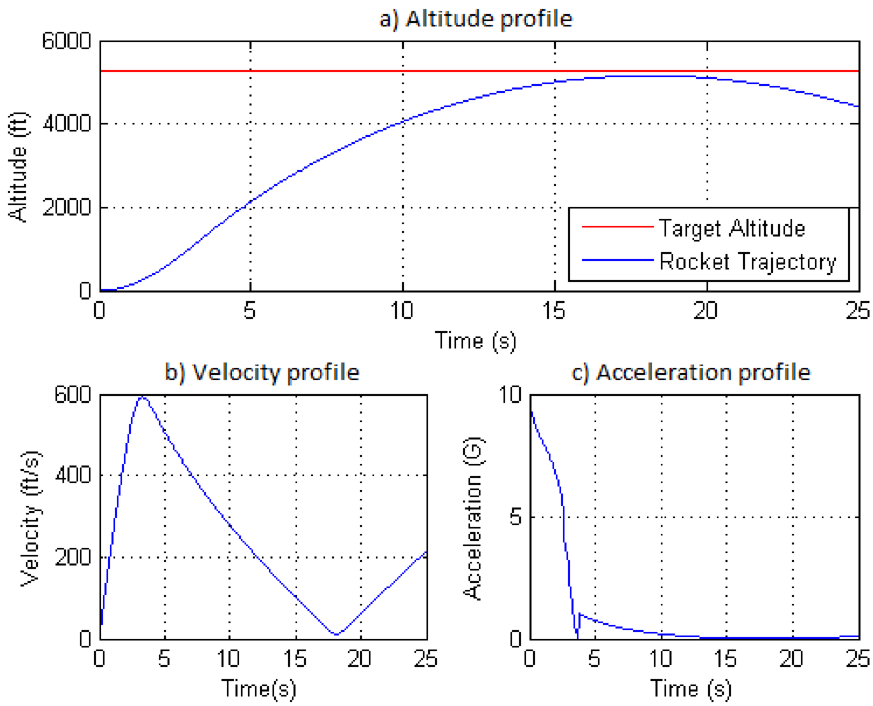


Figure 38: Rocket simulated trajectory with C-BAS inactive; a)Altitude, b)Velocity, c)Acceleration profiles.

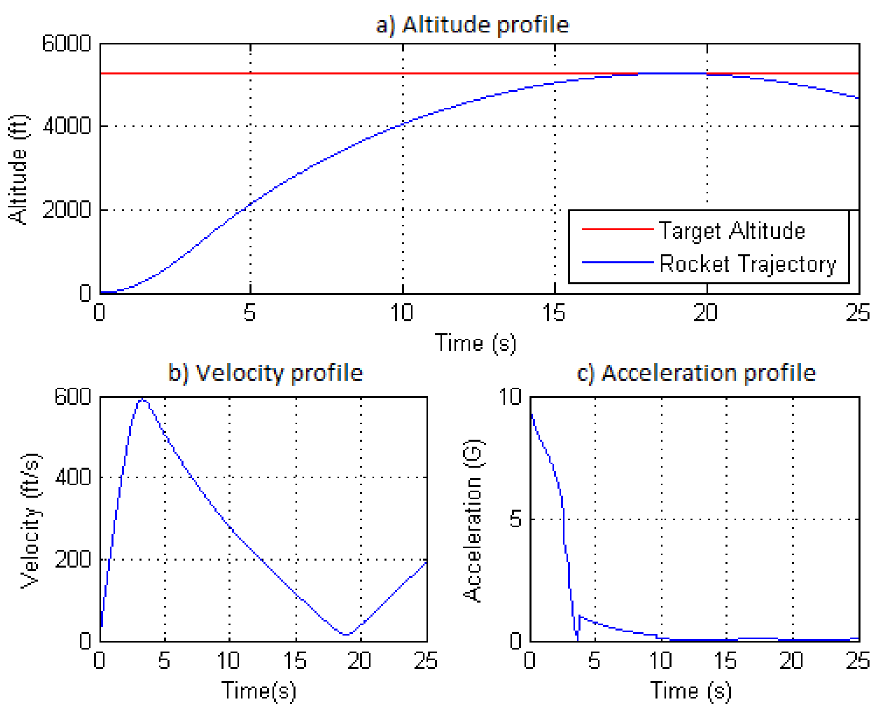


Figure 39: Rocket simulated trajectory with C-BAS active; a)Altitude, b)Velocity, c)Acceleration profiles.

The C-BAS uses a simple but effective pulse-width modulation algorithm to manage the energy of the vehicle. The algorithm must wait until the available energy augmentation can overcome the aerodynamic drag before it can activate the C-BAS. The key to this energy management approach is the potential altitude of the vehicle, derived from the sum of the gravitational potential energy and kinetic energy in the vertical direction. At any point along the trajectory the sum of the mass-specific potential energy is given by

$$\left(\frac{E}{m}\right)_{total} = gh + \frac{V^2}{2} \tag{1}$$

The total specific energy at apogee is related to the energy at any time following motor burnout by

$$\left(\frac{E}{m}\right)_{total} = gh + \left(\frac{V_{horizontal}^2}{2}\right)_{apogee} = gh + \left(\frac{V^2}{2}\right) - \int_t^{t_{apogee}} \left[\left(\frac{1}{2}\rho V^2\right)\left(\frac{C_D A_{ref}}{m}\right) V\right] dt \tag{2}$$

The last term on the right hand side of Equation 9 is the energy depleted by drag forces acting on the rocket. For ballistic trajectories with a nearly vertical initial launch angle, the horizontal velocity of the rocket at motor burnout remains approximately constant while altitude increases. Equation 9 can be rearranged to predict the rocket's apogee altitude based on the energy state estimated at any point along the trajectory.

$$h_{apogee} = h(t) + \frac{(V(t)\sin\gamma)^2}{2g} - \int_t^{t_{apogee}} \left[\left(\frac{1}{2}\rho V^2\right)\left(\frac{C_D A_{ref}}{m}\right) V\right] dt \tag{3}$$

where $V(t)\sin\gamma$ is the vertical component of velocity. Neglecting the effects of aerodynamic drag, the potential altitude is defined as

$$h_{potential} = h(t) + \frac{V_{vertical}^2(t)}{2g} \tag{4}$$

Clearly, as apogee is approached and the overall vehicle drag diminishes, and because rocket velocity also diminishes, the potential altitude defined by Equation 4 becomes an increasingly accurate predictor of the vehicle apogee altitude. If h_{min} is the altitude at which the drag drops below the available thrust level, and h_{target} is the target apogee altitude, then the augmentation algorithm is shown in Figure 40. The C-BAS will be turned on when altitude is between h_{min} and h_{target}, and $h_{potential}$ is lower than h_{target}; otherwise, the C-BAS will be turned off.

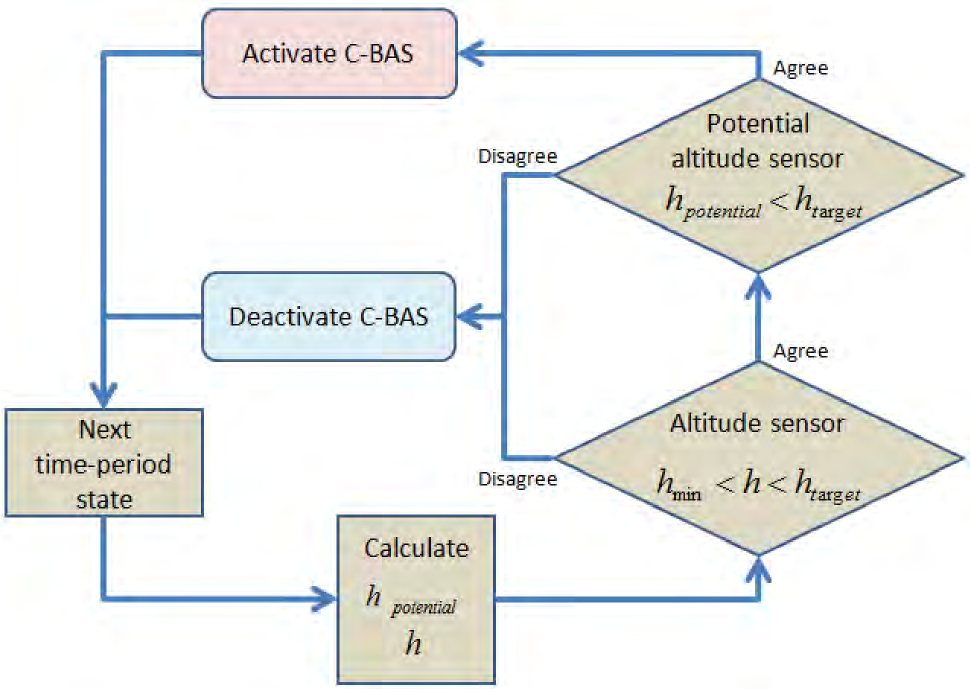


Figure 40: C-BAS algorithm for simulations.

IV.G.3. C-BAS Performance Analysis

In order to determine the change in velocity due to energy augmentation using the C-BAS, Equation 5, the rocket equation, was used.

$$\Delta V = g_0 \cdot I_{sp} \cdot \ln\left(1 + \frac{m_{propellant}}{m_{dry}}\right) \tag{5}$$

The rocket equation depends on the specific impulse of the C-BAS and cold-gas mass over the rocket mass. The rocket equation accounts for changing velocity only when the initial velocity is equal to zero. In order to determine the total changing altitude due to the initial velocity Equation 6, the energy state equation, was used.

$$\frac{\Delta K.E}{m} = \frac{V_2^2 - V_1^2}{2} \tag{6}$$

Rearranging the energy state equation in terms of ΔV and initial velocity gives

$$\frac{\Delta K.E}{m} \approx \Delta h_{potential} = \left(V_1 + \frac{\Delta V}{2}\right) \cdot \frac{\Delta V}{g} \tag{7}$$

The corresponding change of altitude due to cold-gas depends on the initial velocity of the rocket and ΔV. This means that when the C-BAS is activated earlier in flight, the resulting change in potential energy increases.

In Equation 7 the drag force was neglected, but drag is an important factor in determining C-BAS performance. In order to calculate the total drag acting on the rocket, Equation 8 is used.

$$(\Delta h_{potential})_{drag} = \int_{t}^{t_{apogee}} \frac{C_D \cdot A_{ref}}{2 \cdot m} \rho V^3 dt \tag{8}$$

Equation 8 shows that total drag depends heavily on the velocity of the Javelin, so the higher the velocity of the Javelin the more energy is depleted due to drag. Since the last report, the team tested the C-BAS in order to better understand the actual thrust and the total impulse of the system. The C-BAS testing section provides more information on this process. Table 9 summarizes the comparison of C-BAS activation early in flight versus C-BAS activation later in flight. If the C-BAS is activated shortly after motor burnout the change in altitude performance is high, but the drag loss is also high. The opposite applies if C-BAS is activated later in flight.

Table 9: Comparison of C-BAS activation.

	Earlier C-BAS activation	Later C-BAS activation
$\Delta h_{potential}$	High	Low
$(\Delta h_{potential})_{drag}$	High	Low

IV.G.4. Required Augmentation Altitude Change

There are multiple uncertainties that can change the trajectory of the rocket during flight. Therefore, the C-BAS should be able to compensate altitude based on the worst case scenario. The simulation used to analyze uncertainty varied the sources of uncertainty shown in Table 10 and was run 100 times to find the standard deviation for launches that used just the solid motor and solid motor augmented by the C-BAS. All 100 apogee points are shown in Figure 41. Simulation results are shown in Table 11 and it shows that the C-BAS will provide sufficient energy change to reach the apogee altitude of one mile high.

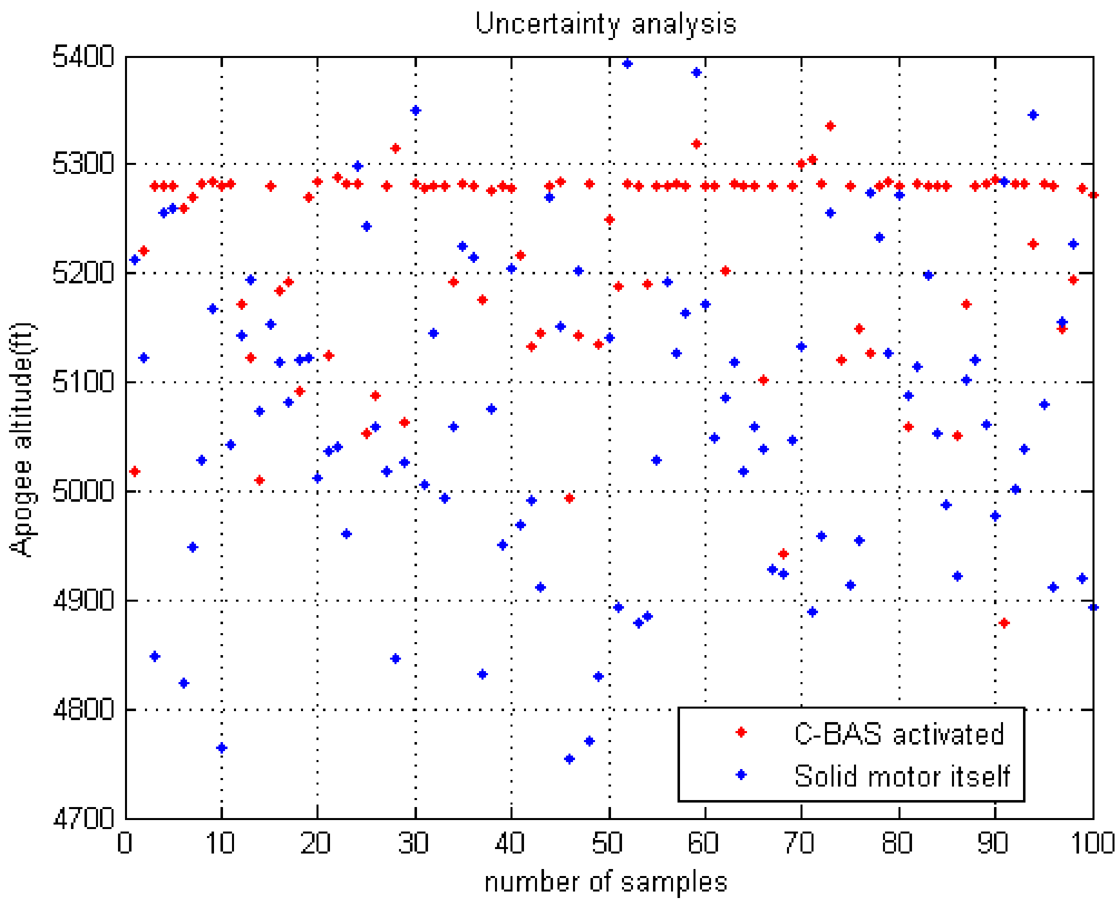


Figure 41: Rocket trajectories with uncertainties.

Figure 41 shows the results of the Monte Carlo analysis performed with the C-BAS active and inactive. Figure 41 shows that using just the solid motor itself, the rocket will only hit the 1% error range of one mile(± 52.8 ft) by 11% of launches within 99.7% confidence level. If the C-BAS is activated the rocket will hit the 1% error range of one mile by 65% of launches. Nominally, the rocket will launch vertically.

Table 10: Rocket Parameters and Uncertainty table for simulation

	Launch Weight (lbs)	Dry mass(lbs)	CO_2 mass(lbs)
Parameters	27.65	22.05	0.75
	Thrust Amplitude	Drag Coefficient	Launching Angle (deg)
Uncertainty(1σ)	±1.7%	±0.03	±4

And the wind model at launch altitude of 787.4 ft from mean sea level, 34.9 degree North latitude and 86.6 degree West Longitude on April 16th, 17:00 is obtained by using GRAM 99 (NASA/MSFC Global Reference Atmospheric Model-1999).

Table 11: Result from Monte-Carlo analysis.

C-BAS	Number of Simulation	Mean Apogee Alt.(ft)	Std.Deviation(ft)
OFF	100	5067.03	146.56
ON	100	5225.78	91.47

IV.H. Aerodynamics

IV.H.1. Static Stability

Center of Gravity In the design phase, models and spreadsheets were used to estimate the center of gravity based on the weight of each component. The center of mass changes during the flight as the motor burns and the ballast CO_2 is released, so the center of mass must be known at all times during the flight. The actual C_G locations are from the flight test configuration. Table 12 shows the C_G locations at key flight mass events.

Table 12: Rocket center of gravity distance from nose.

Flight Condition	CDR Design	FRR Actual
Launch Configuration	4.00 ft (1.22 m)	4.23 ft (1.29 m)
Motor Burnout	3.68 ft (1.12 m)	3.97 ft (1.21 m)
After CO_2 is Exhausted	3.64 ft (1.11 m)	4.00 ft (1.22 m)

Center of Pressure The center of pressure results were calculated with Barrowman's Method.[8] These equations provide a straightforward method to calculate the center of pressure at small angles of attack. The C_P result from the Barrowman's Method is not only reliable, but also provides an effective tool in designing rocket fins for the desired stability margin. In addition to Barrowman's Method, Missile DATCOM, an industry standard software program, and AeroCFD, a commercial rocketry code, were used for a higher-fidelity calculation of the center of pressure. Finally, these results were verified through wind tunnel tests, based on the procedure outlined by the National Association of Rocketry.[7] Figure 42 shows the variation of C_G and C_P estimates over the flight profile.

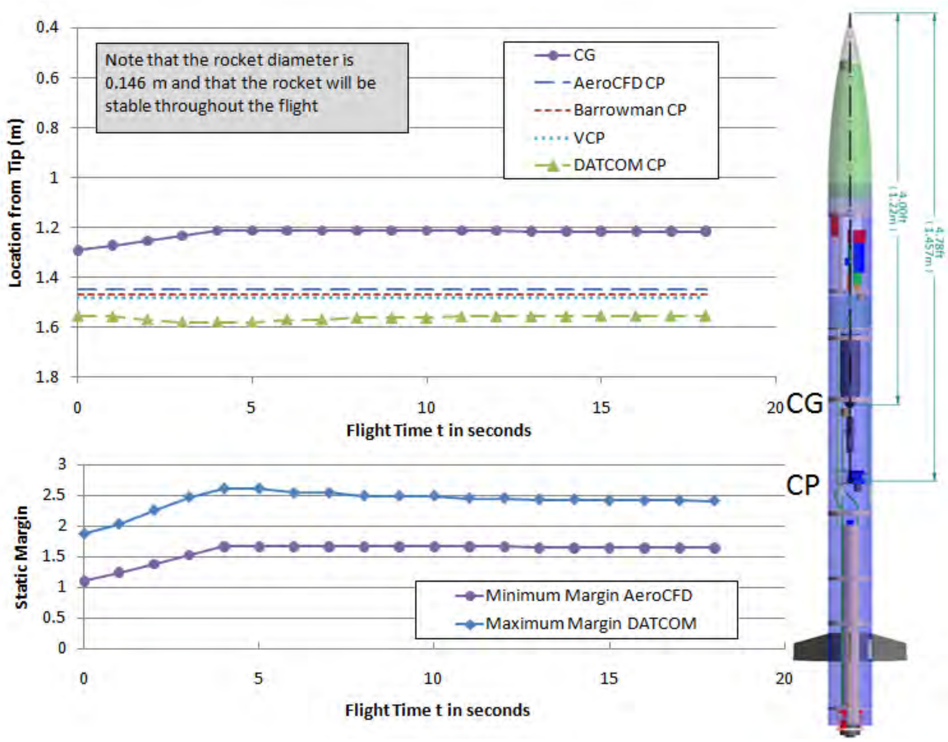


Figure 42: Center of mass and center of pressure over launch profile

The static margin is measured by the number of rocket diameters (caliber) the center of pressure is located behind the center of gravity. One to two caliber is typically required for static stability. Greater than a two caliber margic can potentially cause the rocket to weathercock into the crosswind causing an undesirable angle of attack or an overly stiff system, giving rise to dither drag. Following the flight profile, the rocket is initially properly stable and will avoid weathercocking. As the motor burns the rocket becomes more stable, which is ideal for when the C-BAS system begins operating.

STABILITY FAILURE MODES At launch the rocket has a static margin of 1.10 which is stable. This ensures there is an adequate restoring moment and that there is not too much weathercocking. As the motor burns out, the static margin becomes 1.67. Thus, weathercocking is not an issue. In order to ensure a successful flight, the failure modes were considered and analyzed as well as risk mitigation procedures. Table 13 shows the possible failure modes for this aerodynamic design.

Table 13: Possible modes of failure for the aerodynamic design.

Failure Modes	Rocket Reaction	Likelihood	Mitigation
Rocket becomes unstable	Rocket could deviate from trajectory and crash in the ground	Low	Ensure accurate center of mass location, and perform wind tunnel testing to verify C_p, understand effects of fin misalignment
Rocket is over stable	Rocket could weathercock into a crosswind	Low	Verify that the speed of the rocket leaving the launch rail is large enough to minimize weathercocking, and utilize simulator to measure the effects of fin size on stability
Inaccurate drag predictions	Insufficient Delta V to achieve 1-mile apogee	Medium	Verify simulator drag results with wind tunnel testing, and preliminary flight measurements lighten mass, switch to higher impulse fuel grains
C-BAS thrust asymmetry causes the rocket become unstable	Rocket begins to tumble, parachute deployment issues	Low	The Javelin has been designed so that the rocket is more stable while the C-BAS is operating . Wind tunnel tests and analytical calulations have been done to verify the stability of the rocket at various trim angles.

IV.H.2. Thrust Asymmetry

In addition to stability for all atmospheric effects, the Javelin must also be stable enough to compensate for any thrust assymetry in the C-BAS system. The maximum thrust asymmetry occurs with CO_2 only running out one expansion ramp. The maximum thrust for this case is less than 2.25 lbs (10 N) acting at a distance of 3.13 in (7.95 cm). The Javelin's trim angle was computed with a moment balance of the forces and moments acting on the rocket about the C_G. This took into account the vehicle aerodynamic coefficients CN_α and CM_α and the dynamic pressure for every point along the C-BAS operational window. The Javelin's trim angle (alpha, α) given maximum thrust asymmetry is 2.9 degrees, occuring at apogee as the dynamic pressure is reduced to a minimum. The plot of these analytical results is shown in Figure 43.

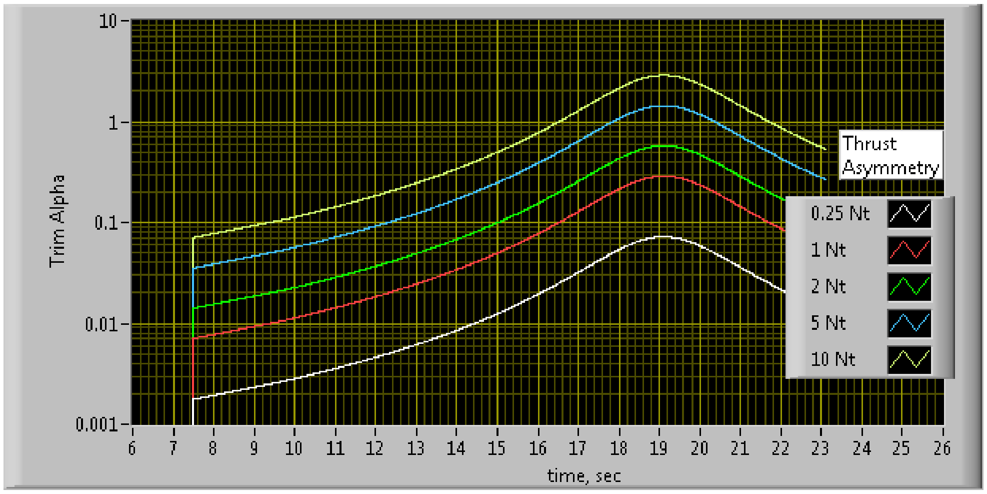


Figure 43: Plot of trim angle due to C-BAS thrust asymetry.

A simple wind tunnel test was performed using a scale model of the Javelin to investigate the rocket's stability, and verify the analytical calculations. The test concept is shown in Figure .

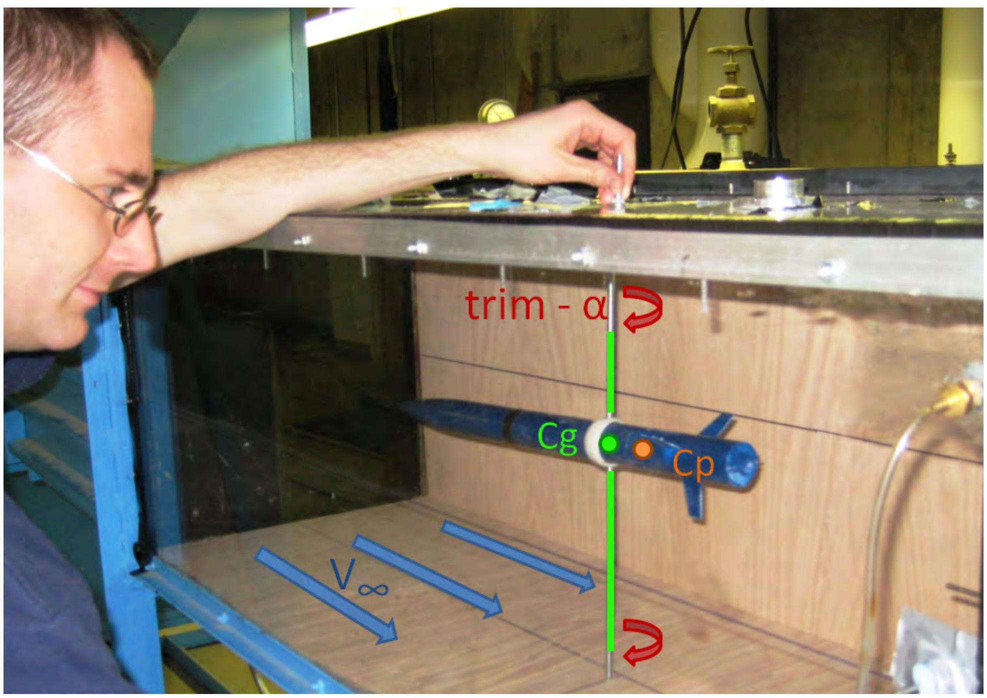


Figure 44: Test concept for C_P location and Javelin stability verification.

A rod was attached to the model, allowing it to pivot freely about that point, simulating the C_G. This point was then moved aftward until the rocket no longer had a restoring moment. This point was marked as C_P. With the C_G at the C_P, any disturbance caused the model to go unstable and begin to tumble, because there was no restoring moment. To test the stability of the Javelin, the rod was then moved forward to the location of the actual scaled location of the Javelin's C_G. The model was then placed at various trim angles and allowed to rotate freely. For angles less than 25 degrees the rocket returned and align with the airflow. Because of the very stable nature of the Javelin, a more than 25 degree trim angle was required to cause the model to become unstable. A clear outcome from the test is that the rocket can handle the maximum thrust asymmetry of 2.9^{o} and remain aerodynamically stable.

IV.H.3. Aerodynamic Drag Calculation

Missile DATCOM was used to verify the C_P result obtained from Barrowman's equations, get another estimate of the drag coefficient, as well as obtain the aerodynamic coefficients for lift and moment. The input file used by DATCOM is shown in Appendix D.A. The Javelin mold lines were described in the input file according to the procedure listed in the Missile DATCOM User's Manual.[?] Aerodynamic data, such as drag, lift, and pitching moment coefficients, as well as center of pressure, were calculated at various Mach numbers along the flight until apogee. Altitudes corresponding to those speeds were obtained from the team's in-house simulations. The results from DATCOM's analysis are shown in Figures 42 and 45. The output file from DATCOM is found in Appendix D.B.

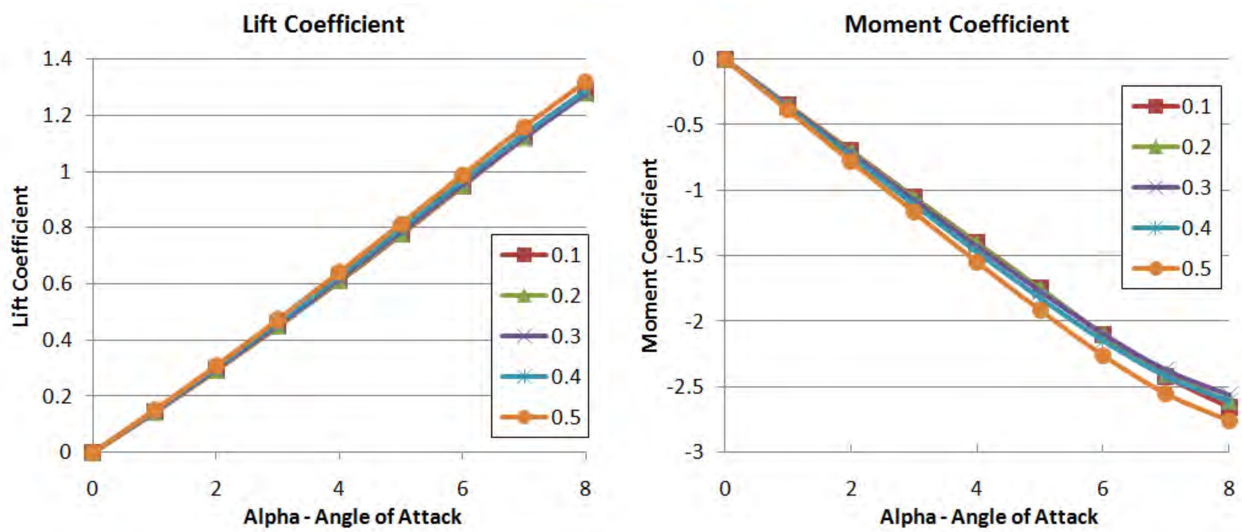


Figure 45: Missile DATCOM results for lift and moment coefficients.

Drag data from DATCOM is valid for Mach numbers between 0.3 and 0.7. C_{D0} from DATCOM is 0.348, an appropriate value towards the bottom of the expected values for C_D.The raw values are reported for the incompressible case and were corrected for compressibility using the Prandtl-Glauert transformation as shown in Equation 9

$$C_{D compressible} = \frac{C_{D incompressible}}{\sqrt{1 - M^2}} \tag{9}$$

which is a conservative correction factor to account for compressibility in flows $0.3 < M < 0.7$. This same correction is applied to all the incompressible drag values to predict drag over the Javelin velocity profile.[10]

Additional Calculation Methods The commercial hobby rocketry program AeroCFD was used to analyze the drag on the vehicle. This program calculated the drag on the Javelin for both the incompressible and compressible cases. The mesh used was refined to the program's capacity. It provided a good first cut, but yielded erroneous values for lift and moment coefficients. AeroCFD yielded a C_{D0} value of 0.358. The correlations of Drew and Jenn were also used to estimate drag on the vehicle.[?] This drag correlation takes into account pressure drag, base drag, and skin friction. This method yielded 0.372 for the C_{D0} value.

Wind Tunnel Wake Survey Testing Setup The team conducted a wake survey to confirm the accuracy and reliability of drag coefficient data obtained from Missile DATCOM and AeroCFD. The test included a student-built 3-D scale model of the Javelin to simulate in-flight conditions. Wind tunnel preparation included research and establishment of appropriate data acquisition (DAQ) hardware, creation of computational algorithms, and calibration of each pressure transducer used in measuring the pressure drop across the wake of the Javelin model.

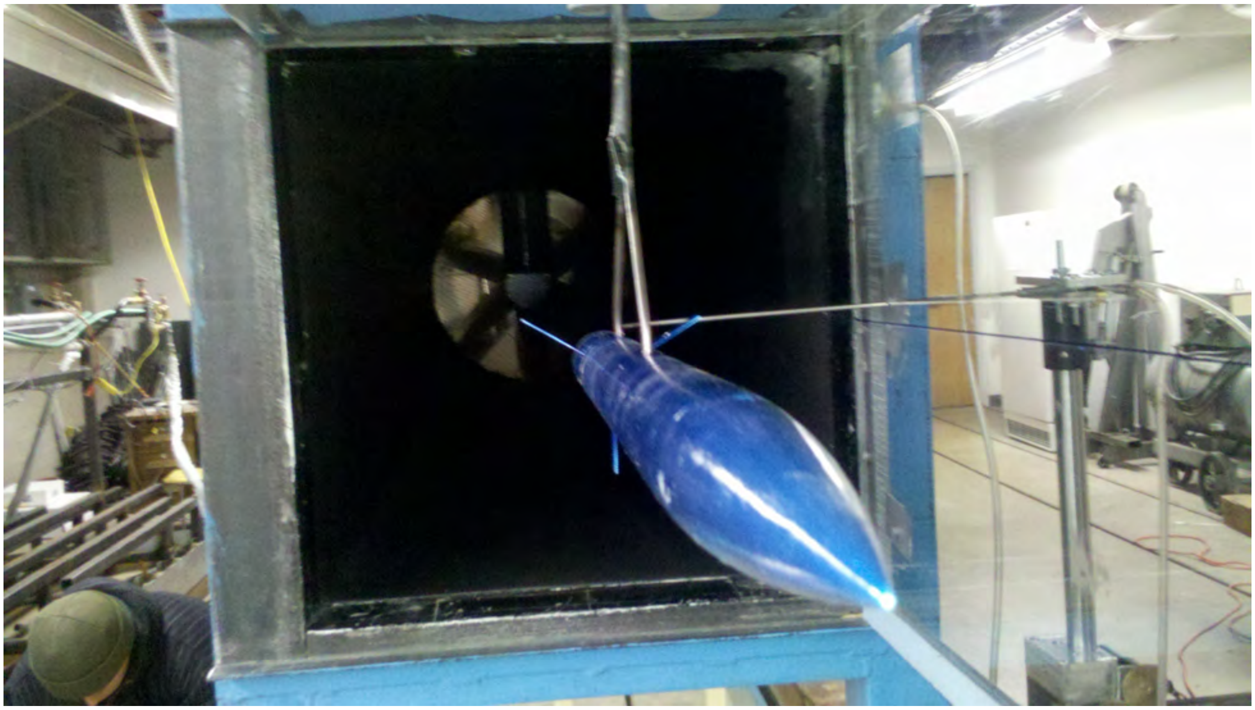


Figure 46: Dynamic view of Javelin model and pitot tube inside wind tunnel.

Figure 46 shows a linear rack-and-pinion traverse mechanism using a two-directional forward/reverse switch in order to precisely position the pitot probe during each sweep of the wake during the test. The hardware configuration setup is shown in Figure 47. Probe position was sensed using a linear potentiometer sensor.

Figure 47: Wind tunnel wake survey hardware setup.

As demonstrated in figure 47, data was acquired with a National Instruments (NI) BNC-2110 adapter which sends binary signals to each differential and absolute pressure transducer inducing a measurement reading at a specified assigned port. Additional necessary hardware included an MKS 223BD differential transducer, an Omega 142PC15A absolute transducer, an Omega 143PC01D differential transducer, an Omega PST-8 power supply, a Wall PST-40B power supply, and a HP 6325A DC power supply, shown in Figure 47. Voltage potential differences were read in by the same BNC-2110 DAQ adapter that decomposes the voltage difference before the output data is processed within a student-built LabVIEW VI. Both the linear traverse motor control and pressure transducers were powered by an AC to DC power supply converter and the BNC-2110 adapter was powered by the computer's pcmcia DAQ card. In order to simplify wiring in the future, the team members created a wiring schematic diagram for future repeatable testing and set up of the hardware configuration, shown in Figure 48.

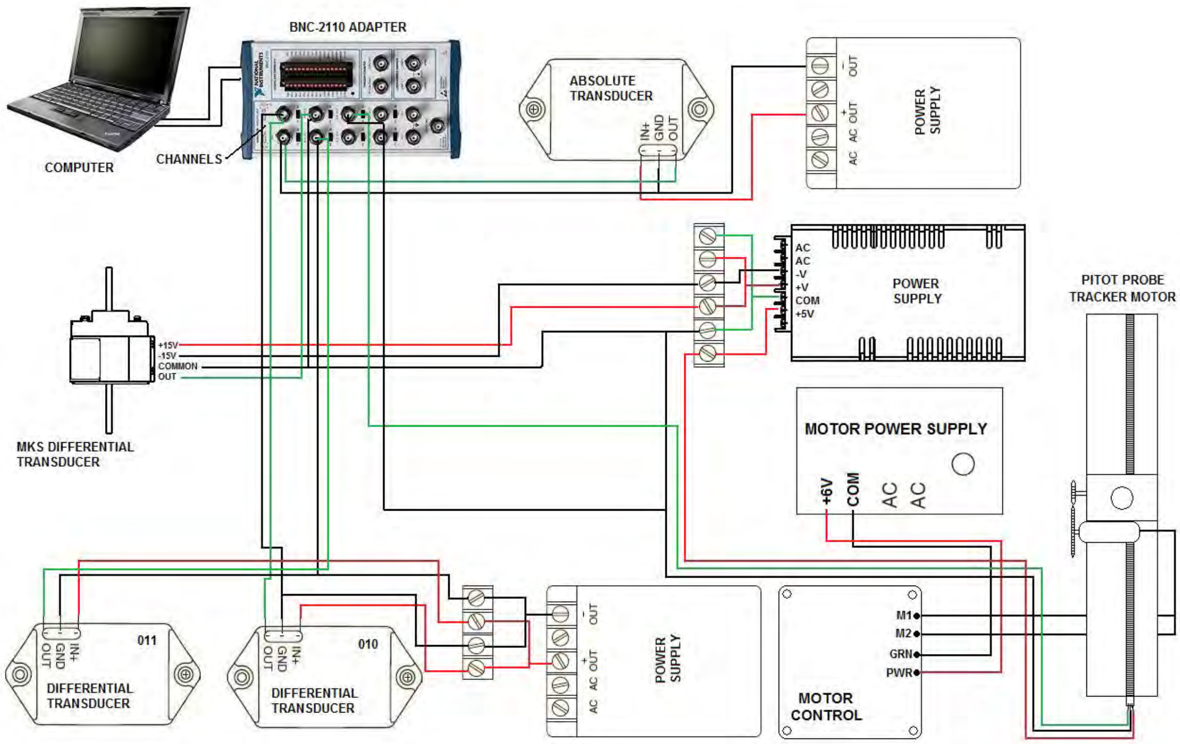


Figure 48: Wind tunnel harware wiring diagram.

The student built VI was used during wind tunnel testing in order to acquire data and provide instantaneous results which were displayed in real-time. This allowed the student to see instantanous pressure drops across the wake with each linear transverse. The model's wake was transversed at vertical increments of 0.2 in. (5 mm). Each pressure transducer was individually calibrated to obtain more accurate test results. During the wake survey the vertical range transversed by the probe was 2.36 in. (60 mm) above and below the centerline of Javelin model with respect the the centerline of the pitot tube. Each increment was predetermined, measured, and marked on the model mounting bracket for consistance. The next step was to secure and verify that the Javelin had zero degree angle of attack with the free stream wind tunnel velocity, ensuring an accurate measurement of C_{D0}. Each of the subsquential sweeps followed the same procedures. This was done until the full wake field had been surveyed. In all cases it was verified that the data had been recorded and saved to an apropriate text file for later analysis.

Wake Survey Results The principal behind the wake survey is a mass and momentum balance interpolated and integrated over the wake, based on the finite data points taken by the passing probe. By combining the mass and momentum equation in cylindrical form, the resulting equation for drag is terms of pressures can be expressed as Equation 10:

$$C_D = \left(\frac{8}{\pi \cdot D_{ref}^2}\right) \cdot \left\{ \int_0^{2\pi} \left[\int_0^{\delta_{max}} \left(\sqrt{\frac{\Delta p_{(r,\theta)}}{\Delta p_{edge}}} \right) \cdot \left(1 - \sqrt{\frac{\Delta p_{(r,\theta)}}{\Delta p_{edge}}} \right) \cdot r \cdot dr \right] d\theta \right\} \tag{10}$$

Figure 49 shows the wake velocities computed from the pressure difference. The velocities are normalized against the free-stream velocity, showing free stream velocities at a value of 1.0. The top row shows the "raw" integrated data where the model's supporting rod is clearly visible. In this form only a rough drag estimate can be made. Spatial deconvolution was used to eliminate the pressure traces due to the supporting rod. The lower portion of the figure shows the filtered data without the rod, which yielded of drag coefficient of 0.38. From the data, the fins are clearly visible as well as the base drag behind the main body.

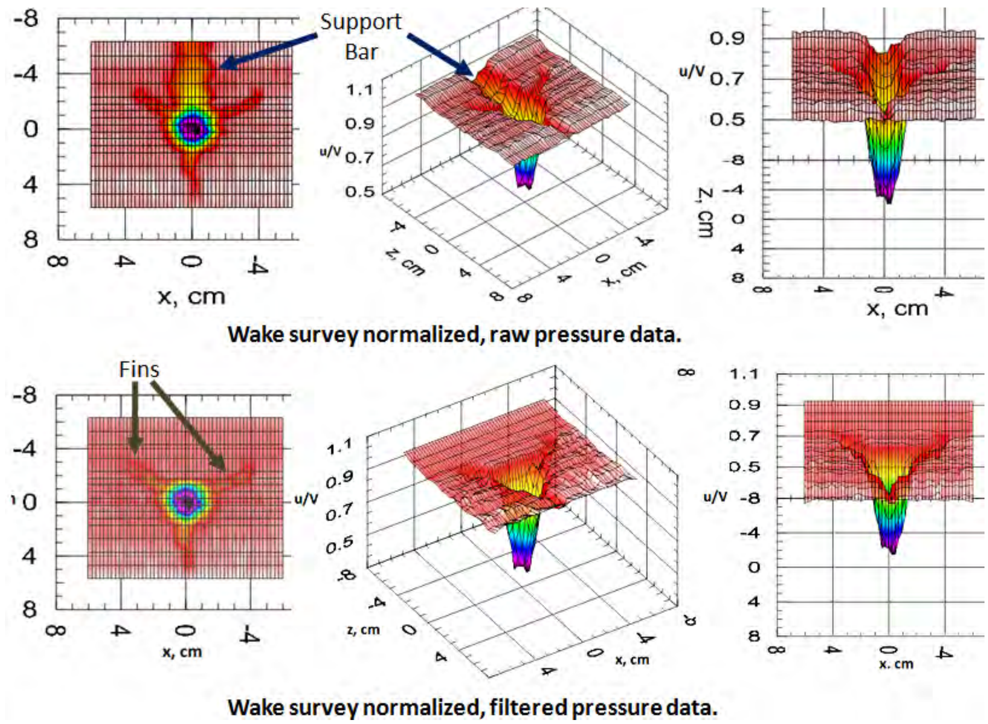


Figure 49

Drag Coefficient Comparison The different estimates C_D have been plotted together in Figure 52. The wind tunnel values are highest, because this estimate used a real model which had some skin friction effects. The surface for that model was fairly rough. The correlation model also took skin friction into account in the computation, rather than just pressure and base drag. The AeroCFD compressible computational correction compared to the AeroCFD data with the Prandtl-Glauert correction shows that the correction can be overly conservative, especially at higher Mach numbers. Based on these different estimates, the average value for C_D is 0.365 with a range of ± 0.017 (95 percent Confidence). This allows the simulation team to more accurately predict the Javelin's trajectory and correctly ballast the rocket.

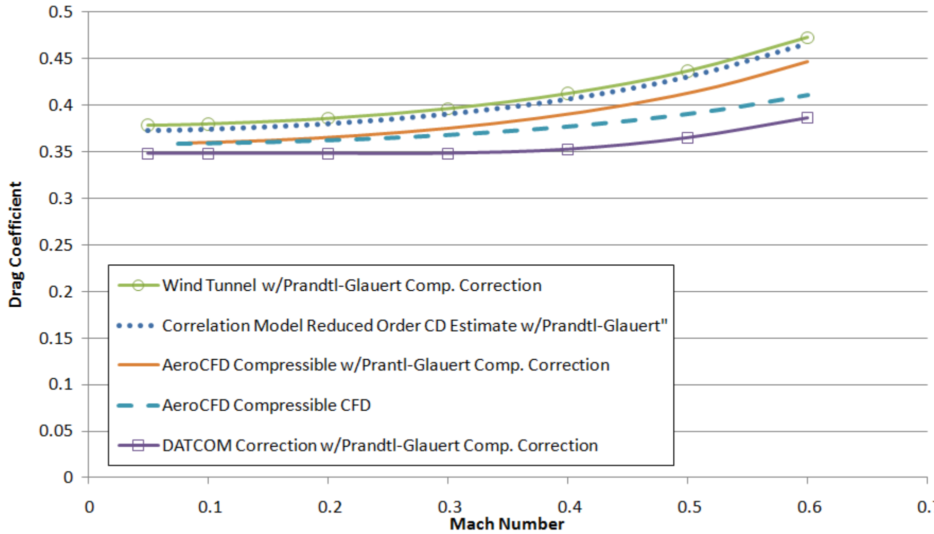


Figure 50: C_{D0} results comparison with compressibilty correction.

As a sanity check, the zero angle of attack drag coefficient values were compared with measured values from previous USU entries in the USLI competition. Figure 51 compares the external mold lines of the Javelin (2011) to the Barracuda (2008) and the Pike (2009). The vehicle body tube diameters for the rockets are identical (14.06 cm). The Javelin is shorter than the Barracuda and significantly longer than the Pike. Accordingly, the C_D on the Javelin should fall somewhere between the actual values collected on the previous rockets. The C_D data from these flights is shown in Figure 52. On this figure both flight and wind tunnel drag coefficient estimates are presented. The flight data is derived from the on-board accelerometer and inertially-derived dynamic pressure measurements and are plotted for the first eight seconds following motor burnout. The wind tunnel drag estimates were obtained using wake survey methods and are plotted as constant horizontal lines on this graph. The large deviations in the flight data were due to airbrake deployment that was a part of the energy management system, designed to significantly increase the drag on the vehicle using specially designed airbrakes. The "clean vehicle" drag coefficient estimates clearly bound the current best value of $C_D = 0.365$ based on Missile DATCOM calculations for the Javelin airframe.

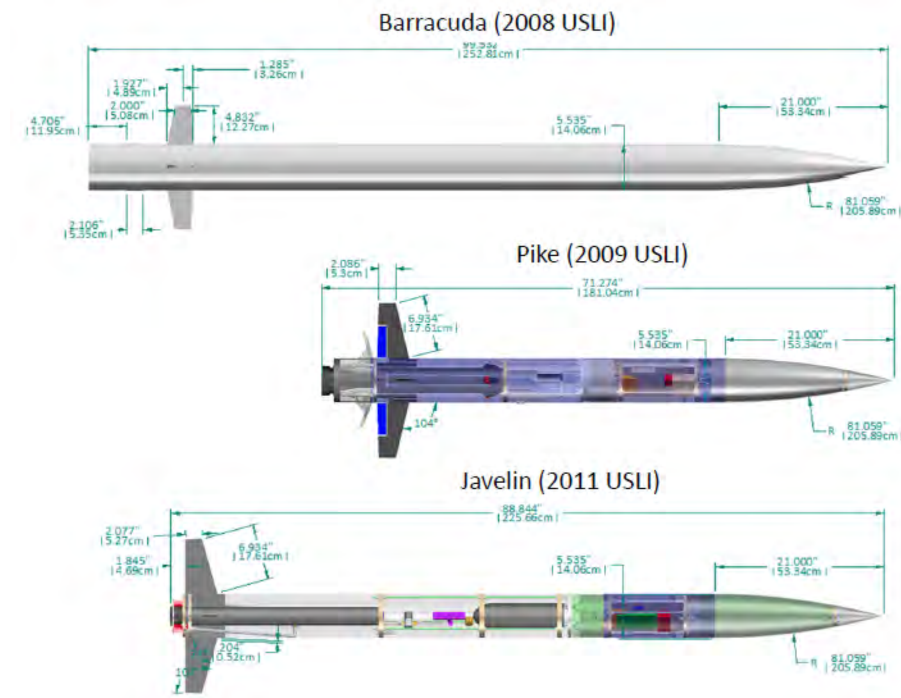


Figure 51: External mold-line comparison of the Javelin and previous USLI entries from Utah State.

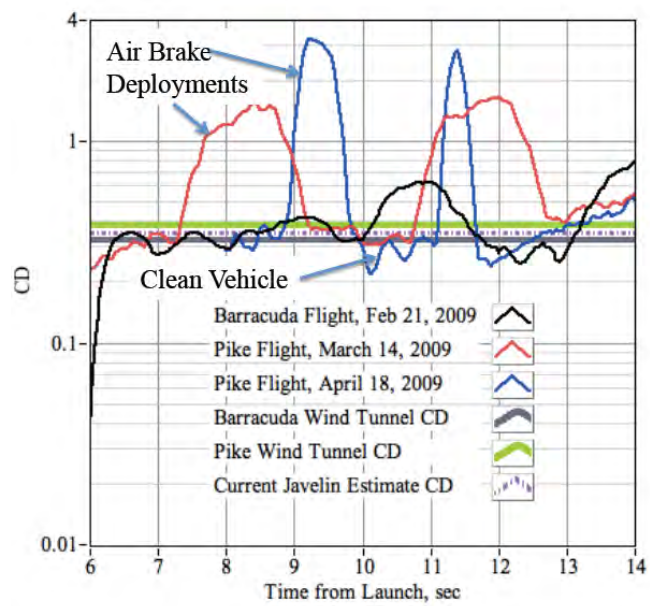


Figure 52: Drag coefficient comparisons of previously obtained flight data to current Javelin measurements.

IV.I. Safety and Environment of Launch Vehicle

IV.I.1. Failure Mode Analysis

The team safety officer, Kyle, is responsible for ensuring the safety plan is followed. Every effort has been made to ensure the safety of those involved in the fabrication, testing, and flight of the Javelin. This plan includes determining all possible failure modes of the rocket, payload integration, and launch operations. Many failure modes have already been identified and are included in Table 14. By understanding where the weak points are in the system, the team is better equipped to eliminate them through design and implementation of controls. The mission success of the Javelin is ensured by the identification and mitigation of all possible failure modes.

The team gained critical experience in eliminating failure modes through the experiences Kyle and Colin had when they built and flew rockets to obtain Level II certification. The following are problems they faced, and the solutions implemented by the team to prevent recurrence.

- Ignition failure- While trying to launch a rocket for Level I certification, the igniter was not properly installed and the motor did not ignite. The igniter had to be reinstalled and fastened to the rocket in a way that it could remain in the correct location for motor ignition.

- Motor retention- The selected motor retainer was not compatible with the rocket kit. The fins for the rocket were attached to the motor tube too far aft and prevented the motor retainer from sitting correctly. There was a chance for the motor casing to fall out of the rocket unless the team could develop a way to properly attach the motor retainer. The problem was solved by using a dremel tool to remove some of the material that was in the way. All components functioned nominally during flight.

- Parachute deployment- While a PerfectFlite was used for parachute deployment on most of the certification flights, a secondary deployment method was desired. The solution was to model the certification flights using the student-built simulation to predict the apogee of the flight for the motors used. The ejection charges within the motor were then set to ignite shortly after the predicted apogee. Without incident, all certification flights had a successful parachute deployment and recovery.

Table 14: Failure modes of the rocket, payload integration, and launch operations.

Failure Modes	Possible Effect of Failure	Planned Mitigation
Rocket:		
-Motor retention failure	Motor and casing are blown out of rocket when parachutes deploy	Properly adhere motor retainer to body tube and motor tube
-E-matches do not light ejection charges (drogue and main)	Rocket descends too quickly and/or becomes unrecoverable	Manual override available to set off e-matches if they do not ignite at the correct times; set main motor ejection charge with a time delay; ejection charges to ensure continual contact between black powder and e-matches
-Main bulkhead blow-through	Motor tears through the rocket	Test the motor and design bulkheads to withstand 2.5 times the maximum load
Payload Integration:		
-Regulator malfunction	Incorrect amount of gas reaches the C-BAS	Test the cold gas system and regulator to ensure all components function properly
-Gas system o-ring failure	All of the gas leaks out of the system	Ensure o-rings are not bumped while installing
-Solenoid malfunction	Valve remains open or closed, not allowing the gas to be pulsed; improper cycling rate	Test the solenoid valve to determine reliability; see if it can cycle as quickly as needed
Launch Operations:		
-Ignition failure (igniter and launch system)	Rocket won't launch	Verify continuity before launch. Make sure batteries in the launch system are new
-Body tube test stand support failure	Test stand collapses	Install platform guides so the platform cannot tip when body tube fractures. Use a plexiglass shield to protect observers from falling/flying parts

IV.I.2. Hazard Evaluation and Risk Mitigation

The Chimaera team has adapted the risk assessment procedure outlined by the NASA Engineering and Safety Center (NESC)[a] to more accurately reflect the likelihood and consequences of the hazards that can be reasonably anticipated in high-power rocketry. The amount of risk the team will see is a function of the severity and the likelihood of an event happening. The greater the consequence and the more frequently an event happens, the more risk one can expect. Figure 53 shows the hazard evaluation matrix used to determine the level of risk for a given hazard. A detailed explanation of how the likelihood and consequence of a hazard can be classified is outlined below.

[a] http://www.rmc.nasa.gov/presentations/Yuchnovicz_NESC.pdf

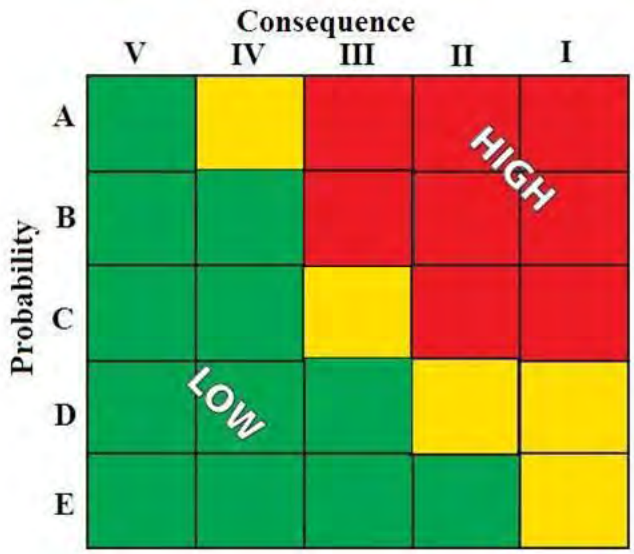


Figure 53: Hazard evaluation matrix used to determine risk level.

Event Likelihood The probability of an event happening is largely based on industry and personal experience. Materials can be characterized to an extent, giving the user an idea of how that particular material will react in a given situation. It is therefore a somewhat subjective matter prescribing the likelihood of any particular hazard or event. Table 15 gives a description of what each level of probability represents.

Table 15: What is the likelihood of a given situation happening?

Level	Likelihood/Probability	This means...
A	Very Likely	It is likely this will happen >90% of the time (9 in 10)
B	High	This happens more often than not (60%, or 3 in 5)
C	Moderate	There is a chance this will happen (25%, or 1 in 4)
D	Low	This rarely happens (1%, or 1 in 100)
E	Very Low	This occurs less than 0.1% of the time (1 in 1000)

Event Severity The severity can be conservatively estimated from experience and by assuming worst-case scenarios. Table 16 gives the classification for the different levels of consequence. The severity of an event will not impact personnel, payload, and environment in the same way. It is necessary to separate these areas in order to understand how an event impacts them differently.

Table 16: Level of consequence and threat to personnel, environment, and payload.

Level	Consequence/Severity	This means...
I	Catastrophic	**Personnel:** Life threatening or permanent disability **Environment:** Massive, irreparable loss or damage; damage results in legal action **Payload:** Complete system failure without ability to resolve; results in mission failure
II	Extreme	**Personnel:** Injury requiring hospitalization/emergency medical attention **Environment:** Large scale damage **Payload:** System failure
III	Moderate	**Personnel:** Requires medical aid, but manageable with a first-aid kit **Environment:** Requires clean up and/or fixing; evidence of incident remains **Payload:** Small damage prevents system from functioning as designed, but still mostly functional
IV	Minor	**Personnel:** Minor abrasions and contusions **Environment:** Requires clean up and/or fixing; no lasting effects **Payload:** Introduces small amount of variance in performance
V	Insignificant	**Personnel:** Temporary confusion, bewilderment, or discomfort **Environment:** Little or no damage; easily cleaned up or fixed with no lasting effects **Payload:** Nominal performance regardless of incident

MITIGATING RISK THROUGH CONTROLS It is possible to mitigate, or alleviate, some amount of risk by introducing controls that will reduce the level of severity or likelihood. Reducing severity requires minimizing the impact of the event. Controls that will reduce the severity of an event include, but are not limited to:

- Personal Protective Equipment (PPE); this will vary depending on the material or situation at hand.
- Maintaining the proper stand-off distance and only operating in areas designated for high-power rocketry use.
- Minimizing the number of personnel involved in a situation.

It should be noted that reducing the severity of an event with respect to personnel may not change the severity with respect to environment or payload, and vice versa. Reducing the likelihood of an event requires limiting the opportunity for that event to happen, such as:

- Eliminating stray electricity.
- Using checklists and procedures that are designed to eliminate accidents.
- Separating explosives from conductive materials.

The Chimaera team will not accept any risks deemed high according to the hazard evaluation matrix. A high risk would expose the team or others, the environment, and the Javelin to situations that may be life threatening, or damaging beyond repair. As such, the controls outlined in Table 17 have been implemented in order to reduce the severity of, and our exposure to, hazardous situations.

Table 17: Risk reduction through control measures.

Identified Hazard	Initial Risk Level	Control Measures	Residual Risk
Motor ignites in transit	**Personnel:** I-E (M)	Store motor in explosives magazine; separate rocket components from the magazine; keep magazine in a locked container on the trailer instead of in the vehicle	V-E (L)
	Environment: III-E (L)		V-E (L)
	Payload: I-E (M)		V-E (L)
Igniter fires while conducting systems check	**Personnel:** I-E (M)	Don't install igniter until systems check is complete; ground out while handling/inserting the motor and igniter; keep launch controller in SAFE mode until systems check completed	I-E (M)
	Environment: V-E (L)		V-E (L)
	Payload: I-E (M)		II-E (L)
Rocket is unstable, tumbles during flight	**Personnel:** II-D (M)	Ensure C_P is aft of C_G in flight configuration every time before flight; install/remove ballast as necessary	III-E (L)
	Environment: III-D (L)		III-E (L)
	Payload: I-D (M)		III-E (L)
Black powder ignites while constructing/loading deployment charges	**Personnel:** II-D (M)	Ground out before using black powder; wear PPE; keep electronic devices off within 5' of black powder	III-E (L)
	Environment: IV-D (L)		IV-E (L)
	Payload: III-D (L)		IV-E (L)

Identified Hazard	Initial Risk Level	Control Measures	Residual Risk
Test stand cannot hold motor	**Personnel:** I-E (M)	Maintain minimum stand-off distance for the motor being tested; ensure test cell is vacant before initiating test; ensure surrounding area is clear of flammable material; check fasteners holding motor to ensure they are snug	IV-E (L)
	Environment: II-E (L)		IV-E (L)
	Payload: II-E (L)		V-E (L)
CO_2 tank dropped and the valve cracks, turning the tank into a projectile	**Personnel:** IV-E (L)	Do not toss tanks; carry extra tanks and o-rings in case of an accident	IV-E (L)
	Environment: V-E (L)		V-E (L)
	Payload: I-E (M)		V-E (L)
Batteries explode	**Personnel:** II-E (L)	Charge only rechargeable batteries; keep batteries out of extreme heat; have spare batteries on hand	III-E (L)
	Environment: III-E (L)		III-E (L)
	Payload: I-E (M)		V-E (L)

IV.I.3. Regulation and Safety Compliance

The team is aware of, and in compliance with, all the National Association of Rocketry (NAR) safety requirements outlined on pages 42 and 43 of the USLI Handbook. Each team member has also signed a Safety Compliance Form in Appendix E that verifies each student understands the following: 1) NASA will conduct range safety inspections of each rocket before it is flown. The USU Chimaera team will comply with the inspection determination; 2) The NASA Range Safety officer has the final say on all rocket safety issues, and has the ability to deny the launch based on safety reasons; 3) If the team is in noncompliance with safety and mission assurance, the rocket will not be launched.

Contact information for USU Environmental, Health, and Safety personnel, as well as the Utah Rocket Club (UROC) contact person is listed in Appendix M.

The team has built on the rich history of safety established by years of experience building and testing amateur and high-power rockets at USU. The current team inherited an extensive list of materials and procedures that has led to the safe and successful launch of many rockets. The safety protocols and launch procedures are used with little if any modification.

Material Handling A solid rocket motor containing Ammonium Perchlorate Composite Propellant (APCP) will be used by USU in the USLI competition. Solid motors use compounds which have strict storage, handling, and transportation requirements. The team has access to facilities capable of storing APCP motors and other low explosives according to applicable laws. All students have been briefed on the risks associated with the propellant to ensure safe preparation and launch practices.

Black powder and electric matches will be used for recovery deployment. Material Safety Data Sheets (MSDS) for potentially hazardous construction materials can be found on the Chimaera website at chimaera.usu.edu. As other potentially hazardous materials are encountered throughout the design and fabrication process, an MSDS for each is obtained and made readily available in the areas where the materials are present.

Explosives Permits Because the rocket design includes black powder charges, electric matches for recovery deployment, and an APCP motor, a low explosives permit is required. A Low Explosives User's Permit (LEUP) was obtained through the Bureau of Alcohol, Tobacco, and Firearms (BATF) by Dr. Stephen Whitmore, the team instructor. The permit was renewed in February 2011, and cosigned by the four team members responsible for handling the explosives: Kyle, Colin, Craig, and Annika.

Purchase, Shipping, Storing, and Transport of Motor National Fire Protection Association (NFPA) 1127 and safety codes of both the NAR and the Tripoli Rocketry Association (TRA) require that high-power motors be sold only to or possessed by certified users. This certification may be granted by a nationally recognized organization to individuals over 18 years of age who demonstrate competence and knowledge in handling, storing, and using such motors. High power motors include all motors above F-class, and all motors that use metallic casings, including reloadable motors, regardless of power class.

The Javelin design includes an L-class, re-loadable rocket motor. The Canadian Association of Rocketry (CAR), NAR, and TRA offer the certification required to use this type of motor. High power rocket motors contain highly flammable substances, such as black powder or ammonium perchlorate, and are considered to be hazardous materials or explosives for shipment purposes by the U.S. Department of Transportation (DOT). The DOT regulations concerning shipment of hazardous materials is contained in the Code of Federal Regulations (CFR) Title 49, Parts 170-179. These regulations specify that it is illegal to send rocket motors by commercial carriers, or to carry them onto an airliner except under exact compliance with these regulations. NFPA 1127 Section 4.19 contains the storage requirements of motors over 2.2 oz (62.5 g). High-power rocket motors, motor reloading kits, and pyrotechnic modules are to be stored at least 25 ft (7.6 m) from smoking, open flames and other sources of heat.

Propellant for high power rocket motors is subject to the storage requirements of 27 CFR 55. This states that propellant shall be stored in a type 3 or 4 indoor magazine, and that no more than 50 lb (23 kg) of propellant shall be stored in one location. The magazine shall be painted red and have the words "explosive-keep fire away" in white block letters at least 76 mm high on the top of the box. The motor must be stored without the ignition element installed. The vehicle used for transportation will not be left unattended with black powder or APCP inside it. No open flame or smoking will be allowed within close proximity of the vehicle containing the magazine. The magazine will be strapped down securely to the floor with fire resistant material. The doors of the vehicle leading to the magazine will be locked at all times. A CO_2 or foam extinguisher along with the MSDS sheets and the contact information of the safety officer and the designated personnel will be made available to the driver and the attendant accompanying the driver. A first aid kit for minor burns will also be made available in the vehicle. Whenever possible, rocket motors and black powder will be bought near the launch site to help mitigate the hazards involved in transporting these materials.

Launch Site Safety Before launch day the student team will receive training in hazard recognition and accident avoidance. On the day of launch the safety officer will conduct a systems safety check on the motor, payload, and recovery. A pre-launch briefing will be conducted with the team before each launch. The recognized hazards will be discussed, as well as methods for mitigating the hazards. Each launch site will be controlled by the local NAR section. The test launches will be overseen by UROC. High-power rocket launches must comply with local, state and federal regulations. The Federal Aviation Administration (FAA) has specific laws governing the use of airspace during high-power rocket launches, as specified in 14 CFR 101. The local NAR section controlling the launch must notify the local FAA Air Traffic Control facility of the details of the launch. It is the responsibility of each rocket's operator to ensure that the launch is conducted within the operating limitations outline in 14 CFR 101.23.

Level II Certification To purchase and use high power rocket motors, an individual must be certified by either the NAR or the TRA. The certification is designed to ensure that the high power motors are being used only for the purpose for which they were designed. Although there are three different levels of certification, the team requires only up to Level II certification for the USLI competition, which allows for the use of J-, K-, and L-class motors.

The certification process is designed to allow the candidate to demonstrate their understanding of the basic physics and safety guidelines that govern the use of high power rockets. Level II certification requires that one obtain Level I certification first; construct, fly and recover a high power rocket in a condition that it can immediately be flown again. Then to obtain Level II, a written exam that tests knowledge of rocket aerodynamics and safety is required. A 90% score is the pass rate for this test.

Shannon Eilers, a graduate research assistant working with the team, has previously obtained Level II certification. For the 2011 USLI competition, Kyle and Colin received Level II certification through the TRA on October 16, 2010. Tim Boschert, the Utah Tripoli Prefect, administered the written and flight tests. UROC obtained the waiver for the flights. The Level II certified persons will ensure that all members of the USU Chimaera team are aware of the risks of high-powered rocket launches, and will help create a safe launch environment.

Manufacturing Safety The team has full access to the USU machine shop and wood shop, which includes a drill press, table saw, sheet metal bender, welding machines, a CNC mill, and any power tools or hand tools that may be required during the construction of the Javelin. Before team members are allowed to use the facilities they are first given instruction on each piece of machinery. The team must abide by the strict rules and guidelines posted in the shop, and outlined in Appendix L.

V. Payload Criteria

V.A. Experiment Concept

The C-BAS will activate at predetermined waypoints during the flight to increase the energy of the Javelin, allowing it to reach the target altitude. The earlier the C-BAS activates, the more effective it becomes because of the already high energy state of the rocket. But it also increases the amount of uncertainty in its performance due to the effects of drag. As drag decreases so does the uncertainty in the performance of the C-BAS. In order to try and optimize the system the waypoints are distributed throughout flight; early in flight when the system is more effective, and later in flight when it is more efficient. Earlier activations increase the energy to roughly the correct state required to reach one mile, and later waypoints fine-tune the energy to bring the Javelin within inches of its target altitude.

Figure 54 plots velocity and drag as a function of time for a typical one-mile launch trajectory. Figure 54 also shows time histories of velocity components, true (AGL) and potential altitudes, drag, and rate of energy change. Note that the potential altitude parameter defined by Equation 4 becomes an increasingly accurate predictor of the apogee altitude as the vehicle slows. In fact, once the vehicle clears 3937 ft (1200 m) AGL, the potential altitude remains virtually constant. Note also that at this altitude, rate of energy dissipation due to the aerodynamic drag is negligible. Figures 54 and 55 compare a typical unaugmented trajectory (C-BAS inactive) to an augmented trajectory (C-BAS active). The data presented in Figure 55 is taken from Thrustcurve.org and represents a Cesaroni L730.[7] High-powered rocket motor for the main propulsion system.

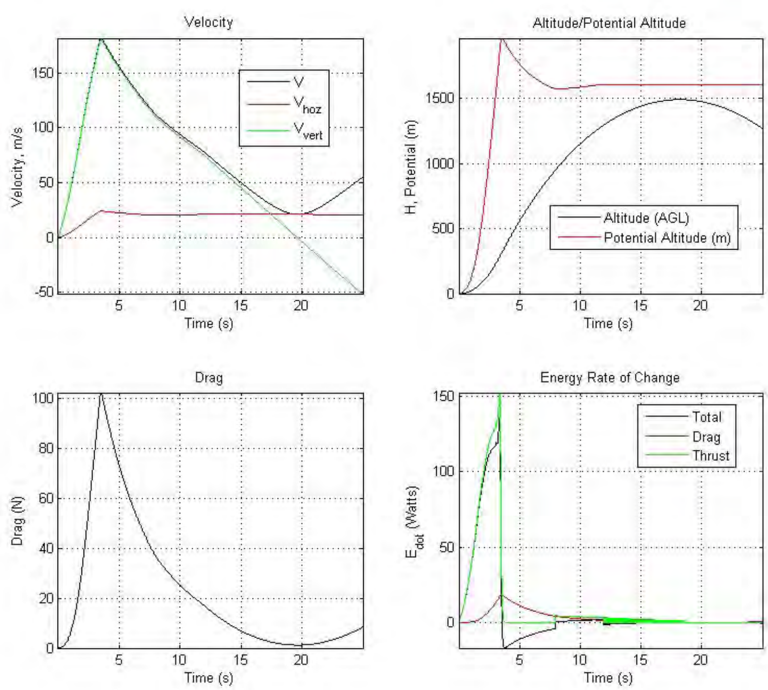


Figure 54: Unaugmented Javelin trajectories (C-BAS inactive).

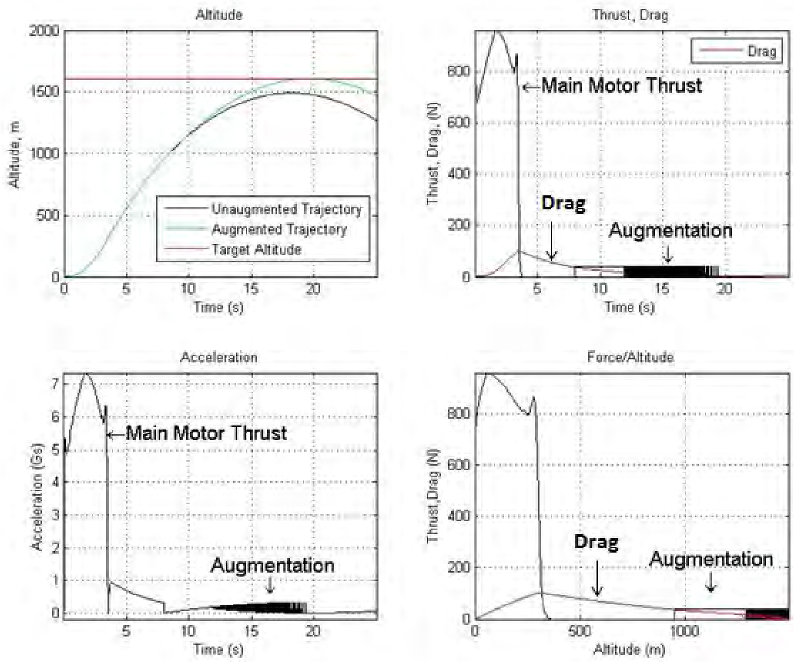


Figure 55: Augmented Javelin trajectory.(C-BAS active).

The key innovation for the C-BAS is the pair of linear isentropic expansion ramps with altitude compensation ability. Because of their derivation from aerospike theory, the ramps can expand the cold gas to atmospheric pressure regardless of launch altitude. This greatly reduces pressure losses typically seen by bell-shaped nozzles flown at altitudes other than those for which they were designed. The C-BAS expansion ramps will be placed symmetrically on either side of the solid motor of the Javelin. The ramps themselves are extremely small, as seen in Figure 56, and provide optimal packaging around the main motor without changing the rocket diameter or length.

A student-developed method of characteristics code was used to determine key dimensions of the expansion ramps and includes the throat area and ramp profile based on a given expansion ratio. This makes it possible to calculate the expected flow rates of cold gas from the system, and as a result the amount of drag reduced. With exception of the expansion ramps, all other components of the C-BAS are commercial off-the-shelf components. Consequently, all components purchased have been tested extensively to determine their performance characteristics. The testing and validation of the C-BAS proved to be substantially challenging. The team has faced problems with solenoid valves not producing enough mass flow, connections not remaining sealed, and leaks in the ramp assembly itself. Overall, these challenges have helped the team engineer the system into a more robust and reliable system.

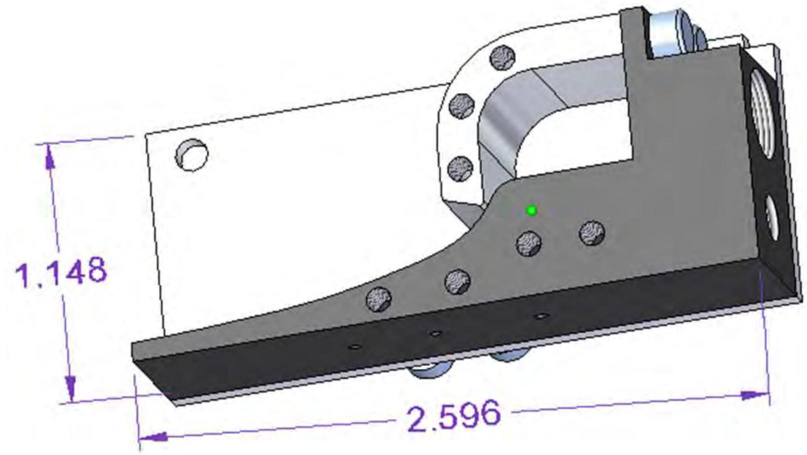


Figure 56: Solid model of the linear expansion ramps.

V.B. Science Value of Payload

The Javelin's payload is of scientific value for two main reasons: integration and implementation of an energy management system, and the analogous nature to linear aerospike theory. The system is designed to augment the energy state of a rocket that cannot reach the desired apogee with the main motor alone. The idea and design of the expansion ramp system in the C-BAS is derived from linear aerospike theory. If successful, these measurements will represent the first in-flight surface pressure data ever collected for a linear isentropic expansion ramp, or aerospike nozzle. In order for NASA to accomplish its vision for large range human and robotic space exploration, significant advances in technology for all systems are required, not least of which is propulsion systems.

Advances in propulsion technologies offer the greatest potential for spacecraft mass reduction. Mass reductions are especially critical for planetary landing and ascent propulsive systems, such as those proposed for the Mars Ascent Vehicle, or other planetary/lunar landers, where the cost of delivering mass to the surface is high. While aerospike nozzles have long been known for their altitude compensation ability during atmospheric flight, they also present significant potential advantages for pure in-space applications.[21]

Aerospike nozzles can be significantly smaller than conventional, high expansion ratio bell nozzles, and theoretically more efficient. Given a fixed vehicle base area, an aerospike nozzle can present a higher area expansion ratio than a bell nozzle, providing better performance in a space environment, or near-vacuum environment like Mars. The potential for nozzle mass reduction and increased specific impulse (I_{sp}) using an aerospike nozzle is the ability to achieve thrust vectoring aeordynamically without active mechanical nozzle gimbals. It also provides a significant potential for reduced system complexity and weight. Due to a perceived low technology readiness level, and in spite of its well-known potential benefits over conventional conical or bell nozzle designs, the aerospike rocket configuration has never been deployed on an operational space vehicle. One of the major reasons for this perception is the lack of high quality ground and flight test data, and its correlation with analytical flow predictions. The team's proposed payload work seeks to conduct fundamental research to fill some of the gaps in the experimental data chain.[22]

V.C. Avionics Systems Architecture

The avionics system consists of a Gumstix Overo Tide processor, which will act as our flight computer, a PerfectFlite altimeter, an R-DAS backup altimeter, an Inertial Measurement Unit (IMU), a level shifting board, a power distribution board, a Bullet 2HP modem, and six differential pressure transducers. Figure 57 shows a block diagram of the avionics system.

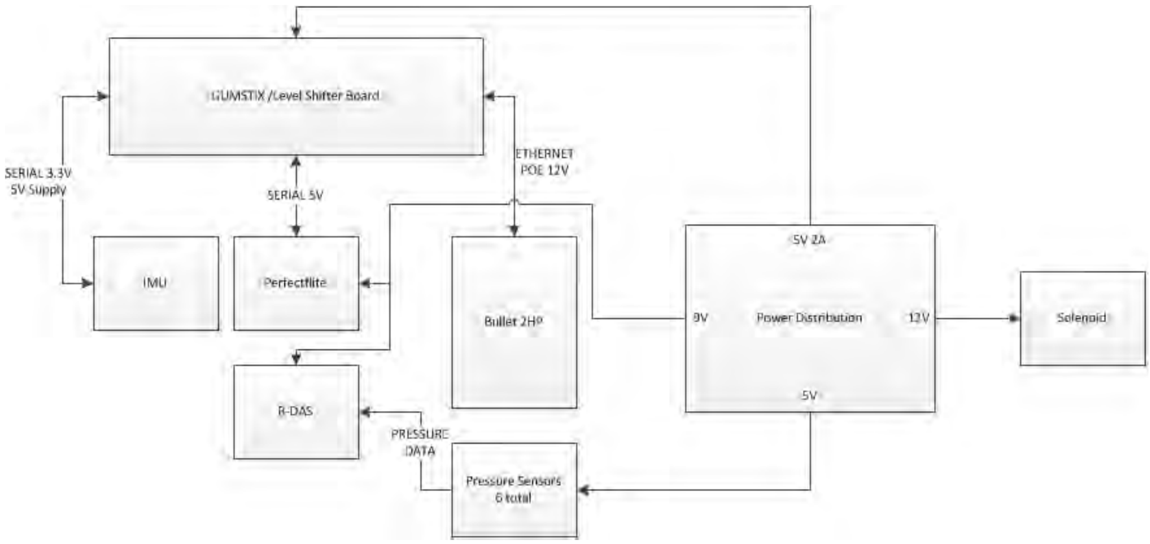


Figure 57: Block diagram of the avionics system.

V.C.1. Processor/IMU

The processor will run a Kalman filter and do some basic computations in order to determine whether the C-BAS should be active or idle, and will send the appropriate signal to the solenoid valve that activates and deactivates the C-BAS. A more detailed explanation of the Kalman filter can be found in Appendix J. The Tide will mount onto the level shifting board, which will provide the 5 VDC/2 Amps needed for operation. The Tide will interface via serial RS-232 communication protocol to the IMU. Because the IMU serial output is a 3.3 volt data signal, the level shifting board is needed to lower that signal to a more appropriate 1.8 volts that the processor can utilize. The IMU provides the necessary flight data the filter needs for calculations, which is acceleration data in three dimensions from three onboard accelerometers, as well as information gathered from the three onboard gyroscopes. The level shifting board was designed and manufactured based on level shifting theory provided online by Phillips Semiconductors.[15]

V.C.2. Primary/Secondary Altimeter

The Perfectflite altimeter is the competition altimeter being used to record altitude data. Because the recovery system is required to be redundant the team will also use a backup R-DAS altimeter in the avionics package. The PerfectFlite altimeter will also report altitude data to the Tide for use by the filter. As the flight progresses toward apogee, the filter will bias calculations toward the data provided by the PerfectFlite altimeter. This provides the team with the ability to eliminate uncertainty in altitude readings by comparing the two early in flight, and making corrections if one is significantly different. Ultimately, very near apogee, the filter will use only the PerfectFlite data to ensure that the competition altitude measured comes strictly from the required altimeter. Also, the Perfectflite is the primary method used to deploy the drogue and main parachutes in the recovery system, and likewise, the R-DAS will be used as the secondary method for deploying the recovery system. The backup altimeter will also log data gathered from the payload. Each altimeter is powered by its own on board 9 V battery. This ensures that the team has two totally seperate systems for recovery deployment to ensure there is no one point where the entire recovery system can fail. External safety pins installed in the vehicle will open switches integrated into the avionics package to allow the team to “safe” the rocket on the rail. This ensures that the ejection charges do not pop while the rocket is being serviced, or prepared for launch.

V.C.3. Communications

A wireless-G modem was integrated into the avionics package to allow information to be transmitted from the rocket to a ground station throughout the flight. The received data will be monitored by a member of the team. The modem is provided 12 volts via Power Over Ethernet (POE), and uses existing 802.11 wireless technology to transmit the data. The ground station consists of a toughbook computer, a second Bullet 2HP, and an antenna. This system was not functioning at the time of the test flight.

V.C.4. Power Distribution

A power distribution board consisting of switches, terminal blocks, and DC-to-DC converters provides components that run on voltages lower than the onboard 12 V battery with the necessary power for operation. Included on the power distribution board are switches for main power, PerfectFlite power, and R-DAS power. This requires that a member of the team manually powers the rocket in order for flight, but integrated external switches prevent the systems from powering up until the external safety pins are removed. In order to avoid unnecessary use of the onboard battery power needed during flight, an external power receptacle and power switching circuit were used. Two diodes were wired together by the anode with a capacitor between the connection and ground, to allow the higher voltage applied by either the external power source or internal battery to pass through the power distribution board. The capacitor is used to ensure that when external power is disconnected and power is switched to the onboard battery, no disruption will occur. Six pressure transducers are installed in the payload bay of the rocket to measure in-flight expansion ramp pressure data. The output signals are routed to the avionics bay where they will be logged by the backup altimeter until they can be processed and evaluated.

V.D. C-BAS Testing

V.D.1. C-BAS Static Test Stand

The static test stand was designed to use a load cell to measure any forces generated by the C-BAS. All tests were repeated multiple times to verify the validity of the acquired data. The instrumentation used during testing included an Omega® PX139 pressure sensor, an Omega® LC101-25 load cell, and a K-type thermocouple. These instruments were attached to a NI® USB-6009 multifunction data acquisition unit with a resolution of 14 bits, which aided in data collection and interpolation for analysis. Figure 58 shows the layout of the C-BAS test stand.

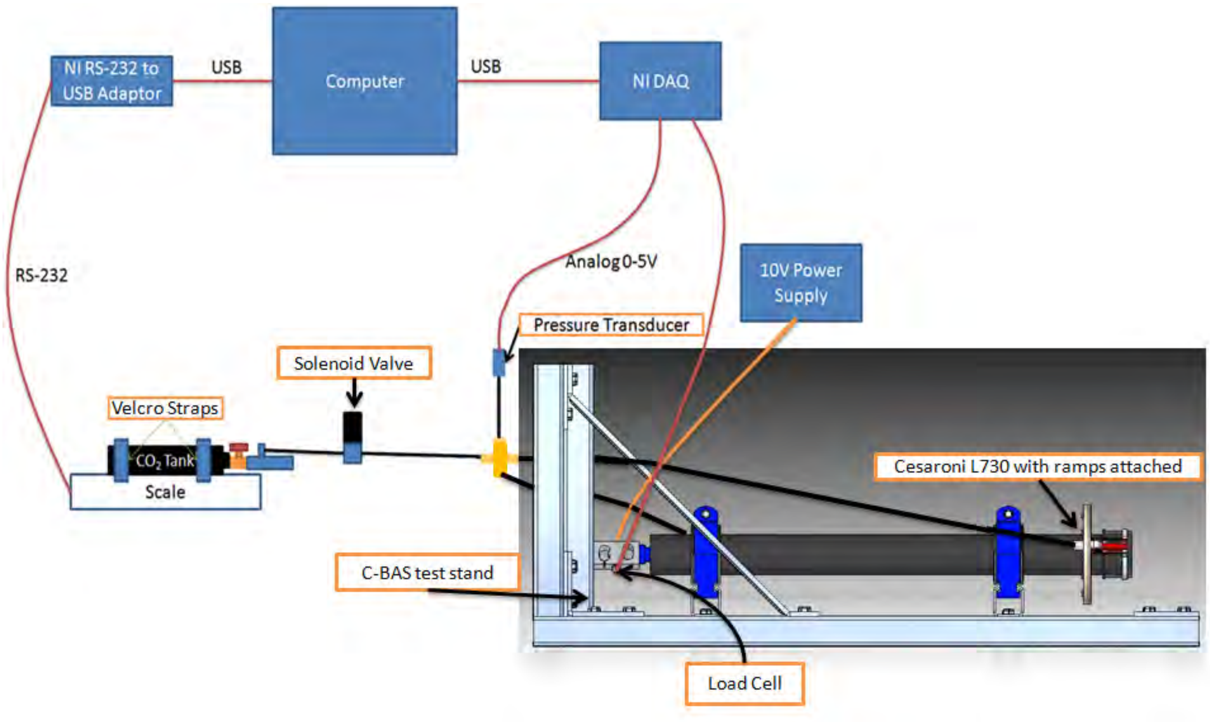


Figure 58: Cold gas test stand.

V.D.2. Flow Pressure Regulation

The operating output pressure of the CO_2 tank is regulated to a maximum pressure of 450 psi. The regulated pressure was set by attaching a T-junction to the output of the pressure regulator with a pressure transducer on one end of the junction, and allowing CO_2 to flow out through the other end. In order to control the flow of CO_2, a solenoid valve was attached between the pressure regulator and the T-junction. This setup is shown in Figure 59.

V.D.3. Leak Testing

The C-BAS was tested for leaks by spraying a bubble-forming high-visibility leak detector around all major component junctions. Regions that showed evidence of leaking were reinforced with a silicone sealant with a temperature range sufficient for all aspects of the rocket flight environment. After applying the sealant, the C-BAS components no longer leak.

V.D.4. C-BAS Operational Tests

The entire payload system was thoroughly tested for operability using the test stand described at the beginning of this section. Momentum flux and stagnation pressure were measured during this test to determine

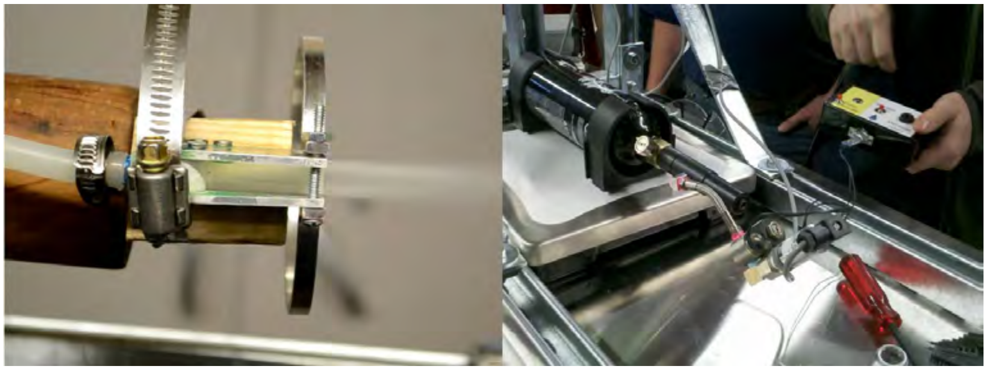


Figure 59: CO_2 output pressure calibration test.

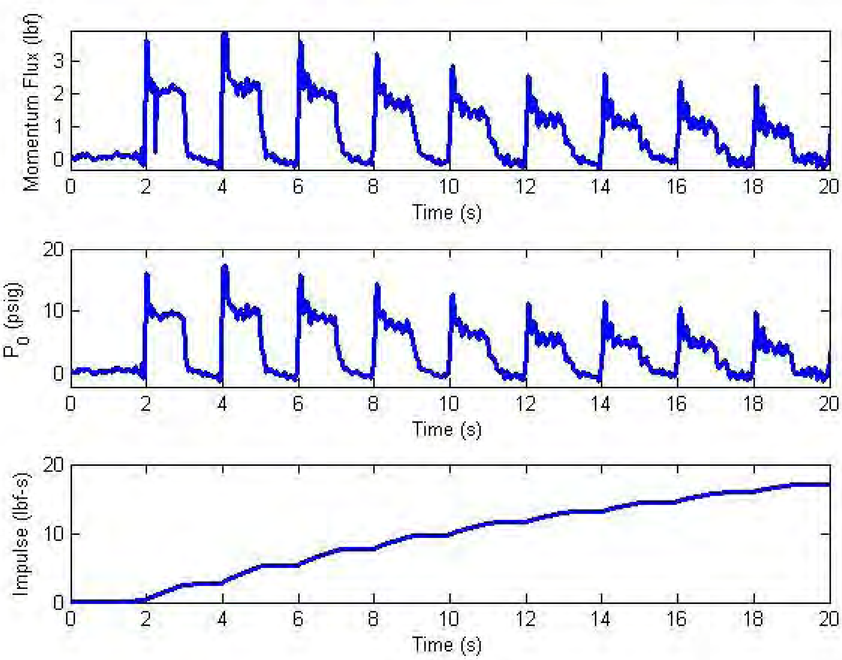


Figure 60: C-BAS pulse test data.

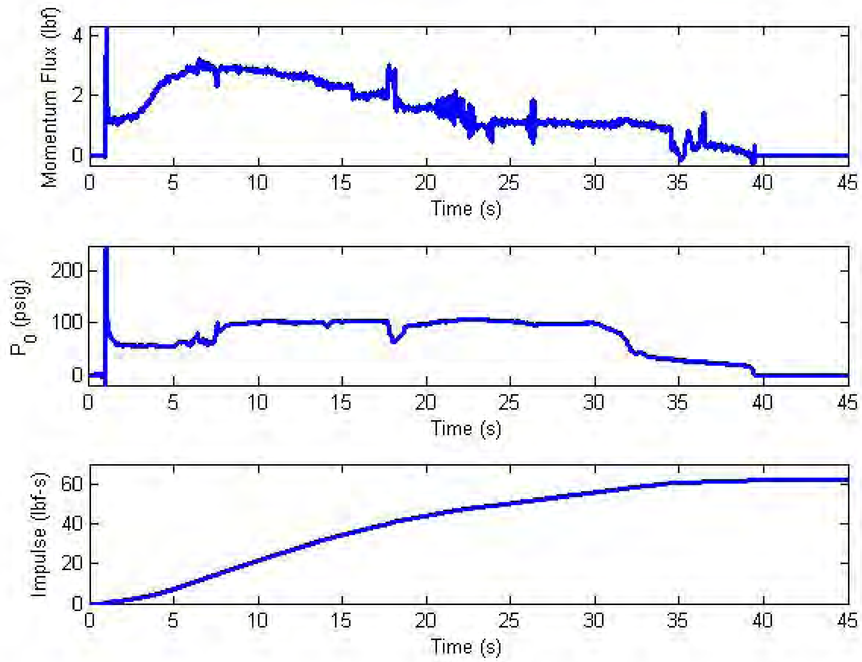


Figure 61: C-BAS continuous test data

the operating characteristics of the C-BAS. The test results also provide a better understanding of what performance can be expected during a flight test. The results of this test are shown in Figures 60 and 61.

The two datasets presented represent the two possible operational modes of the C-BAS. The system may be pulsed, as shown in Figure 60, or continually activated, as shown in Figure 61. The significant fluctuation of pressure and corresponding loss of momentum flux seen in both sets of data show that the system does not perform ideally. This is due to the low quality paintball pressure regulator used in the C-BAS. A better regulator would provide much better system performance, but the hardware cost and development time would become prohibitively high. The anomalies in the momentum flux data that are not correlated to any pressure anomalies are due to freezing around the isentropic expansion ramps. The 61 lbf-s (275 N-s) total impulse of the C-BAS, however, is very close to the predicted 67 lbf-s (300 N-s) of total impulse. The only caveat to this is that the C-BAS takes far longer than expected to get to this impulse. During an actual flight, the C-BAS will have a maximum time of 20 seconds to be actively augmenting the energy state of the rocket. This means that in order to maximize the output of the C-BAS, it must activate as early in flight as possible, and stay on until the desired apogee altitude is achieved. This will yield approximately 43 lbf-s (195 N-s) of total impulse, which is still sufficient to augment the energy state of the rocket by a significant amount.

Another, more beneficial side effect of only getting 20 seconds of effective burn time is the opportunity to switch to a smaller CO_2 tank. The 24 oz tank was replaced with a 12 oz tank. This will not affect the overall performance of the C-BAS, as a full 24 oz tank takes approximately 40 seconds to deplete. The smaller tank yields nearly 2.2 lbm (1 kg) in mass savings, which will improve the overall effectiveness of the C-BAS as a whole.

V.E. Design, Integration and Assembly of Payload

V.E.1. Pneumatic Components

The pneumatic components consist of a CO_2 tank, pressure regulator, solenoid valve, mesh hoses, pressure sensors and expansion nozzles. The CO_2 tank will store sufficient propellant to raise the projected apogee altitude to the target altitude of one mile. A standard 12 oz paintball tank was chosen will be used to store the CO_2 in liquid form. This is a change from the 24 oz tank the system was originally designed with. The larger tank had excess CO_2, which added an unacceptable amount of extra weight to the rocket. The 12 oz CO_2 is also smaller and is easily adaptable into the current design. As the liquid is in a saturated state there will be a two-phase flow effect; the CO_2 will exit the tank in liquid phase and vaporize to the gas phase from the lower ambient pressure. The two-phase flow may affect the pressure of the CO_2 being delivered to the isentropic expansion ramps. Stainless steel mesh hoses will connect the tank to the various components and into the linear isentropic expansion nozzles. The GC Valves® (H40 Series) solenoid valve will be used to turn the cold gas flow on and off electrically.

Figure 62 depicts the cold-gas feed system for the C-BAS. Carbon dioxide was selected over high-pressure air as the cold-gas since it is significantly better in terms of volumetric-impulse efficiency. Ensuring that the thrust exceeds the drag of the vehicle before operation will force the fluid leaving the tank to exit as a liquid, which minimizes propellant cooling due to boil-off. In-flight pressure data will be gathered from three ramp locations for each ramp. All of these measurements can be analyzed later for performance and efficiency calculations of the aerospike system.

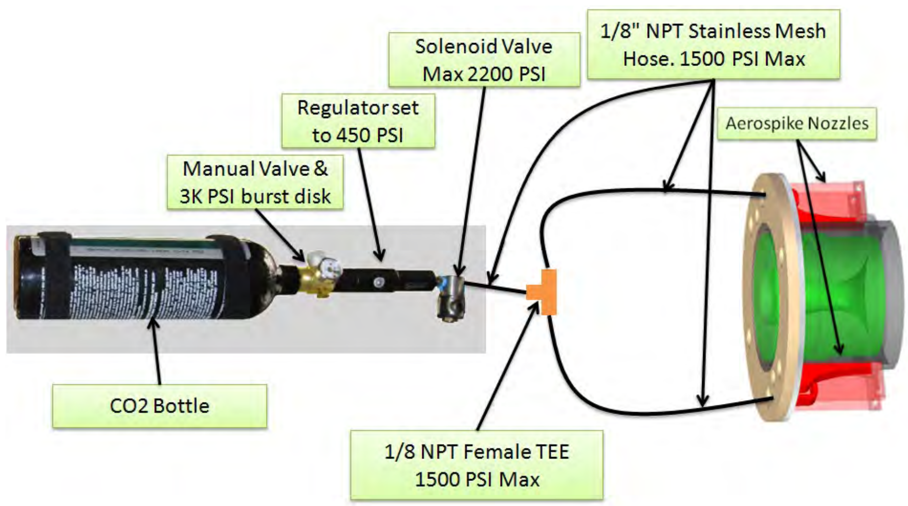


Figure 62: C-BAS component layout.

V.E.2. Precision and Repeatability of Measurement

Measurements taken from the expansion ramps are directed to appropriate pressure sensors. These sensors are Omega® PX139 series with 30, 15, and 5 psi differential readings. The sensors have an accuracy of plus or minus 0.1 percent full scale and have a repeatability of plus or minus 0.3 percent full scale. The data will be recorded on the R-DAS until it can be retrieved using a ground-based computer link.

V.E.3. Payload Assembly

The team used a very simple approach to fix the CO_2 tank in place. The CO_2 tank slides into the payload bay from the forward end of the rocket. One fixed bulkhead is used to center the tank, and a removable one is used to keep it in place. Figure 63 shows a schematic of the payload system integrated into the payload bay.

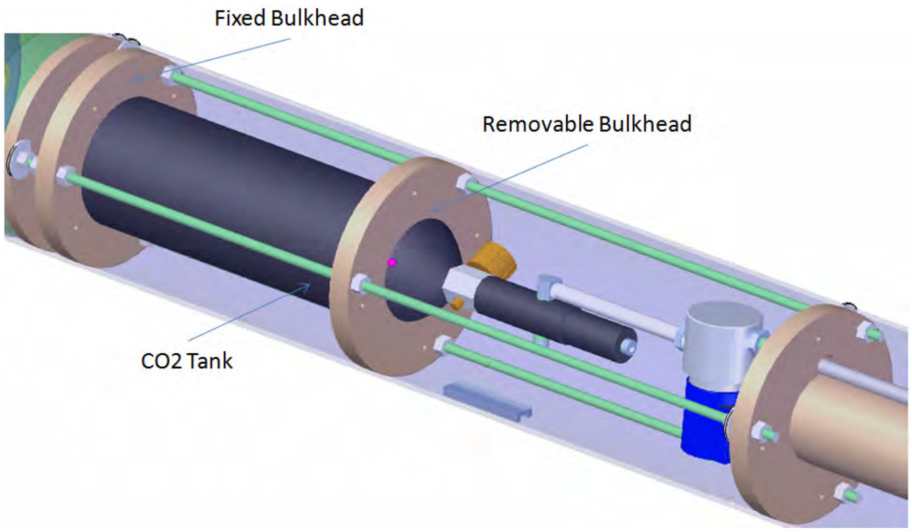


Figure 63: Supports for the CO_2 tanks.

A pressure regulator and solenoid valve are affixed directly to the tank valve. The CO_2 is delivered to the expansion ramps via two mesh hoses. The hoses are secured to the solenoid valve at one end, and exit through the ramps at the other. One access door was cut into the booster section to give access to the valves and piping.

The expansion ramps fit optimally in the boattail of the Javelin. A bulkhead sits in the very tail end of the Javelin, aft of the fins. The expansion ramps are secured to the bulkhead on opposite sides of the boattail and held in place by an aluminum plate.

V.F. Payload Safety

A recurring topic of discussion is the safety of the payload as it is launched. The main concern is temperature fluctuations causing over-expansion of the CO_2 gas, which increases the internal pressure of the tank and could potentially cause the tank to rupture during flight or while on the ground as it is awaiting retrieval. To mitigate this hazard, testing and analyses were performed to verify the tank would not rupture due to temperatures experienced on the launchpad, during flight, and after the flight until rocket retrieval and disassembly.

A static motor test was performed with the motor integrated into the rocket body along with the CO_2 tank in flight configuration. Thermocouples were placed on both the forward and aft of the motor case, and on the CO_2 tank. Temperatures were tracked to verify tank temperature would not be affected by the motor heat. Figure 64 shows the time versus temperature plot of the motor during the test. This data shows where the motor burns out, and where the rocket will reach apogee. According to this data, the motor will not reach the critical temperature of the CO_2 until the rocket has almost reached apogee. For the C-BAS operating conditions, the temperature at which the CO_2 will no longer remain a liquid is 87°F. Figure 65 shows the recorded temperature of the tank during the static test. The tank never exceeds the critical temperature. This is unsurprising, as there is a significant amount of insulation and space between the tank and the motor itself, namely multiple wood and metal bulkheads, which reduce the amount of possible heat transfer to negligible amounts.

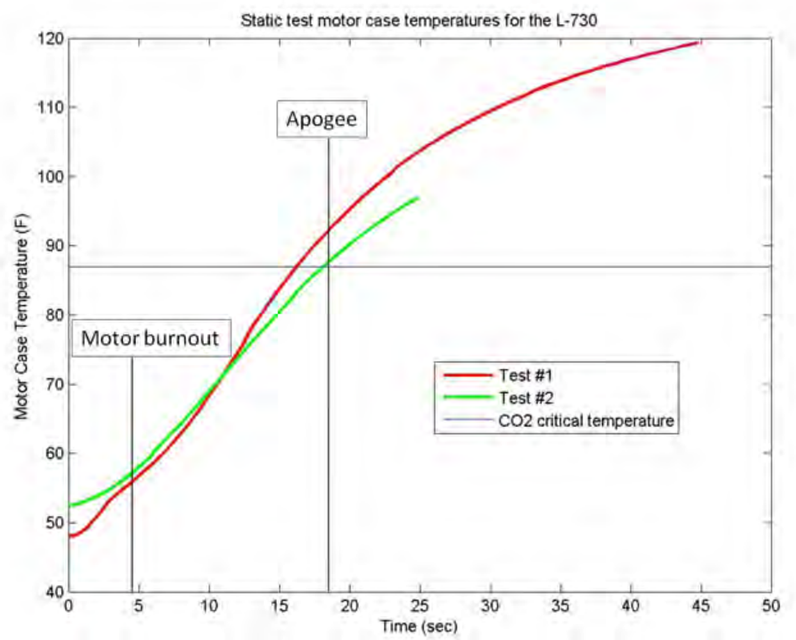


Figure 64: Static test motor tube temperatures.

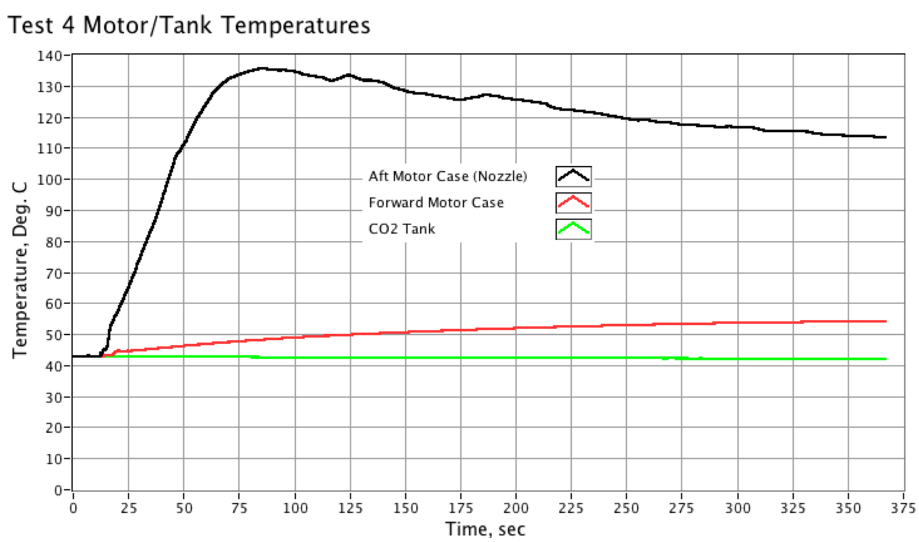


Figure 65: CTI L730 motor static test temperature profiles.

Additionally, a thermal analysis of the tank was performed using steady state equations to determine if leaving the tank in the sun all day would be a problem. The tank was assumed to be a black body for the most extreme circumstances. Therefore the tank was assumed to have an emissivity of 0.8 and absorptivity of 1 as it is placed directly in the sunlight with the sun directly overhead of the tank. The full analysis is provided in Appendix I. To summarize, if the tank were approximately 95°F, the energy rate radiated outward would actually surpass the energy being absorbed from the sun. Essentially, it could never even reach the burst temperature. If the tank were not radiating any heat at all, it would reach 115°F (temperature required to reach design pressure in the tank) in approximately 11.5 minutes if placed in direct sunlight. It would take twice that time to increase the tank pressure to the burst pressure of the tank. It should be emphasized that these numbers assume that there isn't any energy being radiated by the tank, which is definitely not the case. The tank will not be in direct sunlight as it is housed within the rocket, and as such will receive much less energy from the sun as the source, and will not receive any significant amount of energy from the motor.

The analyses and testing conclude there isn't any danger of the tank rupturing from excess temperatures while on the pad, in flight, or after its flight.

VI. Launch Operations

VI.A. Launch Operation

VI.A.1. Final Assembly and Launch Procedures

The final assembly of the Javelin will be accomplished using a series of checklists to ensure the Javelin is adequately prepared for a safe flight. Appendix F includes a detailed overview of the steps that will be taken when constructing the Javelin. The team will also follow extensively developed procedures during launch, all of which will be performed with the use of multiple checklists. The purpose of using checklists is to facilitate the safety of all team members, and mission assurance. These checklists include the procedures for troubleshooting a misfire, hang fire, parachute deployment failure, and undeployed recovery charges. Also included are the necessary steps to complete a successful post-flight inspection. All checklists for launch and preparation can be found in Appendices F and G.

VI.A.2. Recovery Preparation

Recovery preparation have been adapted from the procedures already developed by the previous USU team. These procedures led to the successful preparation and deployment of every recovery system the previous team used. The procedures include proper folding patterns for the parachutes, as well as black powder/e-match preparation.

VI.A.3. Motor Preparation

Motor preparation will be conducted according to the manufacturer's instructions. The procedure of preparing the motor for flight will be walked through and rehearsed so the team is proficient and familiar with the assembly of the L730. The goal is to assemble the motor and have it ready for installation within ten minutes. Ten minutes was determined to be the amount of time a person could maintain fine motor skills in inclement weather before they lost focus and started making mistakes.

VI.A.4. Igniter Installation

By law, the igniter will not be installed into the rocket until the rocket is on the launcher, or in the area specified by the range safety officer. The team has ordered an igniter kit from Firefox Enterprises Inc. The igniters burn for 1-2 seconds at approximately 2000 degrees Fahrenheit, guaranteeing propellant ignition. The igniters will be attached to a thin wooden dowel which will be inserted into the rocket, keeping the igniter head at the top of the rocket. Once inserted, the nozzle cap will be replaced on the nozzle, keeping the igniter in place until motor ignition.

VI.A.5. Setup on Mobile Launch System

During both the competition and test flights, the Javelin will be launched using the mobile launch rail system designed by previous Chimaera rocket teams. The mobile launch system incorporates a launch rail and storage bins for transporting the Javelin and other support equipment. This is all mounted on a mobile, highway legal trailer. The 15 ft launch rail and ARRX LOK truss are mounted to the trailer with steel pins. This allows the rail to be stowed horizontally on the trailer during transport and pivoted vertically during launch. The launch angle will be checked using an inclinometer. Adjustments to the launch angle are made via adjustable jacks on either side of the trailer, as shown in Figure 66. The mobile launch system has undergone extensive operational testing to ensure all launch requirements will be met and that the trailer will be capable of safely launching the Javelin. The launch rail has also been evaluated to ensure it will remain rigid, stable, and will not extend beyond vertical tolerances during launch.

Figure 66: Launch stand leveling jack.

Launch System Improvements The electrical system on the trailer was not functional at the beginning of the semester. The team needed to re-wire the trailer lights to get the connection needed for functional lights during transit. To evaluate the road-worthiness of the mobile launch system, the trailer was tested to ensure the electrical connections remained secure during transit. In addition to this the Chimaera team will perform the needed maintenance and safety checks to ensure the mobile launch system complies with all highway safety regulations.

This year's team has also improved the mobile launch system by designing and constructing a new launch controller to use during the test flights of the Javelin. This new launch controller gives greater reliability to the existing system by eliminating unnecessary components and updating worn hardware. Previous teams have used the "Universal Launch System, Module 1: Base Module" by Pratt Hobbies Inc. This system allows for multiple rocket configurations from cluster motors to hybrids. Over the years this system has fallen into disrepair. Since the current team is not concerned with cluster motors or hybrids, the decision was made to simplify the system and increase the reliability by focusing solely on the launch of single APCP motors. The new system was designed, built, and tested over the Christmas break. Figure 67shows the wiring diagram used to build the system. The controller was designed to include an in-line safety key; when the key is removed the system is incapable of launching a rocket. A continuity circuit including an LED was wired to make sure the igniter was getting power before launching. The continuity check only puts 12 mA through the igniter, which is well below the current required for ignition for most products. A mechanical relay was used to isolate the 12 VDC side of the controller where the rocket is, from the 9 VDC side 500' away where the launch switch is located. The actual launch switch is a momentary contact switch that returns to the "off" position after it is released. The controller can be switched from "pad ARMED" to "pad SAFE" when conducting continuity checks, or troubleshooting a misfire.

The launch controller is capable of successfully igniting devices that require as much as 3 ampere. The team successfully test-fired two different igniters, each requiring around 1 A to ignite. Figure 68 shows the new system now in use by the team. The controller performs flawlessly, giving the Chimaera team confidence in the supporting equipment that will aid in mission success.

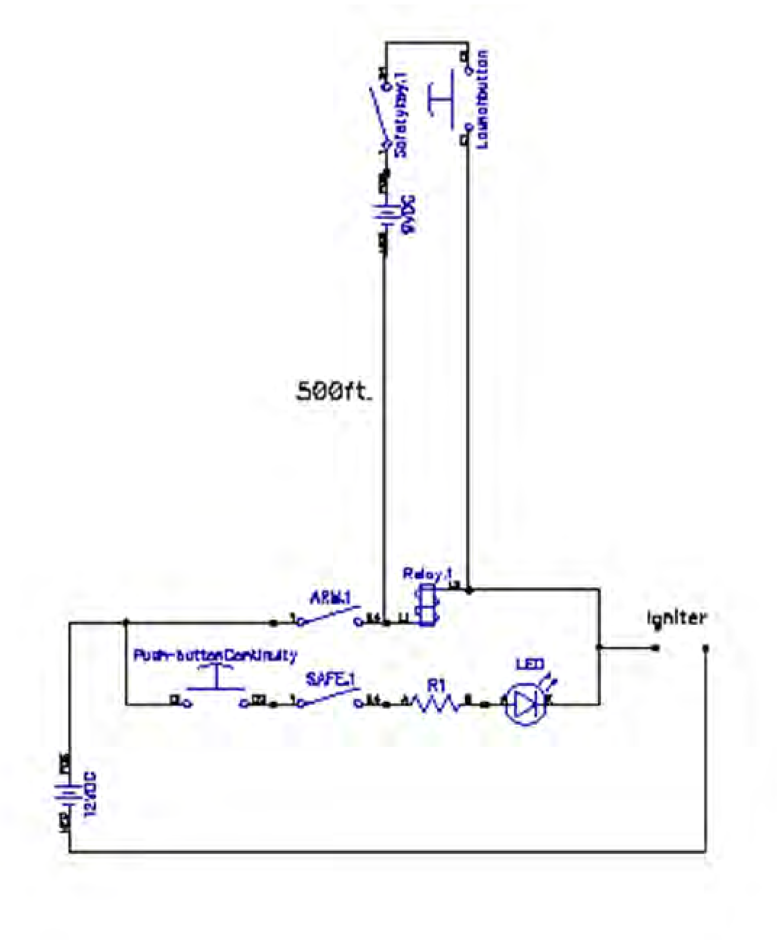


Figure 67: Launch controller wiring diagram.

Figure 68: New launch controller system in the testing phase.

VII. Activity Plan

VII.A. Budget Plan

The team is only allowed $5000 worth of flight hardware, but the cost of this project far exceeds that amount. The team requires funds for testing materials, back ups, certifications, and travel to the competition. Thanks to generous donations from the College of Engineering, the Utah chapter of AIAA, Rocky Mountain Space Grant Foundation, and others, the team has $16,500 at their disposal for the entire project.

Due to limited funding and the $5000 flyable hardware limit, the team keeps meticulous records of all of their spending. A copy of every receipt is given to both the team's procurement officer, Sam, and Program Manager, Dr. Whitmore. All donations, monetary and material, are tracked by the procurement officer. The team has currently spent 50.01 percent of their overall budget. This money has gone toward purchases for instrumentation, motors, payload equipment, and Level II certifications for two of the team members, and outreach supplies. To date, 93.72 percent of the flyable hardware budget has been used. The team is on track to come in slightly under budget on the Javelin, as all foreseeable expenses have already been covered. Extra funds will be diverted to the travel fund, so that students will not have to pay as much out-of-pocket to travel to Huntsville. Figure 69 is a copy of the team's detailed budget.

Hardware	Spent	Allocated	% Used
IMU: Microstrain 3DM-GX3	$1,400.00	$1,400.00	100.00%
RDAS	$343.00	$343.00	100.00%
miniAlt/WD Altimeter	$219.90	$219.90	100.00%
Fins	$72.04	$72.04	100.00%
Gumstix Overo Fire	$270.26	$270.26	100.00%
Pressure Transducers and other Intrumentation	$165.11	$165.11	100.00%
Motor and Solid Fuel	$348.00	$348.00	100.00%
Onboard Camera	$105.95	$105.95	100.00%
Recovery	$150.60	$150.60	100.00%
Body Tube	$260.30	$260.30	100.00%
12 CO2 Tank	$45.75	$45.75	100.00%
Isentropic Expansion Ramps	$587.74	$587.74	100.00%
Payload Tubing and valves	$441.44	$441.44	100.00%
12 CO2 Regulator	$60.71	$60.71	100.00%
Assembly(Bolts, Nuts, Bulkheads, Epoxies, etc)	$258.59	$258.59	100.00%
Avionics General	$155.72	$155.72	100.00%
Other Uncategorired Expenses	$1.96	$114.89	1.71%
Subtotal	$4,887.07	$5,000.00	97.74%
Certifications, Testing and Outreach			
Certifications	$1,162.98	$1,162.98	100.00%
Outreach	$87.41	$100.00	87.41%
Testing	$2,515.83	$2,515.83	100.00%
Subtotal	$3,766.22	$3,778.81	**99.67%**
Travel and Transportation Expenses	$0.00	$8,121.19	**0.00%**
Total	$8,653.29	$16,900.00	**51.20%**

Figure 69: Overall procurement status.

VII.B. Timeline

The team is very aware of the deadlines set by USLI. All critical system testing has been completed, accumulating in a full scale test flight on March 19. Unfortunately, the recovery system failed during the test flight, so the team has more work left than anticipated. The team will rebuild and test launch again on March 26. The avionics need to be refined, but otherwise, no changes will be made to the basic design. The team still expects to be on track for a successful flight in Huntsville on April 16. Figure 70 is the team's top level milestone chart. Specific test dates, report deadlines, and upcoming outreach events can be found on the Chimaera website.

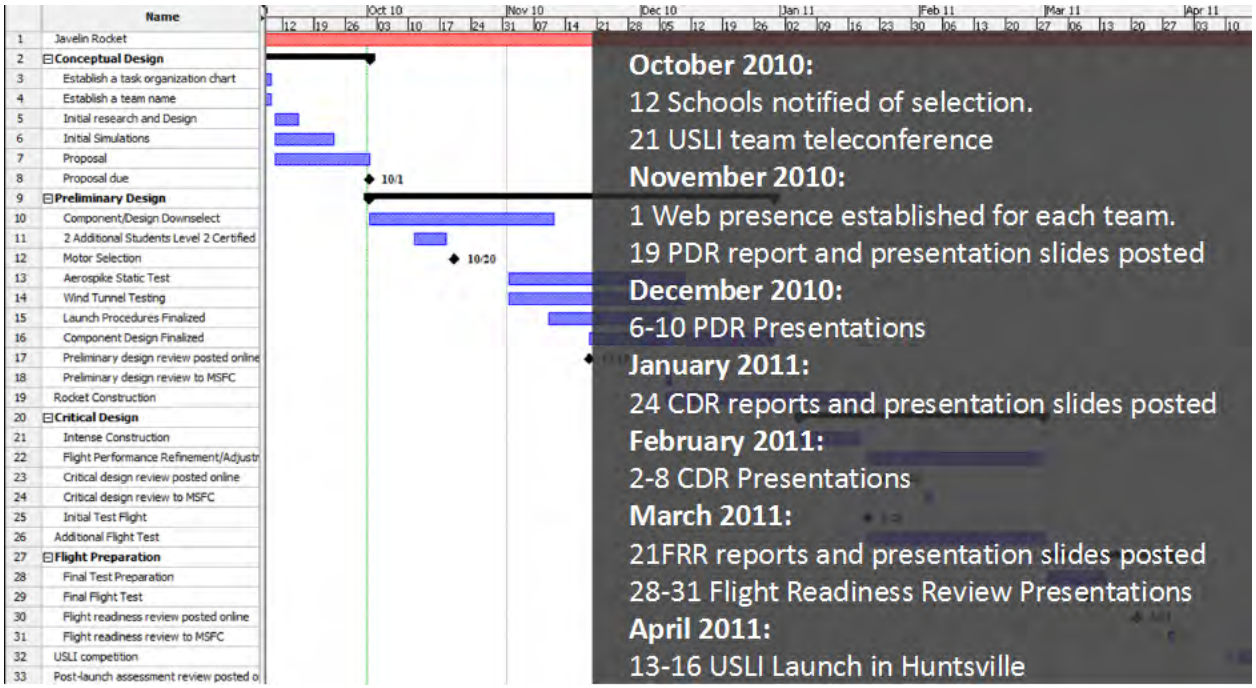


Figure 70: Overview of team's competition schedule.

VII.C. Educational Engagement

Community support is critical for the team's success. Rocket design is a senior project, but the team could not be successful without the immense support and encouragement they receive from the university, interested companies and individuals, and students throughout Cache Valley.

VII.C.1. Community Support

As the reputation of the Chimaera program has spread, the Utah State rocket team has been offered monetary support from several sponsors. The Space Dynamics Laboratory (SDL), a space research center operated by Utah State University Research Foundation, has asked the team for help in numerous outreach events. Even before acceptance into the USLI competition, the team cohosted an event on campus in September, in which more than 150 students participated in a hands-on rocket experience. SDL has donated $5000 toward the development of the rocket.

The team has also received monetary and physical support from NASA Exploration Systems Mission Directorate (ESMD), Rocky Mountain Space Grant Foundation, Microstrain, Total Impulse Rocketry, and the Utah chapter of American Institute of Aeronautics and Astronautics (AIAA).

The team is heavily supported by the College of Engineering and have received funds from the Associated Students of Utah State University (ASUSU) for travel. ASUSU sets aside funds for groups on campus engaged in extracurricular educational programs. Several of the sponsors have requested that the team give a presentation about the project.

VII.C.2. Outreach

The purpose of the team's outreach program is to promote interest in math, science, and engineering education throughout the next generation of young minds. The team has conducted and will continue to host various outreach events at local schools and surrounding area. Figure 71 illustrates some of the activities the team has done thus far.

Figure 71: USU Chimaera Team outreach activities.

In an effort to bring the community closer to the project, each child that is affected through the team's outreach program this year will have the opportunity to fly with the rocket. The name of each child will be placed on a flash drive, attached to the rocket, and sent one mile into the atmosphere; "Almost to space!" as one excited first grader exclaimed. This unique opportunity creates excitement in even the most disinterested teenagers about rockets, space, and what the team is doing. The outreach campaign has thus been titled, "Fly with the USU Rocket Team!" as demonstrated in Figure 72.

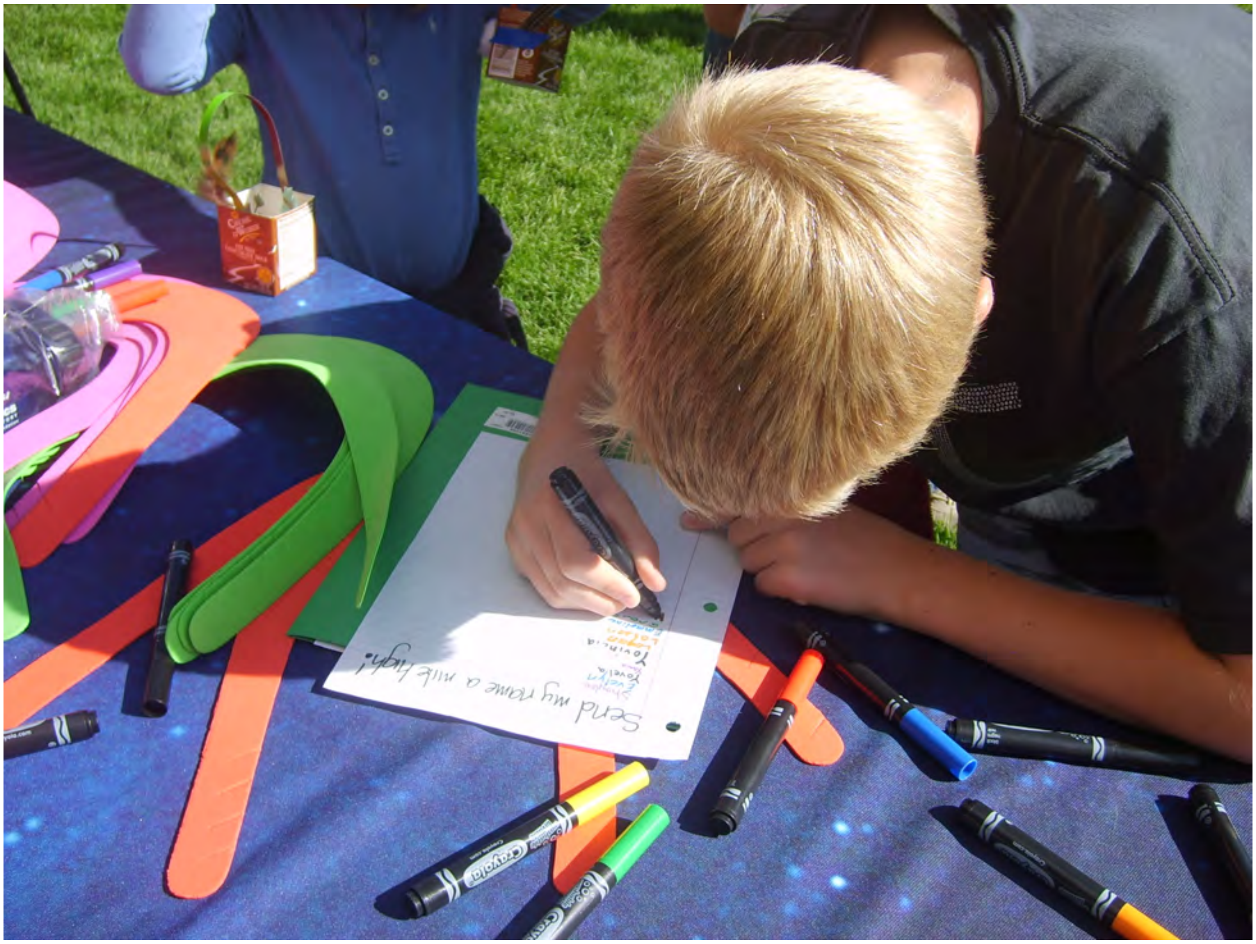


Figure 72: Fly with the USU Rocket Team!

The team has enjoyed the opportunity to work with so many students throughout the year. They've had the opportunity to present many different aspects of science and engineering to hundreds of students across Cache Valley and northern Utah. Table 20 is a summary of the activities and number of students reached to date, followed by more detailed descriptions of each event below.

Table 20: Number of persons reached through outreach events.

Location of Event	Date of Event	Number of Persons Attending
Aggie CARE Day	10 September 2010	96
Hillcrest Elementary Science Club	First Wednesday of every month	35
USU Rocket Day	26 October 2010	99
Surise Elementary Literacy Fair	9 November 2010	105
Logan High School MESA	10 November 2010	13
Logan High School Physics	14 December 2010	93
Utah AIAA Chapter	21 January 2011	37
Northrop Grumman Demonstration	23 February 2011	60
E-Week Community Outreach	23 February 2011	103
Adams Elementary School Science Fair	16 March 2011	50
Total		691

Aggie CARE Day Each year, Utah State University holds an activity day on campus for faculty and their families. The team, in conjunction with SDL, provided an activity booth for the event. Members of the rocket team displayed rocket and lunar lander designs from past Utah State teams, and talked to children ages 3-15 about rockets, space, and research at USU. With assistance from team members, children had the opportunity to launch water bottle rockets. Those interested could answer questions about rockets to earn a free water bottle, supplied by SDL.

Hillcrest Elementary School Science Club The Hillcrest Science Club is made up of 30 third, fourth, and fifth grade students, selected by their teachers because they have shown an exceptional skill and interest in science. The rocket team prepares and teaches a lesson for the club once a month. The first lesson was an exploration of forces on an airplane, culminating in an intense paper airplane competition. In November, the team taught a lesson in satellites and students had the opportunity to construct their own, as well as experiment with the effects of momentum. December's lesson explored what it takes to live and work in space, and students had the opportunity to build a "spacesuit" to protect Astronaut Bob (an apple). In February, the students discovered the gooey awesomeness of non-Newtonian fluids, and in March they were introduced to the basic concepts of engineering. The students were divided into teams and instructed to design and build a roller coaster for a marble. The team will continue to visit the club until the end of the year.

USU Rocket Day The rocket team joined the experimental rocket club on campus to hold a Rocket Day on the Quad. The team talked to USU students about USLI, NASA, the rocket design process, and their project. They displayed the rockets built by two team members for Level II certification and the Pike, the rocket built for USLI two years ago. Serving hot chocolate on the coldest day of the year brought 100 students to the booth.

Sunrise Elementary School Literacy Fair Sunrise Elementary School held a Literacy Fair on November 9 to demonstrate to students age K-5 the importance of reading in various careers. The rocket team hosted a booth at which students learned about the importance of communication in the aerospace industry, then had to follow instructions to build their own model satellite. About 100 students visited the team's booth at this event.

Logan High School MESA Club MESA (Math, Engineering and Science Achievements) is a club designed to introduce women and minorities to the world of math and science, and provide them opportunities to excel in these areas. The rocket team visited Logan High on November 10. They presented about the USLI competition, the design process, and project goals. Team members answered questions about rocket design, engineering, and college coursework. The club is participating in an invention fair at the end of the school year, and the rocket team has been asked to help students with their designs.

Logan High School Physics Drew Neilsen teaches one AP and three general physics classes at Logan High School. The rocket team had the opportunity to visit each of these classes to give a presentation about the rocket project. They presented a modified PDR and discussed with the students the design process, the competition, and team goals. The students, for the most part, were very engaged and asked quite intelligent questions. Having recently designed and tested their own water bottle rockets, the classes were interested to see how the physics they know applies to something more sophisticated. As a result of the evaluations conducted at LHS, the team has added an FAQ page on its website for students to learn about the rocket in more simplified terms. Students may also submit new questions through the website at any time.

Utah AIAA Meeting The team was invited to present their project progress to the local AIAA chapter on January 20. They discussed their design selection process and upcoming tests. Utah State students and employees from Northrop Grumman and Space Dynamics Laboratory were in attendance. The team fielded questions about the C-BAS payload and general design. The highlight of the evening for many spectators was the team's first motor test! The team was able to test their instrumentation and safety procedures, as well as answer many questions about their motor selection process.

National Engineering Week (E-Week) The team had the opportunity to do two outreach activities during national Engineering Week, February 22-25.

Northrop Grumman Presentation and Demonstration The team was invited to the Northrop Grumman facility in Clearfield, Utah, to present their rocket project to employees in the Missile Defense Systems division. The team talked to engineers about their project, and answered questions about the competition and design for two hours. At the end of the visit, the team demonstrated their cold gas system for more than 40 interested employees.

Community Outreach at USU The College of Engineering at USU implemented a new community outreach night this year for E-Week. Members of the community, particularly middle school and high school students, were invited to the college to learn about different aspects of engineering and to see the research being done at the school. The rocket team set up a booth to show off the rocket project, and to talk about the Chimaera rocket program at USU. They had a display of rocket components, including two fully functionally certification rockets. More than 200 students attended the event, and the rocket team personally visited with more than 100 of the attendees.

ADAMS ELEMENTARY SCHOOL SCIENCE FAIR Adams Elementary, an elementary school in Logan, UT, invited the rocket team to participate in their annual science fair. Forty two students displayed science projects of their own, while several science groups from USU had displays and experiments set up around the room. The team brought demonstrations of different spacesuit systems, and students had an opportunity to construct a spacesuit (trash) for their own astronauts (apples), in order to protect them from the elements of space (screwdriver). Approximately 50 students subjected their astronauts to the elements, and 26 apples survived without any bruises!

OTHER SCHOOL AND COMMUNITY OUTREACH The team will visit the MESA club at Mount Logan Middle School on March 25. The rocket team continues to partner with SDL and is continually searching for new opportunities to talk to students about the rocket project and engineering opportunities.

VII.C.3. Website

The web design is set up as an organizational system to keep team members and the community up to date on changes and the current progress of the project. The website has a built-in tracking system, Gantt chart, and all important documents are uploaded as soon as they are completed. The website is continually updated as outreach activities are carried out and tests are performed.

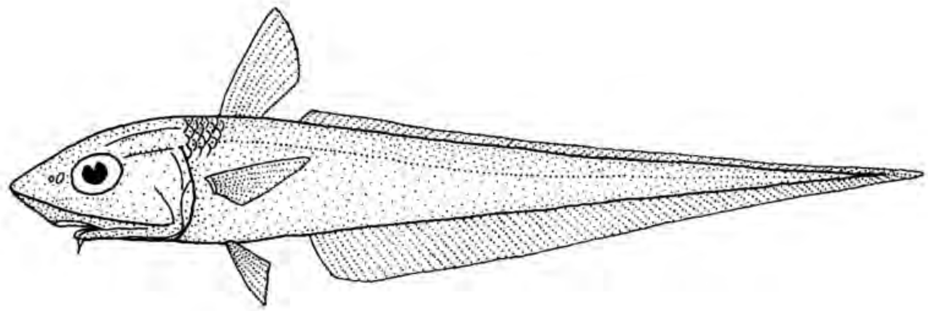
An "Analysis and Testing" section has been added to the website. The team has uploaded videos of all of their tests and they post results of significant test results. Also, an "Upcoming Events" page has been added. Visitors to the website can more easily follow the activities of the team.

VIII. Conclusion

Extensive analyis and tests done on the rocket lead the team to conclude that the Javelin is ready for and capable of safe flight. The Utah State University Chimaera Team has created a unique rocket design that will not only satisfy all requirements imposed by NASA, but will also provide a stable platform for the science payload, the C-BAS, to gather groundbreaking data on performace of isentropic expansion ramps. Many tests, simulations, and trade studies have been performed to ensure that all team-mandated safety factors have been met. In addition, the test flight performed on March 19, 2011 verified that most of the critical flight systems are working correctly. Lessons learned from anomalies found at the test flight will be applied to all future flight operations. The Javelin has been shown to be stable, safe, and reliable.

The team continues to be well-positioned to succeed in the USLI competition. Capitalizing on the talents of team members, the support of community and university sponsors, and simulation and design processes developed by the team, the Javelin represents the pinnacle of achievement for the students involved. The dedication of the Utah State University Chimaera Team to quality and safety will be clear at the competition launch in April.

A. The Javelin



B. Ejection Charge Preparation Procedure

Ejection Charge Preparation

Equipment Checklist:

- Precision scale, or other black powder measuring device
- Empty quarter rolls
- Five-minute glue
- Black powder
- E-matches
- Heat source
- Wax

Keep all flame far away from black powder at all times!

1. Cut quarter roll in half. Seal the side of the coin roll with five-minute glue. Set aside to dry.
2. Melt candle wax into container of your choice. Let wax cool until malleable, then mold around curled end of quarter roll. Cover waxed end with glue. Let dry.

3. Place two e-matches in each container. Bend the match end over so it will sit flat on the wax. Run the wires out and bend them over the top edge of the coin roll.

C. Parachute Packing Procedure

Parachute Folding Instructions

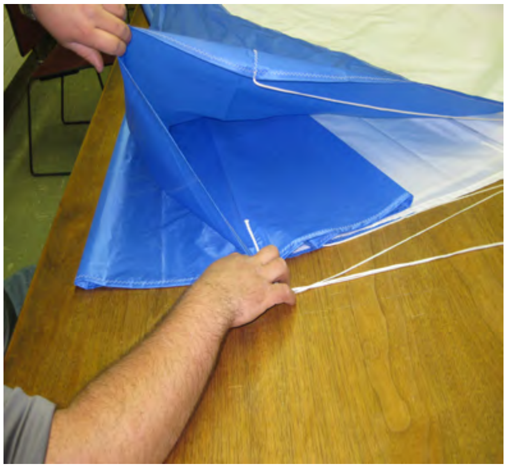
1. Complete equipment checklist.
   - Parachutes
   - Tarp
   - Harnesses
   - Line spreader cog
   - Caribineers
   - Nomex bags
   - Talcum powder

2. Spread tarp out on flat surface. Lay parachute flat across top of tarp.

3. Lightly dust fabric with talcum powder. Powder will act as drying agent and lubricant to help the parachute deploy.

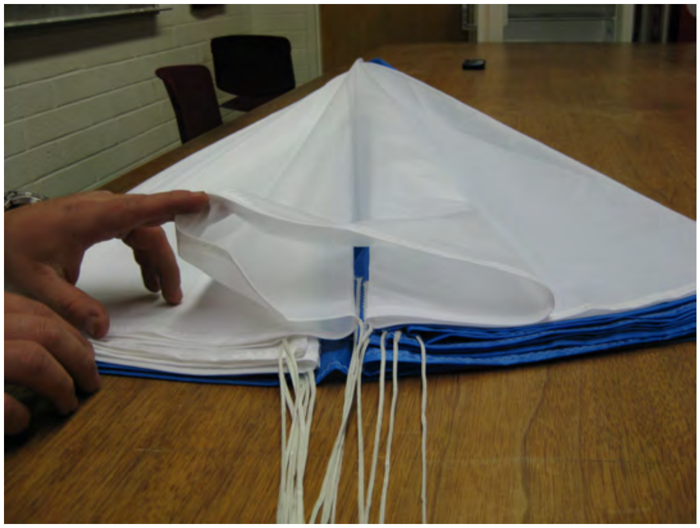
4. Fold parachute panels into fourths.

5. Fan panels over on top of each other until all lines are lined up from a center point. Open folds so that half are on each side of lines. The parachute should be shaped like an ice cream cone with shroud lines instead of an ice cream scoop.



6. Open each flap to center. Fold over. Repeat for all flaps on one side; open; repeat folds for other side; open. Parachute should look like two accordions joined at the centerline. Consult pictures.

7. Untangle shroud lines with the line spreader cog. If this is your first time folding the parachute, tie a knot in the end of the lines. This creates a loop for the carabineers to connect to the harnesses. You shouldn't have to use the cog after this, but always ensure the lines are in good order.



8. Lay shroud lines back on parachute. Loop at tip and bring back to base so that the loop, know, and a couple of inches of line are left lying off of the parachute.

9. Starting at the point end of the parachute, fold the parachute like an accordion, including the shroud lines, until you have a flat, squarish, packaged parachute. The loop and knot should remain outside the folds. (It doesn't matter if the last fold has the lines on top or folded inside.)

10. Secure carabineer to shroud line loop and attach harness at center loop. Place folded parachute in Nomex bag. Fold shroud line ends in figure 8 (or S) shape.

Parachute is ready for storage or packaging in rocket body. Perform this procedure after each parachute use.

D. Missile DATCOM

D.A. Input File

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DIM M
  $FLTCON NALPHA=16., ALT=240., 247., 272.17, 316.2, 384.4,
  ALT(6)=506.11, 600., 1015.14, 1351.1, 1639.5, 1810., 1848.9,
  ALPHA=0.,1.,2.,3.,
  ALPHA(5)=4.,5.,6.,7.,
  ALPHA(9)=8.,9.,10.,11.,
  ALPHA(13)=12.,13.,14.,15.,
  NMACH=12., MACH=0.001, 0.1, 0.2, 0.3, 0.4, 0.5, 0.519,
  MACH(8)=0.4, 0.3, 0.2, 0.1, 0.056, $
  $REFQ XCG=1.220,$
  $AXIBOD LNOSE=0.5334,DNOSE=0.1406, DCENTR=0.1406, LCENTR=1.684,DEXIT=0.,$
  $AXIBOD BASE=.FALSE., BETAN = 0., PRAT = 4., TRAT = 4., JMACH = 2.5,$
  $FINSET1 SECTYP=HEX,XLE=1.955,NPANEL=3.,PHIF=0.,120.,240.,LER=2*0.00125,
  SWEEP=10.,5.13,STA=0.,1.,SSPAN=0.,0.135,CHORD=0.09,0.054,
  ZUPPER=0.0441,0.0735,LMAXU=0.1,LFLATU=0.8,$
  PART
  PLOT
  PRESSURES
  SAVE
  NEXT CASE
  $TRIM SET=1.,$
  PRINT AERO BODY
  PLOT
  NEXT CASE
```

D.B. Output File

```
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 *****
  AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS
  CONERR - INPUT ERROR CHECKING
  ERROR CODES - N* DENOTES THE NUMBER OF OCCURENCES OF EACH ERROR
  A - UNKNOWN VARIABLE NAME
  B - MISSING EQUAL SIGN FOLLOWING VARIABLE NAME
  C - NON-ARRAY VARIABLE HAS AN ARRAY ELEMENTDESIGNATION - (N)
  D - NON-ARRAY VARIABLE HAS MULTIPLE VALUES ASSIGNED
  E - ASSIGNED VALUES EXCEED ARRAY DIMENSION
  F - SYNTAX ERROR
  ************************ INPUT DATA CARDS ************************
  1 DIM M
  2 $FLTCON NALPHA=16., ALT=240., 247., 272.17, 316.2, 384.4,
  3 ALT(6)=506.11, 600., 1015.14, 1351.1, 1639.5, 1810., 1848.9,
  4 ALPHA=0.,1.,2.,3.,
  5 ALPHA(5)=4.,5.,6.,7.,
  6 ALPHA(9)=8.,9.,10.,11.,
  7 ALPHA(13)=12.,13.,14.,15.,
  8 NMACH=12., MACH=0.001, 0.1, 0.2, 0.3, 0.4, 0.5, 0.519,
  9 MACH(8)=0.4, 0.3, 0.2, 0.1, 0.056, $
  10 ** BLANK CARD - IGNORED
  11 $REFQ XCG=1.220,$
  12 $AXIBOD LNOSE=0.5334,DNOSE=0.1406, DCENTR=0.1406, LCENTR=1.684,DEXIT=0.,$
  13 $AXIBOD BASE=.FALSE., BETAN = 0., PRAT = 4., TRAT = 4., JMACH = 2.5,$
  14 $FINSET1 SECTYP=HEX,XLE=1.955,NPANEL=3.,PHIF=0.,120.,240.,LER=2*0.00125,
```

```
** SUBSTITUTING NUMERIC FOR NAME HEX
15 SWEEP=10.,5.13,STA=0.,1.,SSPAN=0.,0.135,CHORD=0.09,0.054,
16 ZUPPER=0.0441,0.0735,LMAXU=0.1,LFLATU=0.8,$
17 ** BLANK CARD - IGNORED
18 PART
19 PLOT
20 PRESSURES
21 SAVE
22 NEXT CASE
23 $TRIM SET=1.,$
24 PRINT AERO BODY
25 PLOT
26 NEXT CASE
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 1
CASE INPUTS
FOLLOWING ARE THE CARDS INPUT FOR THIS CASE
DIM M
$FLTCON NALPHA=16., ALT=240., 247., 272.17, 316.2, 384.4,
ALT(6)=506.11, 600., 1015.14, 1351.1, 1639.5, 1810., 1848.9,
ALPHA=0.,1.,2.,3.,
ALPHA(5)=4.,5.,6.,7.,
ALPHA(9)=8.,9.,10.,11.,
ALPHA(13)=12.,13.,14.,15.,
NMACH=12., MACH=0.001, 0.1, 0.2, 0.3, 0.4, 0.5, 0.519,
MACH(8)=0.4, 0.3, 0.2, 0.1, 0.056, $
$REFQ XCG=1.220,$
$AXIBOD LNOSE=0.5334,DNOSE=0.1406, DCENTR=0.1406, LCENTR=1.684,DEXIT=0.,$
$AXIBOD BASE=.FALSE., BETAN = 0., PRAT = 4., TRAT = 4., JMACH = 2.5,$
$FINSET1 SECTYP=0.,XLE=1.955,NPANEL=3.,PHIF=0.,120.,240.,LER=2*0.00125,
SWEEP=10.,5.13,STA=0.,1.,SSPAN=0.,0.135,CHORD=0.09,0.054,
ZUPPER=0.0441,0.0735,LMAXU=0.1,LFLATU=0.8,$
PART
PLOT
PRESSURES
SAVE
NEXT CASE
* WARNING * THE REFERENCE AREA IS UNSPECIFIED, DEFAULT VALUE ASSUMED
* WARNING * THE REFERENCE LENGTH IS UNSPECIFIED, DEFAULT VALUE ASSUMED
THE BOUNDARY LAYER IS ASSUMED TO BE TURBULENT
THE INPUT UNITS ARE IN METERS, THE SCALE FACTOR IS 1.0000
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 2
AXISYMMETRIC BODY DEFINITION
NOSE CENTERBODY AFT BODY TOTAL
SHAPE OGIVE CYLINDER ——
LENGTH 0.533 1.684 0.000 2.217 M
FINENESS RATIO 3.794 11.977 0.000 15.771
PLANFORM AREA 0.050 0.237 0.000 0.287 M**2
AREA CENTROID 0.333 1.375 0.000 1.193 M
WETTED AREA 0.159 0.744 0.000 0.903 M**2
VOLUME 0.004 0.026 0.000 0.031 M**3
VOL. CENTROID 0.366 1.375 0.000 1.229 M
MOLD LINE CONTOUR
LONGITUDINAL STATIONS 0.0000 0.0533 0.1067 0.1600 0.2134
```

0.2667 0.3200 0.3734 0.4267 0.4801 0.5334 0.7018
0.8702 1.0386 1.2070 1.3754 1.5438 1.7122 1.8806
2.0490 2.2174*
BODY RADII 0.0000 0.0135 0.0256 0.0362 0.0453
0.0530 0.0592 0.0641 0.0675 0.0696 0.0703 0.0703
0.0703 0.0703 0.0703 0.0703 0.0703 0.0703 0.0703
0.0703 0.0703*
NOTE - * INDICATES SLOPE DISCONTINUOUS POINTS
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 3
FIN SET NUMBER 1 AIRFOIL SECTION
NACA S-3-28.3-11.5-43.3
X/C X-UPPER Y-UPPER X-LOWER Y-LOWER MEAN LINE THICKNESS
0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
0.00100 0.00100 0.00020 0.00100 -0.00020 0.00000 0.00041
0.00200 0.00200 0.00041 0.00200 -0.00041 0.00000 0.00081
0.00300 0.00300 0.00061 0.00300 -0.00061 0.00000 0.00122
0.00400 0.00400 0.00081 0.00400 -0.00081 0.00000 0.00163
0.00500 0.00500 0.00102 0.00500 -0.00102 0.00000 0.00203
0.00600 0.00600 0.00122 0.00600 -0.00122 0.00000 0.00244
0.00800 0.00800 0.00163 0.00800 -0.00163 0.00000 0.00325
0.01000 0.01000 0.00203 0.01000 -0.00203 0.00000 0.00406
0.02000 0.02000 0.00406 0.02000 -0.00406 0.00000 0.00813
0.03000 0.03000 0.00610 0.03000 -0.00610 0.00000 0.01219
0.04000 0.04000 0.00813 0.04000 -0.00813 0.00000 0.01625
0.05000 0.05000 0.01016 0.05000 -0.01016 0.00000 0.02032
0.06000 0.06000 0.01219 0.06000 -0.01219 0.00000 0.02438
0.08000 0.08000 0.01625 0.08000 -0.01625 0.00000 0.03251
0.10000 0.10000 0.02032 0.10000 -0.02032 0.00000 0.04064
0.12000 0.12000 0.02438 0.12000 -0.02438 0.00000 0.04876
0.14000 0.14000 0.02845 0.14000 -0.02845 0.00000 0.05689
0.16000 0.16000 0.03251 0.16000 -0.03251 0.00000 0.06502
0.18000 0.18000 0.03657 0.18000 -0.03657 0.00000 0.07314
0.20000 0.20000 0.04064 0.20000 -0.04064 0.00000 0.08127
0.22000 0.22000 0.04470 0.22000 -0.04470 0.00000 0.08940
0.24000 0.24000 0.04876 0.24000 -0.04876 0.00000 0.09753
0.26000 0.26000 0.05283 0.26000 -0.05283 0.00000 0.10565
0.28000 0.28000 0.05689 0.28000 -0.05689 0.00000 0.11378
0.30000 0.30000 0.05750 0.30000 -0.05750 0.00000 0.11500
0.32000 0.32000 0.05750 0.32000 -0.05750 0.00000 0.11500
0.34000 0.34000 0.05750 0.34000 -0.05750 0.00000 0.11500
0.36000 0.36000 0.05750 0.36000 -0.05750 0.00000 0.11500
0.38000 0.38000 0.05750 0.38000 -0.05750 0.00000 0.11500
0.40000 0.40000 0.05750 0.40000 -0.05750 0.00000 0.11500
0.42000 0.42000 0.05750 0.42000 -0.05750 0.00000 0.11500
0.45000 0.45000 0.05750 0.45000 -0.05750 0.00000 0.11500
0.50000 0.50000 0.05750 0.50000 -0.05750 0.00000 0.11500
0.55000 0.55000 0.05750 0.55000 -0.05750 0.00000 0.11500
0.60000 0.60000 0.05750 0.60000 -0.05750 0.00000 0.11500
0.65000 0.65000 0.05750 0.65000 -0.05750 0.00000 0.11500
0.70000 0.70000 0.05750 0.70000 -0.05750 0.00000 0.11500
0.75000 0.75000 0.05062 0.75000 -0.05062 0.00000 0.10123
0.80000 0.80000 0.04049 0.80000 -0.04049 0.00000 0.08099
0.82000 0.82000 0.03644 0.82000 -0.03644 0.00000 0.07289
0.84000 0.84000 0.03239 0.84000 -0.03239 0.00000 0.06479

0.86000 0.86000 0.02835 0.86000 -0.02835 0.00000 0.05669
0.88000 0.88000 0.02430 0.88000 -0.02430 0.00000 0.04859
0.90000 0.90000 0.02025 0.90000 -0.02025 0.00000 0.04049
0.92000 0.92000 0.01620 0.92000 -0.01620 0.00000 0.03239
0.94000 0.94000 0.01215 0.94000 -0.01215 0.00000 0.02430
0.96000 0.96000 0.00810 0.96000 -0.00810 0.00000 0.01620
0.98000 0.98000 0.00405 0.98000 -0.00405 0.00000 0.00810
1.00000 1.00000 0.00000 1.00000 0.00000 0.00000 0.00000
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 4
GEOMETRIC RESULTS FOR FIN SETS
FIN SET NUMBER 1
(DATA FOR ONE PANEL ONLY)
SEGMENT PLAN ASPECT TAPER L.E. T.E. M.A.C. T/C
NUMBER AREA RATIO RATIO SWEEP SWEEP CHORD RATIO
1 0.0097 1.875 0.600 10.000 -5.162 0.074 0.115
TOTAL 0.0097 1.875 0.600 10.000 -5.162 0.074 0.115
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 5
FIN SET 1 SECTION AERODYNAMICS
IDEAL ANGLE OF ATTACK = 0.0000 DEG.
ZERO LIFT ANGLE OF ATTACK = 0.0000 DEG.
IDEAL LIFT COEFFICIENT = 0.0000
ZERO LIFT PITCHING MOMENT COEFFICIENT = 0.0000
MACH ZERO LIFT-CURVE-SLOPE = 0.0834 /DEG.
LEADING EDGE RADIUS = 0.0170 FRACTION CHORD
MAXIMUM AIRFOIL THICKNESS = 0.1150 FRACTION CHORD
DELTA-Y = 1.1886 PERCENT CHORD
MACH = 0.001 CL-ALPHA = 0.0564 /DEG. XAC = 0.1344 CL MAX = 0.6537
MACH = 0.056 CL-ALPHA = 0.0835 /DEG. XAC = 0.3005 CL MAX = 0.6556
MACH = 0.100 CL-ALPHA = 0.0838 /DEG. XAC = 0.3005 CL MAX = 0.6578
MACH = 0.100 CL-ALPHA = 0.0838 /DEG. XAC = 0.3005 CL MAX = 0.6572
MACH = 0.200 CL-ALPHA = 0.0851 /DEG. XAC = 0.3003 CL MAX = 0.6619
MACH = 0.200 CL-ALPHA = 0.0851 /DEG. XAC = 0.3003 CL MAX = 0.6610
MACH = 0.300 CL-ALPHA = 0.0874 /DEG. XAC = 0.2999 CL MAX = 0.6660
MACH = 0.300 CL-ALPHA = 0.0874 /DEG. XAC = 0.2999 CL MAX = 0.6649
MACH = 0.400 CL-ALPHA = 0.0909 /DEG. XAC = 0.2994 CL MAX = 0.6701
MACH = 0.400 CL-ALPHA = 0.0909 /DEG. XAC = 0.2994 CL MAX = 0.6692
MACH = 0.500 CL-ALPHA = 0.0963 /DEG. XAC = 0.2989 CL MAX = 0.6740
MACH = 0.519 CL-ALPHA = 0.0976 /DEG. XAC = 0.2988 CL MAX = 0.6745
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 6
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.00 REYNOLDS NO = 2.269E+04 /M
ALTITUDE = 240.0 M DYNAMIC PRESSURE = 0.07 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.5032 0.0275 0.1370 0.0000
1.00 0.5031 0.0275 0.1372 0.0001
2.00 0.5026 0.0275 0.1373 0.0003
3.00 0.5019 0.0275 0.1374 0.0007
4.00 0.5008 0.0274 0.1375 0.0013

5.00 0.4994 0.0273 0.1375 0.0019
6.00 0.4977 0.0272 0.1375 0.0027
7.00 0.4958 0.0271 0.1374 0.0036
8.00 0.4935 0.0270 0.1373 0.0045
9.00 0.4909 0.0269 0.1372 0.0054
10.00 0.4881 0.0267 0.1370 0.0062
11.00 0.4849 0.0265 0.1367 0.0070
12.00 0.4815 0.0263 0.1365 0.0075
13.00 0.4778 0.0261 0.1361 0.0078
14.00 0.4738 0.0259 0.1358 0.0078
15.00 0.4695 0.0257 0.1354 0.0073
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.740
2.00 0.091 0.012 0.391 0.002 0.740
3.00 0.137 0.028 0.586 0.005 0.740
4.00 0.182 0.049 0.780 0.009 0.740
5.00 0.227 0.077 0.973 0.015 0.740
6.00 0.272 0.111 1.164 0.021 0.740
7.00 0.316 0.151 1.354 0.029 0.740
8.00 0.360 0.197 1.542 0.038 0.740
9.00 0.403 0.248 1.727 0.047 0.740
10.00 0.446 0.306 1.910 0.058 0.740
11.00 0.488 0.369 2.091 0.071 0.740
12.00 0.529 0.439 2.268 0.084 0.740
13.00 0.570 0.513 2.442 0.098 0.740
14.00 0.609 0.594 2.612 0.113 0.740
15.00 0.648 0.680 2.779 0.130 0.740
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 7
FIN SET 1 CA PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.00 REYNOLDS NO = 2.269E+04 /M
ALTITUDE = 240.0 M DYNAMIC PRESSURE = 0.07 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
SINGLE FIN PANEL ZERO-LIFT AXIAL FORCE COMPONENTS
SKIN FRICTION 0.0291
SUBSONIC PRESSURE 0.0070
TRANSONIC WAVE 0.0000
SUPERSONIC WAVE 0.0000
LEADING EDGE 0.0000
TRAILING EDGE 0.0000
TOTAL CAO 0.0361
FIN AXIAL FORCE DUE TO ANGLE OF ATTACK
ALPHA CA DUE TO LIFT (SINGLE PANEL) CA-TOTAL (3 FINS)
0.00 0.0000 0.1082
1.00 0.0000 0.1081
2.00 -0.0001 0.1080
3.00 -0.0002 0.1078
4.00 -0.0003 0.1075
5.00 -0.0003 0.1073
6.00 -0.0002 0.1071

7.00 -0.0001 0.1070
8.00 0.0002 0.1070
9.00 0.0006 0.1072
10.00 0.0009 0.1074
11.00 0.0012 0.1077
12.00 0.0013 0.1079
13.00 0.0008 0.1079
14.00 0.0001 0.1074
15.00 -0.0001 0.1061
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 8
FIN SET 1 CN, CM PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.00 REYNOLDS NO = 2.269E+04 /M
ALTITUDE = 240.0 M DYNAMIC PRESSURE = 0.07 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
NORMAL FORCE SLOPE AT ALPHA ZERO, CNA = 0.02691/DEG (1 PANEL)
CENTER OF PRESSURE FOR LINEAR CN = -5.42787 (CALIBERS FROM C.G.)
CENTER OF PRESSURE FOR NON-LINEAR CN = -5.56657 (CALIBERS FROM C.G.)
ALPHA CN CN CN CM CM CM
LINEAR NON-LINEAR TOTAL LINEAR NON-LINEAR TOTAL
0.00 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1.00 0.0404 0.0008 0.0411 -0.2190 -0.0043 -0.2233
2.00 0.0807 0.0031 0.0838 -0.4379 -0.0172 -0.4551
3.00 0.1209 0.0070 0.1279 -0.6564 -0.0387 -0.6952
4.00 0.1611 0.0124 0.1735 -0.8745 -0.0688 -0.9433
5.00 0.2012 0.0193 0.2205 -1.0918 -0.1075 -1.1993
6.00 0.2410 0.0278 0.2688 -1.3084 -0.1547 -1.4630
7.00 0.2807 0.0378 0.3185 -1.5239 -0.2104 -1.7342
8.00 0.3202 0.0493 0.3696 -1.7382 -0.2745 -2.0127
9.00 0.3595 0.0623 0.4218 -1.9512 -0.3470 -2.2983
10.00 0.3984 0.0769 0.4753 -2.1627 -0.4279 -2.5906
11.00 0.4371 0.0929 0.5300 -2.3725 -0.5171 -2.8896
12.00 0.4754 0.1104 0.5858 -2.5804 -0.6145 -3.1949
13.00 0.5133 0.1208 0.6341 -2.7863 -0.6722 -3.4585
14.00 0.5509 0.1201 0.6709 -2.9900 -0.6684 -3.6584
15.00 0.5879 0.1148 0.7027 -3.1913 -0.6390 -3.8303
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 9
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.00 REYNOLDS NO = 2.269E+04 /M
ALTITUDE = 240.0 M DYNAMIC PRESSURE = 0.07 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 IN PRESENCE OF THE BODY——————-
ALPHA CN CM CA CY CLN CLL
0.00 0.0000 0.0000 0.1082 0.0000 0.0000 0.0000
1.00 0.0578 -0.3136 0.1081 0.0000 0.0000 0.0000
2.00 0.1169 -0.6345 0.1079 0.0000 0.0000 0.0000
3.00 0.1780 -0.9661 0.1078 0.0000 0.0000 0.0000
4.00 0.2405 -1.3052 0.1077 0.0000 0.0000 0.0000

5.00 0.3029 -1.6442 0.1078 0.0000 0.0000 0.0000
6.00 0.3654 -1.9832 0.1081 0.0000 0.0000 0.0000
7.00 0.4285 -2.3259 0.1087 0.0000 0.0000 0.0000
8.00 0.4921 -2.6710 0.1094 0.0000 0.0000 0.0000
9.00 0.5527 -2.9999 0.1102 0.0000 0.0000 0.0000
10.00 0.6068 -3.2939 0.1106 0.0000 0.0000 0.0000
11.00 0.6556 -3.5587 0.1106 0.0000 0.0000 0.0000
12.00 0.6906 -3.7486 0.1096 0.0000 0.0000 0.0000
13.00 0.7177 -3.8958 0.1085 0.0000 0.0000 0.0000
14.00 0.7393 -4.0127 0.1081 0.0000 0.0000 0.0000
15.00 0.7538 -4.0913 0.1084 0.0000 0.0000 0.0000
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 10
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.00 REYNOLDS NO = 2.269E+04 /M
ALTITUDE = 240.0 M DYNAMIC PRESSURE = 0.07 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 PANEL CHARACTERISTICS——————
ALPHA PANEL AEQ (PANEL AXIS SYS.) PANEL CN
0.00 1 0.0000 0.0000
0.00 2 0.0000 0.0000
0.00 3 0.0000 0.0000
1.00 1 0.0000 0.0000
1.00 2 1.2062 0.0334
1.00 3 -1.2062 -0.0334
2.00 1 0.0000 0.0000
2.00 2 2.4023 0.0675
2.00 3 -2.4023 -0.0675
3.00 1 0.0000 0.0000
3.00 2 3.5841 0.1028
3.00 3 -3.5841 -0.1028
4.00 1 0.0000 0.0000
4.00 2 4.7486 0.1388
4.00 3 -4.7486 -0.1388
5.00 1 0.0000 0.0000
5.00 2 5.8801 0.1749
5.00 3 -5.8801 -0.1749
6.00 1 0.0000 0.0000
6.00 2 6.9848 0.2110
6.00 3 -6.9848 -0.2110
7.00 1 0.0000 0.0000
7.00 2 8.0620 0.2474
7.00 3 -8.0620 -0.2474
8.00 1 0.0000 0.0000
8.00 2 9.1110 0.2841
8.00 3 -9.1110 -0.2841
9.00 1 0.0000 0.0000
9.00 2 10.1322 0.3191
9.00 3 -10.1322 -0.3191
10.00 1 0.0000 0.0000
10.00 2 11.1260 0.3504
10.00 3 -11.1260 -0.3504

11.00 1 0.0000 0.0000
11.00 2 12.1764 0.3785
11.00 3 -12.1764 -0.3785
12.00 1 0.0000 0.0000
12.00 2 13.1202 0.3987
12.00 3 -13.1202 -0.3987
13.00 1 0.0000 0.0000
13.00 2 14.0203 0.4144
13.00 3 -14.0203 -0.4144
14.00 1 0.0000 0.0000
14.00 2 14.8958 0.4268
14.00 3 -14.8958 -0.4268
15.00 1 0.0000 0.0000
15.00 2 15.7626 0.4352
15.00 3 -15.7626 -0.4352
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 11
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.00 REYNOLDS NO = 2.269E+04 /M
ALTITUDE = 240.0 M DYNAMIC PRESSURE = 0.07 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
CARRYOVER INTERFERENCE FACTORS - FIN SET 1
ALPHA K-W(B) K-B(W) KK-W(B) KK-B(W) XCP-W(B) XCP-B(W) Y-CP/(B/2)
0.00 1.3959 0.5090 0.9348 0.3583 5.4279 5.4173 0.3996
1.00 1.3927 0.5090 0.9348 0.3583 5.4279 5.4173 0.4009
2.00 1.3870 0.5090 0.9348 0.3583 5.4279 5.4173 0.4022
3.00 1.3797 0.5090 0.9348 0.3583 5.4279 5.4173 0.4036
4.00 1.3712 0.5090 0.9348 0.3583 5.4279 5.4173 0.4051
5.00 1.3618 0.5090 0.9348 0.3583 5.4279 5.4173 0.4065
6.00 1.3517 0.5090 0.9348 0.3583 5.4279 5.4173 0.4076
7.00 1.3410 0.5090 0.9348 0.3583 5.4279 5.4173 0.4081
8.00 1.3299 0.5090 0.9348 0.3583 5.4279 5.4173 0.4086
9.00 1.3185 0.5090 0.9348 0.3583 5.4279 5.4173 0.4091
10.00 1.3069 0.5090 0.9348 0.3583 5.4279 5.4173 0.4095
11.00 1.2951 0.5090 0.9348 0.3583 5.4279 5.4173 0.4099
12.00 1.2833 0.5090 0.9348 0.3583 5.4279 5.4173 0.4102
13.00 1.2714 0.5090 0.9348 0.3583 5.4279 5.4173 0.4108
14.00 1.2596 0.5090 0.9348 0.3583 5.4279 5.4173 0.4113
15.00 1.2480 0.5090 0.9348 0.3583 5.4279 5.4173 0.4117
NOTE - XCP-W(B) USED FOR STABILITY ONLY DIFFERENT VALUES USED FOR HINGE MOMENTS
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 12
FIN SET 1 PANEL BENDING MOMENTS (ABOUT EXPOSED ROOT CHORD)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.00 REYNOLDS NO = 2.269E+04 /M
ALTITUDE = 240.0 M DYNAMIC PRESSURE = 0.07 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00

1.0 0.00E+00 1.28E-02 -1.28E-02
2.0 0.00E+00 2.61E-02 -2.61E-02
3.0 0.00E+00 3.98E-02 -3.98E-02
4.0 0.00E+00 5.40E-02 -5.40E-02
5.0 7.21E-10 6.83E-02 -6.83E-02
6.0 1.26E-09 8.26E-02 -8.26E-02
7.0 0.00E+00 9.69E-02 -9.69E-02
8.0 2.52E-09 1.11E-01 -1.11E-01
9.0 -1.55E-09 1.25E-01 -1.25E-01
10.0 1.89E-09 1.38E-01 -1.38E-01
11.0 0.00E+00 1.49E-01 -1.49E-01
12.0 -5.18E-09 1.57E-01 -1.57E-01
13.0 1.27E-09 1.63E-01 -1.63E-01
14.0 -7.23E-09 1.69E-01 -1.69E-01
15.0 -2.84E-09 1.72E-01 -1.72E-01
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 13
FIN SET 1 PANEL HINGE MOMENTS (ABOUT HINGE LINE)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.00 REYNOLDS NO = 2.269E+04 /M
ALTITUDE = 240.0 M DYNAMIC PRESSURE = 0.07 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 4.00E-03 -4.00E-03
2.0 0.00E+00 8.08E-03 -8.08E-03
3.0 0.00E+00 1.23E-02 -1.23E-02
4.0 0.00E+00 1.66E-02 -1.66E-02
5.0 2.21E-10 2.09E-02 -2.09E-02
6.0 3.85E-10 2.53E-02 -2.53E-02
7.0 0.00E+00 2.96E-02 -2.96E-02
8.0 7.69E-10 3.40E-02 -3.40E-02
9.0 -4.73E-10 3.82E-02 -3.82E-02
10.0 5.76E-10 4.20E-02 -4.20E-02
11.0 0.00E+00 4.53E-02 -4.53E-02
12.0 -1.57E-09 4.78E-02 -4.78E-02
13.0 3.86E-10 4.96E-02 -4.96E-02
14.0 -2.19E-09 5.11E-02 -5.11E-02
15.0 -8.59E-10 5.21E-02 -5.21E-02
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 14
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.00 REYNOLDS NO = 2.269E+04 /M
ALTITUDE = 240.0 M DYNAMIC PRESSURE = 0.07 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
—– LONGITUDINAL —– – LATERAL DIRECTIONAL –
ALPHA CN CM CA CY CLN CLL
0.00 0.000 0.000 0.776 0.000 0.000 0.000
1.00 0.128 -0.232 0.776 0.000 0.000 0.000
2.00 0.263 -0.473 0.776 0.000 0.000 0.000

3.00 0.408 -0.731 0.775 0.000 0.000 0.000
4.00 0.561 -1.000 0.775 0.000 0.000 0.000
5.00 0.720 -1.270 0.774 0.000 0.000 0.000
6.00 0.885 -1.543 0.773 0.000 0.000 0.000
7.00 1.058 -1.824 0.773 0.000 0.000 0.000
8.00 1.237 -2.112 0.772 0.000 0.000 0.000
9.00 1.417 -2.381 0.771 0.000 0.000 0.000
10.00 1.595 -2.606 0.769 0.000 0.000 0.000
11.00 1.770 -2.794 0.766 0.000 0.000 0.000
12.00 1.932 -2.881 0.761 0.000 0.000 0.000
13.00 2.088 -2.912 0.756 0.000 0.000 0.000
14.00 2.241 -2.905 0.751 0.000 0.000 0.000
15.00 2.389 -2.848 0.746 0.000 0.000 0.000
ALPHA CL CD CL/CD X-C.P.
0.00 0.000 0.776 0.000 -1.835
1.00 0.114 0.778 0.147 -1.816
2.00 0.236 0.784 0.301 -1.798
3.00 0.367 0.796 0.461 -1.791
4.00 0.506 0.812 0.623 -1.782
5.00 0.650 0.834 0.779 -1.764
6.00 0.800 0.862 0.928 -1.743
7.00 0.956 0.896 1.067 -1.725
8.00 1.117 0.936 1.193 -1.708
9.00 1.279 0.983 1.302 -1.680
10.00 1.437 1.034 1.390 -1.634
11.00 1.592 1.090 1.461 -1.578
12.00 1.732 1.147 1.510 -1.491
13.00 1.864 1.207 1.545 -1.395
14.00 1.993 1.271 1.568 -1.296
15.00 2.115 1.339 1.579 -1.192
X-C.P. MEAS. FROM MOMENT CENTER IN REF. LENGTHS, NEG. AFT OF MOMENT CENTER
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 15
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.00 REYNOLDS NO = 2.269E+04 /M
ALTITUDE = 240.0 M DYNAMIC PRESSURE = 0.07 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——— DERIVATIVES (PER DEGREE) ———-
ALPHA CNA CMA CYB CLNB CLLB
0.00 0.1236 -0.2268 -0.1276 0.2317 -0.0002
1.00 0.1317 -0.2367 -0.1292 0.2332 0.0004
2.00 0.1402 -0.2495 -0.1325 0.2376 0.0019
3.00 0.1488 -0.2630 -0.1361 0.2417 0.0035
4.00 0.1560 -0.2697 -0.1394 0.2442 0.0047
5.00 0.1622 -0.2719 -0.1392 0.2279 0.0073
6.00 0.1688 -0.2771 -0.1392 0.2123 0.0098
7.00 0.1756 -0.2844 -0.1391 0.1975 0.0129
8.00 0.1798 -0.2783 -0.1378 0.1761 0.0149
9.00 0.1791 -0.2466 -0.1344 0.1434 0.0148
10.00 0.1766 -0.2062 -0.1288 0.0996 0.0130
11.00 0.1687 -0.1373 -0.1310 0.0985 0.0043
12.00 0.1589 -0.0594 -0.1234 0.0446 0.0026

13.00 0.1545 -0.0121 -0.1141 -0.0176 0.0041
14.00 0.1505 0.0324 -0.1039 -0.0844 0.0058
15.00 0.1454 0.0826 -0.0931 -0.1540 0.0057
PANEL DEFLECTION ANGLES (DEGREES)
SET FIN 1 FIN 2 FIN 3 FIN 4 FIN 5 FIN 6 FIN 7 FIN 8
1 0.00 0.00 0.00
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 16
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.06 REYNOLDS NO = 1.096E+06 /M
ALTITUDE = 1848.9 M DYNAMIC PRESSURE = 177.83 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.2220 0.0122 0.1370 0.0000
1.00 0.2219 0.0122 0.1372 0.0000
2.00 0.2217 0.0122 0.1373 0.0001
3.00 0.2214 0.0121 0.1374 0.0003
4.00 0.2209 0.0121 0.1375 0.0005
5.00 0.2203 0.0121 0.1375 0.0008
6.00 0.2195 0.0120 0.1375 0.0011
7.00 0.2187 0.0120 0.1374 0.0013
8.00 0.2177 0.0119 0.1373 0.0016
9.00 0.2165 0.0119 0.1371 0.0017
10.00 0.2153 0.0118 0.1369 0.0016
11.00 0.2139 0.0117 0.1367 0.0014
12.00 0.2124 0.0116 0.1364 0.0009
13.00 0.2107 0.0115 0.1361 0.0000
14.00 0.2090 0.0115 0.1357 -0.0013
15.00 0.2071 0.0114 0.1353 -0.0032
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.741
2.00 0.091 0.012 0.391 0.002 0.741
3.00 0.137 0.028 0.586 0.005 0.742
4.00 0.182 0.050 0.780 0.009 0.742
5.00 0.227 0.077 0.973 0.015 0.743
6.00 0.272 0.111 1.164 0.021 0.744
7.00 0.316 0.152 1.354 0.029 0.744
8.00 0.360 0.198 1.542 0.038 0.745
9.00 0.403 0.250 1.727 0.048 0.745
10.00 0.446 0.308 1.910 0.059 0.746
11.00 0.488 0.373 2.091 0.071 0.747
12.00 0.529 0.443 2.268 0.085 0.747
13.00 0.570 0.519 2.442 0.099 0.748
14.00 0.609 0.600 2.612 0.115 0.748
15.00 0.648 0.688 2.779 0.131 0.749
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 17
FIN SET 1 CA PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.06 REYNOLDS NO = 1.096E+06 /M

ALTITUDE = 1848.9 M DYNAMIC PRESSURE = 177.83 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
SINGLE FIN PANEL ZERO-LIFT AXIAL FORCE COMPONENTS
SKIN FRICTION 0.0095
SUBSONIC PRESSURE 0.0023
TRANSONIC WAVE 0.0000
SUPERSONIC WAVE 0.0000
LEADING EDGE 0.0000
TRAILING EDGE 0.0000
TOTAL CAO 0.0117
FIN AXIAL FORCE DUE TO ANGLE OF ATTACK
ALPHA CA DUE TO LIFT (SINGLE PANEL) CA-TOTAL (3 FINS)
0.00 0.0000 0.0352
1.00 -0.0002 0.0349
2.00 -0.0008 0.0339
3.00 -0.0018 0.0324
4.00 -0.0032 0.0303
5.00 -0.0050 0.0275
6.00 -0.0071 0.0243
7.00 -0.0097 0.0204
8.00 -0.0126 0.0159
9.00 -0.0153 0.0107
10.00 -0.0167 0.0059
11.00 -0.0165 0.0025
12.00 -0.0145 0.0012
13.00 -0.0109 0.0023
14.00 -0.0063 0.0060
15.00 -0.0020 0.0121
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 18
FIN SET 1 CN, CM PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.06 REYNOLDS NO = 1.096E+06 /M
ALTITUDE = 1848.9 M DYNAMIC PRESSURE = 177.83 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
NORMAL FORCE SLOPE AT ALPHA ZERO, CNA = 0.03517/DEG (1 PANEL)
CENTER OF PRESSURE FOR LINEAR CN = -5.42786 (CALIBERS FROM C.G.)
CENTER OF PRESSURE FOR NON-LINEAR CN = -5.56657 (CALIBERS FROM C.G.)
ALPHA CN CN CN CM CM CM
LINEAR NON-LINEAR TOTAL LINEAR NON-LINEAR TOTAL
0.00 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1.00 0.0528 0.0004 0.0532 -0.2864 -0.0025 -0.2888
2.00 0.1055 0.0018 0.1072 -0.5725 -0.0099 -0.5823
3.00 0.1581 0.0040 0.1621 -0.8582 -0.0222 -0.8803
4.00 0.2106 0.0071 0.2177 -1.1432 -0.0394 -1.1826
5.00 0.2630 0.0110 0.2740 -1.4274 -0.0615 -1.4889
6.00 0.3151 0.0159 0.3310 -1.7105 -0.0885 -1.7989
7.00 0.3670 0.0216 0.3887 -1.9922 -0.1203 -2.1125
8.00 0.4187 0.0282 0.4469 -2.2724 -0.1570 -2.4294
9.00 0.4700 0.0357 0.5056 -2.5509 -0.1985 -2.7494
10.00 0.5209 0.0398 0.5607 -2.8274 -0.2214 -3.0488

11.00 0.5714 0.0325 0.6039 -3.1016 -0.1810 -3.2826
12.00 0.6215 0.0200 0.6415 -3.3735 -0.1115 -3.4850
13.00 0.6711 0.0015 0.6726 -3.6426 -0.0084 -3.6510
14.00 0.7202 -0.0239 0.6963 -3.9089 0.1330 -3.7759
15.00 0.7686 -0.0570 0.7116 -4.1721 0.3173 -3.8547
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 19
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.06 REYNOLDS NO = 1.096E+06 /M
ALTITUDE = 1848.9 M DYNAMIC PRESSURE = 177.83 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
———–FIN SET 1 IN PRESENCE OF THE BODY———–-
ALPHA CN CM CA CY CLN CLL
0.00 0.0000 0.0000 0.0352 0.0000 0.0000 0.0000
1.00 0.0743 -0.4034 0.0346 0.0000 0.0000 0.0000
2.00 0.1491 -0.8095 0.0329 0.0000 0.0000 0.0000
3.00 0.2244 -1.2182 0.0301 0.0000 0.0000 0.0000
4.00 0.2991 -1.6237 0.0263 0.0000 0.0000 0.0000
5.00 0.3732 -2.0256 0.0215 0.0000 0.0000 0.0000
6.00 0.4478 -2.4305 0.0159 0.0000 0.0000 0.0000
7.00 0.5174 -2.8081 0.0096 0.0000 0.0000 0.0000
8.00 0.5766 -3.1299 0.0042 0.0000 0.0000 0.0000
9.00 0.6263 -3.3996 0.0017 0.0000 0.0000 0.0000
10.00 0.6670 -3.6204 0.0024 0.0000 0.0000 0.0000
11.00 0.6986 -3.7916 0.0072 0.0000 0.0000 0.0000
12.00 0.7176 -3.8948 0.0144 0.0000 0.0000 0.0000
13.00 0.7373 -4.0020 0.0228 0.0000 0.0000 0.0000
14.00 0.7642 -4.1479 0.0304 0.0000 0.0000 0.0000
15.00 0.7896 -4.2859 0.0373 0.0000 0.0000 0.0000
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 20
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.06 REYNOLDS NO = 1.096E+06 /M
ALTITUDE = 1848.9 M DYNAMIC PRESSURE = 177.83 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
———–FIN SET 1 PANEL CHARACTERISTICS———–
ALPHA PANEL AEQ (PANEL AXIS SYS.) PANEL CN
0.00 1 0.0000 0.0000
0.00 2 0.0000 0.0000
0.00 3 0.0000 0.0000
1.00 1 0.0000 0.0000
1.00 2 1.2062 0.0429
1.00 3 -1.2062 -0.0429
2.00 1 0.0000 0.0000
2.00 2 2.4023 0.0861
2.00 3 -2.4023 -0.0861
3.00 1 0.0000 0.0000
3.00 2 3.5841 0.1296
3.00 3 -3.5841 -0.1296

4.00 1 0.0000 0.0000
4.00 2 4.7486 0.1727
4.00 3 -4.7486 -0.1727
5.00 1 0.0000 0.0000
5.00 2 5.8800 0.2155
5.00 3 -5.8800 -0.2155
6.00 1 0.0000 0.0000
6.00 2 6.9846 0.2585
6.00 3 -6.9846 -0.2585
7.00 1 0.0000 0.0000
7.00 2 8.0617 0.2987
7.00 3 -8.0617 -0.2987
8.00 1 0.0000 0.0000
8.00 2 9.1104 0.3329
8.00 3 -9.1104 -0.3329
9.00 1 0.0000 0.0000
9.00 2 10.1313 0.3616
9.00 3 -10.1313 -0.3616
10.00 1 0.0000 0.0000
10.00 2 11.1246 0.3851
10.00 3 -11.1246 -0.3851
11.00 1 0.0000 0.0000
11.00 2 12.1764 0.4033
11.00 3 -12.1764 -0.4033
12.00 1 0.0000 0.0000
12.00 2 13.1202 0.4143
12.00 3 -13.1202 -0.4143
13.00 1 0.0000 0.0000
13.00 2 14.0203 0.4257
13.00 3 -14.0203 -0.4257
14.00 1 0.0000 0.0000
14.00 2 14.8958 0.4412
14.00 3 -14.8958 -0.4412
15.00 1 0.0000 0.0000
15.00 2 15.7626 0.4559
15.00 3 -15.7626 -0.4559
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 21
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.06 REYNOLDS NO = 1.096E+06 /M
ALTITUDE = 1848.9 M DYNAMIC PRESSURE = 177.83 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
CARRYOVER INTERFERENCE FACTORS - FIN SET 1
ALPHA K-W(B) K-B(W) KK-W(B) KK-B(W) XCP-W(B) XCP-B(W) Y-CP/(B/2)
0.00 1.3959 0.5090 0.9348 0.3583 5.4279 5.4173 0.4030
1.00 1.3927 0.5090 0.9348 0.3583 5.4279 5.4173 0.4045
2.00 1.3870 0.5090 0.9348 0.3583 5.4279 5.4173 0.4061
3.00 1.3797 0.5090 0.9348 0.3583 5.4279 5.4173 0.4076
4.00 1.3712 0.5090 0.9348 0.3583 5.4279 5.4173 0.4092
5.00 1.3618 0.5090 0.9348 0.3583 5.4279 5.4173 0.4103
6.00 1.3517 0.5090 0.9348 0.3583 5.4279 5.4173 0.4107
7.00 1.3410 0.5090 0.9348 0.3583 5.4279 5.4173 0.4111

8.00 1.3299 0.5090 0.9348 0.3583 5.4279 5.4173 0.4114
9.00 1.3185 0.5090 0.9348 0.3583 5.4279 5.4173 0.4117
10.00 1.3069 0.5090 0.9348 0.3583 5.4279 5.4173 0.4120
11.00 1.2951 0.5090 0.9348 0.3583 5.4279 5.4173 0.4122
12.00 1.2833 0.5090 0.9348 0.3583 5.4279 5.4173 0.4126
13.00 1.2714 0.5090 0.9348 0.3583 5.4279 5.4173 0.4130
14.00 1.2596 0.5090 0.9348 0.3583 5.4279 5.4173 0.4136
15.00 1.2480 0.5090 0.9348 0.3583 5.4279 5.4173 0.4141
NOTE - XCP-W(B) USED FOR STABILITY ONLY DIFFERENT VALUES USED FOR HINGE MOMENTS
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 22
FIN SET 1 PANEL BENDING MOMENTS (ABOUT EXPOSED ROOT CHORD)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.06 REYNOLDS NO = 1.096E+06 /M
ALTITUDE = 1848.9 M DYNAMIC PRESSURE = 177.83 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 1.67E-02 -1.67E-02
2.0 0.00E+00 3.36E-02 -3.36E-02
3.0 0.00E+00 5.07E-02 -5.07E-02
4.0 0.00E+00 6.78E-02 -6.78E-02
5.0 9.42E-10 8.49E-02 -8.49E-02
6.0 1.64E-09 1.02E-01 -1.02E-01
7.0 0.00E+00 1.18E-01 -1.18E-01
8.0 3.29E-09 1.32E-01 -1.32E-01
9.0 -2.03E-09 1.43E-01 -1.43E-01
10.0 2.47E-09 1.52E-01 -1.52E-01
11.0 0.00E+00 1.60E-01 -1.60E-01
12.0 -6.72E-09 1.64E-01 -1.64E-01
13.0 1.65E-09 1.69E-01 -1.69E-01
14.0 -9.38E-09 1.75E-01 -1.75E-01
15.0 -3.68E-09 1.81E-01 -1.81E-01
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 23
FIN SET 1 PANEL HINGE MOMENTS (ABOUT HINGE LINE)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.06 REYNOLDS NO = 1.096E+06 /M
ALTITUDE = 1848.9 M DYNAMIC PRESSURE = 177.83 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 5.14E-03 -5.14E-03
2.0 0.00E+00 1.03E-02 -1.03E-02
3.0 0.00E+00 1.55E-02 -1.55E-02
4.0 0.00E+00 2.07E-02 -2.07E-02
5.0 2.86E-10 2.58E-02 -2.58E-02
6.0 4.99E-10 3.10E-02 -3.10E-02
7.0 0.00E+00 3.58E-02 -3.58E-02
8.0 9.98E-10 3.99E-02 -3.99E-02

9.0 -6.15E-10 4.33E-02 -4.33E-02
10.0 7.49E-10 4.61E-02 -4.61E-02
11.0 0.00E+00 4.83E-02 -4.83E-02
12.0 -2.03E-09 4.96E-02 -4.96E-02
13.0 4.98E-10 5.10E-02 -5.10E-02
14.0 -2.83E-09 5.29E-02 -5.29E-02
15.0 -1.11E-09 5.46E-02 -5.46E-02
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 24
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.06 REYNOLDS NO = 1.096E+06 /M
ALTITUDE = 1848.9 M DYNAMIC PRESSURE = 177.83 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
—– LONGITUDINAL —– – LATERAL DIRECTIONAL –
ALPHA CN CM CA CY CLN CLL
0.00 0.000 0.000 0.406 0.000 0.000 0.000
1.00 0.150 -0.354 0.406 0.000 0.000 0.000
2.00 0.307 -0.713 0.404 0.000 0.000 0.000
3.00 0.472 -1.076 0.401 0.000 0.000 0.000
4.00 0.642 -1.436 0.397 0.000 0.000 0.000
5.00 0.817 -1.794 0.392 0.000 0.000 0.000
6.00 0.999 -2.159 0.386 0.000 0.000 0.000
7.00 1.181 -2.489 0.379 0.000 0.000 0.000
8.00 1.355 -2.746 0.373 0.000 0.000 0.000
9.00 1.521 -2.934 0.369 0.000 0.000 0.000
10.00 1.681 -3.059 0.368 0.000 0.000 0.000
11.00 1.833 -3.117 0.371 0.000 0.000 0.000
12.00 1.974 -3.084 0.376 0.000 0.000 0.000
13.00 2.121 -3.060 0.381 0.000 0.000 0.000
14.00 2.283 -3.094 0.385 0.000 0.000 0.000
15.00 2.448 -3.120 0.388 0.000 0.000 0.000
ALPHA CL CD CL/CD X-C.P.
0.00 0.000 0.406 0.000 -2.402
1.00 0.143 0.408 0.350 -2.359
2.00 0.293 0.415 0.707 -2.318
3.00 0.450 0.425 1.058 -2.280
4.00 0.612 0.441 1.388 -2.238
5.00 0.780 0.462 1.688 -2.196
6.00 0.953 0.488 1.952 -2.160
7.00 1.126 0.520 2.165 -2.108
8.00 1.290 0.558 2.313 -2.027
9.00 1.445 0.602 2.398 -1.929
10.00 1.591 0.654 2.432 -1.820
11.00 1.729 0.714 2.422 -1.700
12.00 1.853 0.778 2.381 -1.562
13.00 1.981 0.849 2.334 -1.443
14.00 2.122 0.926 2.291 -1.355
15.00 2.264 1.008 2.245 -1.275
X-C.P. MEAS. FROM MOMENT CENTER IN REF. LENGTHS, NEG. AFT OF MOMENT CENTER
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 25
STATIC AERODYNAMICS FOR BODY-FIN SET 1

******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.06 REYNOLDS NO = 1.096E+06 /M
ALTITUDE = 1848.9 M DYNAMIC PRESSURE = 177.83 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——— DERIVATIVES (PER DEGREE) ———
ALPHA CNA CMA CYB CLNB CLLB
0.00 0.1467 -0.3523 -0.1502 0.3543 -0.0001
1.00 0.1537 -0.3563 -0.1516 0.3547 0.0003
2.00 0.1608 -0.3606 -0.1544 0.3561 0.0012
3.00 0.1671 -0.3616 -0.1571 0.3556 0.0018
4.00 0.1726 -0.3591 -0.1597 0.3543 0.0023
5.00 0.1789 -0.3613 -0.1590 0.3345 0.0056
6.00 0.1821 -0.3476 -0.1571 0.3092 0.0077
7.00 0.1777 -0.2934 -0.1518 0.2653 0.0058
8.00 0.1700 -0.2224 -0.1449 0.2136 0.0028
9.00 0.1630 -0.1561 -0.1382 0.1632 0.0007
10.00 0.1562 -0.0913 -0.1302 0.1057 -0.0016
11.00 0.1466 -0.0128 -0.1326 0.1058 -0.0127
12.00 0.1437 0.0286 -0.1254 0.0539 -0.0108
13.00 0.1544 -0.0047 -0.1197 0.0104 -0.0001
14.00 0.1634 -0.0300 -0.1120 -0.0433 0.0100
15.00 0.1664 -0.0229 -0.0992 -0.1237 0.0122
PANEL DEFLECTION ANGLES (DEGREES)
SET FIN 1 FIN 2 FIN 3 FIN 4 FIN 5 FIN 6 FIN 7 FIN 8
1 0.00 0.00 0.00
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 26
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 2.267E+06 /M
ALTITUDE = 247.0 M DYNAMIC PRESSURE = 688.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1953 0.0107 0.1370 0.0000
1.00 0.1953 0.0107 0.1372 0.0000
2.00 0.1951 0.0107 0.1373 0.0001
3.00 0.1948 0.0107 0.1374 0.0003
4.00 0.1944 0.0107 0.1375 0.0005
5.00 0.1938 0.0107 0.1375 0.0007
6.00 0.1932 0.0106 0.1375 0.0009
7.00 0.1924 0.0106 0.1374 0.0011
8.00 0.1915 0.0105 0.1373 0.0013
9.00 0.1905 0.0105 0.1371 0.0013
10.00 0.1894 0.0104 0.1369 0.0012
11.00 0.1882 0.0104 0.1367 0.0009
12.00 0.1869 0.0103 0.1364 0.0003
13.00 0.1854 0.0102 0.1361 -0.0007
14.00 0.1839 0.0101 0.1357 -0.0022
15.00 0.1822 0.0100 0.1353 -0.0042
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC

0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.741
2.00 0.091 0.012 0.391 0.002 0.742
3.00 0.137 0.028 0.586 0.005 0.743
4.00 0.182 0.050 0.780 0.009 0.744
5.00 0.227 0.078 0.973 0.015 0.745
6.00 0.272 0.112 1.164 0.021 0.746
7.00 0.316 0.152 1.354 0.029 0.747
8.00 0.360 0.199 1.542 0.038 0.749
9.00 0.403 0.251 1.727 0.048 0.750
10.00 0.446 0.310 1.910 0.059 0.751
11.00 0.488 0.375 2.091 0.072 0.752
12.00 0.529 0.446 2.268 0.085 0.753
13.00 0.570 0.523 2.442 0.100 0.754
14.00 0.609 0.606 2.612 0.116 0.755
15.00 0.648 0.694 2.779 0.133 0.756
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 27
FIN SET 1 CA PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 2.267E+06 /M
ALTITUDE = 247.0 M DYNAMIC PRESSURE = 688.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
SINGLE FIN PANEL ZERO-LIFT AXIAL FORCE COMPONENTS
SKIN FRICTION 0.0080
SUBSONIC PRESSURE 0.0019
TRANSONIC WAVE 0.0000
SUPERSONIC WAVE 0.0000
LEADING EDGE 0.0000
TRAILING EDGE 0.0000
TOTAL CAO 0.0099
FIN AXIAL FORCE DUE TO ANGLE OF ATTACK
ALPHA CA DUE TO LIFT (SINGLE PANEL) CA-TOTAL (3 FINS)
0.00 0.0000 0.0298
1.00 -0.0003 0.0293
2.00 -0.0011 0.0280
3.00 -0.0025 0.0258
4.00 -0.0045 0.0229
5.00 -0.0070 0.0191
6.00 -0.0101 0.0144
7.00 -0.0137 0.0089
8.00 -0.0180 0.0025
9.00 -0.0218 -0.0048
10.00 -0.0237 -0.0117
11.00 -0.0231 -0.0164
12.00 -0.0199 -0.0179
13.00 -0.0146 -0.0156
14.00 -0.0083 -0.0097
15.00 -0.0026 -0.0006
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 28
FIN SET 1 CN, CM PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******

MACH NO = 0.10 REYNOLDS NO = 2.267E+06 /M
ALTITUDE = 247.0 M DYNAMIC PRESSURE = 688.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
NORMAL FORCE SLOPE AT ALPHA ZERO, CNA = 0.03525/DEG (1 PANEL)
CENTER OF PRESSURE FOR LINEAR CN = -5.42784 (CALIBERS FROM C.G.)
CENTER OF PRESSURE FOR NON-LINEAR CN = -5.56657 (CALIBERS FROM C.G.)

ALPHA	CN LINEAR	CN NON-LINEAR	CN TOTAL	CM LINEAR	CM NON-LINEAR	CM TOTAL
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.00	0.0529	0.0004	0.0533	-0.2869	-0.0023	-0.2893
2.00	0.1057	0.0017	0.1074	-0.5737	-0.0093	-0.5829
3.00	0.1584	0.0038	0.1622	-0.8599	-0.0209	-0.8808
4.00	0.2111	0.0067	0.2177	-1.1456	-0.0371	-1.1827
5.00	0.2635	0.0104	0.2739	-1.4303	-0.0580	-1.4883
6.00	0.3158	0.0150	0.3308	-1.7140	-0.0834	-1.7974
7.00	0.3678	0.0204	0.3882	-1.9963	-0.1134	-2.1097
8.00	0.4195	0.0266	0.4461	-2.2771	-0.1480	-2.4251
9.00	0.4709	0.0336	0.5045	-2.5561	-0.1871	-2.7433
10.00	0.5220	0.0351	0.5571	-2.8332	-0.1955	-3.0287
11.00	0.5726	0.0266	0.5992	-3.1080	-0.1482	-3.2562
12.00	0.6228	0.0127	0.6355	-3.3804	-0.0707	-3.4511
13.00	0.6725	-0.0075	0.6650	-3.6501	0.0415	-3.6087
14.00	0.7216	-0.0347	0.6869	-3.9169	0.1931	-3.7238
15.00	0.7702	-0.0699	0.7003	-4.1806	0.3890	-3.7916

1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 29
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 2.267E+06 /M
ALTITUDE = 247.0 M DYNAMIC PRESSURE = 688.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 IN PRESENCE OF THE BODY——————-

ALPHA	CN	CM	CA	CY	CLN	CLL
0.00	0.0000	0.0000	0.0298	0.0000	0.0000	0.0000
1.00	0.0744	-0.4039	0.0290	0.0000	0.0000	0.0000
2.00	0.1493	-0.8103	0.0266	0.0000	0.0000	0.0000
3.00	0.2245	-1.2186	0.0226	0.0000	0.0000	0.0000
4.00	0.2990	-1.6231	0.0172	0.0000	0.0000	0.0000
5.00	0.3729	-2.0240	0.0104	0.0000	0.0000	0.0000
6.00	0.4474	-2.4284	0.0024	0.0000	0.0000	0.0000
7.00	0.5164	-2.8030	-0.0067	0.0000	0.0000	0.0000
8.00	0.5741	-3.1163	-0.0145	0.0000	0.0000	0.0000
9.00	0.6214	-3.3730	-0.0178	0.0000	0.0000	0.0000
10.00	0.6597	-3.5807	-0.0160	0.0000	0.0000	0.0000
11.00	0.6912	-3.7519	-0.0086	0.0000	0.0000	0.0000
12.00	0.7129	-3.8697	0.0019	0.0000	0.0000	0.0000
13.00	0.7338	-3.9828	0.0135	0.0000	0.0000	0.0000
14.00	0.7578	-4.1132	0.0235	0.0000	0.0000	0.0000
15.00	0.7801	-4.2344	0.0324	0.0000	0.0000	0.0000

1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 30

AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 2.267E+06 /M
ALTITUDE = 247.0 M DYNAMIC PRESSURE = 688.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 PANEL CHARACTERISTICS———————
ALPHA PANEL AEQ (PANEL AXIS SYS.) PANEL CN
0.00 1 0.0000 0.0000
0.00 2 0.0000 0.0000
0.00 3 0.0000 0.0000
1.00 1 0.0000 0.0000
1.00 2 1.2062 0.0430
1.00 3 -1.2062 -0.0430
2.00 1 0.0000 0.0000
2.00 2 2.4023 0.0862
2.00 3 -2.4023 -0.0862
3.00 1 0.0000 0.0000
3.00 2 3.5841 0.1296
3.00 3 -3.5841 -0.1296
4.00 1 0.0000 0.0000
4.00 2 4.7486 0.1726
4.00 3 -4.7486 -0.1726
5.00 1 0.0000 0.0000
5.00 2 5.8800 0.2153
5.00 3 -5.8800 -0.2153
6.00 1 0.0000 0.0000
6.00 2 6.9845 0.2583
6.00 3 -6.9845 -0.2583
7.00 1 0.0000 0.0000
7.00 2 8.0614 0.2981
7.00 3 -8.0614 -0.2981
8.00 1 0.0000 0.0000
8.00 2 9.1100 0.3315
8.00 3 -9.1100 -0.3315
9.00 1 0.0000 0.0000
9.00 2 10.1305 0.3588
9.00 3 -10.1305 -0.3588
10.00 1 0.0000 0.0000
10.00 2 11.1235 0.3809
10.00 3 -11.1235 -0.3809
11.00 1 0.0000 0.0000
11.00 2 12.1764 0.3991
11.00 3 -12.1764 -0.3991
12.00 1 0.0000 0.0000
12.00 2 13.1202 0.4116
12.00 3 -13.1202 -0.4116
13.00 1 0.0000 0.0000
13.00 2 14.0203 0.4236
13.00 3 -14.0203 -0.4236
14.00 1 0.0000 0.0000
14.00 2 14.8958 0.4375
14.00 3 -14.8958 -0.4375
15.00 1 0.0000 0.0000

15.00 2 15.7626 0.4504
15.00 3 -15.7626 -0.4504
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 31
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 2.267E+06 /M
ALTITUDE = 247.0 M DYNAMIC PRESSURE = 688.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
CARRYOVER INTERFERENCE FACTORS - FIN SET 1
ALPHA K-W(B) K-B(W) KK-W(B) KK-B(W) XCP-W(B) XCP-B(W) Y-CP/(B/2)
0.00 1.3959 0.5090 0.9348 0.3583 5.4278 5.4173 0.4058
1.00 1.3927 0.5090 0.9348 0.3583 5.4278 5.4173 0.4072
2.00 1.3870 0.5090 0.9348 0.3583 5.4278 5.4173 0.4086
3.00 1.3797 0.5090 0.9348 0.3583 5.4278 5.4173 0.4100
4.00 1.3712 0.5090 0.9348 0.3583 5.4278 5.4173 0.4113
5.00 1.3618 0.5090 0.9348 0.3583 5.4278 5.4173 0.4123
6.00 1.3517 0.5090 0.9348 0.3583 5.4278 5.4173 0.4126
7.00 1.3410 0.5090 0.9348 0.3583 5.4278 5.4173 0.4129
8.00 1.3299 0.5090 0.9348 0.3583 5.4278 5.4173 0.4132
9.00 1.3185 0.5090 0.9348 0.3583 5.4278 5.4173 0.4134
10.00 1.3069 0.5090 0.9348 0.3583 5.4278 5.4173 0.4135
11.00 1.2951 0.5090 0.9348 0.3583 5.4278 5.4173 0.4136
12.00 1.2833 0.5090 0.9348 0.3583 5.4278 5.4173 0.4140
13.00 1.2714 0.5090 0.9348 0.3583 5.4278 5.4173 0.4143
14.00 1.2596 0.5090 0.9348 0.3583 5.4278 5.4173 0.4147
15.00 1.2480 0.5090 0.9348 0.3583 5.4278 5.4173 0.4151
NOTE - XCP-W(B) USED FOR STABILITY ONLY DIFFERENT VALUES USED FOR HINGE MOMENTS
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 32
FIN SET 1 PANEL BENDING MOMENTS (ABOUT EXPOSED ROOT CHORD)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 2.267E+06 /M
ALTITUDE = 247.0 M DYNAMIC PRESSURE = 688.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 1.68E-02 -1.68E-02
2.0 0.00E+00 3.38E-02 -3.38E-02
3.0 0.00E+00 5.10E-02 -5.10E-02
4.0 0.00E+00 6.82E-02 -6.82E-02
5.0 9.51E-10 8.52E-02 -8.52E-02
6.0 1.66E-09 1.02E-01 -1.02E-01
7.0 0.00E+00 1.18E-01 -1.18E-01
8.0 3.33E-09 1.31E-01 -1.31E-01
9.0 -2.05E-09 1.42E-01 -1.42E-01
10.0 2.50E-09 1.51E-01 -1.51E-01
11.0 0.00E+00 1.59E-01 -1.59E-01
12.0 -6.75E-09 1.64E-01 -1.64E-01
13.0 1.66E-09 1.69E-01 -1.69E-01

14.0 -9.42E-09 1.74E-01 -1.74E-01
15.0 -3.69E-09 1.80E-01 -1.80E-01
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 33
FIN SET 1 PANEL HINGE MOMENTS (ABOUT HINGE LINE)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 2.267E+06 /M
ALTITUDE = 247.0 M DYNAMIC PRESSURE = 688.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 5.15E-03 -5.15E-03
2.0 0.00E+00 1.03E-02 -1.03E-02
3.0 0.00E+00 1.55E-02 -1.55E-02
4.0 0.00E+00 2.07E-02 -2.07E-02
5.0 2.88E-10 2.58E-02 -2.58E-02
6.0 5.01E-10 3.09E-02 -3.09E-02
7.0 0.00E+00 3.57E-02 -3.57E-02
8.0 1.01E-09 3.97E-02 -3.97E-02
9.0 -6.19E-10 4.30E-02 -4.30E-02
10.0 7.55E-10 4.56E-02 -4.56E-02
11.0 0.00E+00 4.78E-02 -4.78E-02
12.0 -2.03E-09 4.93E-02 -4.93E-02
13.0 4.99E-10 5.08E-02 -5.08E-02
14.0 -2.83E-09 5.24E-02 -5.24E-02
15.0 -1.11E-09 5.40E-02 -5.40E-02
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 34
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 2.267E+06 /M
ALTITUDE = 247.0 M DYNAMIC PRESSURE = 688.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
—– LONGITUDINAL —– – LATERAL DIRECTIONAL –
ALPHA CN CM CA CY CLN CLL
0.00 0.000 0.000 0.373 0.000 0.000 0.000
1.00 0.150 -0.355 0.372 0.000 0.000 0.000
2.00 0.308 -0.714 0.370 0.000 0.000 0.000
3.00 0.472 -1.076 0.366 0.000 0.000 0.000
4.00 0.642 -1.435 0.360 0.000 0.000 0.000
5.00 0.817 -1.792 0.353 0.000 0.000 0.000
6.00 0.999 -2.156 0.345 0.000 0.000 0.000
7.00 1.180 -2.482 0.335 0.000 0.000 0.000
8.00 1.352 -2.727 0.326 0.000 0.000 0.000
9.00 1.516 -2.897 0.322 0.000 0.000 0.000
10.00 1.673 -3.003 0.322 0.000 0.000 0.000
11.00 1.826 -3.061 0.328 0.000 0.000 0.000
12.00 1.971 -3.049 0.336 0.000 0.000 0.000
13.00 2.120 -3.032 0.344 0.000 0.000 0.000
14.00 2.279 -3.044 0.351 0.000 0.000 0.000
15.00 2.441 -3.046 0.356 0.000 0.000 0.000

ALPHA CL CD CL/CD X-C.P.
0.00 0.000 0.373 0.000 -2.405
1.00 0.144 0.375 0.384 -2.361
2.00 0.295 0.380 0.775 -2.320
3.00 0.452 0.390 1.159 -2.281
4.00 0.615 0.404 1.522 -2.237
5.00 0.783 0.423 1.851 -2.194
6.00 0.958 0.447 2.142 -2.157
7.00 1.131 0.476 2.375 -2.103
8.00 1.294 0.511 2.531 -2.017
9.00 1.447 0.555 2.608 -1.912
10.00 1.591 0.608 2.619 -1.796
11.00 1.730 0.670 2.582 -1.677
12.00 1.858 0.738 2.517 -1.547
13.00 1.988 0.813 2.447 -1.430
14.00 2.126 0.892 2.384 -1.336
15.00 2.265 0.975 2.323 -1.248
X-C.P. MEAS. FROM MOMENT CENTER IN REF. LENGTHS, NEG. AFT OF MOMENT CENTER
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 35
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 2.267E+06 /M
ALTITUDE = 247.0 M DYNAMIC PRESSURE = 688.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
———- DERIVATIVES (PER DEGREE) ———-
ALPHA CNA CMA CYB CLNB CLLB
0.00 0.1469 -0.3532 -0.1503 0.3550 -0.0001
1.00 0.1538 -0.3568 -0.1517 0.3553 0.0003
2.00 0.1608 -0.3606 -0.1545 0.3566 0.0011
3.00 0.1670 -0.3607 -0.1572 0.3558 0.0017
4.00 0.1724 -0.3577 -0.1598 0.3542 0.0020
5.00 0.1788 -0.3602 -0.1590 0.3346 0.0055
6.00 0.1818 -0.3451 -0.1571 0.3088 0.0075
7.00 0.1765 -0.2853 -0.1514 0.2627 0.0051
8.00 0.1676 -0.2074 -0.1441 0.2082 0.0015
9.00 0.1601 -0.1379 -0.1371 0.1559 -0.0010
10.00 0.1550 -0.0820 -0.1295 0.1009 -0.0026
11.00 0.1491 -0.0227 -0.1338 0.1106 -0.0118
12.00 0.1471 0.0146 -0.1269 0.0606 -0.0094
13.00 0.1541 0.0023 -0.1196 0.0079 -0.0009
14.00 0.1603 -0.0070 -0.1106 -0.0529 0.0076
15.00 0.1631 0.0024 -0.0989 -0.1277 0.0112
PANEL DEFLECTION ANGLES (DEGREES)
SET FIN 1 FIN 2 FIN 3 FIN 4 FIN 5 FIN 6 FIN 7 FIN 8
1 0.00 0.00 0.00
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 36
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 1.965E+06 /M
ALTITUDE = 1810.0 M DYNAMIC PRESSURE = 569.78 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG

REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.2002 0.0110 0.1370 0.0000
1.00 0.2001 0.0110 0.1372 0.0000
2.00 0.1999 0.0110 0.1373 0.0001
3.00 0.1996 0.0110 0.1374 0.0003
4.00 0.1992 0.0110 0.1375 0.0005
5.00 0.1987 0.0109 0.1375 0.0007
6.00 0.1980 0.0109 0.1375 0.0009
7.00 0.1972 0.0108 0.1374 0.0012
8.00 0.1963 0.0108 0.1373 0.0013
9.00 0.1953 0.0107 0.1371 0.0014
10.00 0.1941 0.0107 0.1369 0.0013
11.00 0.1929 0.0106 0.1367 0.0010
12.00 0.1915 0.0105 0.1364 0.0004
13.00 0.1901 0.0105 0.1361 -0.0006
14.00 0.1885 0.0104 0.1357 -0.0020
15.00 0.1868 0.0103 0.1353 -0.0040
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.741
2.00 0.091 0.012 0.391 0.002 0.742
3.00 0.137 0.028 0.586 0.005 0.743
4.00 0.182 0.050 0.780 0.009 0.744
5.00 0.227 0.078 0.973 0.015 0.745
6.00 0.272 0.112 1.164 0.021 0.746
7.00 0.316 0.152 1.354 0.029 0.747
8.00 0.360 0.199 1.542 0.038 0.749
9.00 0.403 0.251 1.727 0.048 0.750
10.00 0.446 0.310 1.910 0.059 0.751
11.00 0.488 0.375 2.091 0.072 0.752
12.00 0.529 0.446 2.268 0.085 0.753
13.00 0.570 0.523 2.442 0.100 0.754
14.00 0.609 0.606 2.612 0.116 0.755
15.00 0.648 0.694 2.779 0.133 0.756
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 37
FIN SET 1 CA PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 1.965E+06 /M
ALTITUDE = 1810.0 M DYNAMIC PRESSURE = 569.78 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
SINGLE FIN PANEL ZERO-LIFT AXIAL FORCE COMPONENTS
SKIN FRICTION 0.0083
SUBSONIC PRESSURE 0.0020
TRANSONIC WAVE 0.0000
SUPERSONIC WAVE 0.0000
LEADING EDGE 0.0000
TRAILING EDGE 0.0000
TOTAL CAO 0.0102
FIN AXIAL FORCE DUE TO ANGLE OF ATTACK

ALPHA CA DUE TO LIFT (SINGLE PANEL) CA-TOTAL (3 FINS)
0.00 0.0000 0.0307
1.00 -0.0003 0.0303
2.00 -0.0011 0.0290
3.00 -0.0024 0.0269
4.00 -0.0043 0.0241
5.00 -0.0067 0.0204
6.00 -0.0097 0.0159
7.00 -0.0132 0.0106
8.00 -0.0173 0.0044
9.00 -0.0210 -0.0026
10.00 -0.0229 -0.0093
11.00 -0.0223 -0.0138
12.00 -0.0193 -0.0152
13.00 -0.0142 -0.0131
14.00 -0.0080 -0.0075
15.00 -0.0025 0.0012
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 38
FIN SET 1 CN, CM PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 1.965E+06 /M
ALTITUDE = 1810.0 M DYNAMIC PRESSURE = 569.78 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
NORMAL FORCE SLOPE AT ALPHA ZERO, CNA = 0.03525/DEG (1 PANEL)
CENTER OF PRESSURE FOR LINEAR CN = -5.42784 (CALIBERS FROM C.G.)
CENTER OF PRESSURE FOR NON-LINEAR CN = -5.56657 (CALIBERS FROM C.G.)
ALPHA CN CN CN CM CM CM
LINEAR NON-LINEAR TOTAL LINEAR NON-LINEAR TOTAL
0.00 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1.00 0.0529 0.0004 0.0533 -0.2869 -0.0023 -0.2893
2.00 0.1057 0.0017 0.1074 -0.5737 -0.0093 -0.5829
3.00 0.1584 0.0037 0.1622 -0.8599 -0.0208 -0.8808
4.00 0.2111 0.0067 0.2177 -1.1456 -0.0370 -1.1826
5.00 0.2635 0.0104 0.2739 -1.4303 -0.0578 -1.4881
6.00 0.3158 0.0149 0.3307 -1.7140 -0.0832 -1.7972
7.00 0.3678 0.0203 0.3881 -1.9963 -0.1132 -2.1095
8.00 0.4195 0.0265 0.4460 -2.2771 -0.1477 -2.4248
9.00 0.4709 0.0335 0.5045 -2.5561 -0.1867 -2.7428
10.00 0.5220 0.0349 0.5569 -2.8332 -0.1944 -3.0276
11.00 0.5726 0.0264 0.5990 -3.1080 -0.1468 -3.2548
12.00 0.6228 0.0124 0.6352 -3.3804 -0.0690 -3.4495
13.00 0.6725 -0.0078 0.6647 -3.6501 0.0435 -3.6066
14.00 0.7216 -0.0351 0.6865 -3.9169 0.1956 -3.7213
15.00 0.7702 -0.0704 0.6998 -4.1806 0.3920 -3.7886
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 39
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 1.965E+06 /M
ALTITUDE = 1810.0 M DYNAMIC PRESSURE = 569.78 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M

REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
————FIN SET 1 IN PRESENCE OF THE BODY————-
ALPHA CN CM CA CY CLN CLL
0.00 0.0000 0.0000 0.0307 0.0000 0.0000 0.0000
1.00 0.0744 -0.4039 0.0300 0.0000 0.0000 0.0000
2.00 0.1493 -0.8103 0.0276 0.0000 0.0000 0.0000
3.00 0.2245 -1.2186 0.0238 0.0000 0.0000 0.0000
4.00 0.2990 -1.6229 0.0186 0.0000 0.0000 0.0000
5.00 0.3728 -2.0237 0.0121 0.0000 0.0000 0.0000
6.00 0.4473 -2.4281 0.0044 0.0000 0.0000 0.0000
7.00 0.5163 -2.8025 -0.0044 0.0000 0.0000 0.0000
8.00 0.5740 -3.1155 -0.0119 0.0000 0.0000 0.0000
9.00 0.6212 -3.3716 -0.0151 0.0000 0.0000 0.0000
10.00 0.6593 -3.5788 -0.0134 0.0000 0.0000 0.0000
11.00 0.6909 -3.7500 -0.0063 0.0000 0.0000 0.0000
12.00 0.7127 -3.8683 0.0038 0.0000 0.0000 0.0000
13.00 0.7336 -3.9816 0.0150 0.0000 0.0000 0.0000
14.00 0.7575 -4.1115 0.0247 0.0000 0.0000 0.0000
15.00 0.7797 -4.2320 0.0333 0.0000 0.0000 0.0000
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 40
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 1.965E+06 /M
ALTITUDE = 1810.0 M DYNAMIC PRESSURE = 569.78 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
————FIN SET 1 PANEL CHARACTERISTICS————
ALPHA PANEL AEQ (PANEL AXIS SYS.) PANEL CN
0.00 1 0.0000 0.0000
0.00 2 0.0000 0.0000
0.00 3 0.0000 0.0000
1.00 1 0.0000 0.0000
1.00 2 1.2062 0.0430
1.00 3 -1.2062 -0.0430
2.00 1 0.0000 0.0000
2.00 2 2.4023 0.0862
2.00 3 -2.4023 -0.0862
3.00 1 0.0000 0.0000
3.00 2 3.5841 0.1296
3.00 3 -3.5841 -0.1296
4.00 1 0.0000 0.0000
4.00 2 4.7486 0.1726
4.00 3 -4.7486 -0.1726
5.00 1 0.0000 0.0000
5.00 2 5.8800 0.2153
5.00 3 -5.8800 -0.2153
6.00 1 0.0000 0.0000
6.00 2 6.9845 0.2583
6.00 3 -6.9845 -0.2583
7.00 1 0.0000 0.0000
7.00 2 8.0614 0.2981
7.00 3 -8.0614 -0.2981
8.00 1 0.0000 0.0000

8.00 2 9.1100 0.3314
8.00 3 -9.1100 -0.3314
9.00 1 0.0000 0.0000
9.00 2 10.1305 0.3586
9.00 3 -10.1305 -0.3586
10.00 1 0.0000 0.0000
10.00 2 11.1235 0.3807
10.00 3 -11.1235 -0.3807
11.00 1 0.0000 0.0000
11.00 2 12.1764 0.3989
11.00 3 -12.1764 -0.3989
12.00 1 0.0000 0.0000
12.00 2 13.1202 0.4115
12.00 3 -13.1202 -0.4115
13.00 1 0.0000 0.0000
13.00 2 14.0203 0.4235
13.00 3 -14.0203 -0.4235
14.00 1 0.0000 0.0000
14.00 2 14.8958 0.4373
14.00 3 -14.8958 -0.4373
15.00 1 0.0000 0.0000
15.00 2 15.7626 0.4501
15.00 3 -15.7626 -0.4501
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 41
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 1.965E+06 /M
ALTITUDE = 1810.0 M DYNAMIC PRESSURE = 569.78 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
CARRYOVER INTERFERENCE FACTORS - FIN SET 1
ALPHA K-W(B) K-B(W) KK-W(B) KK-B(W) XCP-W(B) XCP-B(W) Y-CP/(B/2)
0.00 1.3959 0.5090 0.9348 0.3583 5.4278 5.4173 0.4058
1.00 1.3927 0.5090 0.9348 0.3583 5.4278 5.4173 0.4072
2.00 1.3870 0.5090 0.9348 0.3583 5.4278 5.4173 0.4086
3.00 1.3797 0.5090 0.9348 0.3583 5.4278 5.4173 0.4100
4.00 1.3712 0.5090 0.9348 0.3583 5.4278 5.4173 0.4113
5.00 1.3618 0.5090 0.9348 0.3583 5.4278 5.4173 0.4123
6.00 1.3517 0.5090 0.9348 0.3583 5.4278 5.4173 0.4126
7.00 1.3410 0.5090 0.9348 0.3583 5.4278 5.4173 0.4129
8.00 1.3299 0.5090 0.9348 0.3583 5.4278 5.4173 0.4132
9.00 1.3185 0.5090 0.9348 0.3583 5.4278 5.4173 0.4134
10.00 1.3069 0.5090 0.9348 0.3583 5.4278 5.4173 0.4135
11.00 1.2951 0.5090 0.9348 0.3583 5.4278 5.4173 0.4136
12.00 1.2833 0.5090 0.9348 0.3583 5.4278 5.4173 0.4140
13.00 1.2714 0.5090 0.9348 0.3583 5.4278 5.4173 0.4143
14.00 1.2596 0.5090 0.9348 0.3583 5.4278 5.4173 0.4147
15.00 1.2480 0.5090 0.9348 0.3583 5.4278 5.4173 0.4151
NOTE - XCP-W(B) USED FOR STABILITY ONLY DIFFERENT VALUES USED FOR HINGE MOMENTS
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 42
FIN SET 1 PANEL BENDING MOMENTS (ABOUT EXPOSED ROOT CHORD)

******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 1.965E+06 /M
ALTITUDE = 1810.0 M DYNAMIC PRESSURE = 569.78 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 1.68E-02 -1.68E-02
2.0 0.00E+00 3.38E-02 -3.38E-02
3.0 0.00E+00 5.10E-02 -5.10E-02
4.0 0.00E+00 6.82E-02 -6.82E-02
5.0 9.51E-10 8.52E-02 -8.52E-02
6.0 1.66E-09 1.02E-01 -1.02E-01
7.0 0.00E+00 1.18E-01 -1.18E-01
8.0 3.33E-09 1.31E-01 -1.31E-01
9.0 -2.05E-09 1.42E-01 -1.42E-01
10.0 2.50E-09 1.51E-01 -1.51E-01
11.0 0.00E+00 1.58E-01 -1.58E-01
12.0 -6.75E-09 1.64E-01 -1.64E-01
13.0 1.66E-09 1.68E-01 -1.68E-01
14.0 -9.41E-09 1.74E-01 -1.74E-01
15.0 -3.69E-09 1.79E-01 -1.79E-01
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 43
FIN SET 1 PANEL HINGE MOMENTS (ABOUT HINGE LINE)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 1.965E+06 /M
ALTITUDE = 1810.0 M DYNAMIC PRESSURE = 569.78 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 5.15E-03 -5.15E-03
2.0 0.00E+00 1.03E-02 -1.03E-02
3.0 0.00E+00 1.55E-02 -1.55E-02
4.0 0.00E+00 2.07E-02 -2.07E-02
5.0 2.88E-10 2.58E-02 -2.58E-02
6.0 5.01E-10 3.09E-02 -3.09E-02
7.0 0.00E+00 3.57E-02 -3.57E-02
8.0 1.01E-09 3.97E-02 -3.97E-02
9.0 -6.19E-10 4.30E-02 -4.30E-02
10.0 7.55E-10 4.56E-02 -4.56E-02
11.0 0.00E+00 4.78E-02 -4.78E-02
12.0 -2.03E-09 4.93E-02 -4.93E-02
13.0 4.99E-10 5.07E-02 -5.07E-02
14.0 -2.83E-09 5.24E-02 -5.24E-02
15.0 -1.11E-09 5.39E-02 -5.39E-02
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 44
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 1.965E+06 /M
ALTITUDE = 1810.0 M DYNAMIC PRESSURE = 569.78 N/M**2

SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
—– LONGITUDINAL —– – LATERAL DIRECTIONAL –

ALPHA	CN	CM	CA	CY	CLN	CLL
0.00	0.000	0.000	0.379	0.000	0.000	0.000
1.00	0.150	-0.355	0.378	0.000	0.000	0.000
2.00	0.308	-0.714	0.376	0.000	0.000	0.000
3.00	0.472	-1.076	0.372	0.000	0.000	0.000
4.00	0.642	-1.435	0.367	0.000	0.000	0.000
5.00	0.817	-1.791	0.360	0.000	0.000	0.000
6.00	0.999	-2.155	0.352	0.000	0.000	0.000
7.00	1.180	-2.481	0.342	0.000	0.000	0.000
8.00	1.352	-2.726	0.334	0.000	0.000	0.000
9.00	1.515	-2.895	0.329	0.000	0.000	0.000
10.00	1.672	-3.000	0.330	0.000	0.000	0.000
11.00	1.825	-3.059	0.335	0.000	0.000	0.000
12.00	1.970	-3.047	0.343	0.000	0.000	0.000
13.00	2.120	-3.031	0.351	0.000	0.000	0.000
14.00	2.279	-3.042	0.357	0.000	0.000	0.000
15.00	2.440	-3.043	0.362	0.000	0.000	0.000

ALPHA	CL	CD	CL/CD	X-C.P.
0.00	0.000	0.379	0.000	-2.405
1.00	0.144	0.381	0.377	-2.361
2.00	0.294	0.387	0.762	-2.320
3.00	0.452	0.396	1.140	-2.280
4.00	0.614	0.411	1.496	-2.237
5.00	0.782	0.430	1.821	-2.193
6.00	0.957	0.454	2.107	-2.157
7.00	1.130	0.483	2.337	-2.102
8.00	1.292	0.519	2.492	-2.016
9.00	1.445	0.562	2.570	-1.911
10.00	1.589	0.615	2.585	-1.795
11.00	1.728	0.677	2.552	-1.676
12.00	1.856	0.745	2.492	-1.546
13.00	1.986	0.819	2.426	-1.430
14.00	2.124	0.898	2.366	-1.335
15.00	2.263	0.981	2.308	-1.247

X-C.P. MEAS. FROM MOMENT CENTER IN REF. LENGTHS, NEG. AFT OF MOMENT CENTER
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 45
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 1.965E+06 /M
ALTITUDE = 1810.0 M DYNAMIC PRESSURE = 569.78 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
———- DERIVATIVES (PER DEGREE) ———-

ALPHA	CNA	CMA	CYB	CLNB	CLLB
0.00	0.1469	-0.3532	-0.1503	0.3550	-0.0001
1.00	0.1538	-0.3568	-0.1517	0.3553	0.0003
2.00	0.1608	-0.3605	-0.1545	0.3565	0.0011
3.00	0.1669	-0.3606	-0.1572	0.3557	0.0017
4.00	0.1724	-0.3576	-0.1598	0.3541	0.0020

5.00 0.1788 -0.3602 -0.1590 0.3345 0.0055
6.00 0.1818 -0.3449 -0.1571 0.3087 0.0075
7.00 0.1764 -0.2850 -0.1514 0.2626 0.0051
8.00 0.1675 -0.2068 -0.1440 0.2080 0.0014
9.00 0.1600 -0.1371 -0.1370 0.1556 -0.0010
10.00 0.1550 -0.0816 -0.1295 0.1007 -0.0026
11.00 0.1492 -0.0230 -0.1338 0.1107 -0.0117
12.00 0.1473 0.0140 -0.1270 0.0608 -0.0093
13.00 0.1541 0.0026 -0.1195 0.0078 -0.0009
14.00 0.1602 -0.0060 -0.1105 -0.0533 0.0075
15.00 0.1629 0.0034 -0.0989 -0.1279 0.0112
PANEL DEFLECTION ANGLES (DEGREES)
SET FIN 1 FIN 2 FIN 3 FIN 4 FIN 5 FIN 6 FIN 7 FIN 8
1 0.00 0.00 0.00
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 46
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 4.525E+06 /M
ALTITUDE = 272.2 M DYNAMIC PRESSURE = 2746.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1737 0.0097 0.1370 0.0000
1.00 0.1737 0.0097 0.1372 0.0000
2.00 0.1735 0.0097 0.1373 0.0001
3.00 0.1732 0.0097 0.1374 0.0002
4.00 0.1729 0.0097 0.1375 0.0004
5.00 0.1724 0.0096 0.1375 0.0006
6.00 0.1718 0.0096 0.1374 0.0008
7.00 0.1711 0.0096 0.1373 0.0010
8.00 0.1703 0.0095 0.1372 0.0010
9.00 0.1695 0.0095 0.1371 0.0010
10.00 0.1685 0.0094 0.1369 0.0009
11.00 0.1674 0.0093 0.1366 0.0004
12.00 0.1662 0.0093 0.1363 -0.0003
13.00 0.1649 0.0092 0.1360 -0.0014
14.00 0.1635 0.0091 0.1356 -0.0030
15.00 0.1621 0.0091 0.1352 -0.0051
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.742
2.00 0.091 0.012 0.391 0.002 0.744
3.00 0.137 0.028 0.586 0.005 0.746
4.00 0.182 0.050 0.780 0.010 0.749
5.00 0.227 0.078 0.973 0.015 0.751
6.00 0.272 0.113 1.164 0.022 0.753
7.00 0.316 0.154 1.354 0.029 0.755
8.00 0.360 0.201 1.542 0.038 0.757
9.00 0.403 0.255 1.727 0.049 0.759
10.00 0.446 0.315 1.910 0.060 0.761
11.00 0.488 0.381 2.091 0.073 0.763
12.00 0.529 0.454 2.268 0.087 0.765

13.00 0.570 0.532 2.442 0.102 0.768
14.00 0.609 0.617 2.612 0.118 0.770
15.00 0.648 0.709 2.779 0.135 0.772
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 47
FIN SET 1 CA PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 4.525E+06 /M
ALTITUDE = 272.2 M DYNAMIC PRESSURE = 2746.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
SINGLE FIN PANEL ZERO-LIFT AXIAL FORCE COMPONENTS
SKIN FRICTION 0.0069
SUBSONIC PRESSURE 0.0017
TRANSONIC WAVE 0.0000
SUPERSONIC WAVE 0.0000
LEADING EDGE 0.0000
TRAILING EDGE 0.0000
TOTAL CAO 0.0085
FIN AXIAL FORCE DUE TO ANGLE OF ATTACK
ALPHA CA DUE TO LIFT (SINGLE PANEL) CA-TOTAL (3 FINS)
0.00 0.0000 0.0256
1.00 -0.0003 0.0250
2.00 -0.0012 0.0236
3.00 -0.0028 0.0212
4.00 -0.0050 0.0178
5.00 -0.0079 0.0135
6.00 -0.0114 0.0083
7.00 -0.0155 0.0021
8.00 -0.0203 -0.0051
9.00 -0.0247 -0.0134
10.00 -0.0266 -0.0212
11.00 -0.0258 -0.0263
12.00 -0.0221 -0.0276
13.00 -0.0161 -0.0247
14.00 -0.0090 -0.0178
15.00 -0.0027 -0.0075
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 48
FIN SET 1 CN, CM PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 4.525E+06 /M
ALTITUDE = 272.2 M DYNAMIC PRESSURE = 2746.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
NORMAL FORCE SLOPE AT ALPHA ZERO, CNA = 0.03558/DEG (1 PANEL)
CENTER OF PRESSURE FOR LINEAR CN = -5.42774 (CALIBERS FROM C.G.)
CENTER OF PRESSURE FOR NON-LINEAR CN = -5.56657 (CALIBERS FROM C.G.)
ALPHA CN CN CN CM CM CM
LINEAR NON-LINEAR TOTAL LINEAR NON-LINEAR TOTAL
0.00 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1.00 0.0534 0.0003 0.0537 -0.2896 -0.0019 -0.2916
2.00 0.1067 0.0014 0.1081 -0.5791 -0.0077 -0.5867

3.00 0.1599 0.0031 0.1630 -0.8680 -0.0173 -0.8853
4.00 0.2130 0.0055 0.2186 -1.1563 -0.0308 -1.1871
5.00 0.2660 0.0086 0.2746 -1.4438 -0.0480 -1.4918
6.00 0.3187 0.0124 0.3312 -1.7301 -0.0691 -1.7992
7.00 0.3713 0.0169 0.3881 -2.0151 -0.0940 -2.1091
8.00 0.4235 0.0220 0.4455 -2.2985 -0.1226 -2.4212
9.00 0.4754 0.0279 0.5032 -2.5802 -0.1550 -2.7352
10.00 0.5269 0.0222 0.5491 -2.8598 -0.1238 -2.9836
11.00 0.5780 0.0103 0.5883 -3.1372 -0.0576 -3.1948
12.00 0.6287 -0.0075 0.6212 -3.4122 0.0417 -3.3705
13.00 0.6788 -0.0321 0.6467 -3.6845 0.1788 -3.5057
14.00 0.7284 -0.0644 0.6640 -3.9538 0.3586 -3.5951
15.00 0.7775 -0.1040 0.6734 -4.2199 0.5791 -3.6409
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 49
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 4.525E+06 /M
ALTITUDE = 272.2 M DYNAMIC PRESSURE = 2746.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 IN PRESENCE OF THE BODY——————-
ALPHA CN CM CA CY CLN CLL
0.00 0.0000 0.0000 0.0256 0.0000 0.0000 0.0000
1.00 0.0750 -0.4069 0.0247 0.0000 0.0000 0.0000
2.00 0.1502 -0.8152 0.0220 0.0000 0.0000 0.0000
3.00 0.2255 -1.2240 0.0175 0.0000 0.0000 0.0000
4.00 0.2999 -1.6278 0.0114 0.0000 0.0000 0.0000
5.00 0.3734 -2.0267 0.0037 0.0000 0.0000 0.0000
6.00 0.4472 -2.4272 -0.0053 0.0000 0.0000 0.0000
7.00 0.5144 -2.7923 -0.0156 0.0000 0.0000 0.0000
8.00 0.5687 -3.0868 -0.0244 0.0000 0.0000 0.0000
9.00 0.6103 -3.3125 -0.0278 0.0000 0.0000 0.0000
10.00 0.6422 -3.4859 -0.0254 0.0000 0.0000 0.0000
11.00 0.6738 -3.6573 -0.0167 0.0000 0.0000 0.0000
12.00 0.7033 -3.8175 -0.0049 0.0000 0.0000 0.0000
13.00 0.7285 -3.9541 0.0079 0.0000 0.0000 0.0000
14.00 0.7470 -4.0547 0.0189 0.0000 0.0000 0.0000
15.00 0.7626 -4.1394 0.0284 0.0000 0.0000 0.0000
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 50
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 4.525E+06 /M
ALTITUDE = 272.2 M DYNAMIC PRESSURE = 2746.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 PANEL CHARACTERISTICS——————
ALPHA PANEL AEQ (PANEL AXIS SYS.) PANEL CN
0.00 1 0.0000 0.0000
0.00 2 0.0000 0.0000
0.00 3 0.0000 0.0000
1.00 1 0.0000 0.0000

1.00 2 1.2062 0.0433
1.00 3 -1.2062 -0.0433
2.00 1 0.0000 0.0000
2.00 2 2.4023 0.0867
2.00 3 -2.4023 -0.0867
3.00 1 0.0000 0.0000
3.00 2 3.5841 0.1302
3.00 3 -3.5841 -0.1302
4.00 1 0.0000 0.0000
4.00 2 4.7486 0.1731
4.00 3 -4.7486 -0.1731
5.00 1 0.0000 0.0000
5.00 2 5.8799 0.2156
5.00 3 -5.8799 -0.2156
6.00 1 0.0000 0.0000
6.00 2 6.9842 0.2582
6.00 3 -6.9842 -0.2582
7.00 1 0.0000 0.0000
7.00 2 8.0609 0.2970
7.00 3 -8.0609 -0.2970
8.00 1 0.0000 0.0000
8.00 2 9.1089 0.3283
8.00 3 -9.1089 -0.3283
9.00 1 0.0000 0.0000
9.00 2 10.1289 0.3524
9.00 3 -10.1289 -0.3524
10.00 1 0.0000 0.0000
10.00 2 11.1211 0.3708
10.00 3 -11.1211 -0.3708
11.00 1 0.0000 0.0000
11.00 2 12.1764 0.3890
11.00 3 -12.1764 -0.3890
12.00 1 0.0000 0.0000
12.00 2 13.1202 0.4061
12.00 3 -13.1202 -0.4061
13.00 1 0.0000 0.0000
13.00 2 14.0203 0.4206
13.00 3 -14.0203 -0.4206
14.00 1 0.0000 0.0000
14.00 2 14.8958 0.4313
14.00 3 -14.8958 -0.4313
15.00 1 0.0000 0.0000
15.00 2 15.7626 0.4403
15.00 3 -15.7626 -0.4403
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 51
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 4.525E+06 /M
ALTITUDE = 272.2 M DYNAMIC PRESSURE = 2746.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
CARRYOVER INTERFERENCE FACTORS - FIN SET 1
ALPHA K-W(B) K-B(W) KK-W(B) KK-B(W) XCP-W(B) XCP-B(W) Y-CP/(B/2)

0.00 1.3959 0.5090 0.9348 0.3583 5.4277 5.4173 0.4120
1.00 1.3927 0.5090 0.9348 0.3583 5.4277 5.4173 0.4131
2.00 1.3870 0.5090 0.9348 0.3583 5.4277 5.4173 0.4142
3.00 1.3797 0.5090 0.9348 0.3583 5.4277 5.4173 0.4153
4.00 1.3712 0.5090 0.9348 0.3583 5.4277 5.4173 0.4164
5.00 1.3618 0.5090 0.9348 0.3583 5.4277 5.4173 0.4170
6.00 1.3517 0.5090 0.9348 0.3583 5.4277 5.4173 0.4171
7.00 1.3410 0.5090 0.9348 0.3583 5.4277 5.4173 0.4171
8.00 1.3299 0.5090 0.9348 0.3583 5.4277 5.4173 0.4171
9.00 1.3185 0.5090 0.9348 0.3583 5.4277 5.4173 0.4171
10.00 1.3069 0.5090 0.9348 0.3583 5.4277 5.4173 0.4171
11.00 1.2951 0.5090 0.9348 0.3583 5.4277 5.4173 0.4171
12.00 1.2833 0.5090 0.9348 0.3583 5.4277 5.4173 0.4172
13.00 1.2714 0.5090 0.9348 0.3583 5.4277 5.4173 0.4174
14.00 1.2596 0.5090 0.9348 0.3583 5.4277 5.4173 0.4176
15.00 1.2480 0.5090 0.9348 0.3583 5.4277 5.4173 0.4178
NOTE - XCP-W(B) USED FOR STABILITY ONLY DIFFERENT VALUES USED FOR HINGE MOMENTS
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 52
FIN SET 1 PANEL BENDING MOMENTS (ABOUT EXPOSED ROOT CHORD)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 4.525E+06 /M
ALTITUDE = 272.2 M DYNAMIC PRESSURE = 2746.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 1.72E-02 -1.72E-02
2.0 0.00E+00 3.45E-02 -3.45E-02
3.0 0.00E+00 5.19E-02 -5.19E-02
4.0 0.00E+00 6.92E-02 -6.92E-02
5.0 9.76E-10 8.63E-02 -8.63E-02
6.0 1.70E-09 1.03E-01 -1.03E-01
7.0 0.00E+00 1.19E-01 -1.19E-01
8.0 3.42E-09 1.31E-01 -1.31E-01
9.0 -2.11E-09 1.41E-01 -1.41E-01
10.0 2.58E-09 1.49E-01 -1.49E-01
11.0 0.00E+00 1.56E-01 -1.56E-01
12.0 -6.86E-09 1.63E-01 -1.63E-01
13.0 1.68E-09 1.69E-01 -1.69E-01
14.0 -9.55E-09 1.73E-01 -1.73E-01
15.0 -3.75E-09 1.77E-01 -1.77E-01
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 53
FIN SET 1 PANEL HINGE MOMENTS (ABOUT HINGE LINE)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 4.525E+06 /M
ALTITUDE = 272.2 M DYNAMIC PRESSURE = 2746.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00

1.0 0.00E+00 5.19E-03 -5.19E-03
2.0 0.00E+00 1.04E-02 -1.04E-02
3.0 0.00E+00 1.56E-02 -1.56E-02
4.0 0.00E+00 2.08E-02 -2.08E-02
5.0 2.92E-10 2.59E-02 -2.59E-02
6.0 5.10E-10 3.10E-02 -3.10E-02
7.0 0.00E+00 3.56E-02 -3.56E-02
8.0 1.03E-09 3.94E-02 -3.94E-02
9.0 -6.33E-10 4.23E-02 -4.23E-02
10.0 7.72E-10 4.45E-02 -4.45E-02
11.0 0.00E+00 4.66E-02 -4.66E-02
12.0 -2.05E-09 4.87E-02 -4.87E-02
13.0 5.03E-10 5.04E-02 -5.04E-02
14.0 -2.86E-09 5.17E-02 -5.17E-02
15.0 -1.12E-09 5.28E-02 -5.28E-02
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 54
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 4.525E+06 /M
ALTITUDE = 272.2 M DYNAMIC PRESSURE = 2746.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
—– LONGITUDINAL —– – LATERAL DIRECTIONAL –
ALPHA CN CM CA CY CLN CLL
0.00 0.000 0.000 0.346 0.000 0.000 0.000
1.00 0.151 -0.359 0.345 0.000 0.000 0.000
2.00 0.309 -0.720 0.343 0.000 0.000 0.000
3.00 0.473 -1.084 0.338 0.000 0.000 0.000
4.00 0.643 -1.442 0.332 0.000 0.000 0.000
5.00 0.818 -1.795 0.324 0.000 0.000 0.000
6.00 1.000 -2.154 0.314 0.000 0.000 0.000
7.00 1.179 -2.467 0.303 0.000 0.000 0.000
8.00 1.347 -2.686 0.294 0.000 0.000 0.000
9.00 1.503 -2.813 0.289 0.000 0.000 0.000
10.00 1.653 -2.871 0.290 0.000 0.000 0.000
11.00 1.807 -2.929 0.297 0.000 0.000 0.000
12.00 1.965 -2.974 0.307 0.000 0.000 0.000
13.00 2.122 -2.990 0.317 0.000 0.000 0.000
14.00 2.276 -2.960 0.324 0.000 0.000 0.000
15.00 2.431 -2.910 0.330 0.000 0.000 0.000
ALPHA CL CD CL/CD X-C.P.
0.00 0.000 0.346 0.000 -2.423
1.00 0.145 0.348 0.417 -2.376
2.00 0.297 0.353 0.840 -2.332
3.00 0.455 0.362 1.256 -2.289
4.00 0.618 0.376 1.645 -2.242
5.00 0.787 0.394 1.997 -2.195
6.00 0.962 0.417 2.305 -2.154
7.00 1.133 0.445 2.548 -2.092
8.00 1.293 0.478 2.703 -1.994
9.00 1.440 0.521 2.764 -1.871
10.00 1.577 0.573 2.753 -1.737
11.00 1.717 0.636 2.699 -1.620

12.00 1.858 0.708 2.623 -1.514
13.00 1.997 0.786 2.540 -1.409
14.00 2.130 0.865 2.462 -1.300
15.00 2.263 0.947 2.388 -1.197
X-C.P. MEAS. FROM MOMENT CENTER IN REF. LENGTHS, NEG. AFT OF MOMENT CENTER
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 55
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 4.525E+06 /M
ALTITUDE = 272.2 M DYNAMIC PRESSURE = 2746.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
———- DERIVATIVES (PER DEGREE) ———-
ALPHA CNA CMA CYB CLNB CLLB
0.00 0.1477 -0.3580 -0.1511 0.3590 -0.0001
1.00 0.1545 -0.3602 -0.1524 0.3592 0.0002
2.00 0.1611 -0.3622 -0.1551 0.3598 0.0009
3.00 0.1670 -0.3605 -0.1577 0.3583 0.0013
4.00 0.1723 -0.3558 -0.1602 0.3562 0.0015
5.00 0.1784 -0.3561 -0.1593 0.3356 0.0048
6.00 0.1806 -0.3357 -0.1571 0.3078 0.0064
7.00 0.1735 -0.2655 -0.1507 0.2576 0.0032
8.00 0.1621 -0.1727 -0.1423 0.1972 -0.0016
9.00 0.1528 -0.0922 -0.1343 0.1389 -0.0053
10.00 0.1519 -0.0578 -0.1278 0.0892 -0.0053
11.00 0.1561 -0.0519 -0.1370 0.1252 -0.0091
12.00 0.1575 -0.0309 -0.1315 0.0820 -0.0050
13.00 0.1554 0.0074 -0.1201 0.0068 -0.0016
14.00 0.1542 0.0403 -0.1078 -0.0727 0.0026
15.00 0.1555 0.0594 -0.0984 -0.1361 0.0092
PANEL DEFLECTION ANGLES (DEGREES)
SET FIN 1 FIN 2 FIN 3 FIN 4 FIN 5 FIN 6 FIN 7 FIN 8
1 0.00 0.00 0.00
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 56
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 3.992E+06 /M
ALTITUDE = 1639.5 M DYNAMIC PRESSURE = 2327.55 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1773 0.0099 0.1370 0.0000
1.00 0.1773 0.0099 0.1372 0.0000
2.00 0.1771 0.0099 0.1373 0.0001
3.00 0.1768 0.0099 0.1374 0.0002
4.00 0.1764 0.0099 0.1375 0.0004
5.00 0.1760 0.0098 0.1375 0.0006
6.00 0.1754 0.0098 0.1374 0.0008
7.00 0.1747 0.0098 0.1373 0.0010
8.00 0.1739 0.0097 0.1372 0.0011
9.00 0.1730 0.0097 0.1371 0.0011

10.00 0.1720 0.0096 0.1369 0.0009
11.00 0.1709 0.0095 0.1366 0.0005
12.00 0.1696 0.0095 0.1363 -0.0002
13.00 0.1683 0.0094 0.1360 -0.0013
14.00 0.1669 0.0093 0.1356 -0.0029
15.00 0.1654 0.0092 0.1352 -0.0050
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.742
2.00 0.091 0.012 0.391 0.002 0.744
3.00 0.137 0.028 0.586 0.005 0.746
4.00 0.182 0.050 0.780 0.010 0.749
5.00 0.227 0.078 0.973 0.015 0.751
6.00 0.272 0.113 1.164 0.022 0.753
7.00 0.316 0.154 1.354 0.029 0.755
8.00 0.360 0.201 1.542 0.038 0.757
9.00 0.403 0.255 1.727 0.049 0.759
10.00 0.446 0.315 1.910 0.060 0.761
11.00 0.488 0.381 2.091 0.073 0.763
12.00 0.529 0.454 2.268 0.087 0.765
13.00 0.570 0.532 2.442 0.102 0.768
14.00 0.609 0.617 2.612 0.118 0.770
15.00 0.648 0.709 2.779 0.135 0.772
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 57
FIN SET 1 CA PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 3.992E+06 /M
ALTITUDE = 1639.5 M DYNAMIC PRESSURE = 2327.55 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
SINGLE FIN PANEL ZERO-LIFT AXIAL FORCE COMPONENTS
SKIN FRICTION 0.0071
SUBSONIC PRESSURE 0.0017
TRANSONIC WAVE 0.0000
SUPERSONIC WAVE 0.0000
LEADING EDGE 0.0000
TRAILING EDGE 0.0000
TOTAL CAO 0.0088
FIN AXIAL FORCE DUE TO ANGLE OF ATTACK
ALPHA CA DUE TO LIFT (SINGLE PANEL) CA-TOTAL (3 FINS)
0.00 0.0000 0.0263
1.00 -0.0003 0.0257
2.00 -0.0012 0.0243
3.00 -0.0028 0.0219
4.00 -0.0049 0.0186
5.00 -0.0077 0.0144
6.00 -0.0112 0.0093
7.00 -0.0153 0.0032
8.00 -0.0200 -0.0039
9.00 -0.0242 -0.0121
10.00 -0.0262 -0.0197
11.00 -0.0254 -0.0247

12.00 -0.0217 -0.0260
13.00 -0.0158 -0.0232
14.00 -0.0088 -0.0165
15.00 -0.0027 -0.0064
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 58
FIN SET 1 CN, CM PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 3.992E+06 /M
ALTITUDE = 1639.5 M DYNAMIC PRESSURE = 2327.55 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
NORMAL FORCE SLOPE AT ALPHA ZERO, CNA = 0.03558/DEG (1 PANEL)
CENTER OF PRESSURE FOR LINEAR CN = -5.42774 (CALIBERS FROM C.G.)
CENTER OF PRESSURE FOR NON-LINEAR CN = -5.56657 (CALIBERS FROM C.G.)
ALPHA CN CN CN CM CM CM
LINEAR NON-LINEAR TOTAL LINEAR NON-LINEAR TOTAL
0.00 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1.00 0.0534 0.0003 0.0537 -0.2896 -0.0019 -0.2915
2.00 0.1067 0.0014 0.1081 -0.5791 -0.0076 -0.5867
3.00 0.1599 0.0031 0.1630 -0.8680 -0.0172 -0.8852
4.00 0.2130 0.0055 0.2185 -1.1563 -0.0306 -1.1869
5.00 0.2660 0.0086 0.2746 -1.4438 -0.0477 -1.4915
6.00 0.3187 0.0123 0.3311 -1.7301 -0.0687 -1.7988
7.00 0.3713 0.0168 0.3880 -2.0151 -0.0934 -2.1085
8.00 0.4235 0.0219 0.4454 -2.2985 -0.1219 -2.4204
9.00 0.4754 0.0277 0.5031 -2.5802 -0.1541 -2.7343
10.00 0.5269 0.0219 0.5488 -2.8598 -0.1217 -2.9816
11.00 0.5780 0.0099 0.5879 -3.1372 -0.0550 -3.1922
12.00 0.6287 -0.0081 0.6206 -3.4122 0.0449 -3.3673
13.00 0.6788 -0.0328 0.6460 -3.6845 0.1827 -3.5017
14.00 0.7284 -0.0653 0.6632 -3.9538 0.3634 -3.5904
15.00 0.7775 -0.1044 0.6731 -4.2199 0.5812 -3.6387
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 59
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 3.992E+06 /M
ALTITUDE = 1639.5 M DYNAMIC PRESSURE = 2327.55 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 IN PRESENCE OF THE BODY——————-
ALPHA CN CM CA CY CLN CLL
0.00 0.0000 0.0000 0.0263 0.0000 0.0000 0.0000
1.00 0.0750 -0.4069 0.0254 0.0000 0.0000 0.0000
2.00 0.1502 -0.8151 0.0227 0.0000 0.0000 0.0000
3.00 0.2255 -1.2238 0.0183 0.0000 0.0000 0.0000
4.00 0.2999 -1.6275 0.0123 0.0000 0.0000 0.0000
5.00 0.3733 -2.0263 0.0048 0.0000 0.0000 0.0000
6.00 0.4470 -2.4263 -0.0041 0.0000 0.0000 0.0000
7.00 0.5142 -2.7908 -0.0142 0.0000 0.0000 0.0000
8.00 0.5684 -3.0849 -0.0229 0.0000 0.0000 0.0000
9.00 0.6098 -3.3099 -0.0262 0.0000 0.0000 0.0000

10.00 0.6416 -3.4822 -0.0239 0.0000 0.0000 0.0000
11.00 0.6731 -3.6535 -0.0154 0.0000 0.0000 0.0000
12.00 0.7029 -3.8150 -0.0038 0.0000 0.0000 0.0000
13.00 0.7282 -3.9523 0.0089 0.0000 0.0000 0.0000
14.00 0.7466 -4.0522 0.0197 0.0000 0.0000 0.0000
15.00 0.7620 -4.1358 0.0290 0.0000 0.0000 0.0000
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 60
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 3.992E+06 /M
ALTITUDE = 1639.5 M DYNAMIC PRESSURE = 2327.55 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
————FIN SET 1 PANEL CHARACTERISTICS————
ALPHA PANEL AEQ (PANEL AXIS SYS.) PANEL CN
0.00 1 0.0000 0.0000
0.00 2 0.0000 0.0000
0.00 3 0.0000 0.0000
1.00 1 0.0000 0.0000
1.00 2 1.2062 0.0433
1.00 3 -1.2062 -0.0433
2.00 1 0.0000 0.0000
2.00 2 2.4023 0.0867
2.00 3 -2.4023 -0.0867
3.00 1 0.0000 0.0000
3.00 2 3.5841 0.1302
3.00 3 -3.5841 -0.1302
4.00 1 0.0000 0.0000
4.00 2 4.7486 0.1731
4.00 3 -4.7486 -0.1731
5.00 1 0.0000 0.0000
5.00 2 5.8799 0.2155
5.00 3 -5.8799 -0.2155
6.00 1 0.0000 0.0000
6.00 2 6.9842 0.2581
6.00 3 -6.9842 -0.2581
7.00 1 0.0000 0.0000
7.00 2 8.0609 0.2969
7.00 3 -8.0609 -0.2969
8.00 1 0.0000 0.0000
8.00 2 9.1089 0.3281
8.00 3 -9.1089 -0.3281
9.00 1 0.0000 0.0000
9.00 2 10.1289 0.3521
9.00 3 -10.1289 -0.3521
10.00 1 0.0000 0.0000
10.00 2 11.1211 0.3704
10.00 3 -11.1211 -0.3704
11.00 1 0.0000 0.0000
11.00 2 12.1764 0.3886
11.00 3 -12.1764 -0.3886
12.00 1 0.0000 0.0000
12.00 2 13.1202 0.4058

12.00 3 -13.1202 -0.4058
13.00 1 0.0000 0.0000
13.00 2 14.0203 0.4204
13.00 3 -14.0203 -0.4204
14.00 1 0.0000 0.0000
14.00 2 14.8958 0.4310
14.00 3 -14.8958 -0.4310
15.00 1 0.0000 0.0000
15.00 2 15.7626 0.4399
15.00 3 -15.7626 -0.4399
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 61
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 3.992E+06 /M
ALTITUDE = 1639.5 M DYNAMIC PRESSURE = 2327.55 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
CARRYOVER INTERFERENCE FACTORS - FIN SET 1
ALPHA K-W(B) K-B(W) KK-W(B) KK-B(W) XCP-W(B) XCP-B(W) Y-CP/(B/2)
0.00 1.3959 0.5090 0.9348 0.3583 5.4277 5.4173 0.4120
1.00 1.3927 0.5090 0.9348 0.3583 5.4277 5.4173 0.4131
2.00 1.3870 0.5090 0.9348 0.3583 5.4277 5.4173 0.4142
3.00 1.3797 0.5090 0.9348 0.3583 5.4277 5.4173 0.4153
4.00 1.3712 0.5090 0.9348 0.3583 5.4277 5.4173 0.4164
5.00 1.3618 0.5090 0.9348 0.3583 5.4277 5.4173 0.4170
6.00 1.3517 0.5090 0.9348 0.3583 5.4277 5.4173 0.4171
7.00 1.3410 0.5090 0.9348 0.3583 5.4277 5.4173 0.4171
8.00 1.3299 0.5090 0.9348 0.3583 5.4277 5.4173 0.4171
9.00 1.3185 0.5090 0.9348 0.3583 5.4277 5.4173 0.4171
10.00 1.3069 0.5090 0.9348 0.3583 5.4277 5.4173 0.4171
11.00 1.2951 0.5090 0.9348 0.3583 5.4277 5.4173 0.4171
12.00 1.2833 0.5090 0.9348 0.3583 5.4277 5.4173 0.4172
13.00 1.2714 0.5090 0.9348 0.3583 5.4277 5.4173 0.4174
14.00 1.2596 0.5090 0.9348 0.3583 5.4277 5.4173 0.4176
15.00 1.2480 0.5090 0.9348 0.3583 5.4277 5.4173 0.4177
NOTE - XCP-W(B) USED FOR STABILITY ONLY DIFFERENT VALUES USED FOR HINGE MOMENTS
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 62
FIN SET 1 PANEL BENDING MOMENTS (ABOUT EXPOSED ROOT CHORD)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 3.992E+06 /M
ALTITUDE = 1639.5 M DYNAMIC PRESSURE = 2327.55 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 1.72E-02 -1.72E-02
2.0 0.00E+00 3.45E-02 -3.45E-02
3.0 0.00E+00 5.19E-02 -5.19E-02
4.0 0.00E+00 6.92E-02 -6.92E-02
5.0 9.76E-10 8.63E-02 -8.63E-02

6.0 1.70E-09 1.03E-01 -1.03E-01
7.0 0.00E+00 1.19E-01 -1.19E-01
8.0 3.42E-09 1.31E-01 -1.31E-01
9.0 -2.11E-09 1.41E-01 -1.41E-01
10.0 2.58E-09 1.48E-01 -1.48E-01
11.0 0.00E+00 1.56E-01 -1.56E-01
12.0 -6.86E-09 1.63E-01 -1.63E-01
13.0 1.68E-09 1.69E-01 -1.69E-01
14.0 -9.55E-09 1.73E-01 -1.73E-01
15.0 -3.75E-09 1.76E-01 -1.76E-01
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 63
FIN SET 1 PANEL HINGE MOMENTS (ABOUT HINGE LINE)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 3.992E+06 /M
ALTITUDE = 1639.5 M DYNAMIC PRESSURE = 2327.55 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 5.19E-03 -5.19E-03
2.0 0.00E+00 1.04E-02 -1.04E-02
3.0 0.00E+00 1.56E-02 -1.56E-02
4.0 0.00E+00 2.08E-02 -2.08E-02
5.0 2.92E-10 2.58E-02 -2.58E-02
6.0 5.10E-10 3.09E-02 -3.09E-02
7.0 0.00E+00 3.56E-02 -3.56E-02
8.0 1.03E-09 3.93E-02 -3.93E-02
9.0 -6.33E-10 4.22E-02 -4.22E-02
10.0 7.72E-10 4.44E-02 -4.44E-02
11.0 0.00E+00 4.66E-02 -4.66E-02
12.0 -2.05E-09 4.87E-02 -4.87E-02
13.0 5.03E-10 5.04E-02 -5.04E-02
14.0 -2.86E-09 5.17E-02 -5.17E-02
15.0 -1.12E-09 5.28E-02 -5.28E-02
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 64
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 3.992E+06 /M
ALTITUDE = 1639.5 M DYNAMIC PRESSURE = 2327.55 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
—– LONGITUDINAL —– – LATERAL DIRECTIONAL –
ALPHA CN CM CA CY CLN CLL
0.00 0.000 0.000 0.350 0.000 0.000 0.000
1.00 0.151 -0.359 0.350 0.000 0.000 0.000
2.00 0.309 -0.720 0.347 0.000 0.000 0.000
3.00 0.473 -1.083 0.343 0.000 0.000 0.000
4.00 0.643 -1.441 0.336 0.000 0.000 0.000
5.00 0.818 -1.795 0.329 0.000 0.000 0.000
6.00 1.000 -2.153 0.319 0.000 0.000 0.000
7.00 1.179 -2.465 0.309 0.000 0.000 0.000

8.00 1.346 -2.683 0.299 0.000 0.000 0.000
9.00 1.503 -2.809 0.295 0.000 0.000 0.000
10.00 1.652 -2.865 0.295 0.000 0.000 0.000
11.00 1.806 -2.923 0.302 0.000 0.000 0.000
12.00 1.964 -2.971 0.311 0.000 0.000 0.000
13.00 2.122 -2.988 0.321 0.000 0.000 0.000
14.00 2.275 -2.956 0.329 0.000 0.000 0.000
15.00 2.430 -2.905 0.334 0.000 0.000 0.000
ALPHA CL CD CL/CD X-C.P.
0.00 0.000 0.350 0.000 -2.423
1.00 0.145 0.352 0.411 -2.376
2.00 0.297 0.358 0.829 -2.332
3.00 0.455 0.367 1.239 -2.289
4.00 0.618 0.381 1.624 -2.241
5.00 0.786 0.399 1.972 -2.194
6.00 0.961 0.422 2.276 -2.153
7.00 1.132 0.450 2.517 -2.091
8.00 1.292 0.484 2.672 -1.993
9.00 1.438 0.526 2.734 -1.869
10.00 1.575 0.578 2.726 -1.735
11.00 1.715 0.641 2.675 -1.618
12.00 1.857 0.713 2.604 -1.512
13.00 1.995 0.790 2.524 -1.408
14.00 2.128 0.869 2.448 -1.299
15.00 2.261 0.951 2.376 -1.196
X-C.P. MEAS. FROM MOMENT CENTER IN REF. LENGTHS, NEG. AFT OF MOMENT CENTER
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 65
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 3.992E+06 /M
ALTITUDE = 1639.5 M DYNAMIC PRESSURE = 2327.55 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——– DERIVATIVES (PER DEGREE) ——–
ALPHA CNA CMA CYB CLNB CLLB
0.00 0.1477 -0.3580 -0.1511 0.3590 -0.0001
1.00 0.1545 -0.3602 -0.1524 0.3591 0.0002
2.00 0.1611 -0.3621 -0.1551 0.3597 0.0009
3.00 0.1670 -0.3604 -0.1577 0.3583 0.0013
4.00 0.1723 -0.3557 -0.1602 0.3561 0.0015
5.00 0.1783 -0.3557 -0.1593 0.3354 0.0048
6.00 0.1805 -0.3350 -0.1570 0.3075 0.0063
7.00 0.1734 -0.2648 -0.1506 0.2573 0.0032
8.00 0.1620 -0.1719 -0.1423 0.1969 -0.0017
9.00 0.1526 -0.0910 -0.1342 0.1385 -0.0054
10.00 0.1518 -0.0570 -0.1277 0.0888 -0.0054
11.00 0.1563 -0.0526 -0.1371 0.1256 -0.0091
12.00 0.1577 -0.0323 -0.1316 0.0826 -0.0048
13.00 0.1554 0.0073 -0.1201 0.0068 -0.0016
14.00 0.1540 0.0415 -0.1077 -0.0732 0.0025
15.00 0.1552 0.0610 -0.0983 -0.1364 0.0091
PANEL DEFLECTION ANGLES (DEGREES)
SET FIN 1 FIN 2 FIN 3 FIN 4 FIN 5 FIN 6 FIN 7 FIN 8

1 0.00 0.00 0.00
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 66
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.760E+06 /M
ALTITUDE = 316.2 M DYNAMIC PRESSURE = 6147.81 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1623 0.0093 0.1370 0.0000
1.00 0.1623 0.0093 0.1372 0.0000
2.00 0.1621 0.0093 0.1373 0.0001
3.00 0.1619 0.0093 0.1374 0.0002
4.00 0.1615 0.0093 0.1374 0.0004
5.00 0.1611 0.0092 0.1374 0.0006
6.00 0.1605 0.0092 0.1374 0.0007
7.00 0.1599 0.0092 0.1373 0.0009
8.00 0.1592 0.0091 0.1372 0.0009
9.00 0.1583 0.0091 0.1370 0.0009
10.00 0.1574 0.0090 0.1368 0.0007
11.00 0.1564 0.0090 0.1365 0.0002
12.00 0.1553 0.0089 0.1362 -0.0006
13.00 0.1541 0.0088 0.1359 -0.0017
14.00 0.1528 0.0088 0.1355 -0.0034
15.00 0.1514 0.0087 0.1351 -0.0057
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.743
2.00 0.091 0.012 0.391 0.002 0.746
3.00 0.137 0.028 0.586 0.005 0.750
4.00 0.182 0.050 0.780 0.010 0.753
5.00 0.227 0.079 0.973 0.015 0.756
6.00 0.272 0.114 1.164 0.022 0.759
7.00 0.316 0.155 1.354 0.030 0.762
8.00 0.360 0.203 1.542 0.039 0.766
9.00 0.403 0.258 1.727 0.049 0.769
10.00 0.446 0.319 1.910 0.061 0.772
11.00 0.488 0.387 2.091 0.074 0.775
12.00 0.529 0.461 2.268 0.088 0.778
13.00 0.570 0.542 2.442 0.104 0.781
14.00 0.609 0.629 2.612 0.120 0.784
15.00 0.648 0.723 2.779 0.138 0.788
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 67
FIN SET 1 CA PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.760E+06 /M
ALTITUDE = 316.2 M DYNAMIC PRESSURE = 6147.81 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
SINGLE FIN PANEL ZERO-LIFT AXIAL FORCE COMPONENTS

SKIN FRICTION 0.0063
SUBSONIC PRESSURE 0.0015
TRANSONIC WAVE 0.0000
SUPERSONIC WAVE 0.0000
LEADING EDGE 0.0000
TRAILING EDGE 0.0000
TOTAL CAO 0.0078
FIN AXIAL FORCE DUE TO ANGLE OF ATTACK
ALPHA CA DUE TO LIFT (SINGLE PANEL) CA-TOTAL (3 FINS)
0.00 0.0000 0.0235
1.00 -0.0003 0.0229
2.00 -0.0013 0.0214
3.00 -0.0030 0.0188
4.00 -0.0053 0.0153
5.00 -0.0083 0.0108
6.00 -0.0120 0.0053
7.00 -0.0164 -0.0012
8.00 -0.0214 -0.0088
9.00 -0.0259 -0.0176
10.00 -0.0278 -0.0256
11.00 -0.0268 -0.0307
12.00 -0.0228 -0.0318
13.00 -0.0165 -0.0286
14.00 -0.0091 -0.0212
15.00 -0.0028 -0.0103
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 68
FIN SET 1 CN, CM PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.760E+06 /M
ALTITUDE = 316.2 M DYNAMIC PRESSURE = 6147.81 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
NORMAL FORCE SLOPE AT ALPHA ZERO, CNA = 0.03616/DEG (1 PANEL)
CENTER OF PRESSURE FOR LINEAR CN = -5.42758 (CALIBERS FROM C.G.)
CENTER OF PRESSURE FOR NON-LINEAR CN = -5.56657 (CALIBERS FROM C.G.)
ALPHA CN CN CN CM CM CM
LINEAR NON-LINEAR TOTAL LINEAR NON-LINEAR TOTAL
0.00 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1.00 0.0542 0.0003 0.0545 -0.2944 -0.0014 -0.2958
2.00 0.1084 0.0010 0.1094 -0.5885 -0.0056 -0.5942
3.00 0.1625 0.0023 0.1648 -0.8823 -0.0126 -0.8949
4.00 0.2165 0.0040 0.2206 -1.1753 -0.0224 -1.1977
5.00 0.2704 0.0063 0.2767 -1.4674 -0.0350 -1.5025
6.00 0.3240 0.0091 0.3330 -1.7584 -0.0504 -1.8089
7.00 0.3774 0.0123 0.3897 -2.0481 -0.0686 -2.1167
8.00 0.4304 0.0161 0.4465 -2.3362 -0.0895 -2.4257
9.00 0.4832 0.0164 0.4996 -2.6225 -0.0915 -2.7139
10.00 0.5355 0.0060 0.5415 -2.9067 -0.0331 -2.9398
11.00 0.5875 -0.0102 0.5773 -3.1887 0.0568 -3.1319
12.00 0.6390 -0.0329 0.6060 -3.4681 0.1833 -3.2848
13.00 0.6900 -0.0632 0.6268 -3.7448 0.3516 -3.3932
14.00 0.7404 -0.1018 0.6386 -4.0186 0.5667 -3.4519
15.00 0.7902 -0.1205 0.6697 -4.2891 0.6709 -3.6182

1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 69
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.760E+06 /M
ALTITUDE = 316.2 M DYNAMIC PRESSURE = 6147.81 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 IN PRESENCE OF THE BODY——————-

ALPHA	CN	CM	CA	CY	CLN	CLL
0.00	0.0000	0.0000	0.0235	0.0000	0.0000	0.0000
1.00	0.0760	-0.4127	0.0225	0.0000	0.0000	0.0000
2.00	0.1520	-0.8248	0.0197	0.0000	0.0000	0.0000
3.00	0.2276	-1.2356	0.0150	0.0000	0.0000	0.0000
4.00	0.3026	-1.6424	0.0085	0.0000	0.0000	0.0000
5.00	0.3757	-2.0393	0.0004	0.0000	0.0000	0.0000
6.00	0.4467	-2.4248	-0.0091	0.0000	0.0000	0.0000
7.00	0.5106	-2.7714	-0.0199	0.0000	0.0000	0.0000
8.00	0.5622	-3.0514	-0.0289	0.0000	0.0000	0.0000
9.00	0.5994	-3.2534	-0.0321	0.0000	0.0000	0.0000
10.00	0.6249	-3.3917	-0.0294	0.0000	0.0000	0.0000
11.00	0.6546	-3.5530	-0.0202	0.0000	0.0000	0.0000
12.00	0.6901	-3.7457	-0.0077	0.0000	0.0000	0.0000
13.00	0.7220	-3.9189	0.0056	0.0000	0.0000	0.0000
14.00	0.7436	-4.0359	0.0166	0.0000	0.0000	0.0000
15.00	0.7612	-4.1314	0.0259	0.0000	0.0000	0.0000

1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 70
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.760E+06 /M
ALTITUDE = 316.2 M DYNAMIC PRESSURE = 6147.81 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 PANEL CHARACTERISTICS——————

ALPHA	PANEL	AEQ (PANEL AXIS SYS.)	PANEL CN
0.00	1	0.0000	0.0000
0.00	2	0.0000	0.0000
0.00	3	0.0000	0.0000
1.00	1	0.0000	0.0000
1.00	2	1.2062	0.0439
1.00	3	-1.2062	-0.0439
2.00	1	0.0000	0.0000
2.00	2	2.4023	0.0877
2.00	3	-2.4023	-0.0877
3.00	1	0.0000	0.0000
3.00	2	3.5841	0.1314
3.00	3	-3.5841	-0.1314
4.00	1	0.0000	0.0000
4.00	2	4.7486	0.1747
4.00	3	-4.7486	-0.1747
5.00	1	0.0000	0.0000
5.00	2	5.8798	0.2169

5.00 3 -5.8798 -0.2169
6.00 1 0.0000 0.0000
6.00 2 6.9839 0.2579
6.00 3 -6.9839 -0.2579
7.00 1 0.0000 0.0000
7.00 2 8.0603 0.2948
7.00 3 -8.0603 -0.2948
8.00 1 0.0000 0.0000
8.00 2 9.1079 0.3246
8.00 3 -9.1079 -0.3246
9.00 1 0.0000 0.0000
9.00 2 10.1272 0.3461
9.00 3 -10.1272 -0.3461
10.00 1 0.0000 0.0000
10.00 2 11.1186 0.3608
10.00 3 -11.1186 -0.3608
11.00 1 0.0000 0.0000
11.00 2 12.1764 0.3779
11.00 3 -12.1764 -0.3779
12.00 1 0.0000 0.0000
12.00 2 13.1202 0.3984
12.00 3 -13.1202 -0.3984
13.00 1 0.0000 0.0000
13.00 2 14.0203 0.4169
13.00 3 -14.0203 -0.4169
14.00 1 0.0000 0.0000
14.00 2 14.8958 0.4293
14.00 3 -14.8958 -0.4293
15.00 1 0.0000 0.0000
15.00 2 15.7626 0.4395
15.00 3 -15.7626 -0.4395
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 71
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.760E+06 /M
ALTITUDE = 316.2 M DYNAMIC PRESSURE = 6147.81 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
CARRYOVER INTERFERENCE FACTORS - FIN SET 1
ALPHA K-W(B) K-B(W) KK-W(B) KK-B(W) XCP-W(B) XCP-B(W) Y-CP/(B/2)
0.00 1.3959 0.5090 0.9348 0.3583 5.4276 5.4173 0.4182
1.00 1.3927 0.5090 0.9348 0.3583 5.4276 5.4173 0.4190
2.00 1.3870 0.5090 0.9348 0.3583 5.4276 5.4173 0.4198
3.00 1.3797 0.5090 0.9348 0.3583 5.4276 5.4173 0.4206
4.00 1.3712 0.5090 0.9348 0.3583 5.4276 5.4173 0.4214
5.00 1.3618 0.5090 0.9348 0.3583 5.4276 5.4173 0.4217
6.00 1.3517 0.5090 0.9348 0.3583 5.4276 5.4173 0.4215
7.00 1.3410 0.5090 0.9348 0.3583 5.4276 5.4173 0.4213
8.00 1.3299 0.5090 0.9348 0.3583 5.4276 5.4173 0.4211
9.00 1.3185 0.5090 0.9348 0.3583 5.4276 5.4173 0.4209
10.00 1.3069 0.5090 0.9348 0.3583 5.4276 5.4173 0.4209
11.00 1.2951 0.5090 0.9348 0.3583 5.4276 5.4173 0.4208
12.00 1.2833 0.5090 0.9348 0.3583 5.4276 5.4173 0.4206

13.00 1.2714 0.5090 0.9348 0.3583 5.4276 5.4173 0.4206
14.00 1.2596 0.5090 0.9348 0.3583 5.4276 5.4173 0.4207
15.00 1.2480 0.5090 0.9348 0.3583 5.4276 5.4173 0.4207
NOTE - XCP-W(B) USED FOR STABILITY ONLY DIFFERENT VALUES USED FOR HINGE MOMENTS
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 72
FIN SET 1 PANEL BENDING MOMENTS (ABOUT EXPOSED ROOT CHORD)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.760E+06 /M
ALTITUDE = 316.2 M DYNAMIC PRESSURE = 6147.81 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 1.77E-02 -1.77E-02
2.0 0.00E+00 3.54E-02 -3.54E-02
3.0 0.00E+00 5.31E-02 -5.31E-02
4.0 0.00E+00 7.07E-02 -7.07E-02
5.0 1.01E-09 8.78E-02 -8.78E-02
6.0 1.76E-09 1.04E-01 -1.04E-01
7.0 0.00E+00 1.19E-01 -1.19E-01
8.0 3.55E-09 1.31E-01 -1.31E-01
9.0 -2.19E-09 1.40E-01 -1.40E-01
10.0 2.68E-09 1.46E-01 -1.46E-01
11.0 0.00E+00 1.53E-01 -1.53E-01
12.0 -7.02E-09 1.61E-01 -1.61E-01
13.0 1.72E-09 1.68E-01 -1.68E-01
14.0 -9.77E-09 1.73E-01 -1.73E-01
15.0 -3.83E-09 1.78E-01 -1.78E-01
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 73
FIN SET 1 PANEL HINGE MOMENTS (ABOUT HINGE LINE)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.760E+06 /M
ALTITUDE = 316.2 M DYNAMIC PRESSURE = 6147.81 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 5.27E-03 -5.27E-03
2.0 0.00E+00 1.05E-02 -1.05E-02
3.0 0.00E+00 1.58E-02 -1.58E-02
4.0 0.00E+00 2.10E-02 -2.10E-02
5.0 2.99E-10 2.60E-02 -2.60E-02
6.0 5.23E-10 3.10E-02 -3.10E-02
7.0 0.00E+00 3.54E-02 -3.54E-02
8.0 1.05E-09 3.90E-02 -3.90E-02
9.0 -6.51E-10 4.16E-02 -4.16E-02
10.0 7.96E-10 4.33E-02 -4.33E-02
11.0 0.00E+00 4.54E-02 -4.54E-02
12.0 -2.09E-09 4.78E-02 -4.78E-02
13.0 5.12E-10 5.01E-02 -5.01E-02

14.0 -2.90E-09 5.16E-02 -5.16E-02
15.0 -1.14E-09 5.28E-02 -5.28E-02
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 74
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.760E+06 /M
ALTITUDE = 316.2 M DYNAMIC PRESSURE = 6147.81 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
—– LONGITUDINAL —– – LATERAL DIRECTIONAL –
ALPHA CN CM CA CY CLN CLL
0.00 0.000 0.000 0.332 0.000 0.000 0.000
1.00 0.153 -0.367 0.331 0.000 0.000 0.000
2.00 0.311 -0.733 0.328 0.000 0.000 0.000
3.00 0.476 -1.099 0.324 0.000 0.000 0.000
4.00 0.647 -1.461 0.317 0.000 0.000 0.000
5.00 0.822 -1.812 0.309 0.000 0.000 0.000
6.00 1.000 -2.150 0.299 0.000 0.000 0.000
7.00 1.175 -2.438 0.287 0.000 0.000 0.000
8.00 1.340 -2.637 0.277 0.000 0.000 0.000
9.00 1.492 -2.731 0.273 0.000 0.000 0.000
10.00 1.633 -2.739 0.274 0.000 0.000 0.000
11.00 1.786 -2.782 0.282 0.000 0.000 0.000
12.00 1.954 -2.873 0.292 0.000 0.000 0.000
13.00 2.123 -2.939 0.303 0.000 0.000 0.000
14.00 2.283 -2.931 0.310 0.000 0.000 0.000
15.00 2.443 -2.896 0.315 0.000 0.000 0.000
ALPHA CL CD CL/CD X-C.P.
0.00 0.000 0.332 0.000 -2.458
1.00 0.147 0.334 0.440 -2.405
2.00 0.300 0.339 0.884 -2.355
3.00 0.459 0.348 1.318 -2.307
4.00 0.623 0.361 1.725 -2.259
5.00 0.792 0.379 2.088 -2.205
6.00 0.964 0.402 2.399 -2.150
7.00 1.132 0.428 2.641 -2.074
8.00 1.289 0.461 2.793 -1.967
9.00 1.430 0.503 2.843 -1.831
10.00 1.560 0.554 2.817 -1.677
11.00 1.700 0.618 2.752 -1.557
12.00 1.851 0.692 2.674 -1.470
13.00 2.000 0.772 2.590 -1.385
14.00 2.140 0.853 2.508 -1.284
15.00 2.278 0.937 2.431 -1.185
X-C.P. MEAS. FROM MOMENT CENTER IN REF. LENGTHS, NEG. AFT OF MOMENT CENTER
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 75
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.760E+06 /M
ALTITUDE = 316.2 M DYNAMIC PRESSURE = 6147.81 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M

REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——– DERIVATIVES (PER DEGREE) ——–
ALPHA CNA CMA CYB CLNB CLLB
0.00 0.1494 -0.3673 -0.1526 0.3670 -0.0001
1.00 0.1557 -0.3667 -0.1538 0.3666 0.0001
2.00 0.1619 -0.3662 -0.1563 0.3661 0.0005
3.00 0.1678 -0.3640 -0.1589 0.3646 0.0008
4.00 0.1727 -0.3565 -0.1614 0.3621 0.0010
5.00 0.1766 -0.3444 -0.1596 0.3363 0.0031
6.00 0.1768 -0.3125 -0.1564 0.3032 0.0037
7.00 0.1700 -0.2427 -0.1501 0.2534 0.0008
8.00 0.1581 -0.1459 -0.1416 0.1916 -0.0042
9.00 0.1463 -0.0511 -0.1322 0.1255 -0.0094
10.00 0.1474 -0.0259 -0.1259 0.0765 -0.0088
11.00 0.1605 -0.0668 -0.1395 0.1357 -0.0080
12.00 0.1682 -0.0786 -0.1363 0.1045 -0.0008
13.00 0.1644 -0.0291 -0.1238 0.0227 0.0013
14.00 0.1602 0.0217 -0.1099 -0.0659 0.0038
15.00 0.1604 0.0484 -0.1009 -0.1278 0.0111
PANEL DEFLECTION ANGLES (DEGREES)
SET FIN 1 FIN 2 FIN 3 FIN 4 FIN 5 FIN 6 FIN 7 FIN 8
1 0.00 0.00 0.00
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 76
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.150E+06 /M
ALTITUDE = 1351.1 M DYNAMIC PRESSURE = 5425.47 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1648 0.0095 0.1370 0.0000
1.00 0.1647 0.0094 0.1372 0.0000
2.00 0.1646 0.0094 0.1373 0.0001
3.00 0.1643 0.0094 0.1374 0.0002
4.00 0.1640 0.0094 0.1374 0.0004
5.00 0.1635 0.0094 0.1374 0.0006
6.00 0.1630 0.0093 0.1374 0.0007
7.00 0.1623 0.0093 0.1373 0.0009
8.00 0.1616 0.0093 0.1372 0.0010
9.00 0.1607 0.0092 0.1370 0.0009
10.00 0.1598 0.0092 0.1368 0.0007
11.00 0.1588 0.0091 0.1365 0.0002
12.00 0.1576 0.0090 0.1362 -0.0005
13.00 0.1564 0.0090 0.1359 -0.0017
14.00 0.1551 0.0089 0.1355 -0.0033
15.00 0.1537 0.0088 0.1351 -0.0056
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.743
2.00 0.091 0.012 0.391 0.002 0.746
3.00 0.137 0.028 0.586 0.005 0.750
4.00 0.182 0.050 0.780 0.010 0.753

5.00 0.227 0.079 0.973 0.015 0.756
6.00 0.272 0.114 1.164 0.022 0.759
7.00 0.316 0.155 1.354 0.030 0.762
8.00 0.360 0.203 1.542 0.039 0.766
9.00 0.403 0.258 1.727 0.049 0.769
10.00 0.446 0.319 1.910 0.061 0.772
11.00 0.488 0.387 2.091 0.074 0.775
12.00 0.529 0.461 2.268 0.088 0.778
13.00 0.570 0.542 2.442 0.104 0.781
14.00 0.609 0.629 2.612 0.120 0.784
15.00 0.648 0.723 2.779 0.138 0.788
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 77
FIN SET 1 CA PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.150E+06 /M
ALTITUDE = 1351.1 M DYNAMIC PRESSURE = 5425.47 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
SINGLE FIN PANEL ZERO-LIFT AXIAL FORCE COMPONENTS
SKIN FRICTION 0.0064
SUBSONIC PRESSURE 0.0015
TRANSONIC WAVE 0.0000
SUPERSONIC WAVE 0.0000
LEADING EDGE 0.0000
TRAILING EDGE 0.0000
TOTAL CAO 0.0080
FIN AXIAL FORCE DUE TO ANGLE OF ATTACK
ALPHA CA DUE TO LIFT (SINGLE PANEL) CA-TOTAL (3 FINS)
0.00 0.0000 0.0239
1.00 -0.0003 0.0234
2.00 -0.0013 0.0218
3.00 -0.0030 0.0193
4.00 -0.0053 0.0158
5.00 -0.0083 0.0113
6.00 -0.0119 0.0059
7.00 -0.0163 -0.0006
8.00 -0.0213 -0.0082
9.00 -0.0257 -0.0168
10.00 -0.0276 -0.0248
11.00 -0.0266 -0.0299
12.00 -0.0226 -0.0310
13.00 -0.0163 -0.0278
14.00 -0.0090 -0.0205
15.00 -0.0028 -0.0097
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 78
FIN SET 1 CN, CM PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.150E+06 /M
ALTITUDE = 1351.1 M DYNAMIC PRESSURE = 5425.47 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M

NORMAL FORCE SLOPE AT ALPHA ZERO, CNA = 0.03616/DEG (1 PANEL)
CENTER OF PRESSURE FOR LINEAR CN = -5.42758 (CALIBERS FROM C.G.)
CENTER OF PRESSURE FOR NON-LINEAR CN = -5.56657 (CALIBERS FROM C.G.)

ALPHA	CN	CN	CN	CM	CM	CM
	LINEAR	NON-LINEAR	TOTAL	LINEAR	NON-LINEAR	TOTAL
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.00	0.0542	0.0002	0.0545	-0.2944	-0.0014	-0.2958
2.00	0.1084	0.0010	0.1094	-0.5885	-0.0056	-0.5941
3.00	0.1625	0.0022	0.1648	-0.8823	-0.0125	-0.8947
4.00	0.2165	0.0040	0.2205	-1.1753	-0.0222	-1.1975
5.00	0.2704	0.0062	0.2766	-1.4674	-0.0347	-1.5021
6.00	0.3240	0.0090	0.3329	-1.7584	-0.0499	-1.8083
7.00	0.3774	0.0122	0.3895	-2.0481	-0.0679	-2.1160
8.00	0.4304	0.0159	0.4463	-2.3362	-0.0885	-2.4247
9.00	0.4832	0.0161	0.4992	-2.6225	-0.0894	-2.7119
10.00	0.5355	0.0055	0.5410	-2.9067	-0.0305	-2.9372
11.00	0.5875	-0.0108	0.5767	-3.1887	0.0601	-3.1285
12.00	0.6390	-0.0337	0.6053	-3.4681	0.1875	-3.2806
13.00	0.6900	-0.0641	0.6259	-3.7448	0.3566	-3.3882
14.00	0.7404	-0.1029	0.6375	-4.0186	0.5727	-3.4458
15.00	0.7902	-0.1209	0.6693	-4.2891	0.6732	-3.6159

1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 79
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.150E+06 /M
ALTITUDE = 1351.1 M DYNAMIC PRESSURE = 5425.47 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 IN PRESENCE OF THE BODY——————-

ALPHA	CN	CM	CA	CY	CLN	CLL
0.00	0.0000	0.0000	0.0239	0.0000	0.0000	0.0000
1.00	0.0760	-0.4127	0.0230	0.0000	0.0000	0.0000
2.00	0.1519	-0.8247	0.0202	0.0000	0.0000	0.0000
3.00	0.2276	-1.2353	0.0155	0.0000	0.0000	0.0000
4.00	0.3025	-1.6420	0.0091	0.0000	0.0000	0.0000
5.00	0.3756	-2.0387	0.0011	0.0000	0.0000	0.0000
6.00	0.4465	-2.4236	-0.0084	0.0000	0.0000	0.0000
7.00	0.5103	-2.7695	-0.0192	0.0000	0.0000	0.0000
8.00	0.5618	-3.0490	-0.0281	0.0000	0.0000	0.0000
9.00	0.5988	-3.2501	-0.0313	0.0000	0.0000	0.0000
10.00	0.6241	-3.3874	-0.0286	0.0000	0.0000	0.0000
11.00	0.6537	-3.5479	-0.0194	0.0000	0.0000	0.0000
12.00	0.6892	-3.7409	-0.0071	0.0000	0.0000	0.0000
13.00	0.7213	-3.9148	0.0061	0.0000	0.0000	0.0000
14.00	0.7430	-4.0328	0.0171	0.0000	0.0000	0.0000
15.00	0.7608	-4.1294	0.0263	0.0000	0.0000	0.0000

1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 80
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.150E+06 /M
ALTITUDE = 1351.1 M DYNAMIC PRESSURE = 5425.47 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG

REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 PANEL CHARACTERISTICS———————
ALPHA PANEL AEQ (PANEL AXIS SYS.) PANEL CN
0.00 1 0.0000 0.0000
0.00 2 0.0000 0.0000
0.00 3 0.0000 0.0000
1.00 1 0.0000 0.0000
1.00 2 1.2062 0.0439
1.00 3 -1.2062 -0.0439
2.00 1 0.0000 0.0000
2.00 2 2.4023 0.0877
2.00 3 -2.4023 -0.0877
3.00 1 0.0000 0.0000
3.00 2 3.5841 0.1314
3.00 3 -3.5841 -0.1314
4.00 1 0.0000 0.0000
4.00 2 4.7486 0.1747
4.00 3 -4.7486 -0.1747
5.00 1 0.0000 0.0000
5.00 2 5.8798 0.2169
5.00 3 -5.8798 -0.2169
6.00 1 0.0000 0.0000
6.00 2 6.9839 0.2578
6.00 3 -6.9839 -0.2578
7.00 1 0.0000 0.0000
7.00 2 8.0603 0.2946
7.00 3 -8.0603 -0.2946
8.00 1 0.0000 0.0000
8.00 2 9.1079 0.3243
8.00 3 -9.1079 -0.3243
9.00 1 0.0000 0.0000
9.00 2 10.1272 0.3457
9.00 3 -10.1272 -0.3457
10.00 1 0.0000 0.0000
10.00 2 11.1186 0.3603
10.00 3 -11.1186 -0.3603
11.00 1 0.0000 0.0000
11.00 2 12.1764 0.3774
11.00 3 -12.1764 -0.3774
12.00 1 0.0000 0.0000
12.00 2 13.1202 0.3979
12.00 3 -13.1202 -0.3979
13.00 1 0.0000 0.0000
13.00 2 14.0203 0.4164
13.00 3 -14.0203 -0.4164
14.00 1 0.0000 0.0000
14.00 2 14.8958 0.4290
14.00 3 -14.8958 -0.4290
15.00 1 0.0000 0.0000
15.00 2 15.7626 0.4393
15.00 3 -15.7626 -0.4393
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 81
AERODYNAMIC FORCE AND MOMENT SYNTHESIS

******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.150E+06 /M
ALTITUDE = 1351.1 M DYNAMIC PRESSURE = 5425.47 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
CARRYOVER INTERFERENCE FACTORS - FIN SET 1
ALPHA K-W(B) K-B(W) KK-W(B) KK-B(W) XCP-W(B) XCP-B(W) Y-CP/(B/2)
0.00 1.3959 0.5090 0.9348 0.3583 5.4276 5.4173 0.4182
1.00 1.3927 0.5090 0.9348 0.3583 5.4276 5.4173 0.4190
2.00 1.3870 0.5090 0.9348 0.3583 5.4276 5.4173 0.4198
3.00 1.3797 0.5090 0.9348 0.3583 5.4276 5.4173 0.4206
4.00 1.3712 0.5090 0.9348 0.3583 5.4276 5.4173 0.4214
5.00 1.3618 0.5090 0.9348 0.3583 5.4276 5.4173 0.4217
6.00 1.3517 0.5090 0.9348 0.3583 5.4276 5.4173 0.4215
7.00 1.3410 0.5090 0.9348 0.3583 5.4276 5.4173 0.4213
8.00 1.3299 0.5090 0.9348 0.3583 5.4276 5.4173 0.4211
9.00 1.3185 0.5090 0.9348 0.3583 5.4276 5.4173 0.4209
10.00 1.3069 0.5090 0.9348 0.3583 5.4276 5.4173 0.4209
11.00 1.2951 0.5090 0.9348 0.3583 5.4276 5.4173 0.4208
12.00 1.2833 0.5090 0.9348 0.3583 5.4276 5.4173 0.4206
13.00 1.2714 0.5090 0.9348 0.3583 5.4276 5.4173 0.4206
14.00 1.2596 0.5090 0.9348 0.3583 5.4276 5.4173 0.4207
15.00 1.2480 0.5090 0.9348 0.3583 5.4276 5.4173 0.4207
NOTE - XCP-W(B) USED FOR STABILITY ONLY DIFFERENT VALUES USED FOR HINGE MOMENTS
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 82
FIN SET 1 PANEL BENDING MOMENTS (ABOUT EXPOSED ROOT CHORD)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.150E+06 /M
ALTITUDE = 1351.1 M DYNAMIC PRESSURE = 5425.47 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 1.77E-02 -1.77E-02
2.0 0.00E+00 3.54E-02 -3.54E-02
3.0 0.00E+00 5.31E-02 -5.31E-02
4.0 0.00E+00 7.07E-02 -7.07E-02
5.0 1.01E-09 8.78E-02 -8.78E-02
6.0 1.76E-09 1.04E-01 -1.04E-01
7.0 0.00E+00 1.19E-01 -1.19E-01
8.0 3.55E-09 1.31E-01 -1.31E-01
9.0 -2.19E-09 1.40E-01 -1.40E-01
10.0 2.68E-09 1.46E-01 -1.46E-01
11.0 0.00E+00 1.52E-01 -1.52E-01
12.0 -7.02E-09 1.61E-01 -1.61E-01
13.0 1.72E-09 1.68E-01 -1.68E-01
14.0 -9.77E-09 1.73E-01 -1.73E-01
15.0 -3.83E-09 1.77E-01 -1.77E-01
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 83
FIN SET 1 PANEL HINGE MOMENTS (ABOUT HINGE LINE)

******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.150E+06 /M
ALTITUDE = 1351.1 M DYNAMIC PRESSURE = 5425.47 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 5.27E-03 -5.27E-03
2.0 0.00E+00 1.05E-02 -1.05E-02
3.0 0.00E+00 1.58E-02 -1.58E-02
4.0 0.00E+00 2.10E-02 -2.10E-02
5.0 2.99E-10 2.60E-02 -2.60E-02
6.0 5.23E-10 3.10E-02 -3.10E-02
7.0 0.00E+00 3.54E-02 -3.54E-02
8.0 1.05E-09 3.89E-02 -3.89E-02
9.0 -6.51E-10 4.15E-02 -4.15E-02
10.0 7.96E-10 4.33E-02 -4.33E-02
11.0 0.00E+00 4.53E-02 -4.53E-02
12.0 -2.09E-09 4.78E-02 -4.78E-02
13.0 5.12E-10 5.00E-02 -5.00E-02
14.0 -2.90E-09 5.15E-02 -5.15E-02
15.0 -1.14E-09 5.27E-02 -5.27E-02
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 84
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.150E+06 /M
ALTITUDE = 1351.1 M DYNAMIC PRESSURE = 5425.47 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
—– LONGITUDINAL —– – LATERAL DIRECTIONAL –
ALPHA CN CM CA CY CLN CLL
0.00 0.000 0.000 0.335 0.000 0.000 0.000
1.00 0.153 -0.367 0.334 0.000 0.000 0.000
2.00 0.311 -0.733 0.332 0.000 0.000 0.000
3.00 0.476 -1.099 0.327 0.000 0.000 0.000
4.00 0.647 -1.461 0.320 0.000 0.000 0.000
5.00 0.822 -1.812 0.312 0.000 0.000 0.000
6.00 1.000 -2.149 0.302 0.000 0.000 0.000
7.00 1.175 -2.435 0.291 0.000 0.000 0.000
8.00 1.340 -2.633 0.281 0.000 0.000 0.000
9.00 1.491 -2.726 0.277 0.000 0.000 0.000
10.00 1.632 -2.733 0.278 0.000 0.000 0.000
11.00 1.785 -2.775 0.285 0.000 0.000 0.000
12.00 1.953 -2.866 0.295 0.000 0.000 0.000
13.00 2.122 -2.934 0.306 0.000 0.000 0.000
14.00 2.282 -2.927 0.313 0.000 0.000 0.000
15.00 2.443 -2.893 0.318 0.000 0.000 0.000
ALPHA CL CD CL/CD X-C.P.
0.00 0.000 0.335 0.000 -2.458
1.00 0.147 0.337 0.435 -2.405
2.00 0.300 0.342 0.875 -2.355
3.00 0.459 0.351 1.305 -2.307

4.00 0.623 0.365 1.709 -2.258
5.00 0.791 0.382 2.069 -2.205
6.00 0.963 0.405 2.378 -2.149
7.00 1.131 0.432 2.619 -2.073
8.00 1.287 0.465 2.771 -1.966
9.00 1.429 0.506 2.822 -1.829
10.00 1.559 0.557 2.798 -1.675
11.00 1.698 0.621 2.736 -1.555
12.00 1.849 0.695 2.660 -1.468
13.00 1.998 0.775 2.578 -1.383
14.00 2.138 0.856 2.498 -1.282
15.00 2.277 0.940 2.423 -1.184
X-C.P. MEAS. FROM MOMENT CENTER IN REF. LENGTHS, NEG. AFT OF MOMENT CENTER
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 85
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.150E+06 /M
ALTITUDE = 1351.1 M DYNAMIC PRESSURE = 5425.47 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——– DERIVATIVES (PER DEGREE) ——–
ALPHA CNA CMA CYB CLNB CLLB
0.00 0.1494 -0.3673 -0.1526 0.3669 -0.0001
1.00 0.1557 -0.3667 -0.1538 0.3666 0.0001
2.00 0.1619 -0.3660 -0.1563 0.3660 0.0005
3.00 0.1678 -0.3639 -0.1589 0.3645 0.0008
4.00 0.1726 -0.3563 -0.1614 0.3620 0.0010
5.00 0.1765 -0.3438 -0.1595 0.3360 0.0031
6.00 0.1767 -0.3116 -0.1563 0.3028 0.0036
7.00 0.1698 -0.2418 -0.1501 0.2531 0.0007
8.00 0.1579 -0.1450 -0.1415 0.1913 -0.0042
9.00 0.1461 -0.0498 -0.1321 0.1250 -0.0095
10.00 0.1472 -0.0246 -0.1258 0.0760 -0.0089
11.00 0.1605 -0.0664 -0.1395 0.1356 -0.0081
12.00 0.1683 -0.0792 -0.1364 0.1047 -0.0008
13.00 0.1646 -0.0303 -0.1239 0.0231 0.0014
14.00 0.1605 0.0203 -0.1100 -0.0654 0.0039
15.00 0.1607 0.0468 -0.1010 -0.1272 0.0112
PANEL DEFLECTION ANGLES (DEGREES)
SET FIN 1 FIN 2 FIN 3 FIN 4 FIN 5 FIN 6 FIN 7 FIN 8
1 0.00 0.00 0.00
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 86
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.958E+06 /M
ALTITUDE = 384.4 M DYNAMIC PRESSURE = 10840.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1545 0.0092 0.1370 0.0000
1.00 0.1545 0.0092 0.1372 0.0000

2.00 0.1544 0.0092 0.1373 0.0001
3.00 0.1541 0.0092 0.1374 0.0002
4.00 0.1538 0.0092 0.1374 0.0004
5.00 0.1534 0.0092 0.1374 0.0005
6.00 0.1529 0.0091 0.1373 0.0007
7.00 0.1522 0.0091 0.1373 0.0008
8.00 0.1515 0.0090 0.1371 0.0009
9.00 0.1508 0.0090 0.1370 0.0008
10.00 0.1499 0.0089 0.1367 0.0005
11.00 0.1489 0.0089 0.1365 0.0000
12.00 0.1479 0.0088 0.1362 -0.0008
13.00 0.1467 0.0088 0.1358 -0.0020
14.00 0.1455 0.0087 0.1354 -0.0037
15.00 0.1442 0.0086 0.1350 -0.0061
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.744
2.00 0.091 0.012 0.391 0.002 0.749
3.00 0.137 0.028 0.586 0.005 0.753
4.00 0.182 0.050 0.780 0.010 0.757
5.00 0.227 0.079 0.973 0.015 0.761
6.00 0.272 0.115 1.164 0.022 0.766
7.00 0.316 0.157 1.354 0.030 0.770
8.00 0.360 0.206 1.542 0.039 0.774
9.00 0.403 0.261 1.727 0.050 0.778
10.00 0.446 0.323 1.910 0.062 0.783
11.00 0.488 0.393 2.091 0.075 0.787
12.00 0.529 0.469 2.268 0.090 0.791
13.00 0.570 0.552 2.442 0.105 0.795
14.00 0.609 0.641 2.612 0.123 0.799
15.00 0.648 0.738 2.779 0.141 0.803
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 87
FIN SET 1 CA PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.958E+06 /M
ALTITUDE = 384.4 M DYNAMIC PRESSURE = 10840.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
SINGLE FIN PANEL ZERO-LIFT AXIAL FORCE COMPONENTS
SKIN FRICTION 0.0059
SUBSONIC PRESSURE 0.0014
TRANSONIC WAVE 0.0000
SUPERSONIC WAVE 0.0000
LEADING EDGE 0.0000
TRAILING EDGE 0.0000
TOTAL CAO 0.0074
FIN AXIAL FORCE DUE TO ANGLE OF ATTACK
ALPHA CA DUE TO LIFT (SINGLE PANEL) CA-TOTAL (3 FINS)
0.00 0.0000 0.0221
1.00 -0.0003 0.0215
2.00 -0.0014 0.0199
3.00 -0.0031 0.0173

4.00 -0.0055 0.0136
5.00 -0.0086 0.0090
6.00 -0.0124 0.0033
7.00 -0.0169 -0.0035
8.00 -0.0222 -0.0113
9.00 -0.0267 -0.0203
10.00 -0.0286 -0.0285
11.00 -0.0275 -0.0337
12.00 -0.0234 -0.0348
13.00 -0.0168 -0.0314
14.00 -0.0093 -0.0237
15.00 -0.0029 -0.0125
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 88
FIN SET 1 CN, CM PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.958E+06 /M
ALTITUDE = 384.4 M DYNAMIC PRESSURE = 10840.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
NORMAL FORCE SLOPE AT ALPHA ZERO, CNA = 0.03705/DEG (1 PANEL)
CENTER OF PRESSURE FOR LINEAR CN = -5.42732 (CALIBERS FROM C.G.)
CENTER OF PRESSURE FOR NON-LINEAR CN = -5.56657 (CALIBERS FROM C.G.)
ALPHA CN CN CN CM CM CM
LINEAR NON-LINEAR TOTAL LINEAR NON-LINEAR TOTAL
0.00 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1.00 0.0556 0.0002 0.0558 -0.3016 -0.0011 -0.3027
2.00 0.1111 0.0008 0.1119 -0.6029 -0.0046 -0.6075
3.00 0.1665 0.0018 0.1684 -0.9038 -0.0102 -0.9140
4.00 0.2218 0.0033 0.2251 -1.2040 -0.0182 -1.2222
5.00 0.2770 0.0051 0.2821 -1.5033 -0.0284 -1.5317
6.00 0.3319 0.0073 0.3393 -1.8014 -0.0409 -1.8423
7.00 0.3866 0.0100 0.3966 -2.0981 -0.0556 -2.1537
8.00 0.4410 0.0130 0.4540 -2.3932 -0.0726 -2.4658
9.00 0.4950 0.0107 0.5057 -2.6865 -0.0593 -2.7458
10.00 0.5486 -0.0014 0.5472 -2.9777 0.0080 -2.9697
11.00 0.6019 -0.0195 0.5824 -3.2665 0.1083 -3.1582
12.00 0.6546 -0.0443 0.6103 -3.5528 0.2468 -3.3060
13.00 0.7068 -0.0770 0.6299 -3.8363 0.4285 -3.4078
14.00 0.7585 -0.1182 0.6403 -4.1167 0.6579 -3.4588
15.00 0.8096 -0.1285 0.6811 -4.3938 0.7152 -3.6786
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 89
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.958E+06 /M
ALTITUDE = 384.4 M DYNAMIC PRESSURE = 10840.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 IN PRESENCE OF THE BODY——————-
ALPHA CN CM CA CY CLN CLL
0.00 0.0000 0.0000 0.0221 0.0000 0.0000 0.0000
1.00 0.0778 -0.4223 0.0211 0.0000 0.0000 0.0000

2.00 0.1553 -0.8429 0.0181 0.0000 0.0000 0.0000
3.00 0.2324 -1.2612 0.0133 0.0000 0.0000 0.0000
4.00 0.3087 -1.6756 0.0066 0.0000 0.0000 0.0000
5.00 0.3828 -2.0777 -0.0018 0.0000 0.0000 0.0000
6.00 0.4539 -2.4632 -0.0116 0.0000 0.0000 0.0000
7.00 0.5174 -2.8079 -0.0228 0.0000 0.0000 0.0000
8.00 0.5688 -3.0869 -0.0319 0.0000 0.0000 0.0000
9.00 0.6053 -3.2850 -0.0352 0.0000 0.0000 0.0000
10.00 0.6293 -3.4156 -0.0323 0.0000 0.0000 0.0000
11.00 0.6587 -3.5748 -0.0227 0.0000 0.0000 0.0000
12.00 0.6960 -3.7773 -0.0098 0.0000 0.0000 0.0000
13.00 0.7309 -3.9669 0.0038 0.0000 0.0000 0.0000
14.00 0.7560 -4.1030 0.0150 0.0000 0.0000 0.0000
15.00 0.7772 -4.2179 0.0244 0.0000 0.0000 0.0000
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 90
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.958E+06 /M
ALTITUDE = 384.4 M DYNAMIC PRESSURE = 10840.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 PANEL CHARACTERISTICS——————
ALPHA PANEL AEQ (PANEL AXIS SYS.) PANEL CN
0.00 1 0.0000 0.0000
0.00 2 0.0000 0.0000
0.00 3 0.0000 0.0000
1.00 1 0.0000 0.0000
1.00 2 1.2062 0.0449
1.00 3 -1.2062 -0.0449
2.00 1 0.0000 0.0000
2.00 2 2.4023 0.0897
2.00 3 -2.4023 -0.0897
3.00 1 0.0000 0.0000
3.00 2 3.5841 0.1342
3.00 3 -3.5841 -0.1342
4.00 1 0.0000 0.0000
4.00 2 4.7486 0.1782
4.00 3 -4.7486 -0.1782
5.00 1 0.0000 0.0000
5.00 2 5.8797 0.2210
5.00 3 -5.8797 -0.2210
6.00 1 0.0000 0.0000
6.00 2 6.9836 0.2620
6.00 3 -6.9836 -0.2620
7.00 1 0.0000 0.0000
7.00 2 8.0597 0.2987
7.00 3 -8.0597 -0.2987
8.00 1 0.0000 0.0000
8.00 2 9.1068 0.3284
8.00 3 -9.1068 -0.3284
9.00 1 0.0000 0.0000
9.00 2 10.1256 0.3494
9.00 3 -10.1256 -0.3494

10.00 1 0.0000 0.0000
10.00 2 11.1162 0.3633
10.00 3 -11.1162 -0.3633
11.00 1 0.0000 0.0000
11.00 2 12.1764 0.3803
11.00 3 -12.1764 -0.3803
12.00 1 0.0000 0.0000
12.00 2 13.1202 0.4018
12.00 3 -13.1202 -0.4018
13.00 1 0.0000 0.0000
13.00 2 14.0203 0.4220
13.00 3 -14.0203 -0.4220
14.00 1 0.0000 0.0000
14.00 2 14.8958 0.4365
14.00 3 -14.8958 -0.4365
15.00 1 0.0000 0.0000
15.00 2 15.7626 0.4487
15.00 3 -15.7626 -0.4487
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 91
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.958E+06 /M
ALTITUDE = 384.4 M DYNAMIC PRESSURE = 10840.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
CARRYOVER INTERFERENCE FACTORS - FIN SET 1
ALPHA K-W(B) K-B(W) KK-W(B) KK-B(W) XCP-W(B) XCP-B(W) Y-CP/(B/2)
0.00 1.3959 0.5090 0.9348 0.3583 5.4273 5.4173 0.4245
1.00 1.3927 0.5090 0.9348 0.3583 5.4273 5.4173 0.4250
2.00 1.3870 0.5090 0.9348 0.3583 5.4273 5.4173 0.4255
3.00 1.3797 0.5090 0.9348 0.3583 5.4273 5.4173 0.4259
4.00 1.3712 0.5090 0.9348 0.3583 5.4273 5.4173 0.4264
5.00 1.3618 0.5090 0.9348 0.3583 5.4273 5.4173 0.4264
6.00 1.3517 0.5090 0.9348 0.3583 5.4273 5.4173 0.4258
7.00 1.3410 0.5090 0.9348 0.3583 5.4273 5.4173 0.4254
8.00 1.3299 0.5090 0.9348 0.3583 5.4273 5.4173 0.4250
9.00 1.3185 0.5090 0.9348 0.3583 5.4273 5.4173 0.4247
10.00 1.3069 0.5090 0.9348 0.3583 5.4273 5.4173 0.4246
11.00 1.2951 0.5090 0.9348 0.3583 5.4273 5.4173 0.4244
12.00 1.2833 0.5090 0.9348 0.3583 5.4273 5.4173 0.4241
13.00 1.2714 0.5090 0.9348 0.3583 5.4273 5.4173 0.4238
14.00 1.2596 0.5090 0.9348 0.3583 5.4273 5.4173 0.4237
15.00 1.2480 0.5090 0.9348 0.3583 5.4273 5.4173 0.4235
NOTE - XCP-W(B) USED FOR STABILITY ONLY DIFFERENT VALUES USED FOR HINGE MOMENTS
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 92
FIN SET 1 PANEL BENDING MOMENTS (ABOUT EXPOSED ROOT CHORD)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.958E+06 /M
ALTITUDE = 384.4 M DYNAMIC PRESSURE = 10840.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M

REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 1.83E-02 -1.83E-02
2.0 0.00E+00 3.66E-02 -3.66E-02
3.0 0.00E+00 5.49E-02 -5.49E-02
4.0 0.00E+00 7.30E-02 -7.30E-02
5.0 1.05E-09 9.05E-02 -9.05E-02
6.0 1.84E-09 1.07E-01 -1.07E-01
7.0 0.00E+00 1.22E-01 -1.22E-01
8.0 3.71E-09 1.34E-01 -1.34E-01
9.0 -2.29E-09 1.43E-01 -1.43E-01
10.0 2.80E-09 1.48E-01 -1.48E-01
11.0 0.00E+00 1.55E-01 -1.55E-01
12.0 -7.24E-09 1.64E-01 -1.64E-01
13.0 1.77E-09 1.72E-01 -1.72E-01
14.0 -1.01E-08 1.78E-01 -1.78E-01
15.0 -3.95E-09 1.82E-01 -1.82E-01
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 93
FIN SET 1 PANEL HINGE MOMENTS (ABOUT HINGE LINE)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.958E+06 /M
ALTITUDE = 384.4 M DYNAMIC PRESSURE = 10840.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 5.41E-03 -5.41E-03
2.0 0.00E+00 1.08E-02 -1.08E-02
3.0 0.00E+00 1.61E-02 -1.61E-02
4.0 0.00E+00 2.14E-02 -2.14E-02
5.0 3.09E-10 2.66E-02 -2.66E-02
6.0 5.41E-10 3.15E-02 -3.15E-02
7.0 0.00E+00 3.59E-02 -3.59E-02
8.0 1.09E-09 3.95E-02 -3.95E-02
9.0 -6.76E-10 4.21E-02 -4.21E-02
10.0 8.28E-10 4.37E-02 -4.37E-02
11.0 0.00E+00 4.58E-02 -4.58E-02
12.0 -2.14E-09 4.84E-02 -4.84E-02
13.0 5.25E-10 5.08E-02 -5.08E-02
14.0 -2.98E-09 5.25E-02 -5.25E-02
15.0 -1.17E-09 5.40E-02 -5.40E-02
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 94
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.958E+06 /M
ALTITUDE = 384.4 M DYNAMIC PRESSURE = 10840.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
—– LONGITUDINAL —– – LATERAL DIRECTIONAL –
ALPHA CN CM CA CY CLN CLL

0.00 0.000 0.000 0.323 0.000 0.000 0.000
1.00 0.155 -0.380 0.322 0.000 0.000 0.000
2.00 0.316 -0.758 0.319 0.000 0.000 0.000
3.00 0.483 -1.134 0.314 0.000 0.000 0.000
4.00 0.656 -1.507 0.307 0.000 0.000 0.000
5.00 0.832 -1.865 0.299 0.000 0.000 0.000
6.00 1.011 -2.203 0.288 0.000 0.000 0.000
7.00 1.186 -2.488 0.277 0.000 0.000 0.000
8.00 1.352 -2.685 0.267 0.000 0.000 0.000
9.00 1.503 -2.774 0.262 0.000 0.000 0.000
10.00 1.643 -2.771 0.264 0.000 0.000 0.000
11.00 1.798 -2.812 0.272 0.000 0.000 0.000
12.00 1.970 -2.915 0.282 0.000 0.000 0.000
13.00 2.145 -3.005 0.293 0.000 0.000 0.000
14.00 2.312 -3.023 0.301 0.000 0.000 0.000
15.00 2.480 -3.015 0.306 0.000 0.000 0.000
ALPHA CL CD CL/CD X-C.P.
0.00 0.000 0.323 0.000 -2.507
1.00 0.149 0.325 0.460 -2.452
2.00 0.305 0.330 0.923 -2.399
3.00 0.466 0.339 1.374 -2.349
4.00 0.633 0.352 1.796 -2.298
5.00 0.803 0.370 2.169 -2.242
6.00 0.975 0.392 2.485 -2.179
7.00 1.144 0.419 2.729 -2.097
8.00 1.301 0.452 2.878 -1.987
9.00 1.443 0.494 2.921 -1.846
10.00 1.573 0.545 2.885 -1.686
11.00 1.713 0.610 2.810 -1.564
12.00 1.868 0.686 2.725 -1.480
13.00 2.024 0.768 2.635 -1.401
14.00 2.171 0.851 2.550 -1.307
15.00 2.316 0.938 2.471 -1.216
X-C.P. MEAS. FROM MOMENT CENTER IN REF. LENGTHS, NEG. AFT OF MOMENT CENTER
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 95
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.958E+06 /M
ALTITUDE = 384.4 M DYNAMIC PRESSURE = 10840.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
———- DERIVATIVES (PER DEGREE) ———-
ALPHA CNA CMA CYB CLNB CLLB
0.00 0.1520 -0.3810 -0.1550 0.3800 0.0000
1.00 0.1580 -0.3791 -0.1562 0.3794 0.0001
2.00 0.1640 -0.3772 -0.1586 0.3783 0.0003
3.00 0.1699 -0.3744 -0.1612 0.3767 0.0006
4.00 0.1745 -0.3653 -0.1636 0.3739 0.0006
5.00 0.1776 -0.3480 -0.1614 0.3454 0.0024
6.00 0.1771 -0.3112 -0.1578 0.3096 0.0025
7.00 0.1703 -0.2407 -0.1514 0.2590 -0.0003
8.00 0.1583 -0.1425 -0.1427 0.1959 -0.0052
9.00 0.1459 -0.0429 -0.1327 0.1264 -0.0108

10.00 0.1475 -0.0190 -0.1263 0.0760 -0.0100
11.00 0.1631 -0.0719 -0.1414 0.1433 -0.0084
12.00 0.1734 -0.0966 -0.1391 0.1160 0.0001
13.00 0.1712 -0.0537 -0.1269 0.0352 0.0030
14.00 0.1677 -0.0050 -0.1129 -0.0544 0.0058
15.00 0.1684 0.0213 -0.1036 -0.1183 0.0132
PANEL DEFLECTION ANGLES (DEGREES)
SET FIN 1 FIN 2 FIN 3 FIN 4 FIN 5 FIN 6 FIN 7 FIN 8
1 0.00 0.00 0.00
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 96
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.458E+06 /M
ALTITUDE = 1015.1 M DYNAMIC PRESSURE = 10047.93 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1559 0.0093 0.1370 0.0000
1.00 0.1559 0.0093 0.1372 0.0000
2.00 0.1557 0.0093 0.1373 0.0001
3.00 0.1555 0.0093 0.1374 0.0002
4.00 0.1552 0.0093 0.1374 0.0004
5.00 0.1548 0.0092 0.1374 0.0005
6.00 0.1542 0.0092 0.1373 0.0007
7.00 0.1536 0.0092 0.1373 0.0008
8.00 0.1529 0.0091 0.1371 0.0009
9.00 0.1521 0.0091 0.1370 0.0008
10.00 0.1512 0.0090 0.1367 0.0005
11.00 0.1503 0.0090 0.1365 0.0001
12.00 0.1492 0.0089 0.1362 -0.0008
13.00 0.1480 0.0088 0.1358 -0.0020
14.00 0.1468 0.0088 0.1354 -0.0037
15.00 0.1455 0.0087 0.1350 -0.0060
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.744
2.00 0.091 0.012 0.391 0.002 0.749
3.00 0.137 0.028 0.586 0.005 0.753
4.00 0.182 0.050 0.780 0.010 0.757
5.00 0.227 0.079 0.973 0.015 0.761
6.00 0.272 0.115 1.164 0.022 0.766
7.00 0.316 0.157 1.354 0.030 0.770
8.00 0.360 0.206 1.542 0.039 0.774
9.00 0.403 0.261 1.727 0.050 0.778
10.00 0.446 0.323 1.910 0.062 0.783
11.00 0.488 0.393 2.091 0.075 0.787
12.00 0.529 0.469 2.268 0.090 0.791
13.00 0.570 0.552 2.442 0.105 0.795
14.00 0.609 0.641 2.612 0.123 0.799
15.00 0.648 0.738 2.779 0.141 0.803
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
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FIN SET 1 CA PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.458E+06 /M
ALTITUDE = 1015.1 M DYNAMIC PRESSURE = 10047.93 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
SINGLE FIN PANEL ZERO-LIFT AXIAL FORCE COMPONENTS
SKIN FRICTION 0.0060
SUBSONIC PRESSURE 0.0014
TRANSONIC WAVE 0.0000
SUPERSONIC WAVE 0.0000
LEADING EDGE 0.0000
TRAILING EDGE 0.0000
TOTAL CAO 0.0075
FIN AXIAL FORCE DUE TO ANGLE OF ATTACK
ALPHA CA DUE TO LIFT (SINGLE PANEL) CA-TOTAL (3 FINS)
0.00 0.0000 0.0224
1.00 -0.0003 0.0218
2.00 -0.0014 0.0202
3.00 -0.0031 0.0176
4.00 -0.0055 0.0139
5.00 -0.0086 0.0093
6.00 -0.0124 0.0036
7.00 -0.0168 -0.0031
8.00 -0.0220 -0.0109
9.00 -0.0265 -0.0199
10.00 -0.0285 -0.0280
11.00 -0.0274 -0.0332
12.00 -0.0233 -0.0342
13.00 -0.0168 -0.0308
14.00 -0.0093 -0.0232
15.00 -0.0029 -0.0120
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 98
FIN SET 1 CN, CM PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.458E+06 /M
ALTITUDE = 1015.1 M DYNAMIC PRESSURE = 10047.93 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
NORMAL FORCE SLOPE AT ALPHA ZERO, CNA = 0.03705/DEG (1 PANEL)
CENTER OF PRESSURE FOR LINEAR CN = -5.42732 (CALIBERS FROM C.G.)
CENTER OF PRESSURE FOR NON-LINEAR CN = -5.56657 (CALIBERS FROM C.G.)
ALPHA CN CN CN CM CM CM
LINEAR NON-LINEAR TOTAL LINEAR NON-LINEAR TOTAL
0.00 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1.00 0.0556 0.0002 0.0558 -0.3016 -0.0011 -0.3027
2.00 0.1111 0.0008 0.1119 -0.6029 -0.0045 -0.6074
3.00 0.1665 0.0018 0.1683 -0.9038 -0.0101 -0.9139
4.00 0.2218 0.0032 0.2251 -1.2040 -0.0180 -1.2220
5.00 0.2770 0.0050 0.2820 -1.5033 -0.0281 -1.5314
6.00 0.3319 0.0073 0.3392 -1.8014 -0.0404 -1.8418
7.00 0.3866 0.0099 0.3965 -2.0981 -0.0550 -2.1531

8.00 0.4410 0.0129 0.4538 -2.3932 -0.0718 -2.4650
9.00 0.4950 0.0103 0.5053 -2.6865 -0.0576 -2.7441
10.00 0.5486 -0.0018 0.5468 -2.9777 0.0102 -2.9675
11.00 0.6019 -0.0200 0.5819 -3.2665 0.1111 -3.1554
12.00 0.6546 -0.0450 0.6097 -3.5528 0.2502 -3.3026
13.00 0.7068 -0.0777 0.6291 -3.8363 0.4327 -3.4035
14.00 0.7585 -0.1185 0.6400 -4.1167 0.6598 -3.4569
15.00 0.8096 -0.1288 0.6808 -4.3938 0.7171 -3.6768
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 99
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.458E+06 /M
ALTITUDE = 1015.1 M DYNAMIC PRESSURE = 10047.93 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 IN PRESENCE OF THE BODY——————-
ALPHA CN CM CA CY CLN CLL
0.00 0.0000 0.0000 0.0224 0.0000 0.0000 0.0000
1.00 0.0778 -0.4222 0.0214 0.0000 0.0000 0.0000
2.00 0.1553 -0.8428 0.0184 0.0000 0.0000 0.0000
3.00 0.2323 -1.2610 0.0136 0.0000 0.0000 0.0000
4.00 0.3087 -1.6753 0.0069 0.0000 0.0000 0.0000
5.00 0.3827 -2.0772 -0.0014 0.0000 0.0000 0.0000
6.00 0.4537 -2.4622 -0.0112 0.0000 0.0000 0.0000
7.00 0.5171 -2.8063 -0.0223 0.0000 0.0000 0.0000
8.00 0.5684 -3.0848 -0.0314 0.0000 0.0000 0.0000
9.00 0.6048 -3.2822 -0.0346 0.0000 0.0000 0.0000
10.00 0.6287 -3.4119 -0.0317 0.0000 0.0000 0.0000
11.00 0.6579 -3.5706 -0.0222 0.0000 0.0000 0.0000
12.00 0.6953 -3.7734 -0.0094 0.0000 0.0000 0.0000
13.00 0.7303 -3.9638 0.0041 0.0000 0.0000 0.0000
14.00 0.7556 -4.1007 0.0153 0.0000 0.0000 0.0000
15.00 0.7769 -4.2163 0.0246 0.0000 0.0000 0.0000
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 100
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.458E+06 /M
ALTITUDE = 1015.1 M DYNAMIC PRESSURE = 10047.93 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 PANEL CHARACTERISTICS——————
ALPHA PANEL AEQ (PANEL AXIS SYS.) PANEL CN
0.00 1 0.0000 0.0000
0.00 2 0.0000 0.0000
0.00 3 0.0000 0.0000
1.00 1 0.0000 0.0000
1.00 2 1.2062 0.0449
1.00 3 -1.2062 -0.0449
2.00 1 0.0000 0.0000
2.00 2 2.4023 0.0897
2.00 3 -2.4023 -0.0897

3.00 1 0.0000 0.0000
3.00 2 3.5841 0.1341
3.00 3 -3.5841 -0.1341
4.00 1 0.0000 0.0000
4.00 2 4.7486 0.1782
4.00 3 -4.7486 -0.1782
5.00 1 0.0000 0.0000
5.00 2 5.8797 0.2210
5.00 3 -5.8797 -0.2210
6.00 1 0.0000 0.0000
6.00 2 6.9836 0.2619
6.00 3 -6.9836 -0.2619
7.00 1 0.0000 0.0000
7.00 2 8.0597 0.2985
7.00 3 -8.0597 -0.2985
8.00 1 0.0000 0.0000
8.00 2 9.1068 0.3282
8.00 3 -9.1068 -0.3282
9.00 1 0.0000 0.0000
9.00 2 10.1256 0.3492
9.00 3 -10.1256 -0.3492
10.00 1 0.0000 0.0000
10.00 2 11.1162 0.3630
10.00 3 -11.1162 -0.3630
11.00 1 0.0000 0.0000
11.00 2 12.1764 0.3798
11.00 3 -12.1764 -0.3798
12.00 1 0.0000 0.0000
12.00 2 13.1202 0.4014
12.00 3 -13.1202 -0.4014
13.00 1 0.0000 0.0000
13.00 2 14.0203 0.4217
13.00 3 -14.0203 -0.4217
14.00 1 0.0000 0.0000
14.00 2 14.8958 0.4362
14.00 3 -14.8958 -0.4362
15.00 1 0.0000 0.0000
15.00 2 15.7626 0.4485
15.00 3 -15.7626 -0.4485
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 101
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.458E+06 /M
ALTITUDE = 1015.1 M DYNAMIC PRESSURE = 10047.93 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
CARRYOVER INTERFERENCE FACTORS - FIN SET 1
ALPHA K-W(B) K-B(W) KK-W(B) KK-B(W) XCP-W(B) XCP-B(W) Y-CP/(B/2)
0.00 1.3959 0.5090 0.9348 0.3583 5.4273 5.4173 0.4245
1.00 1.3927 0.5090 0.9348 0.3583 5.4273 5.4173 0.4250
2.00 1.3870 0.5090 0.9348 0.3583 5.4273 5.4173 0.4255
3.00 1.3797 0.5090 0.9348 0.3583 5.4273 5.4173 0.4259
4.00 1.3712 0.5090 0.9348 0.3583 5.4273 5.4173 0.4264

5.00 1.3618 0.5090 0.9348 0.3583 5.4273 5.4173 0.4264
6.00 1.3517 0.5090 0.9348 0.3583 5.4273 5.4173 0.4258
7.00 1.3410 0.5090 0.9348 0.3583 5.4273 5.4173 0.4254
8.00 1.3299 0.5090 0.9348 0.3583 5.4273 5.4173 0.4250
9.00 1.3185 0.5090 0.9348 0.3583 5.4273 5.4173 0.4247
10.00 1.3069 0.5090 0.9348 0.3583 5.4273 5.4173 0.4246
11.00 1.2951 0.5090 0.9348 0.3583 5.4273 5.4173 0.4244
12.00 1.2833 0.5090 0.9348 0.3583 5.4273 5.4173 0.4241
13.00 1.2714 0.5090 0.9348 0.3583 5.4273 5.4173 0.4238
14.00 1.2596 0.5090 0.9348 0.3583 5.4273 5.4173 0.4237
15.00 1.2480 0.5090 0.9348 0.3583 5.4273 5.4173 0.4235
NOTE - XCP-W(B) USED FOR STABILITY ONLY DIFFERENT VALUES USED FOR HINGE MOMENTS
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 102
FIN SET 1 PANEL BENDING MOMENTS (ABOUT EXPOSED ROOT CHORD)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.458E+06 /M
ALTITUDE = 1015.1 M DYNAMIC PRESSURE = 10047.93 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 1.83E-02 -1.83E-02
2.0 0.00E+00 3.66E-02 -3.66E-02
3.0 0.00E+00 5.49E-02 -5.49E-02
4.0 0.00E+00 7.30E-02 -7.30E-02
5.0 1.05E-09 9.05E-02 -9.05E-02
6.0 1.84E-09 1.07E-01 -1.07E-01
7.0 0.00E+00 1.22E-01 -1.22E-01
8.0 3.71E-09 1.34E-01 -1.34E-01
9.0 -2.29E-09 1.42E-01 -1.42E-01
10.0 2.80E-09 1.48E-01 -1.48E-01
11.0 0.00E+00 1.55E-01 -1.55E-01
12.0 -7.24E-09 1.63E-01 -1.63E-01
13.0 1.77E-09 1.72E-01 -1.72E-01
14.0 -1.01E-08 1.77E-01 -1.77E-01
15.0 -3.95E-09 1.82E-01 -1.82E-01
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 103
FIN SET 1 PANEL HINGE MOMENTS (ABOUT HINGE LINE)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.458E+06 /M
ALTITUDE = 1015.1 M DYNAMIC PRESSURE = 10047.93 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 5.41E-03 -5.41E-03
2.0 0.00E+00 1.08E-02 -1.08E-02
3.0 0.00E+00 1.61E-02 -1.61E-02
4.0 0.00E+00 2.14E-02 -2.14E-02
5.0 3.09E-10 2.66E-02 -2.66E-02

6.0 5.41E-10 3.15E-02 -3.15E-02
7.0 0.00E+00 3.59E-02 -3.59E-02
8.0 1.09E-09 3.95E-02 -3.95E-02
9.0 -6.76E-10 4.20E-02 -4.20E-02
10.0 8.28E-10 4.37E-02 -4.37E-02
11.0 0.00E+00 4.57E-02 -4.57E-02
12.0 -2.14E-09 4.83E-02 -4.83E-02
13.0 5.25E-10 5.07E-02 -5.07E-02
14.0 -2.98E-09 5.25E-02 -5.25E-02
15.0 -1.17E-09 5.40E-02 -5.40E-02
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 104
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.458E+06 /M
ALTITUDE = 1015.1 M DYNAMIC PRESSURE = 10047.93 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
—– LONGITUDINAL —– – LATERAL DIRECTIONAL –
ALPHA CN CM CA CY CLN CLL
0.00 0.000 0.000 0.325 0.000 0.000 0.000
1.00 0.155 -0.380 0.324 0.000 0.000 0.000
2.00 0.316 -0.758 0.321 0.000 0.000 0.000
3.00 0.483 -1.134 0.316 0.000 0.000 0.000
4.00 0.656 -1.507 0.309 0.000 0.000 0.000
5.00 0.832 -1.864 0.301 0.000 0.000 0.000
6.00 1.011 -2.202 0.290 0.000 0.000 0.000
7.00 1.186 -2.486 0.279 0.000 0.000 0.000
8.00 1.351 -2.682 0.269 0.000 0.000 0.000
9.00 1.502 -2.770 0.264 0.000 0.000 0.000
10.00 1.643 -2.766 0.266 0.000 0.000 0.000
11.00 1.797 -2.806 0.274 0.000 0.000 0.000
12.00 1.969 -2.910 0.284 0.000 0.000 0.000
13.00 2.144 -3.000 0.295 0.000 0.000 0.000
14.00 2.312 -3.020 0.303 0.000 0.000 0.000
15.00 2.480 -3.013 0.308 0.000 0.000 0.000
ALPHA CL CD CL/CD X-C.P.
0.00 0.000 0.325 0.000 -2.507
1.00 0.149 0.326 0.457 -2.452
2.00 0.305 0.332 0.918 -2.399
3.00 0.466 0.341 1.367 -2.348
4.00 0.633 0.354 1.786 -2.298
5.00 0.803 0.372 2.158 -2.241
6.00 0.975 0.394 2.472 -2.178
7.00 1.143 0.421 2.715 -2.096
8.00 1.301 0.454 2.864 -1.985
9.00 1.442 0.496 2.908 -1.844
10.00 1.571 0.547 2.873 -1.684
11.00 1.712 0.611 2.799 -1.562
12.00 1.867 0.687 2.716 -1.478
13.00 2.023 0.770 2.628 -1.400
14.00 2.170 0.853 2.544 -1.306
15.00 2.316 0.939 2.466 -1.215
X-C.P. MEAS. FROM MOMENT CENTER IN REF. LENGTHS, NEG. AFT OF MOMENT CENTER

1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 105
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.458E+06 /M
ALTITUDE = 1015.1 M DYNAMIC PRESSURE = 10047.93 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
———- DERIVATIVES (PER DEGREE) ———-

ALPHA	CNA	CMA	CYB	CLNB	CLLB
0.00	0.1520	-0.3810	-0.1550	0.3800	0.0000
1.00	0.1580	-0.3791	-0.1562	0.3794	0.0001
2.00	0.1640	-0.3771	-0.1586	0.3783	0.0003
3.00	0.1698	-0.3742	-0.1612	0.3766	0.0006
4.00	0.1745	-0.3651	-0.1636	0.3738	0.0006
5.00	0.1775	-0.3475	-0.1613	0.3452	0.0023
6.00	0.1770	-0.3105	-0.1577	0.3093	0.0025
7.00	0.1702	-0.2399	-0.1513	0.2587	-0.0003
8.00	0.1582	-0.1416	-0.1426	0.1956	-0.0052
9.00	0.1457	-0.0418	-0.1327	0.1260	-0.0109
10.00	0.1473	-0.0180	-0.1262	0.0756	-0.0101
11.00	0.1631	-0.0718	-0.1414	0.1433	-0.0084
12.00	0.1736	-0.0973	-0.1392	0.1163	0.0002
13.00	0.1714	-0.0548	-0.1269	0.0356	0.0031
14.00	0.1679	-0.0061	-0.1130	-0.0540	0.0059
15.00	0.1686	0.0203	-0.1037	-0.1180	0.0133

PANEL DEFLECTION ANGLES (DEGREES)
SET FIN 1 FIN 2 FIN 3 FIN 4 FIN 5 FIN 6 FIN 7 FIN 8
1 0.00 0.00 0.00
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 106
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.50 REYNOLDS NO = 1.107E+07 /M
ALTITUDE = 506.1 M DYNAMIC PRESSURE = 16693.65 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1486 0.0094 0.1370 0.0000
1.00 0.1486 0.0094 0.1372 0.0000
2.00 0.1485 0.0094 0.1373 0.0001
3.00 0.1482 0.0094 0.1373 0.0002
4.00 0.1479 0.0093 0.1374 0.0003
5.00 0.1475 0.0093 0.1374 0.0005
6.00 0.1470 0.0093 0.1373 0.0006
7.00 0.1464 0.0093 0.1372 0.0008
8.00 0.1458 0.0092 0.1371 0.0008
9.00 0.1450 0.0092 0.1369 0.0007
10.00 0.1442 0.0091 0.1367 0.0004
11.00 0.1432 0.0091 0.1364 -0.0001
12.00 0.1422 0.0090 0.1361 -0.0009
13.00 0.1411 0.0089 0.1357 -0.0022
14.00 0.1399 0.0088 0.1353 -0.0040

15.00 0.1387 0.0088 0.1349 -0.0064
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.745
2.00 0.091 0.013 0.391 0.002 0.751
3.00 0.137 0.028 0.586 0.005 0.756
4.00 0.182 0.051 0.780 0.010 0.761
5.00 0.227 0.080 0.973 0.015 0.767
6.00 0.272 0.116 1.164 0.022 0.772
7.00 0.316 0.158 1.354 0.030 0.777
8.00 0.360 0.208 1.542 0.040 0.783
9.00 0.403 0.264 1.727 0.051 0.788
10.00 0.446 0.328 1.910 0.063 0.793
11.00 0.488 0.398 2.091 0.076 0.798
12.00 0.529 0.476 2.268 0.091 0.804
13.00 0.570 0.561 2.442 0.107 0.809
14.00 0.609 0.653 2.612 0.125 0.814
15.00 0.648 0.752 2.779 0.144 0.819
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 107
FIN SET 1 CA PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.50 REYNOLDS NO = 1.107E+07 /M
ALTITUDE = 506.1 M DYNAMIC PRESSURE = 16693.65 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
SINGLE FIN PANEL ZERO-LIFT AXIAL FORCE COMPONENTS
SKIN FRICTION 0.0057
SUBSONIC PRESSURE 0.0014
TRANSONIC WAVE 0.0000
SUPERSONIC WAVE 0.0000
LEADING EDGE 0.0000
TRAILING EDGE 0.0000
TOTAL CAO 0.0070
FIN AXIAL FORCE DUE TO ANGLE OF ATTACK
ALPHA CA DUE TO LIFT (SINGLE PANEL) CA-TOTAL (3 FINS)
0.00 0.0000 0.0211
1.00 -0.0004 0.0205
2.00 -0.0014 0.0188
3.00 -0.0032 0.0161
4.00 -0.0057 0.0123
5.00 -0.0089 0.0075
6.00 -0.0128 0.0017
7.00 -0.0175 -0.0053
8.00 -0.0229 -0.0134
9.00 -0.0276 -0.0227
10.00 -0.0296 -0.0312
11.00 -0.0285 -0.0365
12.00 -0.0242 -0.0377
13.00 -0.0175 -0.0342
14.00 -0.0097 -0.0263
15.00 -0.0030 -0.0147
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1

AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 108
FIN SET 1 CN, CM PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.50 REYNOLDS NO = 1.107E+07 /M
ALTITUDE = 506.1 M DYNAMIC PRESSURE = 16693.65 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
NORMAL FORCE SLOPE AT ALPHA ZERO, CNA = 0.03832/DEG (1 PANEL)
CENTER OF PRESSURE FOR LINEAR CN = -5.42698 (CALIBERS FROM C.G.)
CENTER OF PRESSURE FOR NON-LINEAR CN = -5.56657 (CALIBERS FROM C.G.)

ALPHA	CN LINEAR	CN NON-LINEAR	CN TOTAL	CM LINEAR	CM NON-LINEAR	CM TOTAL
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.00	0.0575	0.0002	0.0577	-0.3119	-0.0011	-0.3130
2.00	0.1149	0.0008	0.1157	-0.6235	-0.0044	-0.6279
3.00	0.1722	0.0018	0.1740	-0.9346	-0.0100	-0.9446
4.00	0.2294	0.0032	0.2326	-1.2451	-0.0177	-1.2628
5.00	0.2865	0.0050	0.2914	-1.5546	-0.0277	-1.5822
6.00	0.3433	0.0071	0.3504	-1.8629	-0.0398	-1.9027
7.00	0.3998	0.0097	0.4095	-2.1697	-0.0541	-2.2238
8.00	0.4560	0.0127	0.4687	-2.4749	-0.0706	-2.5455
9.00	0.5119	0.0111	0.5230	-2.7782	-0.0616	-2.8398
10.00	0.5674	-0.0008	0.5666	-3.0793	0.0045	-3.0748
11.00	0.6224	-0.0186	0.6039	-3.3780	0.1034	-3.2747
12.00	0.6770	-0.0431	0.6339	-3.6741	0.2399	-3.4342
13.00	0.7310	-0.0753	0.6557	-3.9672	0.4193	-3.5479
14.00	0.7845	-0.1162	0.6683	-4.2572	0.6468	-3.6104
15.00	0.8373	-0.1304	0.7068	-4.5438	0.7260	-3.8178

1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 109
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.50 REYNOLDS NO = 1.107E+07 /M
ALTITUDE = 506.1 M DYNAMIC PRESSURE = 16693.65 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 IN PRESENCE OF THE BODY——————-

ALPHA	CN	CM	CA	CY	CLN	CLL
0.00	0.0000	0.0000	0.0211	0.0000	0.0000	0.0000
1.00	0.0804	-0.4365	0.0201	0.0000	0.0000	0.0000
2.00	0.1605	-0.8713	0.0170	0.0000	0.0000	0.0000
3.00	0.2402	-1.3034	0.0120	0.0000	0.0000	0.0000
4.00	0.3189	-1.7307	0.0051	0.0000	0.0000	0.0000
5.00	0.3954	-2.1458	-0.0035	0.0000	0.0000	0.0000
6.00	0.4691	-2.5455	-0.0137	0.0000	0.0000	0.0000
7.00	0.5352	-2.9045	-0.0252	0.0000	0.0000	0.0000
8.00	0.5890	-3.1965	-0.0347	0.0000	0.0000	0.0000
9.00	0.6280	-3.4079	-0.0381	0.0000	0.0000	0.0000
10.00	0.6546	-3.5525	-0.0352	0.0000	0.0000	0.0000
11.00	0.6863	-3.7248	-0.0253	0.0000	0.0000	0.0000
12.00	0.7250	-3.9343	-0.0121	0.0000	0.0000	0.0000
13.00	0.7607	-4.1286	0.0021	0.0000	0.0000	0.0000
14.00	0.7866	-4.2687	0.0138	0.0000	0.0000	0.0000

15.00 0.8085 -4.3878 0.0236 0.0000 0.0000 0.0000
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 110
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.50 REYNOLDS NO = 1.107E+07 /M
ALTITUDE = 506.1 M DYNAMIC PRESSURE = 16693.65 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 PANEL CHARACTERISTICS——————
ALPHA PANEL AEQ (PANEL AXIS SYS.) PANEL CN
0.00 1 0.0000 0.0000
0.00 2 0.0000 0.0000
0.00 3 0.0000 0.0000
1.00 1 0.0000 0.0000
1.00 2 1.2062 0.0464
1.00 3 -1.2062 -0.0464
2.00 1 0.0000 0.0000
2.00 2 2.4023 0.0927
2.00 3 -2.4023 -0.0927
3.00 1 0.0000 0.0000
3.00 2 3.5841 0.1387
3.00 3 -3.5841 -0.1387
4.00 1 0.0000 0.0000
4.00 2 4.7486 0.1841
4.00 3 -4.7486 -0.1841
5.00 1 0.0000 0.0000
5.00 2 5.8796 0.2283
5.00 3 -5.8796 -0.2283
6.00 1 0.0000 0.0000
6.00 2 6.9834 0.2708
6.00 3 -6.9834 -0.2708
7.00 1 0.0000 0.0000
7.00 2 8.0591 0.3090
7.00 3 -8.0591 -0.3090
8.00 1 0.0000 0.0000
8.00 2 9.1058 0.3401
8.00 3 -9.1058 -0.3401
9.00 1 0.0000 0.0000
9.00 2 10.1239 0.3626
9.00 3 -10.1239 -0.3626
10.00 1 0.0000 0.0000
10.00 2 11.1137 0.3779
10.00 3 -11.1137 -0.3779
11.00 1 0.0000 0.0000
11.00 2 12.1764 0.3963
11.00 3 -12.1764 -0.3963
12.00 1 0.0000 0.0000
12.00 2 13.1202 0.4186
12.00 3 -13.1202 -0.4186
13.00 1 0.0000 0.0000
13.00 2 14.0203 0.4392
13.00 3 -14.0203 -0.4392
14.00 1 0.0000 0.0000

14.00 2 14.8958 0.4541
14.00 3 -14.8958 -0.4541
15.00 1 0.0000 0.0000
15.00 2 15.7626 0.4668
15.00 3 -15.7626 -0.4668
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 111
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.50 REYNOLDS NO = 1.107E+07 /M
ALTITUDE = 506.1 M DYNAMIC PRESSURE = 16693.65 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
CARRYOVER INTERFERENCE FACTORS - FIN SET 1
ALPHA K-W(B) K-B(W) KK-W(B) KK-B(W) XCP-W(B) XCP-B(W) Y-CP/(B/2)
0.00 1.3959 0.5090 0.9348 0.3583 5.4270 5.4173 0.4307
1.00 1.3927 0.5090 0.9348 0.3583 5.4270 5.4173 0.4309
2.00 1.3870 0.5090 0.9348 0.3583 5.4270 5.4173 0.4311
3.00 1.3797 0.5090 0.9348 0.3583 5.4270 5.4173 0.4312
4.00 1.3712 0.5090 0.9348 0.3583 5.4270 5.4173 0.4314
5.00 1.3618 0.5090 0.9348 0.3583 5.4270 5.4173 0.4309
6.00 1.3517 0.5090 0.9348 0.3583 5.4270 5.4173 0.4301
7.00 1.3410 0.5090 0.9348 0.3583 5.4270 5.4173 0.4293
8.00 1.3299 0.5090 0.9348 0.3583 5.4270 5.4173 0.4287
9.00 1.3185 0.5090 0.9348 0.3583 5.4270 5.4173 0.4283
10.00 1.3069 0.5090 0.9348 0.3583 5.4270 5.4173 0.4280
11.00 1.2951 0.5090 0.9348 0.3583 5.4270 5.4173 0.4277
12.00 1.2833 0.5090 0.9348 0.3583 5.4270 5.4173 0.4271
13.00 1.2714 0.5090 0.9348 0.3583 5.4270 5.4173 0.4266
14.00 1.2596 0.5090 0.9348 0.3583 5.4270 5.4173 0.4262
15.00 1.2480 0.5090 0.9348 0.3583 5.4270 5.4173 0.4258
NOTE - XCP-W(B) USED FOR STABILITY ONLY DIFFERENT VALUES USED FOR HINGE MOMENTS
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 112
FIN SET 1 PANEL BENDING MOMENTS (ABOUT EXPOSED ROOT CHORD)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.50 REYNOLDS NO = 1.107E+07 /M
ALTITUDE = 506.1 M DYNAMIC PRESSURE = 16693.65 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 1.92E-02 -1.92E-02
2.0 0.00E+00 3.84E-02 -3.84E-02
3.0 0.00E+00 5.74E-02 -5.74E-02
4.0 0.00E+00 7.63E-02 -7.63E-02
5.0 1.11E-09 9.44E-02 -9.44E-02
6.0 1.93E-09 1.12E-01 -1.12E-01
7.0 0.00E+00 1.27E-01 -1.27E-01
8.0 3.91E-09 1.40E-01 -1.40E-01
9.0 -2.42E-09 1.49E-01 -1.49E-01
10.0 2.96E-09 1.55E-01 -1.55E-01

11.0 0.00E+00 1.63E-01 -1.63E-01
12.0 -7.54E-09 1.72E-01 -1.72E-01
13.0 1.85E-09 1.80E-01 -1.80E-01
14.0 -1.05E-08 1.86E-01 -1.86E-01
15.0 -4.10E-09 1.91E-01 -1.91E-01
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 113
FIN SET 1 PANEL HINGE MOMENTS (ABOUT HINGE LINE)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.50 REYNOLDS NO = 1.107E+07 /M
ALTITUDE = 506.1 M DYNAMIC PRESSURE = 16693.65 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 5.60E-03 -5.60E-03
2.0 0.00E+00 1.12E-02 -1.12E-02
3.0 0.00E+00 1.67E-02 -1.67E-02
4.0 0.00E+00 2.22E-02 -2.22E-02
5.0 3.23E-10 2.75E-02 -2.75E-02
6.0 5.65E-10 3.27E-02 -3.27E-02
7.0 0.00E+00 3.73E-02 -3.73E-02
8.0 1.15E-09 4.10E-02 -4.10E-02
9.0 -7.10E-10 4.38E-02 -4.38E-02
10.0 8.70E-10 4.56E-02 -4.56E-02
11.0 0.00E+00 4.78E-02 -4.78E-02
12.0 -2.22E-09 5.05E-02 -5.05E-02
13.0 5.44E-10 5.30E-02 -5.30E-02
14.0 -3.09E-09 5.48E-02 -5.48E-02
15.0 -1.21E-09 5.63E-02 -5.63E-02
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 114
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.50 REYNOLDS NO = 1.107E+07 /M
ALTITUDE = 506.1 M DYNAMIC PRESSURE = 16693.65 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
—– LONGITUDINAL —– – LATERAL DIRECTIONAL –
ALPHA CN CM CA CY CLN CLL
0.00 0.000 0.000 0.316 0.000 0.000 0.000
1.00 0.159 -0.400 0.315 0.000 0.000 0.000
2.00 0.323 -0.797 0.312 0.000 0.000 0.000
3.00 0.494 -1.192 0.307 0.000 0.000 0.000
4.00 0.670 -1.582 0.300 0.000 0.000 0.000
5.00 0.850 -1.959 0.291 0.000 0.000 0.000
6.00 1.033 -2.316 0.281 0.000 0.000 0.000
7.00 1.212 -2.621 0.268 0.000 0.000 0.000
8.00 1.382 -2.836 0.258 0.000 0.000 0.000
9.00 1.538 -2.943 0.254 0.000 0.000 0.000
10.00 1.683 -2.961 0.255 0.000 0.000 0.000
11.00 1.842 -3.019 0.263 0.000 0.000 0.000
12.00 2.018 -3.133 0.274 0.000 0.000 0.000

13.00 2.196 -3.229 0.286 0.000 0.000 0.000
14.00 2.367 -3.253 0.294 0.000 0.000 0.000
15.00 2.539 -3.251 0.300 0.000 0.000 0.000
ALPHA CL CD CL/CD X-C.P.
0.00 0.000 0.316 0.000 -2.575
1.00 0.153 0.318 0.481 -2.519
2.00 0.312 0.323 0.965 -2.466
3.00 0.477 0.333 1.435 -2.414
4.00 0.647 0.346 1.871 -2.362
5.00 0.821 0.364 2.255 -2.304
6.00 0.998 0.387 2.578 -2.243
7.00 1.171 0.414 2.826 -2.162
8.00 1.332 0.448 2.975 -2.053
9.00 1.479 0.491 3.012 -1.914
10.00 1.613 0.544 2.968 -1.759
11.00 1.758 0.610 2.882 -1.639
12.00 1.917 0.688 2.787 -1.553
13.00 2.075 0.772 2.687 -1.471
14.00 2.226 0.858 2.595 -1.374
15.00 2.375 0.946 2.509 -1.281
X-C.P. MEAS. FROM MOMENT CENTER IN REF. LENGTHS, NEG. AFT OF MOMENT CENTER
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 115
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.50 REYNOLDS NO = 1.107E+07 /M
ALTITUDE = 506.1 M DYNAMIC PRESSURE = 16693.65 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
———- DERIVATIVES (PER DEGREE) ———-
ALPHA CNA CMA CYB CLNB CLLB
0.00 0.1556 -0.4005 -0.1586 0.3995 0.0000
1.00 0.1616 -0.3985 -0.1598 0.3988 0.0001
2.00 0.1676 -0.3963 -0.1622 0.3977 0.0003
3.00 0.1734 -0.3927 -0.1647 0.3957 0.0005
4.00 0.1780 -0.3832 -0.1672 0.3927 0.0004
5.00 0.1814 -0.3668 -0.1649 0.3636 0.0023
6.00 0.1812 -0.3310 -0.1612 0.3273 0.0027
7.00 0.1745 -0.2596 -0.1546 0.2751 0.0000
8.00 0.1626 -0.1608 -0.1456 0.2104 -0.0048
9.00 0.1506 -0.0620 -0.1356 0.1398 -0.0101
10.00 0.1523 -0.0379 -0.1288 0.0872 -0.0092
11.00 0.1674 -0.0861 -0.1444 0.1562 -0.0085
12.00 0.1769 -0.1050 -0.1415 0.1257 -0.0003
13.00 0.1746 -0.0600 -0.1289 0.0421 0.0027
14.00 0.1714 -0.0109 -0.1146 -0.0499 0.0059
15.00 0.1724 0.0152 -0.1051 -0.1159 0.0136
PANEL DEFLECTION ANGLES (DEGREES)
SET FIN 1 FIN 2 FIN 3 FIN 4 FIN 5 FIN 6 FIN 7 FIN 8
1 0.00 0.00 0.00
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 116
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******

MACH NO = 0.52 REYNOLDS NO = 1.140E+07 /M
ALTITUDE = 600.0 M DYNAMIC PRESSURE = 17784.96 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1478 0.0095 0.1368 0.0000
1.00 0.1477 0.0095 0.1370 0.0000
2.00 0.1476 0.0094 0.1371 0.0001
3.00 0.1474 0.0094 0.1372 0.0002
4.00 0.1471 0.0094 0.1372 0.0003
5.00 0.1467 0.0094 0.1372 0.0005
6.00 0.1462 0.0094 0.1371 0.0006
7.00 0.1456 0.0093 0.1370 0.0008
8.00 0.1449 0.0093 0.1369 0.0008
9.00 0.1442 0.0092 0.1367 0.0007
10.00 0.1433 0.0092 0.1365 0.0004
11.00 0.1424 0.0091 0.1362 -0.0001
12.00 0.1414 0.0091 0.1359 -0.0010
13.00 0.1403 0.0090 0.1355 -0.0022
14.00 0.1391 0.0089 0.1351 -0.0040
15.00 0.1379 0.0088 0.1347 -0.0065
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.746
2.00 0.091 0.013 0.391 0.002 0.751
3.00 0.137 0.028 0.586 0.005 0.757
4.00 0.182 0.051 0.780 0.010 0.762
5.00 0.227 0.080 0.973 0.015 0.768
6.00 0.272 0.116 1.164 0.022 0.773
7.00 0.316 0.159 1.354 0.030 0.779
8.00 0.360 0.208 1.542 0.040 0.784
9.00 0.403 0.265 1.727 0.051 0.790
10.00 0.446 0.329 1.910 0.063 0.795
11.00 0.488 0.400 2.091 0.076 0.801
12.00 0.529 0.478 2.268 0.091 0.806
13.00 0.570 0.563 2.442 0.108 0.812
14.00 0.609 0.655 2.612 0.125 0.817
15.00 0.648 0.755 2.779 0.144 0.822
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 117
FIN SET 1 CA PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.52 REYNOLDS NO = 1.140E+07 /M
ALTITUDE = 600.0 M DYNAMIC PRESSURE = 17784.96 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
SINGLE FIN PANEL ZERO-LIFT AXIAL FORCE COMPONENTS
SKIN FRICTION 0.0056
SUBSONIC PRESSURE 0.0014
TRANSONIC WAVE 0.0000
SUPERSONIC WAVE 0.0000
LEADING EDGE 0.0000

TRAILING EDGE 0.0000
TOTAL CAO 0.0070
FIN AXIAL FORCE DUE TO ANGLE OF ATTACK
ALPHA CA DUE TO LIFT (SINGLE PANEL) CA-TOTAL (3 FINS)
0.00 0.0000 0.0210
1.00 -0.0004 0.0203
2.00 -0.0014 0.0187
3.00 -0.0032 0.0159
4.00 -0.0057 0.0122
5.00 -0.0089 0.0073
6.00 -0.0129 0.0014
7.00 -0.0176 -0.0056
8.00 -0.0230 -0.0137
9.00 -0.0277 -0.0230
10.00 -0.0297 -0.0316
11.00 -0.0286 -0.0370
12.00 -0.0243 -0.0381
13.00 -0.0176 -0.0346
14.00 -0.0097 -0.0266
15.00 -0.0030 -0.0150
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 118
FIN SET 1 CN, CM PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.52 REYNOLDS NO = 1.140E+07 /M
ALTITUDE = 600.0 M DYNAMIC PRESSURE = 17784.96 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
NORMAL FORCE SLOPE AT ALPHA ZERO, CNA = 0.03861/DEG (1 PANEL)
CENTER OF PRESSURE FOR LINEAR CN = -5.42692 (CALIBERS FROM C.G.)
CENTER OF PRESSURE FOR NON-LINEAR CN = -5.56657 (CALIBERS FROM C.G.)
ALPHA CN CN CN CM CM CM
LINEAR NON-LINEAR TOTAL LINEAR NON-LINEAR TOTAL
0.00 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1.00 0.0579 0.0002 0.0581 -0.3143 -0.0010 -0.3153
2.00 0.1158 0.0008 0.1165 -0.6283 -0.0042 -0.6325
3.00 0.1735 0.0017 0.1752 -0.9418 -0.0094 -0.9512
4.00 0.2312 0.0030 0.2342 -1.2546 -0.0168 -1.2714
5.00 0.2887 0.0047 0.2934 -1.5665 -0.0262 -1.5927
6.00 0.3459 0.0068 0.3527 -1.8771 -0.0377 -1.9148
7.00 0.4029 0.0092 0.4121 -2.1864 -0.0512 -2.2376
8.00 0.4595 0.0120 0.4715 -2.4939 -0.0668 -2.5607
9.00 0.5159 0.0099 0.5257 -2.7995 -0.0550 -2.8545
10.00 0.5718 -0.0023 0.5694 -3.1029 0.0129 -3.0900
11.00 0.6272 -0.0204 0.6068 -3.4039 0.1138 -3.2902
12.00 0.6822 -0.0454 0.6368 -3.7022 0.2526 -3.4496
13.00 0.7366 -0.0781 0.6585 -3.9976 0.4347 -3.5630
14.00 0.7905 -0.1195 0.6710 -4.2898 0.6650 -3.6248
15.00 0.8437 -0.1323 0.7114 -4.5786 0.7363 -3.8424
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 119
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.52 REYNOLDS NO = 1.140E+07 /M

ALTITUDE = 600.0 M DYNAMIC PRESSURE = 17784.96 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 IN PRESENCE OF THE BODY——————-

ALPHA	CN	CM	CA	CY	CLN	CLL
0.00	0.0000	0.0000	0.0210	0.0000	0.0000	0.0000
1.00	0.0810	-0.4397	0.0199	0.0000	0.0000	0.0000
2.00	0.1617	-0.8775	0.0168	0.0000	0.0000	0.0000
3.00	0.2418	-1.3123	0.0118	0.0000	0.0000	0.0000
4.00	0.3211	-1.7423	0.0048	0.0000	0.0000	0.0000
5.00	0.3979	-2.1596	-0.0038	0.0000	0.0000	0.0000
6.00	0.4718	-2.5606	-0.0140	0.0000	0.0000	0.0000
7.00	0.5381	-2.9204	-0.0256	0.0000	0.0000	0.0000
8.00	0.5921	-3.2134	-0.0351	0.0000	0.0000	0.0000
9.00	0.6311	-3.4251	-0.0386	0.0000	0.0000	0.0000
10.00	0.6577	-3.5692	-0.0356	0.0000	0.0000	0.0000
11.00	0.6896	-3.7423	-0.0256	0.0000	0.0000	0.0000
12.00	0.7287	-3.9546	-0.0124	0.0000	0.0000	0.0000
13.00	0.7652	-4.1528	0.0018	0.0000	0.0000	0.0000
14.00	0.7919	-4.2974	0.0136	0.0000	0.0000	0.0000
15.00	0.8146	-4.4207	0.0234	0.0000	0.0000	0.0000

1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 120
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.52 REYNOLDS NO = 1.140E+07 /M
ALTITUDE = 600.0 M DYNAMIC PRESSURE = 17784.96 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
——————FIN SET 1 PANEL CHARACTERISTICS——————

ALPHA	PANEL	AEQ (PANEL AXIS SYS.)	PANEL CN
0.00	1	0.0000	0.0000
0.00	2	0.0000	0.0000
0.00	3	0.0000	0.0000
1.00	1	0.0000	0.0000
1.00	2	1.2062	0.0468
1.00	3	-1.2062	-0.0468
2.00	1	0.0000	0.0000
2.00	2	2.4023	0.0934
2.00	3	-2.4023	-0.0934
3.00	1	0.0000	0.0000
3.00	2	3.5841	0.1396
3.00	3	-3.5841	-0.1396
4.00	1	0.0000	0.0000
4.00	2	4.7486	0.1854
4.00	3	-4.7486	-0.1854
5.00	1	0.0000	0.0000
5.00	2	5.8795	0.2298
5.00	3	-5.8795	-0.2298
6.00	1	0.0000	0.0000
6.00	2	6.9833	0.2724
6.00	3	-6.9833	-0.2724
7.00	1	0.0000	0.0000

7.00 2 8.0590 0.3107
7.00 3 -8.0590 -0.3107
8.00 1 0.0000 0.0000
8.00 2 9.1056 0.3419
8.00 3 -9.1056 -0.3419
9.00 1 0.0000 0.0000
9.00 2 10.1236 0.3644
9.00 3 -10.1236 -0.3644
10.00 1 0.0000 0.0000
10.00 2 11.1132 0.3797
10.00 3 -11.1132 -0.3797
11.00 1 0.0000 0.0000
11.00 2 12.1764 0.3981
11.00 3 -12.1764 -0.3981
12.00 1 0.0000 0.0000
12.00 2 13.1202 0.4207
12.00 3 -13.1202 -0.4207
13.00 1 0.0000 0.0000
13.00 2 14.0203 0.4418
13.00 3 -14.0203 -0.4418
14.00 1 0.0000 0.0000
14.00 2 14.8958 0.4572
14.00 3 -14.8958 -0.4572
15.00 1 0.0000 0.0000
15.00 2 15.7626 0.4703
15.00 3 -15.7626 -0.4703
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 121
AERODYNAMIC FORCE AND MOMENT SYNTHESIS
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.52 REYNOLDS NO = 1.140E+07 /M
ALTITUDE = 600.0 M DYNAMIC PRESSURE = 17784.96 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
CARRYOVER INTERFERENCE FACTORS - FIN SET 1
ALPHA K-W(B) K-B(W) KK-W(B) KK-B(W) XCP-W(B) XCP-B(W) Y-CP/(B/2)
0.00 1.3959 0.5090 0.9348 0.3583 5.4269 5.4173 0.4319
1.00 1.3927 0.5090 0.9348 0.3583 5.4269 5.4173 0.4320
2.00 1.3870 0.5090 0.9348 0.3583 5.4269 5.4173 0.4321
3.00 1.3797 0.5090 0.9348 0.3583 5.4269 5.4173 0.4322
4.00 1.3712 0.5090 0.9348 0.3583 5.4269 5.4173 0.4323
5.00 1.3618 0.5090 0.9348 0.3583 5.4269 5.4173 0.4317
6.00 1.3517 0.5090 0.9348 0.3583 5.4269 5.4173 0.4309
7.00 1.3410 0.5090 0.9348 0.3583 5.4269 5.4173 0.4301
8.00 1.3299 0.5090 0.9348 0.3583 5.4269 5.4173 0.4294
9.00 1.3185 0.5090 0.9348 0.3583 5.4269 5.4173 0.4290
10.00 1.3069 0.5090 0.9348 0.3583 5.4269 5.4173 0.4287
11.00 1.2951 0.5090 0.9348 0.3583 5.4269 5.4173 0.4283
12.00 1.2833 0.5090 0.9348 0.3583 5.4269 5.4173 0.4277
13.00 1.2714 0.5090 0.9348 0.3583 5.4269 5.4173 0.4270
14.00 1.2596 0.5090 0.9348 0.3583 5.4269 5.4173 0.4266
15.00 1.2480 0.5090 0.9348 0.3583 5.4269 5.4173 0.4262
NOTE - XCP-W(B) USED FOR STABILITY ONLY DIFFERENT VALUES USED FOR HINGE MOMENTS

1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 122
FIN SET 1 PANEL BENDING MOMENTS (ABOUT EXPOSED ROOT CHORD)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.52 REYNOLDS NO = 1.140E+07 /M
ALTITUDE = 600.0 M DYNAMIC PRESSURE = 17784.96 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 1.94E-02 -1.94E-02
2.0 0.00E+00 3.87E-02 -3.87E-02
3.0 0.00E+00 5.79E-02 -5.79E-02
4.0 0.00E+00 7.69E-02 -7.69E-02
5.0 1.12E-09 9.52E-02 -9.52E-02
6.0 1.96E-09 1.13E-01 -1.13E-01
7.0 0.00E+00 1.28E-01 -1.28E-01
8.0 3.95E-09 1.41E-01 -1.41E-01
9.0 -2.45E-09 1.50E-01 -1.50E-01
10.0 3.00E-09 1.56E-01 -1.56E-01
11.0 0.00E+00 1.64E-01 -1.64E-01
12.0 -7.61E-09 1.73E-01 -1.73E-01
13.0 1.86E-09 1.81E-01 -1.81E-01
14.0 -1.06E-08 1.87E-01 -1.87E-01
15.0 -4.14E-09 1.92E-01 -1.92E-01
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 123
FIN SET 1 PANEL HINGE MOMENTS (ABOUT HINGE LINE)
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.52 REYNOLDS NO = 1.140E+07 /M
ALTITUDE = 600.0 M DYNAMIC PRESSURE = 17784.96 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA PANL 1 PANL 2 PANL 3 PANL 4 PANL 5 PANL 6 PANL 7 PANL 8
0.0 0.00E+00 0.00E+00 0.00E+00
1.0 0.00E+00 5.65E-03 -5.65E-03
2.0 0.00E+00 1.13E-02 -1.13E-02
3.0 0.00E+00 1.69E-02 -1.69E-02
4.0 0.00E+00 2.24E-02 -2.24E-02
5.0 3.26E-10 2.77E-02 -2.77E-02
6.0 5.71E-10 3.29E-02 -3.29E-02
7.0 0.00E+00 3.75E-02 -3.75E-02
8.0 1.16E-09 4.13E-02 -4.13E-02
9.0 -7.17E-10 4.40E-02 -4.40E-02
10.0 8.79E-10 4.58E-02 -4.58E-02
11.0 0.00E+00 4.81E-02 -4.81E-02
12.0 -2.24E-09 5.08E-02 -5.08E-02
13.0 5.48E-10 5.33E-02 -5.33E-02
14.0 -3.11E-09 5.52E-02 -5.52E-02
15.0 -1.22E-09 5.68E-02 -5.68E-02
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 124
STATIC AERODYNAMICS FOR BODY-FIN SET 1

******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.52 REYNOLDS NO = 1.140E+07 /M
ALTITUDE = 600.0 M DYNAMIC PRESSURE = 17784.96 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
—– LONGITUDINAL —– – LATERAL DIRECTIONAL –
ALPHA CN CM CA CY CLN CLL
0.00 0.000 0.000 0.315 0.000 0.000 0.000
1.00 0.159 -0.404 0.314 0.000 0.000 0.000
2.00 0.325 -0.806 0.311 0.000 0.000 0.000
3.00 0.496 -1.204 0.306 0.000 0.000 0.000
4.00 0.673 -1.598 0.299 0.000 0.000 0.000
5.00 0.854 -1.978 0.290 0.000 0.000 0.000
6.00 1.037 -2.337 0.279 0.000 0.000 0.000
7.00 1.217 -2.643 0.267 0.000 0.000 0.000
8.00 1.387 -2.860 0.257 0.000 0.000 0.000
9.00 1.543 -2.967 0.252 0.000 0.000 0.000
10.00 1.688 -2.984 0.254 0.000 0.000 0.000
11.00 1.848 -3.044 0.262 0.000 0.000 0.000
12.00 2.024 -3.161 0.273 0.000 0.000 0.000
13.00 2.204 -3.263 0.284 0.000 0.000 0.000
14.00 2.377 -3.293 0.293 0.000 0.000 0.000
15.00 2.550 -3.297 0.298 0.000 0.000 0.000
ALPHA CL CD CL/CD X-C.P.
0.00 0.000 0.315 0.000 -2.590
1.00 0.154 0.317 0.486 -2.534
2.00 0.314 0.322 0.974 -2.480
3.00 0.479 0.331 1.446 -2.428
4.00 0.650 0.345 1.885 -2.375
5.00 0.825 0.363 2.271 -2.317
6.00 1.002 0.386 2.595 -2.254
7.00 1.175 0.413 2.843 -2.172
8.00 1.337 0.447 2.990 -2.062
9.00 1.484 0.490 3.026 -1.924
10.00 1.618 0.543 2.980 -1.768
11.00 1.764 0.610 2.893 -1.647
12.00 1.923 0.688 2.796 -1.562
13.00 2.084 0.773 2.696 -1.480
14.00 2.235 0.859 2.602 -1.386
15.00 2.386 0.948 2.516 -1.293
X-C.P. MEAS. FROM MOMENT CENTER IN REF. LENGTHS, NEG. AFT OF MOMENT CENTER
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 125
STATIC AERODYNAMICS FOR BODY-FIN SET 1
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.52 REYNOLDS NO = 1.140E+07 /M
ALTITUDE = 600.0 M DYNAMIC PRESSURE = 17784.96 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
———- DERIVATIVES (PER DEGREE) ———-
ALPHA CNA CMA CYB CLNB CLLB
0.00 0.1564 -0.4051 -0.1594 0.4039 0.0000
1.00 0.1624 -0.4028 -0.1606 0.4032 0.0001

2.00 0.1684 -0.4002 -0.1630 0.4019 0.0003
3.00 0.1741 -0.3965 -0.1655 0.3998 0.0004
4.00 0.1787 -0.3865 -0.1679 0.3967 0.0003
5.00 0.1819 -0.3692 -0.1655 0.3671 0.0022
6.00 0.1816 -0.3324 -0.1618 0.3302 0.0025
7.00 0.1748 -0.2609 -0.1551 0.2777 -0.0002
8.00 0.1629 -0.1617 -0.1461 0.2126 -0.0050
9.00 0.1508 -0.0620 -0.1359 0.1413 -0.0103
10.00 0.1526 -0.0382 -0.1291 0.0882 -0.0094
11.00 0.1681 -0.0886 -0.1450 0.1590 -0.0086
12.00 0.1781 -0.1097 -0.1423 0.1291 -0.0001
13.00 0.1761 -0.0659 -0.1296 0.0454 0.0031
14.00 0.1730 -0.0170 -0.1153 -0.0471 0.0063
15.00 0.1741 0.0093 -0.1056 -0.1138 0.0141
PANEL DEFLECTION ANGLES (DEGREES)
SET FIN 1 FIN 2 FIN 3 FIN 4 FIN 5 FIN 6 FIN 7 FIN 8
1 0.00 0.00 0.00
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 1
CASE INPUTS
FOLLOWING ARE THE CARDS INPUT FOR THIS CASE
$TRIM SET=1.,$
PRINT AERO BODY
PLOT
NEXT CASE
* WARNING * THE REFERENCE AREA IS UNSPECIFIED, DEFAULT VALUE ASSUMED
* WARNING * THE REFERENCE LENGTH IS UNSPECIFIED, DEFAULT VALUE ASSUMED
THE BOUNDARY LAYER IS ASSUMED TO BE TURBULENT
THE INPUT UNITS ARE IN METERS, THE SCALE FACTOR IS 1.0000
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 2
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.00 REYNOLDS NO = 2.269E+04 /M
ALTITUDE = 240.0 M DYNAMIC PRESSURE = 0.07 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.5032 0.0275 0.1370 0.0000
1.00 0.5031 0.0275 0.1372 0.0001
2.00 0.5026 0.0275 0.1373 0.0003
3.00 0.5019 0.0275 0.1374 0.0007
4.00 0.5008 0.0274 0.1375 0.0013
5.00 0.4994 0.0273 0.1375 0.0019
6.00 0.4977 0.0272 0.1375 0.0027
7.00 0.4958 0.0271 0.1374 0.0036
8.00 0.4935 0.0270 0.1373 0.0045
9.00 0.4909 0.0269 0.1372 0.0054
10.00 0.4881 0.0267 0.1370 0.0062
11.00 0.4849 0.0265 0.1367 0.0070
12.00 0.4815 0.0263 0.1365 0.0075
13.00 0.4778 0.0261 0.1361 0.0078
14.00 0.4738 0.0259 0.1358 0.0078
15.00 0.4695 0.0257 0.1354 0.0073

CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.740
2.00 0.091 0.012 0.391 0.002 0.740
3.00 0.137 0.028 0.586 0.005 0.740
4.00 0.182 0.049 0.780 0.009 0.740
5.00 0.227 0.077 0.973 0.015 0.740
6.00 0.272 0.111 1.164 0.021 0.740
7.00 0.316 0.151 1.354 0.029 0.740
8.00 0.360 0.197 1.542 0.038 0.740
9.00 0.403 0.248 1.727 0.047 0.740
10.00 0.446 0.306 1.910 0.058 0.740
11.00 0.488 0.369 2.091 0.071 0.740
12.00 0.529 0.439 2.268 0.084 0.740
13.00 0.570 0.513 2.442 0.098 0.740
14.00 0.609 0.594 2.612 0.113 0.740
15.00 0.648 0.680 2.779 0.130 0.740
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 3
STATIC AERODYNAMIC COEFFICIENTS TRIMMED IN PITCH
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.00 REYNOLDS NO = 2.269E+04 /M
ALTITUDE = 240.0 M DYNAMIC PRESSURE = 0.07 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA DELTA CL CD CN CA
0.00 0.00 0.000 0.776 0.000 0.776
1.00 -1.37 0.071 0.779 0.085 0.778
2.00 -2.81 0.149 0.784 0.176 0.778
3.00 -4.26 0.232 0.790 0.273 0.777
4.00 -5.65 0.322 0.801 0.377 0.777
5.00 -7.06 0.416 0.817 0.486 0.778
6.00 -8.48 0.516 0.836 0.601 0.777
7.00 -9.83 0.622 0.857 0.721 0.775
8.00 -11.15 0.731 0.886 0.847 0.776
9.00 -12.48 0.845 0.920 0.978 0.776
10.00 -13.74 0.963 0.956 1.114 0.775
11.00 -14.98 1.085 0.996 1.255 0.771
12.00 -15.82 1.211 1.042 1.401 0.768
13.00 -16.44 1.340 1.091 1.551 0.761
14.00 -16.94 1.473 1.143 1.706 0.753
15.00 -17.34 1.608 1.200 1.864 0.743
PANELS FROM FIN SET 1 WERE DEFLECTED OVER THE RANGE -25.00 TO 20.00 DEG
PANEL 1 WAS FIXED
PANEL 2 WAS VARIED
PANEL 3 WAS FIXED
NOTE - *NT* PRINTED WHEN NO TRIM POINT COULD BE FOUND
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 4
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.06 REYNOLDS NO = 1.096E+06 /M
ALTITUDE = 1848.9 M DYNAMIC PRESSURE = 177.83 N/M**2

SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.2220 0.0122 0.1370 0.0000
1.00 0.2219 0.0122 0.1372 0.0000
2.00 0.2217 0.0122 0.1373 0.0001
3.00 0.2214 0.0121 0.1374 0.0003
4.00 0.2209 0.0121 0.1375 0.0005
5.00 0.2203 0.0121 0.1375 0.0008
6.00 0.2195 0.0120 0.1375 0.0011
7.00 0.2187 0.0120 0.1374 0.0013
8.00 0.2177 0.0119 0.1373 0.0016
9.00 0.2165 0.0119 0.1371 0.0017
10.00 0.2153 0.0118 0.1369 0.0016
11.00 0.2139 0.0117 0.1367 0.0014
12.00 0.2124 0.0116 0.1364 0.0009
13.00 0.2107 0.0115 0.1361 0.0000
14.00 0.2090 0.0115 0.1357 -0.0013
15.00 0.2071 0.0114 0.1353 -0.0032
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.741
2.00 0.091 0.012 0.391 0.002 0.741
3.00 0.137 0.028 0.586 0.005 0.742
4.00 0.182 0.050 0.780 0.009 0.742
5.00 0.227 0.077 0.973 0.015 0.743
6.00 0.272 0.111 1.164 0.021 0.744
7.00 0.316 0.152 1.354 0.029 0.744
8.00 0.360 0.198 1.542 0.038 0.745
9.00 0.403 0.250 1.727 0.048 0.745
10.00 0.446 0.308 1.910 0.059 0.746
11.00 0.488 0.373 2.091 0.071 0.747
12.00 0.529 0.443 2.268 0.085 0.747
13.00 0.570 0.519 2.442 0.099 0.748
14.00 0.609 0.600 2.612 0.115 0.748
15.00 0.648 0.688 2.779 0.131 0.749
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 5
STATIC AERODYNAMIC COEFFICIENTS TRIMMED IN PITCH
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.06 REYNOLDS NO = 1.096E+06 /M
ALTITUDE = 1848.9 M DYNAMIC PRESSURE = 177.83 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA DELTA CL CD CN CA
0.00 0.00 0.000 0.406 0.000 0.406
1.00 -1.65 0.078 0.410 0.085 0.409
2.00 -3.32 0.162 0.415 0.176 0.409
3.00 -4.96 0.252 0.420 0.273 0.406
4.00 -6.57 0.347 0.434 0.377 0.408
5.00 -8.14 0.449 0.449 0.486 0.408
6.00 -9.71 0.556 0.467 0.601 0.406

7.00 -11.20 0.667 0.492 0.722 0.407
8.00 -12.56 0.784 0.520 0.848 0.406
9.00 -13.74 0.905 0.552 0.980 0.404
10.00 -14.76 1.030 0.588 1.117 0.400
11.00 -15.76 1.159 0.632 1.259 0.399
12.00 -16.39 1.292 0.680 1.405 0.397
13.00 -16.84 1.428 0.733 1.557 0.393
14.00 -17.30 1.568 0.791 1.712 0.388
15.00 -17.90 1.709 0.855 1.873 0.384
PANELS FROM FIN SET 1 WERE DEFLECTED OVER THE RANGE -25.00 TO 20.00 DEG
PANEL 1 WAS FIXED
PANEL 2 WAS VARIED
PANEL 3 WAS FIXED
NOTE - *NT* PRINTED WHEN NO TRIM POINT COULD BE FOUND
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 6
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 2.267E+06 /M
ALTITUDE = 247.0 M DYNAMIC PRESSURE = 688.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1953 0.0107 0.1370 0.0000
1.00 0.1953 0.0107 0.1372 0.0000
2.00 0.1951 0.0107 0.1373 0.0001
3.00 0.1948 0.0107 0.1374 0.0003
4.00 0.1944 0.0107 0.1375 0.0005
5.00 0.1938 0.0107 0.1375 0.0007
6.00 0.1932 0.0106 0.1375 0.0009
7.00 0.1924 0.0106 0.1374 0.0011
8.00 0.1915 0.0105 0.1373 0.0013
9.00 0.1905 0.0105 0.1371 0.0013
10.00 0.1894 0.0104 0.1369 0.0012
11.00 0.1882 0.0104 0.1367 0.0009
12.00 0.1869 0.0103 0.1364 0.0003
13.00 0.1854 0.0102 0.1361 -0.0007
14.00 0.1839 0.0101 0.1357 -0.0022
15.00 0.1822 0.0100 0.1353 -0.0042
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.741
2.00 0.091 0.012 0.391 0.002 0.742
3.00 0.137 0.028 0.586 0.005 0.743
4.00 0.182 0.050 0.780 0.009 0.744
5.00 0.227 0.078 0.973 0.015 0.745
6.00 0.272 0.112 1.164 0.021 0.746
7.00 0.316 0.152 1.354 0.029 0.747
8.00 0.360 0.199 1.542 0.038 0.749
9.00 0.403 0.251 1.727 0.048 0.750
10.00 0.446 0.310 1.910 0.059 0.751
11.00 0.488 0.375 2.091 0.072 0.752
12.00 0.529 0.446 2.268 0.085 0.753

13.00 0.570 0.523 2.442 0.100 0.754
14.00 0.609 0.606 2.612 0.116 0.755
15.00 0.648 0.694 2.779 0.133 0.756
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 7
STATIC AERODYNAMIC COEFFICIENTS TRIMMED IN PITCH
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 2.267E+06 /M
ALTITUDE = 247.0 M DYNAMIC PRESSURE = 688.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA DELTA CL CD CN CA
0.00 0.00 0.000 0.373 0.000 0.373
1.00 -1.65 0.078 0.376 0.085 0.375
2.00 -3.32 0.163 0.380 0.176 0.374
3.00 -4.96 0.254 0.386 0.274 0.372
4.00 -6.57 0.350 0.398 0.377 0.373
5.00 -8.14 0.452 0.413 0.487 0.372
6.00 -9.70 0.560 0.430 0.602 0.369
7.00 -11.19 0.673 0.453 0.723 0.368
8.00 -12.53 0.790 0.481 0.850 0.366
9.00 -13.68 0.913 0.511 0.982 0.362
10.00 -14.66 1.040 0.547 1.119 0.359
11.00 -15.62 1.170 0.592 1.261 0.358
12.00 -16.26 1.304 0.642 1.409 0.357
13.00 -16.75 1.441 0.697 1.561 0.355
14.00 -17.23 1.582 0.757 1.718 0.352
15.00 -17.78 1.725 0.823 1.879 0.349
PANELS FROM FIN SET 1 WERE DEFLECTED OVER THE RANGE -25.00 TO 20.00 DEG
PANEL 1 WAS FIXED
PANEL 2 WAS VARIED
PANEL 3 WAS FIXED
NOTE - *NT* PRINTED WHEN NO TRIM POINT COULD BE FOUND
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 8
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 1.965E+06 /M
ALTITUDE = 1810.0 M DYNAMIC PRESSURE = 569.78 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.2002 0.0110 0.1370 0.0000
1.00 0.2001 0.0110 0.1372 0.0000
2.00 0.1999 0.0110 0.1373 0.0001
3.00 0.1996 0.0110 0.1374 0.0003
4.00 0.1992 0.0110 0.1375 0.0005
5.00 0.1987 0.0109 0.1375 0.0007
6.00 0.1980 0.0109 0.1375 0.0009
7.00 0.1972 0.0108 0.1374 0.0012
8.00 0.1963 0.0108 0.1373 0.0013
9.00 0.1953 0.0107 0.1371 0.0014
10.00 0.1941 0.0107 0.1369 0.0013

11.00 0.1929 0.0106 0.1367 0.0010
12.00 0.1915 0.0105 0.1364 0.0004
13.00 0.1901 0.0105 0.1361 -0.0006
14.00 0.1885 0.0104 0.1357 -0.0020
15.00 0.1868 0.0103 0.1353 -0.0040
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.741
2.00 0.091 0.012 0.391 0.002 0.742
3.00 0.137 0.028 0.586 0.005 0.743
4.00 0.182 0.050 0.780 0.009 0.744
5.00 0.227 0.078 0.973 0.015 0.745
6.00 0.272 0.112 1.164 0.021 0.746
7.00 0.316 0.152 1.354 0.029 0.747
8.00 0.360 0.199 1.542 0.038 0.749
9.00 0.403 0.251 1.727 0.048 0.750
10.00 0.446 0.310 1.910 0.059 0.751
11.00 0.488 0.375 2.091 0.072 0.752
12.00 0.529 0.446 2.268 0.085 0.753
13.00 0.570 0.523 2.442 0.100 0.754
14.00 0.609 0.606 2.612 0.116 0.755
15.00 0.648 0.694 2.779 0.133 0.756
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 9
STATIC AERODYNAMIC COEFFICIENTS TRIMMED IN PITCH
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.10 REYNOLDS NO = 1.965E+06 /M
ALTITUDE = 1810.0 M DYNAMIC PRESSURE = 569.78 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA DELTA CL CD CN CA
0.00 0.00 0.000 0.379 0.000 0.379
1.00 -1.65 0.078 0.382 0.085 0.381
2.00 -3.32 0.163 0.387 0.176 0.381
3.00 -4.96 0.253 0.392 0.274 0.378
4.00 -6.57 0.350 0.405 0.377 0.379
5.00 -8.14 0.452 0.419 0.487 0.378
6.00 -9.70 0.559 0.436 0.602 0.375
7.00 -11.19 0.672 0.460 0.723 0.375
8.00 -12.53 0.789 0.487 0.850 0.373
9.00 -13.68 0.912 0.518 0.982 0.369
10.00 -14.65 1.038 0.554 1.119 0.366
11.00 -15.61 1.169 0.599 1.261 0.365
12.00 -16.25 1.302 0.648 1.409 0.363
13.00 -16.74 1.440 0.703 1.561 0.361
14.00 -17.23 1.580 0.763 1.718 0.359
15.00 -17.77 1.723 0.829 1.879 0.355
PANELS FROM FIN SET 1 WERE DEFLECTED OVER THE RANGE -25.00 TO 20.00 DEG
PANEL 1 WAS FIXED
PANEL 2 WAS VARIED
PANEL 3 WAS FIXED
NOTE - *NT* PRINTED WHEN NO TRIM POINT COULD BE FOUND
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2

AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 10
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 4.525E+06 /M
ALTITUDE = 272.2 M DYNAMIC PRESSURE = 2746.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1737 0.0097 0.1370 0.0000
1.00 0.1737 0.0097 0.1372 0.0000
2.00 0.1735 0.0097 0.1373 0.0001
3.00 0.1732 0.0097 0.1374 0.0002
4.00 0.1729 0.0097 0.1375 0.0004
5.00 0.1724 0.0096 0.1375 0.0006
6.00 0.1718 0.0096 0.1374 0.0008
7.00 0.1711 0.0096 0.1373 0.0010
8.00 0.1703 0.0095 0.1372 0.0010
9.00 0.1695 0.0095 0.1371 0.0010
10.00 0.1685 0.0094 0.1369 0.0009
11.00 0.1674 0.0093 0.1366 0.0004
12.00 0.1662 0.0093 0.1363 -0.0003
13.00 0.1649 0.0092 0.1360 -0.0014
14.00 0.1635 0.0091 0.1356 -0.0030
15.00 0.1621 0.0091 0.1352 -0.0051
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.742
2.00 0.091 0.012 0.391 0.002 0.744
3.00 0.137 0.028 0.586 0.005 0.746
4.00 0.182 0.050 0.780 0.010 0.749
5.00 0.227 0.078 0.973 0.015 0.751
6.00 0.272 0.113 1.164 0.022 0.753
7.00 0.316 0.154 1.354 0.029 0.755
8.00 0.360 0.201 1.542 0.038 0.757
9.00 0.403 0.255 1.727 0.049 0.759
10.00 0.446 0.315 1.910 0.060 0.761
11.00 0.488 0.381 2.091 0.073 0.763
12.00 0.529 0.454 2.268 0.087 0.765
13.00 0.570 0.532 2.442 0.102 0.768
14.00 0.609 0.617 2.612 0.118 0.770
15.00 0.648 0.709 2.779 0.135 0.772
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 11
STATIC AERODYNAMIC COEFFICIENTS TRIMMED IN PITCH
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 4.525E+06 /M
ALTITUDE = 272.2 M DYNAMIC PRESSURE = 2746.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA DELTA CL CD CN CA
0.00 0.00 0.000 0.346 0.000 0.346
1.00 -1.66 0.079 0.349 0.085 0.348

2.00 -3.33 0.164 0.353 0.176 0.347
3.00 -4.97 0.255 0.359 0.274 0.345
4.00 -6.58 0.352 0.371 0.377 0.345
5.00 -8.14 0.455 0.385 0.487 0.344
6.00 -9.69 0.564 0.402 0.603 0.340
7.00 -11.16 0.678 0.425 0.724 0.339
8.00 -12.46 0.797 0.451 0.852 0.336
9.00 -13.54 0.921 0.482 0.985 0.332
10.00 -14.41 1.050 0.518 1.123 0.327
11.00 -15.26 1.182 0.561 1.267 0.325
12.00 -15.93 1.318 0.613 1.417 0.325
13.00 -16.56 1.458 0.670 1.571 0.325
14.00 -17.12 1.600 0.733 1.730 0.324
15.00 -17.58 1.747 0.799 1.894 0.320
PANELS FROM FIN SET 1 WERE DEFLECTED OVER THE RANGE -25.00 TO 20.00 DEG
PANEL 1 WAS FIXED
PANEL 2 WAS VARIED
PANEL 3 WAS FIXED
NOTE - *NT* PRINTED WHEN NO TRIM POINT COULD BE FOUND
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 12
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 3.992E+06 /M
ALTITUDE = 1639.5 M DYNAMIC PRESSURE = 2327.55 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1773 0.0099 0.1370 0.0000
1.00 0.1773 0.0099 0.1372 0.0000
2.00 0.1771 0.0099 0.1373 0.0001
3.00 0.1768 0.0099 0.1374 0.0002
4.00 0.1764 0.0099 0.1375 0.0004
5.00 0.1760 0.0098 0.1375 0.0006
6.00 0.1754 0.0098 0.1374 0.0008
7.00 0.1747 0.0098 0.1373 0.0010
8.00 0.1739 0.0097 0.1372 0.0011
9.00 0.1730 0.0097 0.1371 0.0011
10.00 0.1720 0.0096 0.1369 0.0009
11.00 0.1709 0.0095 0.1366 0.0005
12.00 0.1696 0.0095 0.1363 -0.0002
13.00 0.1683 0.0094 0.1360 -0.0013
14.00 0.1669 0.0093 0.1356 -0.0029
15.00 0.1654 0.0092 0.1352 -0.0050
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.742
2.00 0.091 0.012 0.391 0.002 0.744
3.00 0.137 0.028 0.586 0.005 0.746
4.00 0.182 0.050 0.780 0.010 0.749
5.00 0.227 0.078 0.973 0.015 0.751
6.00 0.272 0.113 1.164 0.022 0.753
7.00 0.316 0.154 1.354 0.029 0.755

8.00 0.360 0.201 1.542 0.038 0.757
9.00 0.403 0.255 1.727 0.049 0.759
10.00 0.446 0.315 1.910 0.060 0.761
11.00 0.488 0.381 2.091 0.073 0.763
12.00 0.529 0.454 2.268 0.087 0.765
13.00 0.570 0.532 2.442 0.102 0.768
14.00 0.609 0.617 2.612 0.118 0.770
15.00 0.648 0.709 2.779 0.135 0.772
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 13
STATIC AERODYNAMIC COEFFICIENTS TRIMMED IN PITCH
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.20 REYNOLDS NO = 3.992E+06 /M
ALTITUDE = 1639.5 M DYNAMIC PRESSURE = 2327.55 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA DELTA CL CD CN CA
0.00 0.00 0.000 0.350 0.000 0.350
1.00 -1.66 0.079 0.354 0.085 0.352
2.00 -3.33 0.164 0.358 0.176 0.352
3.00 -4.97 0.255 0.363 0.274 0.349
4.00 -6.58 0.352 0.375 0.377 0.350
5.00 -8.14 0.455 0.390 0.487 0.348
6.00 -9.69 0.563 0.406 0.603 0.345
7.00 -11.16 0.677 0.429 0.724 0.344
8.00 -12.46 0.796 0.456 0.852 0.341
9.00 -13.54 0.920 0.486 0.985 0.336
10.00 -14.40 1.049 0.522 1.123 0.332
11.00 -15.25 1.181 0.566 1.267 0.330
12.00 -15.92 1.317 0.617 1.417 0.330
13.00 -16.55 1.457 0.675 1.571 0.330
14.00 -17.11 1.599 0.737 1.730 0.328
15.00 -17.57 1.746 0.804 1.894 0.324
PANELS FROM FIN SET 1 WERE DEFLECTED OVER THE RANGE -25.00 TO 20.00 DEG
PANEL 1 WAS FIXED
PANEL 2 WAS VARIED
PANEL 3 WAS FIXED
NOTE - *NT* PRINTED WHEN NO TRIM POINT COULD BE FOUND
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 14
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.760E+06 /M
ALTITUDE = 316.2 M DYNAMIC PRESSURE = 6147.81 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1623 0.0093 0.1370 0.0000
1.00 0.1623 0.0093 0.1372 0.0000
2.00 0.1621 0.0093 0.1373 0.0001
3.00 0.1619 0.0093 0.1374 0.0002
4.00 0.1615 0.0093 0.1374 0.0004
5.00 0.1611 0.0092 0.1374 0.0006

6.00 0.1605 0.0092 0.1374 0.0007
7.00 0.1599 0.0092 0.1373 0.0009
8.00 0.1592 0.0091 0.1372 0.0009
9.00 0.1583 0.0091 0.1370 0.0009
10.00 0.1574 0.0090 0.1368 0.0007
11.00 0.1564 0.0090 0.1365 0.0002
12.00 0.1553 0.0089 0.1362 -0.0006
13.00 0.1541 0.0088 0.1359 -0.0017
14.00 0.1528 0.0088 0.1355 -0.0034
15.00 0.1514 0.0087 0.1351 -0.0057
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.743
2.00 0.091 0.012 0.391 0.002 0.746
3.00 0.137 0.028 0.586 0.005 0.750
4.00 0.182 0.050 0.780 0.010 0.753
5.00 0.227 0.079 0.973 0.015 0.756
6.00 0.272 0.114 1.164 0.022 0.759
7.00 0.316 0.155 1.354 0.030 0.762
8.00 0.360 0.203 1.542 0.039 0.766
9.00 0.403 0.258 1.727 0.049 0.769
10.00 0.446 0.319 1.910 0.061 0.772
11.00 0.488 0.387 2.091 0.074 0.775
12.00 0.529 0.461 2.268 0.088 0.778
13.00 0.570 0.542 2.442 0.104 0.781
14.00 0.609 0.629 2.612 0.120 0.784
15.00 0.648 0.723 2.779 0.138 0.788
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 15
STATIC AERODYNAMIC COEFFICIENTS TRIMMED IN PITCH
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.760E+06 /M
ALTITUDE = 316.2 M DYNAMIC PRESSURE = 6147.81 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA DELTA CL CD CN CA
0.00 0.00 0.000 0.332 0.000 0.332
1.00 -1.68 0.079 0.335 0.085 0.334
2.00 -3.35 0.164 0.339 0.176 0.333
3.00 -4.99 0.256 0.345 0.274 0.331
4.00 -6.61 0.354 0.357 0.378 0.331
5.00 -8.17 0.457 0.371 0.488 0.329
6.00 -9.68 0.566 0.387 0.604 0.326
7.00 -11.11 0.681 0.410 0.726 0.324
8.00 -12.36 0.801 0.436 0.854 0.320
9.00 -13.39 0.927 0.466 0.988 0.316
10.00 -14.16 1.057 0.502 1.128 0.311
11.00 -14.90 1.191 0.545 1.273 0.307
12.00 -15.57 1.329 0.597 1.424 0.307
13.00 -16.32 1.471 0.656 1.581 0.309
14.00 -16.99 1.616 0.721 1.743 0.309
15.00 -17.50 1.765 0.789 1.909 0.305
PANELS FROM FIN SET 1 WERE DEFLECTED OVER THE RANGE -25.00 TO 20.00 DEG

PANEL 1 WAS FIXED
PANEL 2 WAS VARIED
PANEL 3 WAS FIXED
NOTE - *NT* PRINTED WHEN NO TRIM POINT COULD BE FOUND
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 16
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.150E+06 /M
ALTITUDE = 1351.1 M DYNAMIC PRESSURE = 5425.47 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1648 0.0095 0.1370 0.0000
1.00 0.1647 0.0094 0.1372 0.0000
2.00 0.1646 0.0094 0.1373 0.0001
3.00 0.1643 0.0094 0.1374 0.0002
4.00 0.1640 0.0094 0.1374 0.0004
5.00 0.1635 0.0094 0.1374 0.0006
6.00 0.1630 0.0093 0.1374 0.0007
7.00 0.1623 0.0093 0.1373 0.0009
8.00 0.1616 0.0093 0.1372 0.0010
9.00 0.1607 0.0092 0.1370 0.0009
10.00 0.1598 0.0092 0.1368 0.0007
11.00 0.1588 0.0091 0.1365 0.0002
12.00 0.1576 0.0090 0.1362 -0.0005
13.00 0.1564 0.0090 0.1359 -0.0017
14.00 0.1551 0.0089 0.1355 -0.0033
15.00 0.1537 0.0088 0.1351 -0.0056
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.743
2.00 0.091 0.012 0.391 0.002 0.746
3.00 0.137 0.028 0.586 0.005 0.750
4.00 0.182 0.050 0.780 0.010 0.753
5.00 0.227 0.079 0.973 0.015 0.756
6.00 0.272 0.114 1.164 0.022 0.759
7.00 0.316 0.155 1.354 0.030 0.762
8.00 0.360 0.203 1.542 0.039 0.766
9.00 0.403 0.258 1.727 0.049 0.769
10.00 0.446 0.319 1.910 0.061 0.772
11.00 0.488 0.387 2.091 0.074 0.775
12.00 0.529 0.461 2.268 0.088 0.778
13.00 0.570 0.542 2.442 0.104 0.781
14.00 0.609 0.629 2.612 0.120 0.784
15.00 0.648 0.723 2.779 0.138 0.788
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 17
STATIC AERODYNAMIC COEFFICIENTS TRIMMED IN PITCH
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.30 REYNOLDS NO = 6.150E+06 /M
ALTITUDE = 1351.1 M DYNAMIC PRESSURE = 5425.47 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG

REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA DELTA CL CD CN CA
0.00 0.00 0.000 0.335 0.000 0.335
1.00 -1.68 0.079 0.338 0.085 0.337
2.00 -3.35 0.164 0.342 0.176 0.336
3.00 -4.99 0.256 0.348 0.274 0.334
4.00 -6.61 0.353 0.360 0.378 0.334
5.00 -8.17 0.457 0.374 0.488 0.333
6.00 -9.68 0.566 0.390 0.604 0.329
7.00 -11.10 0.681 0.413 0.726 0.327
8.00 -12.35 0.801 0.439 0.854 0.323
9.00 -13.38 0.926 0.469 0.988 0.319
10.00 -14.15 1.056 0.505 1.128 0.314
11.00 -14.88 1.191 0.548 1.273 0.311
12.00 -15.56 1.329 0.600 1.424 0.310
13.00 -16.30 1.470 0.659 1.581 0.312
14.00 -16.97 1.615 0.724 1.743 0.312
15.00 -17.49 1.764 0.792 1.909 0.308
PANELS FROM FIN SET 1 WERE DEFLECTED OVER THE RANGE -25.00 TO 20.00 DEG
PANEL 1 WAS FIXED
PANEL 2 WAS VARIED
PANEL 3 WAS FIXED
NOTE - *NT* PRINTED WHEN NO TRIM POINT COULD BE FOUND
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 18
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.958E+06 /M
ALTITUDE = 384.4 M DYNAMIC PRESSURE = 10840.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1545 0.0092 0.1370 0.0000
1.00 0.1545 0.0092 0.1372 0.0000
2.00 0.1544 0.0092 0.1373 0.0001
3.00 0.1541 0.0092 0.1374 0.0002
4.00 0.1538 0.0092 0.1374 0.0004
5.00 0.1534 0.0092 0.1374 0.0005
6.00 0.1529 0.0091 0.1373 0.0007
7.00 0.1522 0.0091 0.1373 0.0008
8.00 0.1515 0.0090 0.1371 0.0009
9.00 0.1508 0.0090 0.1370 0.0008
10.00 0.1499 0.0089 0.1367 0.0005
11.00 0.1489 0.0089 0.1365 0.0000
12.00 0.1479 0.0088 0.1362 -0.0008
13.00 0.1467 0.0088 0.1358 -0.0020
14.00 0.1455 0.0087 0.1354 -0.0037
15.00 0.1442 0.0086 0.1350 -0.0061
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.744
2.00 0.091 0.012 0.391 0.002 0.749

3.00 0.137 0.028 0.586 0.005 0.753
4.00 0.182 0.050 0.780 0.010 0.757
5.00 0.227 0.079 0.973 0.015 0.761
6.00 0.272 0.115 1.164 0.022 0.766
7.00 0.316 0.157 1.354 0.030 0.770
8.00 0.360 0.206 1.542 0.039 0.774
9.00 0.403 0.261 1.727 0.050 0.778
10.00 0.446 0.323 1.910 0.062 0.783
11.00 0.488 0.393 2.091 0.075 0.787
12.00 0.529 0.469 2.268 0.090 0.791
13.00 0.570 0.552 2.442 0.105 0.795
14.00 0.609 0.641 2.612 0.123 0.799
15.00 0.648 0.738 2.779 0.141 0.803
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 19
STATIC AERODYNAMIC COEFFICIENTS TRIMMED IN PITCH
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.958E+06 /M
ALTITUDE = 384.4 M DYNAMIC PRESSURE = 10840.75 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA DELTA CL CD CN CA
0.00 0.00 0.000 0.323 0.000 0.323
1.00 -1.70 0.079 0.326 0.085 0.325
2.00 -3.39 0.165 0.330 0.176 0.324
3.00 -5.05 0.257 0.336 0.274 0.322
4.00 -6.69 0.355 0.348 0.378 0.322
5.00 -8.26 0.458 0.362 0.488 0.320
6.00 -9.77 0.568 0.378 0.605 0.317
7.00 -11.18 0.684 0.401 0.728 0.315
8.00 -12.43 0.805 0.427 0.857 0.311
9.00 -13.45 0.931 0.458 0.992 0.306
10.00 -14.22 1.063 0.494 1.133 0.302
11.00 -14.94 1.199 0.537 1.280 0.298
12.00 -15.63 1.339 0.589 1.432 0.298
13.00 -16.41 1.482 0.650 1.591 0.300
14.00 -17.13 1.630 0.716 1.755 0.301
15.00 -17.71 1.782 0.786 1.924 0.298
PANELS FROM FIN SET 1 WERE DEFLECTED OVER THE RANGE -25.00 TO 20.00 DEG
PANEL 1 WAS FIXED
PANEL 2 WAS VARIED
PANEL 3 WAS FIXED
NOTE - *NT* PRINTED WHEN NO TRIM POINT COULD BE FOUND
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 20
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.458E+06 /M
ALTITUDE = 1015.1 M DYNAMIC PRESSURE = 10047.93 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1559 0.0093 0.1370 0.0000

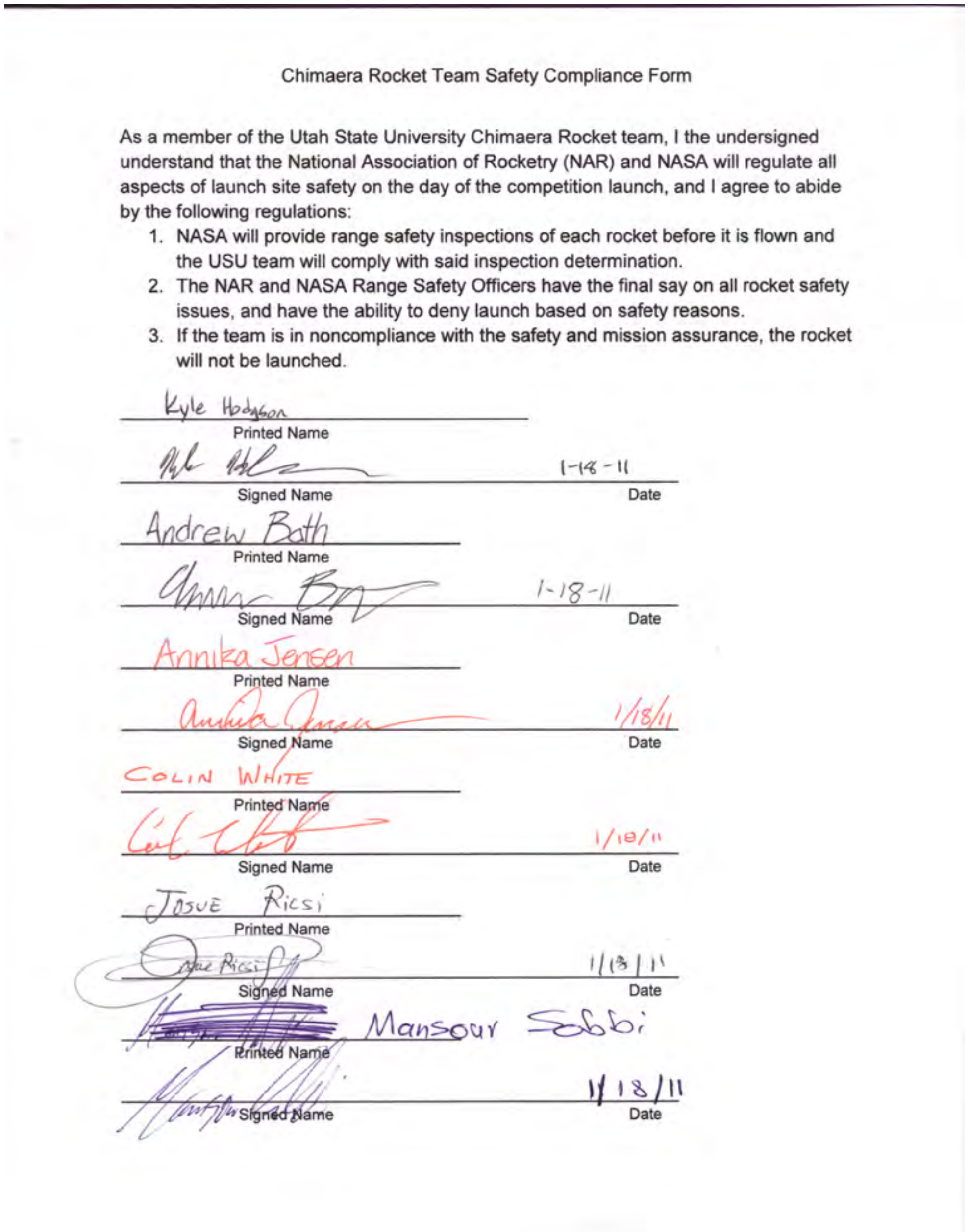
1.00 0.1559 0.0093 0.1372 0.0000
2.00 0.1557 0.0093 0.1373 0.0001
3.00 0.1555 0.0093 0.1374 0.0002
4.00 0.1552 0.0093 0.1374 0.0004
5.00 0.1548 0.0092 0.1374 0.0005
6.00 0.1542 0.0092 0.1373 0.0007
7.00 0.1536 0.0092 0.1373 0.0008
8.00 0.1529 0.0091 0.1371 0.0009
9.00 0.1521 0.0091 0.1370 0.0008
10.00 0.1512 0.0090 0.1367 0.0005
11.00 0.1503 0.0090 0.1365 0.0001
12.00 0.1492 0.0089 0.1362 -0.0008
13.00 0.1480 0.0088 0.1358 -0.0020
14.00 0.1468 0.0088 0.1354 -0.0037
15.00 0.1455 0.0087 0.1350 -0.0060
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.744
2.00 0.091 0.012 0.391 0.002 0.749
3.00 0.137 0.028 0.586 0.005 0.753
4.00 0.182 0.050 0.780 0.010 0.757
5.00 0.227 0.079 0.973 0.015 0.761
6.00 0.272 0.115 1.164 0.022 0.766
7.00 0.316 0.157 1.354 0.030 0.770
8.00 0.360 0.206 1.542 0.039 0.774
9.00 0.403 0.261 1.727 0.050 0.778
10.00 0.446 0.323 1.910 0.062 0.783
11.00 0.488 0.393 2.091 0.075 0.787
12.00 0.529 0.469 2.268 0.090 0.791
13.00 0.570 0.552 2.442 0.105 0.795
14.00 0.609 0.641 2.612 0.123 0.799
15.00 0.648 0.738 2.779 0.141 0.803
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 21
STATIC AERODYNAMIC COEFFICIENTS TRIMMED IN PITCH
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.40 REYNOLDS NO = 8.458E+06 /M
ALTITUDE = 1015.1 M DYNAMIC PRESSURE = 10047.93 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA DELTA CL CD CN CA
0.00 0.00 0.000 0.325 0.000 0.325
1.00 -1.70 0.079 0.328 0.085 0.326
2.00 -3.39 0.165 0.332 0.176 0.326
3.00 -5.05 0.257 0.337 0.274 0.323
4.00 -6.69 0.354 0.349 0.378 0.324
5.00 -8.26 0.458 0.364 0.488 0.322
6.00 -9.76 0.568 0.380 0.605 0.319
7.00 -11.18 0.684 0.403 0.728 0.316
8.00 -12.43 0.805 0.429 0.857 0.313
9.00 -13.45 0.931 0.459 0.992 0.308
10.00 -14.21 1.063 0.495 1.133 0.303
11.00 -14.93 1.199 0.538 1.280 0.300

12.00 -15.61 1.339 0.591 1.432 0.300
13.00 -16.39 1.482 0.652 1.591 0.302
14.00 -17.12 1.630 0.718 1.755 0.302
15.00 -17.70 1.781 0.787 1.924 0.300
PANELS FROM FIN SET 1 WERE DEFLECTED OVER THE RANGE -25.00 TO 20.00 DEG
PANEL 1 WAS FIXED
PANEL 2 WAS VARIED
PANEL 3 WAS FIXED
NOTE - *NT* PRINTED WHEN NO TRIM POINT COULD BE FOUND
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 22
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.50 REYNOLDS NO = 1.107E+07 /M
ALTITUDE = 506.1 M DYNAMIC PRESSURE = 16693.65 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1486 0.0094 0.1370 0.0000
1.00 0.1486 0.0094 0.1372 0.0000
2.00 0.1485 0.0094 0.1373 0.0001
3.00 0.1482 0.0094 0.1373 0.0002
4.00 0.1479 0.0093 0.1374 0.0003
5.00 0.1475 0.0093 0.1374 0.0005
6.00 0.1470 0.0093 0.1373 0.0006
7.00 0.1464 0.0093 0.1372 0.0008
8.00 0.1458 0.0092 0.1371 0.0008
9.00 0.1450 0.0092 0.1369 0.0007
10.00 0.1442 0.0091 0.1367 0.0004
11.00 0.1432 0.0091 0.1364 -0.0001
12.00 0.1422 0.0090 0.1361 -0.0009
13.00 0.1411 0.0089 0.1357 -0.0022
14.00 0.1399 0.0088 0.1353 -0.0040
15.00 0.1387 0.0088 0.1349 -0.0064
CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.745
2.00 0.091 0.013 0.391 0.002 0.751
3.00 0.137 0.028 0.586 0.005 0.756
4.00 0.182 0.051 0.780 0.010 0.761
5.00 0.227 0.080 0.973 0.015 0.767
6.00 0.272 0.116 1.164 0.022 0.772
7.00 0.316 0.158 1.354 0.030 0.777
8.00 0.360 0.208 1.542 0.040 0.783
9.00 0.403 0.264 1.727 0.051 0.788
10.00 0.446 0.328 1.910 0.063 0.793
11.00 0.488 0.398 2.091 0.076 0.798
12.00 0.529 0.476 2.268 0.091 0.804
13.00 0.570 0.561 2.442 0.107 0.809
14.00 0.609 0.653 2.612 0.125 0.814
15.00 0.648 0.752 2.779 0.144 0.819
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 23

STATIC AERODYNAMIC COEFFICIENTS TRIMMED IN PITCH
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.50 REYNOLDS NO = 1.107E+07 /M
ALTITUDE = 506.1 M DYNAMIC PRESSURE = 16693.65 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA DELTA CL CD CN CA
0.00 0.00 0.000 0.316 0.000 0.316
1.00 -1.73 0.079 0.319 0.085 0.318
2.00 -3.45 0.165 0.323 0.176 0.317
3.00 -5.13 0.257 0.329 0.274 0.315
4.00 -6.80 0.355 0.341 0.378 0.316
5.00 -8.40 0.460 0.356 0.489 0.314
6.00 -9.93 0.570 0.372 0.606 0.311
7.00 -11.39 0.686 0.396 0.729 0.309
8.00 -12.68 0.808 0.422 0.859 0.306
9.00 -13.74 0.936 0.453 0.995 0.301
10.00 -14.55 1.068 0.490 1.137 0.297
11.00 -15.36 1.206 0.534 1.286 0.295
12.00 -16.08 1.347 0.588 1.440 0.295
13.00 -16.88 1.493 0.650 1.601 0.297
14.00 -17.63 1.642 0.717 1.767 0.299
15.00 -18.23 1.797 0.788 1.939 0.296
PANELS FROM FIN SET 1 WERE DEFLECTED OVER THE RANGE -25.00 TO 20.00 DEG
PANEL 1 WAS FIXED
PANEL 2 WAS VARIED
PANEL 3 WAS FIXED
NOTE - *NT* PRINTED WHEN NO TRIM POINT COULD BE FOUND
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 24
BODY ALONE PARTIAL OUTPUT
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.52 REYNOLDS NO = 1.140E+07 /M
ALTITUDE = 600.0 M DYNAMIC PRESSURE = 17784.96 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA CA-FRIC CA-PRES/WAVE CA-BASE CA-PROT CA-SEP CA-ALP
0.00 0.1478 0.0095 0.1368 0.0000
1.00 0.1477 0.0095 0.1370 0.0000
2.00 0.1476 0.0094 0.1371 0.0001
3.00 0.1474 0.0094 0.1372 0.0002
4.00 0.1471 0.0094 0.1372 0.0003
5.00 0.1467 0.0094 0.1372 0.0005
6.00 0.1462 0.0094 0.1371 0.0006
7.00 0.1456 0.0093 0.1370 0.0008
8.00 0.1449 0.0093 0.1369 0.0008
9.00 0.1442 0.0092 0.1367 0.0007
10.00 0.1433 0.0092 0.1365 0.0004
11.00 0.1424 0.0091 0.1362 -0.0001
12.00 0.1414 0.0091 0.1359 -0.0010
13.00 0.1403 0.0090 0.1355 -0.0022
14.00 0.1391 0.0089 0.1351 -0.0040
15.00 0.1379 0.0088 0.1347 -0.0065

CROSS FLOW DRAG PROPORTIONALITY FACTOR = 0.74173
ALPHA CN-POTEN CN-VISC CN-SEP CM-POTEN CM-VISC CM-SEP CDC
0.00 0.000 0.000 0.000 0.000 0.740
1.00 0.046 0.003 0.196 0.001 0.746
2.00 0.091 0.013 0.391 0.002 0.751
3.00 0.137 0.028 0.586 0.005 0.757
4.00 0.182 0.051 0.780 0.010 0.762
5.00 0.227 0.080 0.973 0.015 0.768
6.00 0.272 0.116 1.164 0.022 0.773
7.00 0.316 0.159 1.354 0.030 0.779
8.00 0.360 0.208 1.542 0.040 0.784
9.00 0.403 0.265 1.727 0.051 0.790
10.00 0.446 0.329 1.910 0.063 0.795
11.00 0.488 0.400 2.091 0.076 0.801
12.00 0.529 0.478 2.268 0.091 0.806
13.00 0.570 0.563 2.442 0.108 0.812
14.00 0.609 0.655 2.612 0.125 0.817
15.00 0.648 0.755 2.779 0.144 0.822
1 ***** THE USAF AUTOMATED MISSILE DATCOM * REV 3/99 ***** CASE 2
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 25
STATIC AERODYNAMIC COEFFICIENTS TRIMMED IN PITCH
******* FLIGHT CONDITIONS AND REFERENCE QUANTITIES *******
MACH NO = 0.52 REYNOLDS NO = 1.140E+07 /M
ALTITUDE = 600.0 M DYNAMIC PRESSURE = 17784.96 N/M**2
SIDESLIP = 0.00 DEG ROLL = 0.00 DEG
REF AREA = 0.016 M**2 MOMENT CENTER = 1.220 M
REF LENGTH = 0.14 M LAT REF LENGTH = 0.14 M
ALPHA DELTA CL CD CN CA
0.00 0.00 0.000 0.315 0.000 0.315
1.00 -1.74 0.079 0.318 0.085 0.317
2.00 -3.46 0.165 0.322 0.176 0.316
3.00 -5.15 0.257 0.328 0.274 0.314
4.00 -6.82 0.355 0.340 0.378 0.315
5.00 -8.43 0.460 0.355 0.489 0.313
6.00 -9.96 0.570 0.371 0.606 0.310
7.00 -11.42 0.686 0.395 0.730 0.308
8.00 -12.71 0.809 0.421 0.859 0.305
9.00 -13.78 0.936 0.452 0.996 0.300
10.00 -14.59 1.069 0.489 1.138 0.296
11.00 -15.40 1.207 0.534 1.287 0.294
12.00 -16.13 1.349 0.588 1.442 0.295
13.00 -16.94 1.495 0.650 1.603 0.297
14.00 -17.70 1.645 0.717 1.770 0.298
15.00 -18.32 1.800 0.788 1.942 0.296
PANELS FROM FIN SET 1 WERE DEFLECTED OVER THE RANGE -25.00 TO 20.00 DEG
PANEL 1 WAS FIXED
PANEL 2 WAS VARIED
PANEL 3 WAS FIXED
NOTE - *NT* PRINTED WHEN NO TRIM POINT COULD BE FOUND
*** END OF JOB ***

E. Team Safety Compliance Form



Chimaera Rocket Team Safety Compliance Form

As a member of the Utah State University Chimaera Rocket team, I the undersigned understand that the National Association of Rocketry (NAR) and NASA will regulate all aspects of launch site safety on the day of the competition launch, and I agree to abide by the following regulations:

1. NASA will provide range safety inspections of each rocket before it is flown and the USU team will comply with said inspection determination.
2. The NAR and NASA Range Safety Officers have the final say on all rocket safety issues, and have the ability to deny launch based on safety reasons.
3. If the team is in noncompliance with the safety and mission assurance, the rocket will not be launched.

Kyle Hodgson
Printed Name

Signed Name — Date: 1-18-11

Andrew Bath
Printed Name

Signed Name — Date: 1-18-11

Annika Jensen
Printed Name

Signed Name — Date: 1/18/11

COLIN WHITE
Printed Name

Signed Name — Date: 1/18/11

JOSUE RICSI
Printed Name

Signed Name — Date: 1/18/11

Mansour Sobbi
Printed Name

Signed Name — Date: 1/18/11

F. Manufacturing Instructions

F.A. Manufacturing Guidelines

- All adhesion surfaces must be sanded first using a 100-120 grit sandpaper. Dry fit all components before gluing them in place.
- Any time "glue" is referenced, epoxy should be used.
- All bulkheads must be bonded to the body tube using J-B WELD® and a Popsicle stick (or gloved finger) to create a fillet. All adhesion processes will be done using standard model rocketry epoxy or J-B WELD®. Instructions on mixing epoxy MUST be followed strictly to ensure correct bond integrity (i.e. If you are using 30-minute quick cure epoxy, make sure you have the bond ready to be cured within 30 minutes.)

- When attaching the fins to the rocket, use epoxy to create a fillet on the motor tube, and on both sides of the body tube.
  - Mix some talcum powder or baby powder into the epoxy until it forms a paste-like substance. Use this to make the fillets between the fins and exterior of the body tube.
- Use J-B WELD® when attaching the motor retaining bulkhead and motor retaining ring.
- A pressure relief hole measuring approx. 5/32" should be drilled in each component: payload section, avionics section, nosecone.
- DO NOT INSTALL THE MOTOR UNTIL YOU ARE READY TO LAUNCH!! When installing the motor, follow the manufacturer's instructions. Make sure the motor retaining ring is installed securely after the motor is installed.
- Black powder charges for the parachutes should not be installed until at the launch site.
- The igniter should not be installed until the rocket is in the launch configuration, or until the rocket is in a pre-designated area as instructed by the range safety officer.

F.A.1. Assembly instructions

COMPLETELY READ AND UNDERSTAND THE STEP BEFORE PROCEEDING

MOTOR AND FINS

1. Drill holes through the forward centering ring for the CBAS hoses.
2. Glue forward centering ring to the motor tube.
3. Make slits in the body tube for the fins.
4. Cut out and attach the avionics access doors and payload access doors (if applicable).
5. Glue forward centering ring on motor tube to the airframe, making sure the holes for the CBAS are NOT lined up with the slots for the fins.
   (a) using clear tape, tape three-four pieces of tape onto the aft centering ring, leaving tabs you can use to pull on the centering ring. Place the aft centering ring on the motor tube while gluing the forward centering ring on, but DO NOT GLUE THE AFT CENTERING RING YET. Use the tape tabs to remove it after the forward centering ring is glued in place and dry.
6. Glue fins onto the motor tube one at a time by first placing a small bead of quick cure epoxy on the root of the fin (the part that actually touches the motor tube. Hold in place until it doesn't move anymore. Then make the fillets between the motor tube and fin root, and on the interior and exterior of the motor tube.
   (a) When attaching the fins it is essential to get them perpendicular to the motor tube and airframe. If the fins are not perpendicular it can increase drag, and make the rocket "wobble" during flight. For straight flight the fins **must** be perpendicular.

PAYLOAD

1. Drill holes in the aft payload bulkhead for threaded rods. Epoxy nuts on one side of the hole.
2. Glue the aft payload bulkhead in place.
3. Assemble solenoid valve, regulator, and tubing for the CBAS. Insert and fasten to the aft payload bulkhead.
4. Insert the threaded rods into the aft bulkhead and thread on nuts to the height required to give enough room for the solenoid valve and regulator.

5. Drill holes into the mid-bay payload bulkhead for the threaded rods. Glue onto the airframe just above the nuts previously threaded on in step 4. Thread three more nuts and lock washers onto the rods to lock the bulkhead in place.

6. Thread three more nuts onto the threaded rods to support the forward payload bulkhead. Place the CO_2 tank into the mid-bay bulkhead and dry fit the forward payload bulkhead to determine ideal positioning. Remove CO_2 tank and forward bulkhead. Drill two holes in the bulkhead for the eye-bolts that will be used to fasten the shock cord to the lower rocket assembly and the avionics bay. Attach the eye-bolts and glue the forward payload bulkhead in place. Attach shock cord to the eye-bolts.

Avionics

1. glue coupler to avionics bay, leaving approx. 3" exposed.

2. Cut a slit in the avionics aft bulkhead big enough to pass through a piece of shock cord.

3. Take one end of the shock cord and pass it through the slit. Using a D-ring, pass the shock cord through D-ring and back down through the slit. Pull the D-ring tight against the bulkhead, making a small tail with the short end of the shock cord. Epoxy the tail to the bulkhead, using a clamp to press it tightly against the bulkhead. Once dry, pull the D-ring snugly against the bulkhead and glue in place.

4. Glue the avionics aft bulkhead to the coupler and attach shock cord from the payload section to the D-ring.

5. Install the avionics package onto the threaded rods and line it up with the avionics access door. Once the correct position is known, glue it in place.

    (a) Lock the avionics bay in place using nuts and lock washers.

6. Drill a hole in the forward avionics bay bulkhead to slide it on the threaded rods. Drill a hole in the center of the bulkhead and insert an eye-bolt. Attach the shock cord connected to the nosecone to this eye-bolt.

Recovery See Appendices B and C.

Nosecone

1. Fashion small bulkhead, approx. 1.5-2" dia. Cut a slit in the middle of the bulkhead and attach D-ring as in Avionics-step 3.

2. Pack main parachute into the nosecone. Pack flame retardant cloth, then ejection charges.

3. Attach nosecone to the avionics bay using shear pins.

G. Static/Launch Checklist, Troubleshooting, Post-Flight

Checklist for the Static Test

Date: _______________

Time: _______________

0.0 Persons Conducting Static Test Fire.
Team Lead Approval: ___________________________
Team Instructor Approval: ____________________________
Team Safety Officer Approval: _________________________

1.0 Material Checklist.
(To be completed before leaving campus facilities; items placed in vehicle)

1.1.0 Motor firing and Control Checklist

- 1.1.1.0 Motor.
  - 1.1.1.1 propellant grains.
  - 1.1.1.2 Large O-rings.
  - 1.1.1.3 Phenolic liner tube.
  - 1.1.1.4 Motor casing.
  - 1.1.1.5 Forward end closer with adapter.
  - 1.1.1.6 Nozzle.
  - 1.1.1.7 Nozzle washer.
- 1.1.2 Grease.
- 1.1.3 Nitrile/latex gloves.
- 1.1.4 Grounding wire.
- 1.1.5 Manufacturers motor assembly instructions.
- 1.1.6 Nut driver/flat head screwdriver (to tighten clamps).
- 1.1.7.0 Motor ignition system.
  - 1.1.7.1 Orange box.
  - 1.1.7.2 Alligator clips for the battery.
  - 1.1.7.3 Igniter wire.
  - 1.1.7.4 Launch controller.
  - 1.1.7.5 Safety interlock.
  - 1.1.7.6 Two small alligator clips for the igniter.
  - 1.1.7.7 Fully charged 12 V deep cycle battery.
- 1.1.8 Motor igniter and spares.
- 1.1.9 Wipes for motor clean up.
- 1.1.10 Wooden stick or broom-handle to push out burnt grains after the test.

1.2.0 Instrumentation Checklist

- 1.2.1 Wiring diagram.
- 1.2.2 Grounding wire.
- 1.2.4 Cables and connectors.
- 1.2.5 Pressure sensor (serial # _______________).
- 1.2.6 Electrical tape for securing wires.
- 1.2.7 Flash drive.
- 1.2.8 Test stand instrumentation (C-DAQ and supporting items).
- 1.2.9 Surge protector.
- 1.2.10 Laptop power cord for test computer (Toughbook).
- 1.2.11 Laptop power cord for control computer (Lance).
- 1.2.12 Laptop computer with LabView VI (Toughbook).

G.A. Launch Procedures

Persons Conducting Launch

- ☐ Team Supervisor Approval:_________
- ☐ Team Instructor Approval:_________
- ☐ Team Safety Officer Approval:_________

Rocket Details and Launch Environment

- ☐ Rocket Clean Mass:_____________________________
- ☐ Motor Initial Mass:_________________________
- ☐ Motor Final Mass:__________________________
- ☐ Nozzle Throat Diameter:_____________________
- ☐ Temperature at time of launch:_______________
- ☐ Barometric Pressure:_______________________
- ☐ Launch Altitude:____________________________

Traveling Preparation (To be completed before leaving campus facilities; items placed in vehicle)

- ☐ Charge all batteries.
- ☐ Install batteries.
- ☐ Check tire pressure.
- ☐ Check lights.
- ☐ Secure rail to bed.
- ☐ Check hitch to ensure it is secure.
- ☐ Remove loose materials from trailer.
- ☐ Place spare tire in towing vehicle.

Recovery Preparation

- ☐ Inspect parachutes.
- ☐ Inspect harnesses.
- ☐ Inspect quick links.
- ☐ Check impedance in electric matches.
- ☐ Slip Nomex sleeve and cloth over the short ends of the harnesses.
- ☐ Attach quick links to loops in the ends of the harnesses.
- ☐ Apply baby powder to parachutes.
- ☐ Untangle shroud lines.
- ☐ Attach parachutes to harnesses.
- ☐ Fold parachutes.
- ☐ Place parachutes in deployment bags.

Prepare Drogue Parachute.

- ☐ Extinguish all cigarettes.
- ☐ Verify that no flame sources are located within 25 feet of recovery charge preparation area.
- ☐ Put on PPE.
- ☐ Measure out drogue chute black powder charges.
- ☐ Pour black powder into ejection charge canister underneath the avionics section.
- ☐ Tape two electric matches to the side of the ejection canister with 1.5" free to bend into black powder.
- ☐ Bury match heads in black powder.
- ☐ Insert plug on top of black powder and pack with a wooden dowel.
- ☐ Seal ejection charge canister with tape.
- ☐ Attach quick links on the fabricated end of the drogue harness to the two U-bolts in the payload section bulkhead.
- ☐ Connect the electric match leads to the wire posts on the avionics section bulkhead.
- ☐ Attach quick link in loose end of harness to remaining U-bolt.
- ☐ Wrap harness and parachute in Nomex cloth.
- ☐ Being careful not to disconnect any wires, insert the parachute into the avionics section coupler.
- ☐ Ensure that all between bulkheads are still connected.
- ☐ Slide avionics section into booster section and insert shear pins.

Prepare Main Parachute.

- ☐ Extinguish all cigarettes.
- ☐ Verify that no flame sources are located within 25 feet of recovery charge preparation area.
- ☐ Put on PPE.
- ☐ Measure out main chute black powder charge.
- ☐ Pour black powder into ejection charge canister.
- ☐ Attach leads from two electric matches to the wires in the nosecone bulkhead.
- ☐ Tape the electric matches to the side of the ejection canister with 1.5" free to bend into black powder.
- ☐ Bury match heads in black powder.
- ☐ Insert plug on top of black powder and pack with a wooden dowel.
- ☐ Seal ejection charge canister with tape.
- ☐ Attach the quick link on the short end of the harness to the U-bolt in the nose cone.
- ☐ Wrap harness and parachute with Nomex cloth.
- ☐ Being careful not to disturb the ejection charge; insert the parachute into the nose cone with the electric match wires and unconnected end of the harness protruding.
- ☐ Attach loose quick link to U-bolt in the top avionics section bulkhead.
- ☐ Connect the e-matches to the avionics section.
- ☐ Slide nose cone into avionics section and insert shear pins.

Motor Preparation   Motor Preparation Leader:_____

- ☐ Visually inspect to make sure the motor is clean and free from defects.
- ☐ Extinguish all cigarettes.
- ☐ Verify that no flame sources are located within 25 feet of motor preparation area.
- ☐ Inspect reload components.
- ☐ Assemble motor per manufacturer's instructions.
- ☐ Lightly coat the inside of the tracking smoke well in the forward bulkhead with grease.
- ☐ Lightly coat grease on the outside surface of the tracking smoke element.
- ☐ Lightly grease the four small o-rings.
- ☐ Place the tracking smoke module with vertical orientation on a flat horizontal surface.
- ☐ Slide the O-rings onto the module. It is necessary to have the o-rings tied to one end of the smoke element.
- ☐ With the o-rings on the tracking smoke element flush to the bottom of element and on a flat surface, align and slide the forward bulkhead onto the assembled tracking module.
- ☐ Set the forward bulkhead pre-assembly to one side for now.
- ☐ Lightly grease two large o-rings.
- ☐ Place two greased large o-rings into the grooves in the nozzle.
- ☐ Wipe a film of grease on the inside diameter of both ends of the motor case.
- ☐ Using a twisting motion, install the nozzle into the end of the case.
- ☐ Install three (3) propellant grains into the liner tube.
- ☐ Apply a light coat of grease to the outside of the liner.
- ☐ Install liner assembly into the case until seated against the nozzle.
- ☐ Lightly grease two large o-rings.
- ☐ Place two greased large o-rings into the grooves in the forward bulkhead
- ☐ Using a twisting motion, install the forward bulkhead into the forward end of the case until it is seated against the propellant grains. The forward bulkhead is oriented so that the threaded hole faces outwards.
- ☐ Install the 75 mm threaded ring into the internally threaded Slimline motor retainer.

Igniter Installation   Igniter Installation Leader:________

- ☐ To be preformed after Javelin is loaded on the rail and in the launch position.
- ☐ Continuity check on igniter.
- ☐ Insert igniter into motor.
- ☐ Make sure that igniter is at the top of the motor and tape leads to side of Blast bucket.
- ☐ Touch wires from launch control box together to verify that they are not receiving current.
- ☐ Attach wires to igniter leads.

- ☐ Leave wires in a position where they will not short out.
- ☐ Recheck the continuity of the igniter.
- ☐ Flip launch control box to pad armed.
- ☐ Retreat to safety zone.

Setup on Launcher Launcher Setup Leader:________

- ☐ Send spotters (with radios!) out to watch for rocket landing.
- ☐ Clear the area of anything that could impede mounting the rocket (trip hazards, obstructions, etc).
- ☐ Put on hard hats.
- ☐ Load the rocket on the rail gently.
- ☐ Insert assembled motor into motor mount tube.
- ☐ Insert spacing ring.
- ☐ Insert retaining ring and tighten.
- ☐ Ensure motor retaining ring is properly tightened and there is no longitudinal play in the motor.
- ☐ Lift the rail to vertical.
- ☐ Secure rail to trailer.
- ☐ Level trailer again.
- ☐ Setup Blast plate.
- ☐ Ensure all non-essential personnel are beyond 300 ft from rocket.
- ☐ Power on PerfectFlite and RDAS.
- ☐ Verify that the PerfectFlite has continuity (three quick beeps, repeating).
- ☐ Verify that the RDAS has continuity (one short beep per second).
- ☐ Wait until all devices complete powering on.
- ☐ After the Gumstix is powered on, wait for "Booted" and "Logged In" lights to turn on (this may take several minutes).
- ☐ Press "Execute Program"; confirm avionics is sending data.

Troubleshooting Procedure Troubleshooting Leader________
Launch Failure Troubleshooting

- ☐ Remove safety interlock key from launch controller or disconnect the battery.
- ☐ Do not approach the rocket for a minimum of two minutes.
- ☐ Wait for range safety officer to declare the range open.
- ☐ The range safety officer carefully approaches the rocket wearing personal protective equipment (PPE).
- ☐ Remove the igniter from the motor.
- ☐ If the igniter is burned replace it.

☐ Check for shorts in the wiring.

☐ Check battery power.

☐ Follow the appropriate launch procedures to re-attempt the launch.

☐ Two people carefully approach the rocket wearing PPE. Hang Fire

☐ Wait for the motor to stop burning and cool down.

☐ Wait for range safety officer to declare the range open.

☐ Try to minimize all volatile components before approaching the rocket.

☐ Contact the safety officer of the launch site.

☐ Do not approach the rocket for at least five minutes after the motor has stopped.

☐ Two people carefully approach the rocket wearing PPE.

☐ Insert PerfectFlite and RDAS safety RBF plugs to disarm the recovery system.

Recovery System Deployment Failure

☐ Keep all personnel at a safe distance and contact the launch site safety officer.

☐ Cautiously approach the rocket with a CO_2 or foam fire extinguisher and proper PPE (hardhat, gloves, safety glasses).

☐ Attempt to locate deployment charges. If intact, follow "Undeployed Recovery Charges" procedure.

☐ Locate and remove all rocket debris from the crash site.

☐ Store and document the debris for further investigation. Undeployed Recovery Charges

☐ Clear all personnel except one (range safety officer or recovery team member) from the site.

☐ Point the charge in a safe direction.

☐ Wearing PPE, complete the circuit in an electric match using a battery.

Post Flight Inspection   Post Flight Inspection Leader:________

☐ Receive go-ahead from range safety officer.

☐ Insert safety interlock key into launch controller.

☐ Perform a five second countdown, pressing and holding the ignition button at zero.

In-Flight

☐ Watch for parachute deployments.

☐ Keep track of rocket during descent.

☐ At touchdown, take pictures and make note of landmarks that will aid in ground recovery.

☐ Leave at least one spotter with a radio or cell phone at the launch area to keep the ground recovery team on course.

☐ Carry a radio or cell phone and keep in contact.

☐ Two team members (team leader and assistant), wearing safety glasses, approach the rocket slowly and check for safety hazards such as unexpended recovery charges.

☐ If undeployed recovery charges, follow emergency safety procedures.

☐ Team leader sounds "all clear".

☐ Stop recording on the flight camera.

☐ Insert the PerfectFlite/RDAS safety RBF-plug into the top stereo jack.

☐ If connected via modem, issue shut down command. then insert power-plug into bottom stereo jack. if not connected insert power-plug into the bottom stereo jack to power down main flight computer.

☐ Carefully fold parachutes taking care to not tangle shroud lines.

☐ Disconnect harnesses from the rocket.

☐ Allow motor case and nozzle to cool before handling.

☐ Carry rocket parts back to launch area.

☐ Disassemble parts for transport/storage.

☐ Vent excess CO_2.

☐ Remove motor case from motor mount tube (Make sure it is no longer hot before handling).

☐ Remove spent reload from motor casing and discard in trash bag.

☐ Clean any parts that will be reused.

☐ Perform an overall inspection of the rocket looking for any damage that may have occurred during flight or landing.

☐ Perform an overall cleaning to remove dirt/burned black powder/etc.

G.B. Motor Assembly Procedure

Adapted from Pro54® Instructions, retrieved from http://www.pro38.com/pdfs/Pro54_instructions.pdf

MOTOR ASSEMBLY PROCEDURE ☐ 1.0 Inspect the motor casing for damage. Discard and replace if damaged. Modification of the casing can cause property damage or result in serious personal injury.

☐ 2.0 Leave the protective cap on the nozzle for now.

☐ 3.0 Most reloads will only use one o-ring per closure, but provision has been made for two if required in future products. Check that the o-rings are installed in the forward and rear closures properly. Also check the o-rings for any inadvertent damage. If the o-rings appear damaged in any way, DO NOT proceed. Instead, contact your Pro54™ dealer to arrange for replacement or remedy.

☐ 4.0 The o-rings are pre-lubricated at the factory, but we recommended that you apply a light film of silicone o-ring lubricant to the inside edge of the motor casing where the reload kit will be inserted. This will make installation and removal of the reload kit much easier!

Insert the delay/ejection module into the forward end of the case liner. A small gap between the forward end of the liner and the shoulder on the delay/ejection module is normal.

☐ 5.0 Insert the reload kit assembly into the casing, forward closure first. There will be some resistance as the o-rings compress into the casing. To ease insertion, place the nozzle end against a smooth surface and push carefully on the forward end of the casing until the reload kit is completely inserted into the motor case. Be careful not to damage the nozzle. Once fully inserted, the rear closure/nozzle assembly should be flush or slightly protrude (up to about 1/16") of the threaded end of the motor case. If not, remove the reload kit and investigate.

☐ 6.0 Remove the nozzle cap, and screw the retaining ring onto the rear of the motor case. Snug it up until it feels seated against the rear closure, and the forward closure is firmly seated against the forward lip of the motor case. Do not over tighten - hand tight is sufficient. The cap will rotate approximately 3-3/4 turns to fully seat against an empty case, and it should engage by at least 3 turns when the reload is installed. Reinstall the nozzle cap.

☐ 7.0 Your Pro54™ motor is now ready to be installed in your rocket. DO NOT install the igniter until the rocket is mounted on the launch pad, or in a location approved by the Range Safety Officer.

H. Manufacturing Drawing Package

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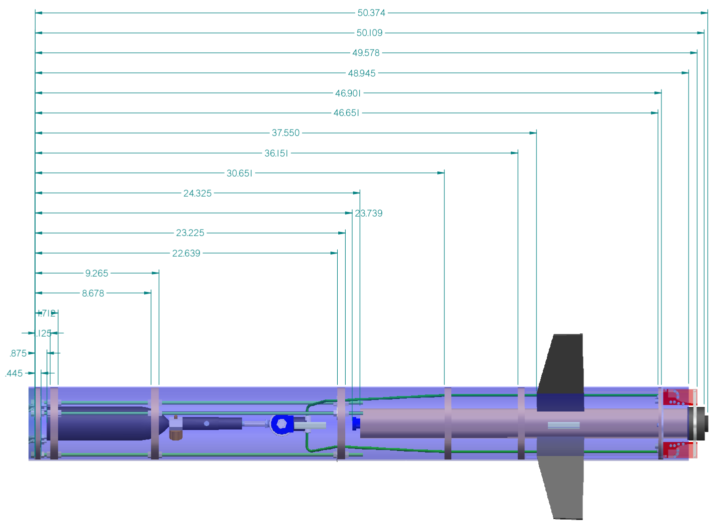
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE
DRAWN	S. Mosquea	03/18/11
CHECKED	A. Jensen	03/20/11
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

Solid Edge

TITLE
Bottom Assembly

SIZE	DWG NO	REV
A2		

FILE NAME: Javelin_design2.dft

SCALE:	WEIGHT:	SHEET 1 OF 1

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

Item Number	Document Number	Title	Material	Quantity
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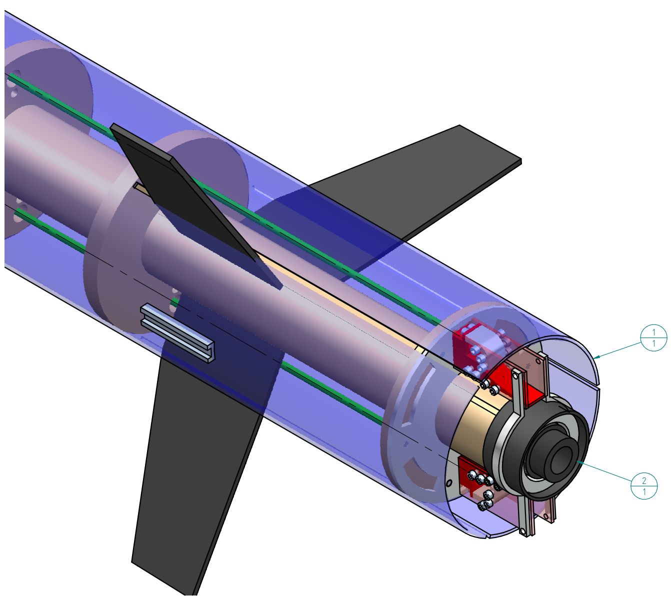
2		Motor Assembly		1



	NAME	DATE
DRAWN	S. Mosquea	03/18/11
CHECKED	A. Jensen	03/20/11
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

Solid Edge

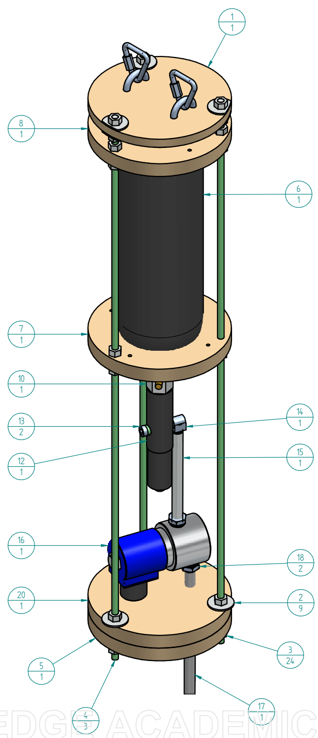
TITLE
BOAT-TAIL

SIZE	DWG NO	REV
A2		

FILE NAME: Javelin_design.dft

SCALE:	WEIGHT:	SHEET 1 OF 1

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



Item Number	Document Number	Title	Material	Quantity
1		Payload Bulkeads Assembly		1
2		1/4" Nut Washer	Aluminum, 1060	9
3		1/4" Nut	Aluminum, 1060	24
4		Threaded Rods	Aluminum, 1060	3
5		Motor Wood Bulkhead	Wood, Birch	1
6		24 Oz CO2 Tank	Tank	1
7		Motor Wood Bulkhead	Wood, Birch	1
8		Motor Wood Bulkhead	Wood, Birch	1
9*			(None)	1
10		Control Valve	Stainless steel	1
11*			(None)	1
12		Regulator	noNE	1
13		Plug	Stainless steel	2
14		Ninety Degree Elbow	Stainless steel	1
15		Small Rigid Tube McMaster: 44665K308	Aluminum, 6061-T6	1
16		Solenoid Valve		1
17			(None)	1
18		Bushing, McMaster: 4464K381	Stainless steel	2
19*		Tee McMaster: 3861T510	Aluminum, 6061-T6	1
20		Motor Wood Bulkhead (Blind)	Wood, Birch	1

	NAME	DATE
DRAWN	S. Mosquera	01/22/11
CHECKED		
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

Solid Edge

TITLE Payload Assembly

SIZE A2	DWG NO	REV

FILE NAME: payload.dft

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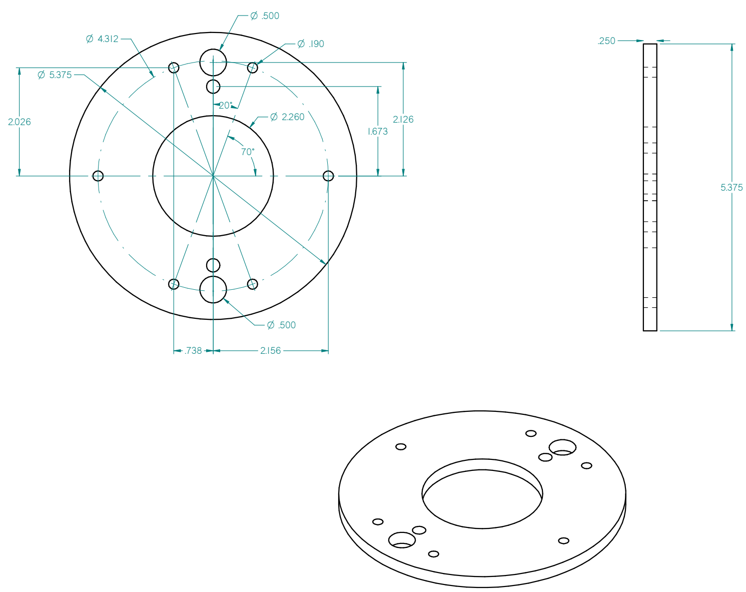
REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE
DRAWN	S. Mosquea	01/22/11
CHECKED		
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

Solid Edge

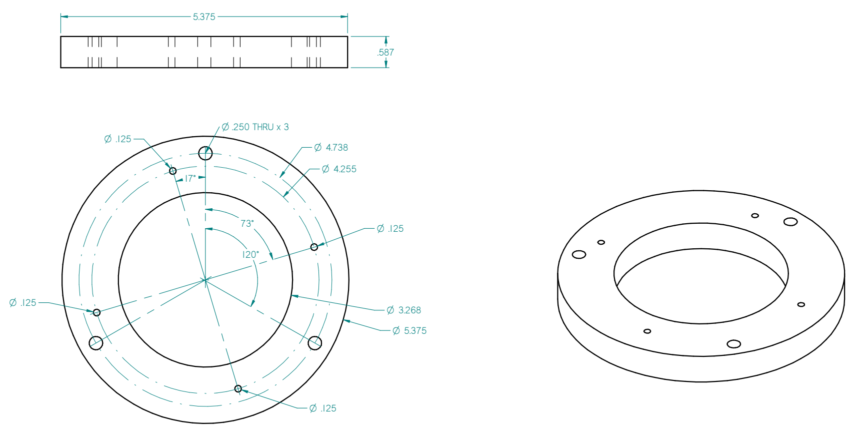
TITLE
Bracket Bulkhead

SIZE A2	DWG NO	REV

FILE NAME: Bottom_Ring.dft

SCALE:	WEIGHT:	SHEET 1 OF 1

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE
DRAWN	S. Mosquea	2/27/2011
CHECKED		
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

Solid Edge

TITLE
CO2 FORWARD FIXED BULKHEAD

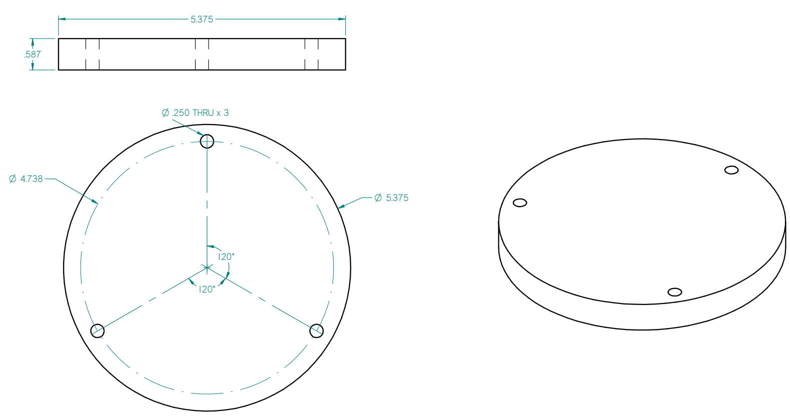
SIZE	DWG NO	REV
A2		

FILE NAME: CO2_2nd-Bulkhead.dft

SCALE:	WEIGHT:	SHEET 1 OF 1

REVISION HISTORY

REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE
DRAWN	S. Mosquea	02/28/11
CHECKED		
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

Solid Edge

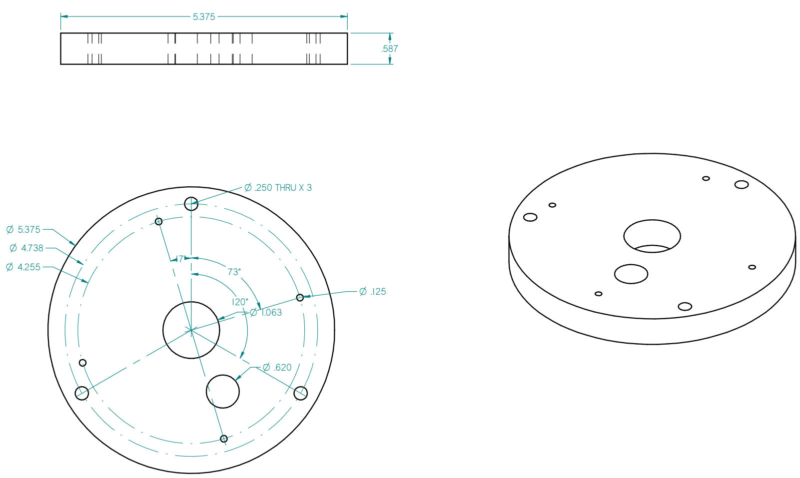
TITLE
Blind Forward Motor Bulkhead

SIZE	DWG NO	REV
A2		

FILE NAME: motor bulkhead -Blind.dft

SCALE:	WEIGHT:	SHEET 1 OF 1

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE
DRAWN	S. Mosquea	2/28/11
CHECKED		
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

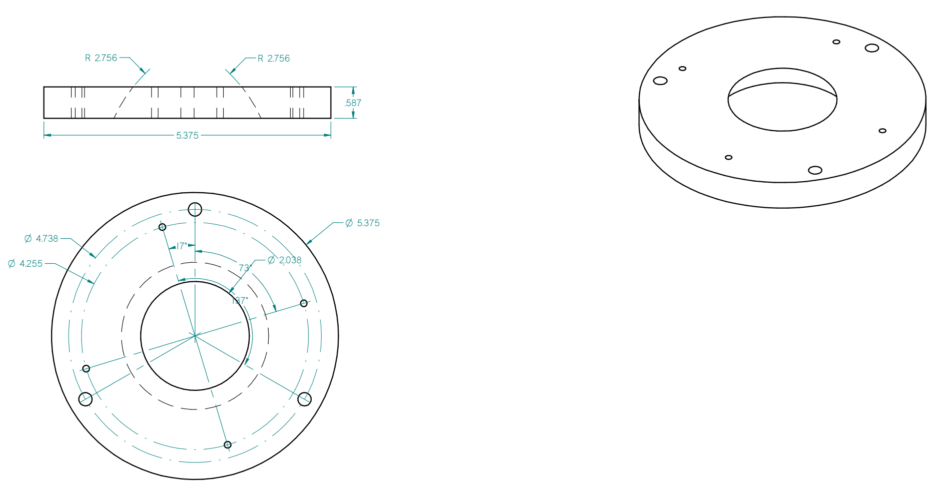
Solid Edge

TITLE
Forward Motor Bulkhead

SIZE A2	DWG NO	REV

FILE NAME: motor bulkhead.dft

SCALE:	WEIGHT:	SHEET 1 OF 1



REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

	NAME	DATE
DRAWN	S. Mosquea	2/27/2011
CHECKED		
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

Solid Edge

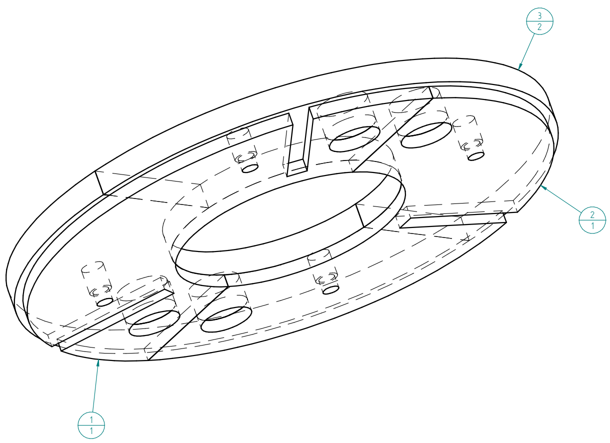
TITLE
Aft CO2 Moveable Bulkhead

SIZE A2 | DWG NO | REV

FILE NAME: CO2_Bulkhead.dft

SCALE: | WEIGHT: | SHEET 1 OF 1

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



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2		1/8" Aluminum Plate	Aluminum, 6061-T6	1
3			Wood, Birch	2

	NAME	DATE
DRAWN	S. Mosquea	03/20/11
CHECKED	A. Jensen	03/20/11
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

Solid Edge

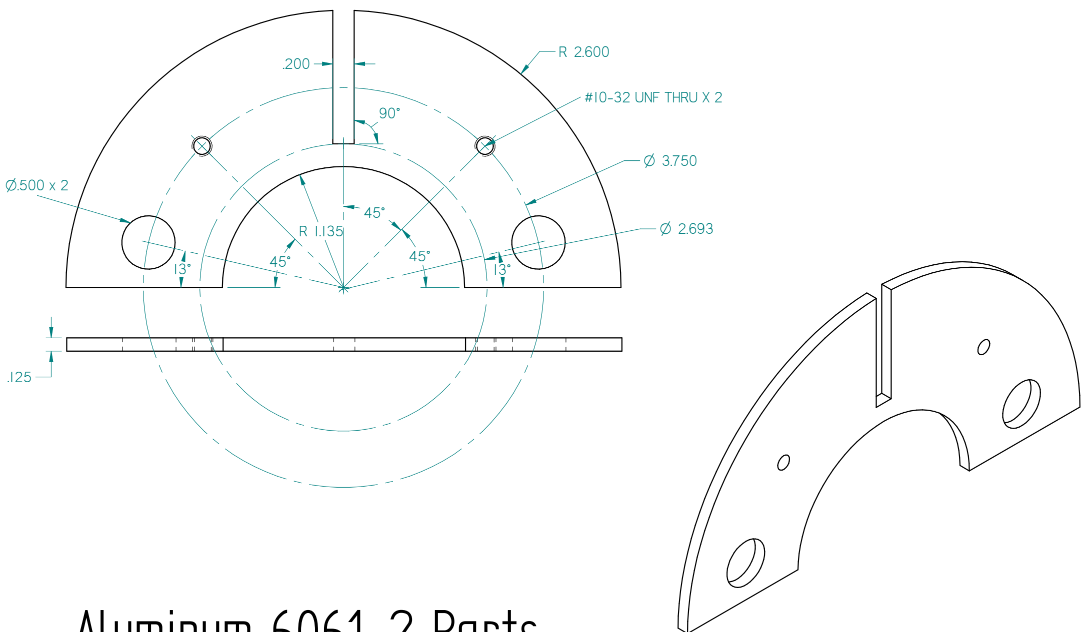
TITLE: FIN JIG ASSEMBLY

SIZE: A2 | DWG NO | REV

FILE NAME: finfig_fnal.dft

SCALE: | WEIGHT: | SHEET 1 OF 1

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



Aluminum 6061, 2 Parts

	NAME	DATE
DRAWN	SMM	03/07/11
CHECKED		
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

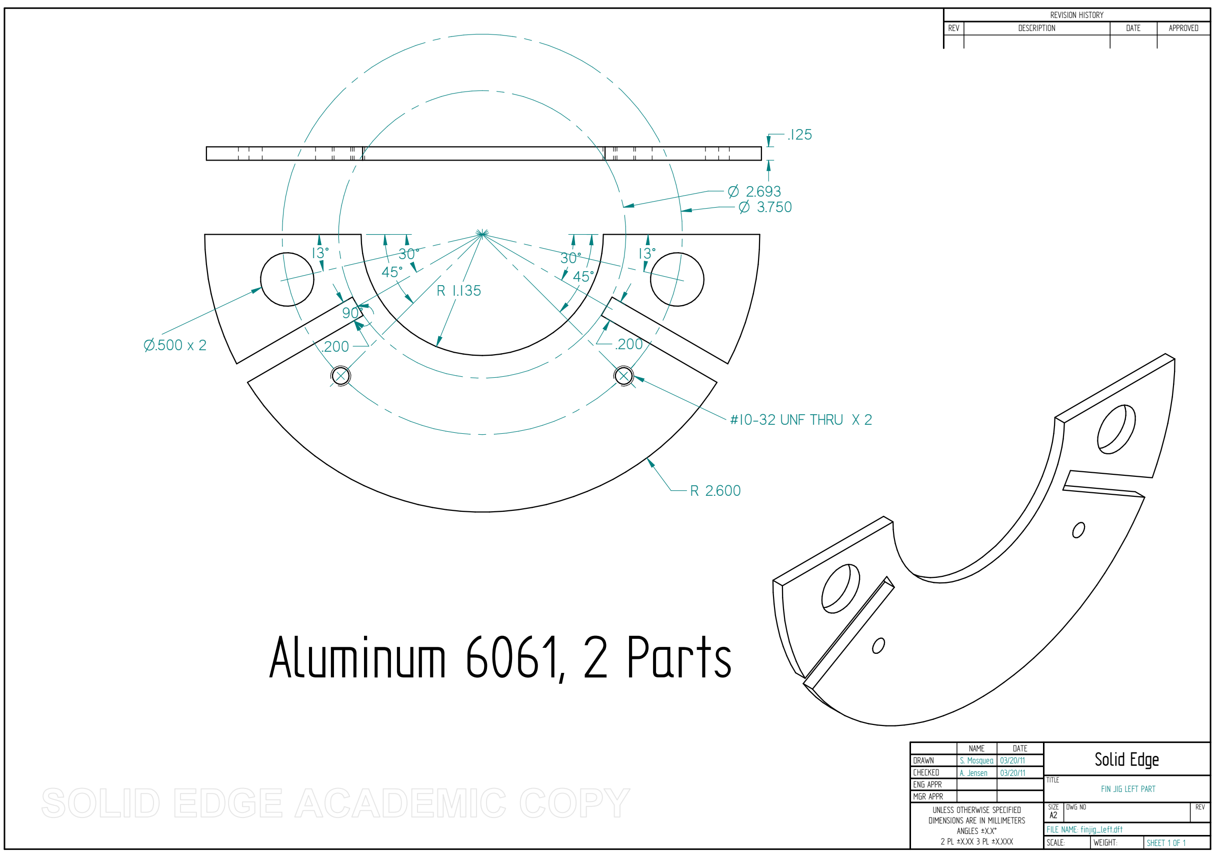
Solid Edge

TITLE

SIZE A2	DWG NO	REV

FILE NAME: finjig_right.dft

SCALE:	WEIGHT:	SHEET 1 OF 1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REV
DESCRIPTION
DATE
APPROVED
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30°
45°
13°
90°
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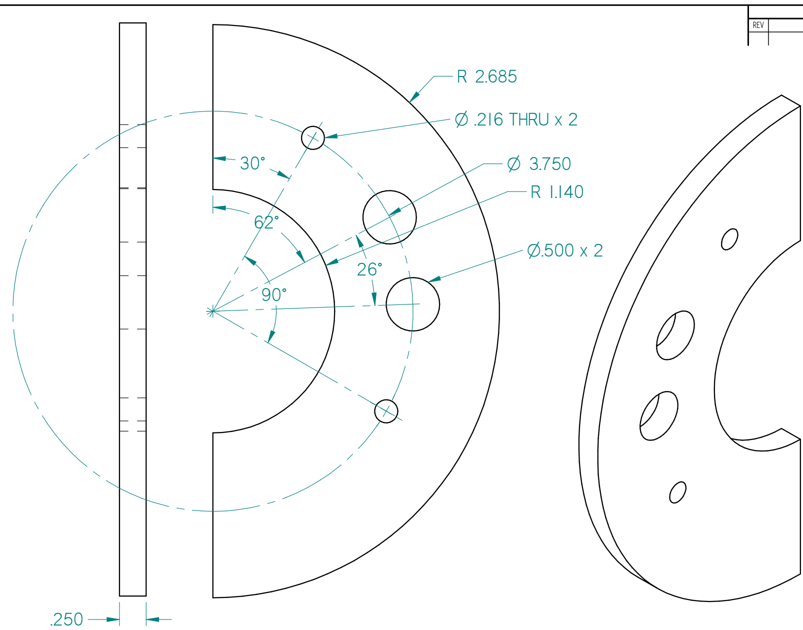
.200
Ø.500 x 2
#10-32 UNF THRU X 2
R 2.600
Aluminum 6061, 2 Parts
SOLID EDGE ACADEMIC COPY
NAME
DATE
DRAWN
S. Mosquea
03/20/11
CHECKED
A. Jensen
03/20/11
ENG APPR
MGR APPR
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX
Solid Edge
TITLE
FIN JIG LEFT PART
SIZE
A2
DWG NO
REV
FILE NAME: finjig_left.dft
SCALE:
WEIGHT:
SHEET 1 OF 1



REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

Wood, 4 parts

	NAME	DATE
DRAWN	S. Mosquea	03/20/11
CHECKED	A. Jensen	03/20/11
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

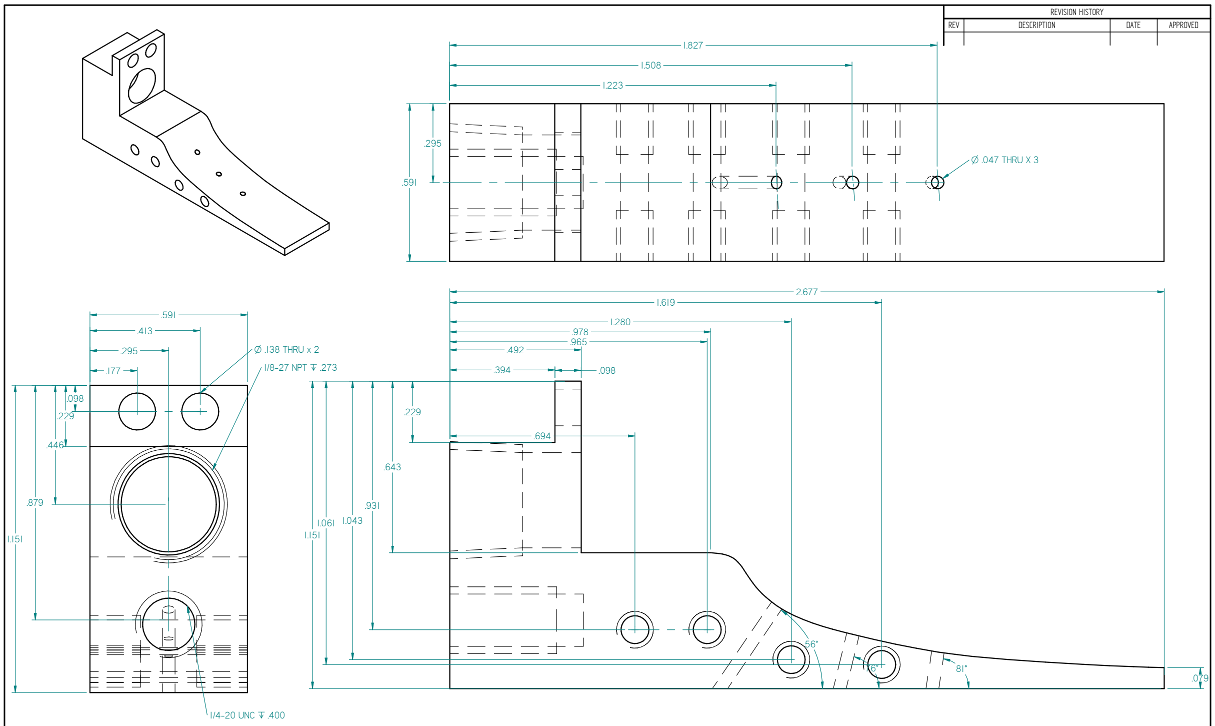
Solid Edge

TITLE FIN JIG WOOD PART

SIZE	DWG NO	REV
A2		

FILE NAME: wood-DOWN.dft

SCALE:	WEIGHT:	SHEET 1 OF 1



REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED

	NAME	DATE
DRAWN	S. Mosquea	02/28/11
CHECKED		
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

Solid Edge

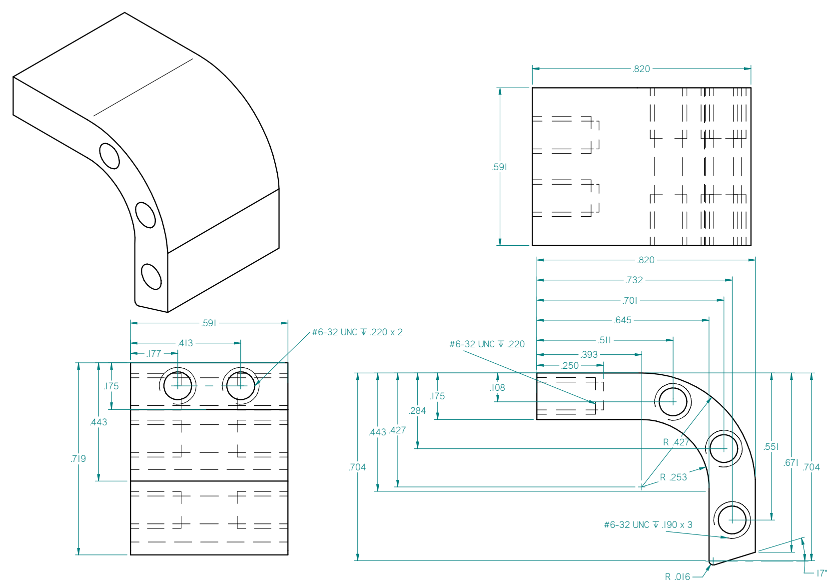
TITLE
Aerpospike Main Part

SIZE A2	DWG NO	REV

FILE NAME: Aerospike_Main-dimensioned.dft

SCALE:	WEIGHT:	SHEET 1 OF 1

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE
DRAWN	S. Mosquea	02/28/11
CHECKED		
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

Solid Edge

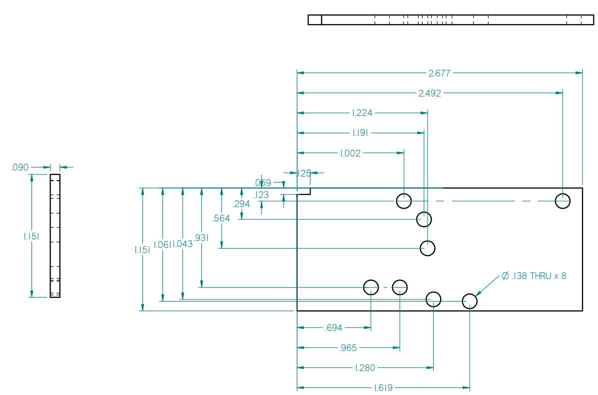
TITLE
Aerospike Thin Part

SIZE	DWG NO	REV
A2		

FILE NAME: Aerospike_Thin-dimensioned.dft

SCALE:	WEIGHT:	SHEET 1 OF 1

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED



	NAME	DATE
DRAWN	S. Mosquea	02/28/11
CHECKED		
ENG APPR		
MGR APPR		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
ANGLES ±X.X°
2 PL ±X.XX 3 PL ±X.XXX

Solid Edge

TITLE
Side Plates

SIZE	DWG NO	REV
A2		

FILE NAME: Aerospike_Plate-dimensioned.dft

SCALE:	WEIGHT:	SHEET 1 OF 1

I. CO_2 Tank Temperature Safety

DOT 3AL Temperature/Pressure Analysis

Regulation states Rupture Pressure is 5/3 service pressure

$$Service_{Pressure} := 1800psi$$

$$Tank_{Rupture\_Pressure} := Service_{Pressure} \cdot \left(\frac{5}{3}\right) = 3 \times 10^{3} \cdot psi$$

$$Burst_{Disk\_Pressure} := Tank_{Rupture\_Pressure} \cdot .8 = 2.4 \times 10^{3} \cdot psi$$

$$Tank_{Projected\_Area} := \left[9in + \frac{(12in - 9in)}{2}\right] \cdot 2.5in = 26.25 \cdot in^{2}$$

$$Solar_{Radiation} := 1366 \frac{W}{m^{2}}$$

$$\gamma := 1.3$$

$$R_{u} := 8314.4126 \frac{J}{kg \cdot K}$$

$$MW_{CO2} := 44$$

$$C_{AL} := 902 \frac{J}{kg \cdot K}$$

$$M_{Tank} := .677kg = 1.493 lb$$

$$M_{CO2} := 12oz = 0.75 \cdot lb$$

$$C_{v} := \left(\frac{1}{\gamma - 1}\right) \cdot \frac{R_{u}}{MW_{CO2}} = 629.88 \cdot \frac{J}{kg \cdot K}$$

$$Tank_{Surface} := 2.5in \cdot \pi \cdot 9in + \pi \cdot \frac{3.25^{2}}{4} in^{2} + \frac{2.5in \cdot \pi \left[\left(\frac{2.5}{2}\right)^{2} in^{2} + (12 - 9)^{2} in^{2}\right]^{.5}}{2} = 0.059 \cdot m^{2}$$

J. C-BAS Avionics State Estimation and Energy Management System

Appendix J. C-BAS Avionics State Estimation and Energy Management Algorithms

I. Coordinate Definitions

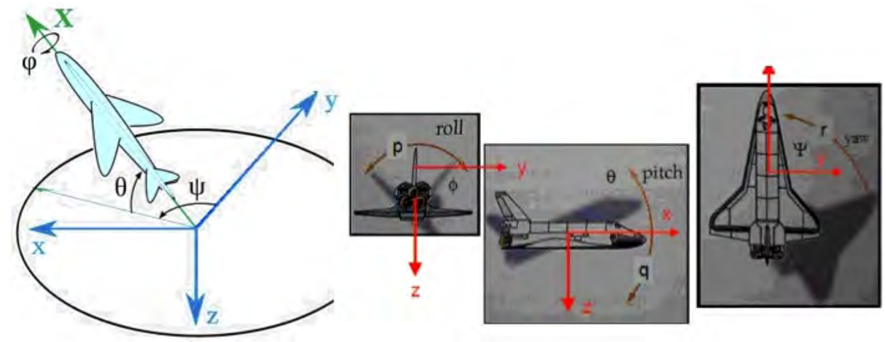


Figure 1. Coordinate System Definition

All rotations and angular rates defined as positive in "clockwise" or "right-handed" direction. The origin of the coordinate system is assumed aligned with the Inertial Measurement Unit (IMU) axis point. The IMU used for this application is described in detail in Section V of this document.

$$\begin{bmatrix} \begin{matrix}\phi \\ \theta\end{matrix} \rightarrow \textit{measured from local horizontal} \\ \psi \rightarrow \textit{clockwise from true north} \end{bmatrix} \begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} \textit{roll rate} \rightarrow \textit{about } x\textit{-axis} \\ \textit{pitch rate} \rightarrow \textit{about } y\textit{-axis} \\ \textit{yaw rate} \rightarrow \textit{about } z-\textit{axis} \end{bmatrix} \quad \text{(AJ1}$$

$$\begin{bmatrix} u \\ v \\ w \end{bmatrix} = \begin{bmatrix} \textit{Velocity component along vehicle longituidinal (x) axis, + fwd} \\ \textit{Velocity component along vehicle lateral (y) axis, + starboard} \\ \textit{Velocity component along vehicle normal (z) axis, + down} \end{bmatrix} \quad \text{(AJ2}$$

Figure 2. IMU Axis Orientation in Avionics Bay.

II. Equations of Motion

Linear Acceleration, Velocity

The linear vehicle velocity will be calculated by direct integration of the IMU-sensed linear accelerations. Accounting for the flight path curvature and accounting for the effect of gravity on the accelerometers[1]

$$\frac{\sum \vec{F}}{M} = \frac{\partial \vec{V}}{\partial t} + \vec{\omega} \times \vec{V}$$

$$\rightarrow \vec{\omega} \times \vec{V} = \begin{bmatrix} \vec{i} & \vec{j} & \vec{k} \\ p & q & r \\ u & v & w \end{bmatrix} = \begin{bmatrix} q \cdot w - r \cdot v \\ r \cdot u - p \cdot w \\ p \cdot v - q \cdot u \end{bmatrix} = \begin{bmatrix} 0 & -r & q \\ r & 0 & -p \\ -q & p & 0 \end{bmatrix} \cdot \begin{bmatrix} u \\ v \\ w \end{bmatrix}$$

$$\frac{\sum \vec{F}}{M} = g_0 \begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix} + g \cdot \begin{bmatrix} -\sin\theta \\ \sin\phi\cos\theta \\ \cos\phi\cos\theta \end{bmatrix}$$

(AJ3

$$solve\ for\ \frac{\partial \vec{V}}{\partial t} \rightarrow$$

$$\begin{bmatrix} \dot{u} \\ \dot{v} \\ \dot{w} \end{bmatrix} = \begin{bmatrix} 0 & r & -q \\ -r & 0 & p \\ q & -p & 0 \end{bmatrix} \cdot \begin{bmatrix} u \\ v \\ w \end{bmatrix} + g_0 \begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix} + g \cdot \begin{bmatrix} -\sin\theta \\ \sin\phi\cos\theta \\ \cos\phi\cos\theta \end{bmatrix}$$

(AJ4

Examining the components of M, the direction cosine matrix that transforms from the inertial to body axis-coordinate frames (Ref. 1, Chapt. 4)

$$\vec{\vec{M}} = \{M_{ij}\} =$$

$$\begin{bmatrix} \cos\theta\cos\psi & \cos\theta\sin\psi & -\sin\theta \\ \sin\phi\sin\theta\cos\psi - \cos\phi\sin\psi & \sin\phi\sin\theta\sin\psi + \cos\phi\cos\psi & \sin\phi\cos\theta \\ \cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi & \cos\phi\sin\theta\sin\psi - \sin\phi\cos\psi & \cos\phi\cos\theta \end{bmatrix} \quad \textit{(AJ5}$$

The gravity vector can be expressed as a function of the direction cosine elements

$$\vec{g} = g \cdot \begin{bmatrix} -\sin\theta \\ \sin\phi\cos\theta \\ \cos\phi\cos\theta \end{bmatrix} = g \cdot \begin{bmatrix} M_{13} \\ M_{23} \\ M_{33} \end{bmatrix} \quad \vec{g} = g \cdot \begin{bmatrix} -\sin\theta \\ \sin\phi\cos\theta \\ \cos\phi\cos\theta \end{bmatrix} = g \cdot \begin{bmatrix} M_{31} \\ M_{32} \\ M_{33} \end{bmatrix} \quad \textit{(AJ6}$$

Gravity Model

The first harmonic of the acceleration gravity is given as a function of mean sea level (*MSL*) altitude and geodetic latitude (λ), with corrections for centrifugal force due to the earth's rotation,

$$g = 1000_{\frac{m}{km}} \cdot \left(\frac{\mu}{\left(R_\oplus + h_{\underset{KM}{MSL}}\right)^2} - \Omega_\oplus^{\;2} \cdot \left(R_\oplus + h_{\underset{km}{MSL}}\right) \right) \rightarrow \begin{bmatrix} \mu = 3.9860044 \times 10^5_{\frac{km^3}{\sec^2}} \\ R_\oplus = \dfrac{R_{eq}}{\sqrt{1 + \dfrac{e^2}{1-e^2}\sin^2\lambda}} \\ R_{eq} = 6378.13649_{km} \\ e = 0.08181980 \\ \Omega_\oplus = 7.2929115 \times 10^{-5}_{\frac{rad}{\sec}} \end{bmatrix} \quad \text{(AJ7}$$

Another, reasonably accurate, less complex algorithm suitable for real time calculations is[2]

$$g_{alternate} = 9.780318_{\frac{m}{\sec^2}} \times \left[1 + 0.0053024 \cdot \sin^2(\lambda) + 0.0000058 \cdot \sin^2(2\lambda)\right] - 3.086 \cdot 10^{-6}_{\frac{1}{\sec^2}} \cdot h_{\underset{meters}{MSL}} \quad \text{(AJ8}$$

At the Bragg Farms launch site (USLI competition) – latitude 34.898°, altitude 240 meters MSL — the two competing models calculate

$$\begin{bmatrix} g \\ g_{alternate} \end{bmatrix} = \begin{bmatrix} 9.79138 \\ 9.79650 \end{bmatrix}_{\frac{m}{\sec^2}} \quad \text{(AJ9}$$

Thus the models have a difference of approximately 0.052% or less than 0.00052 g's. This difference is well within the accuracy level of the acceleration measurements and may be considered as negligible. Either model is acceptable for this application.

Altitude

The vehicle altitude is calculated by integrating the vertical velocity estimate. The transformation of the velocity vector from body axis to inertial axis is

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{bmatrix}_{inertial} = M^T \cdot \begin{bmatrix} u \\ v \\ w \end{bmatrix}_{\substack{body \\ axis}} = \begin{bmatrix} \cos\theta\cos\psi & \sin\phi\sin\theta\cos\psi - \cos\phi\sin\psi & \cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi \\ \cos\theta\sin\psi & \sin\phi\sin\theta\sin\psi + \cos\phi\cos\psi & \cos\phi\sin\theta\sin\psi - \sin\phi\cos\psi \\ -\sin\theta & \sin\phi\cos\theta & \cos\phi\cos\theta \end{bmatrix} \cdot \begin{bmatrix} u \\ v \\ w \end{bmatrix}_{\substack{body \\ axis}}$$

. (AJ10

The rate of altitude change can thus be written as

$$\dot{h} = -\dot{z}_{inertial} = \begin{bmatrix} \sin\theta & -\sin\phi\cos\theta & -\cos\phi\cos\theta \end{bmatrix} \cdot \begin{bmatrix} u \\ v \\ w \end{bmatrix} = \begin{bmatrix} -M_{13} & -M_{23} & -M_{33} \end{bmatrix} \cdot \begin{bmatrix} u \\ v \\ w \end{bmatrix}$$

(AJ11

Collected State Equations

There are 4 state variables to be directly estimated from the Kalman filter equations. The energy state (potential altitude) of the vehicle is calculated from these states. The collected velocity and altitude state equations are

$$\begin{bmatrix} \dot{u} \\ \dot{v} \\ \dot{w} \\ \dot{h} \end{bmatrix} = \begin{bmatrix} 0 & r & -q & 0 \\ -r & 0 & p & 0 \\ q & -p & 0 & 0 \\ -M_{13} & -M_{23} & -M_{33} & -\frac{1}{\tau} \end{bmatrix} \cdot \begin{bmatrix} u \\ v \\ w \\ h \end{bmatrix} + g_0 \begin{bmatrix} A_x + \frac{g}{g_0} \cdot M_{13} \\ A_y + \frac{g}{g_0} \cdot M_{23} \\ A_z + \frac{g}{g_0} \cdot M_{33} \\ 0 \end{bmatrix}$$

(AJ12

The time constant, τ, is included in the altitude equation to allow for low-pass filtering of the altimeter-based altitude data, which tends to be rather noisy. The acceleration and attitude data are already filtered by the onboard sensor fusion algorithms of the IMU and do not need to be low-pass filtered in the real time estimation algorithm.

Accelerometer Corrections for Center of Gravity Offset

Because the rocket avionics bay location will not allow the IMU to be placed precisely at the center of gravity of the vehicle; it becomes necessary to correct the sensed accelerations for centrifugal force resulting from angular rotations about the center of gravity of the vehicle. These transformations equations are[3]

$$\begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix}_{cg} = \begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix}_{IMU} + \frac{1}{g_0} \begin{bmatrix} \left(r^2 + q^2\right) \cdot X_{IMU} - \left(p \cdot q - \dot{r}\right) \cdot Y_{IMU} - \left(r \cdot p + \dot{q}\right) \cdot Z_{IMU} \\ -\left(p \cdot q + \dot{r}\right) \cdot X_{IMU} + \left(p^2 + r^2\right) \cdot Y_{IMU} - \left(r \cdot q - \dot{p}\right) \cdot Z_{IMU} \\ -\left(r \cdot p - \dot{q}\right) \cdot X_{IMU} - \left(r \cdot q + \dot{p}\right) \cdot Y_{IMU} + \left(q^2 + p^2\right) \cdot Z_{IMU} \end{bmatrix}$$ (AJ13

Since the angular acceleration rates $\{\dot{p} \quad \dot{q} \quad \dot{r}\}$ are not available in real time, only the centrifugal-force corrections due to angular rates will be performed. The *cg-corrected* acceleration values will be used in the Kalman filter calculations. For a rigid airframe, the angular rates at the IMU will be the same as those values at the center of gravity. The {X, Y, and Z} positions of the IMU are measured along from the *cg* location to the *IMU* with positive directions along the axis system defined in Figure 1.

Observation Equations

Due to imperfections in the accelerometer sensors, the measured *Accel* vector can be in error by an additive constant (bias). Thus if these sensed measurements are integrated "open-loop", the velocity and subsequent altitude estimates will drift with time. A stable altitude measurement is needed to minimize this drift effect. For this application to PerfectFlite™ altitude measurement is used to stabilize the integration. The resulting observation equation is

$$\left[h_{PerfectFlite}\right] = \left[0 \quad 0 \quad 0 \quad 1\right] \begin{bmatrix} u \\ v \\ w \\ h \end{bmatrix},$$ (AJ14

where the $[u \ v \ w \ h]^T$ is the current state vector estimate. Since the PerfectFlite data provides the "judged altitude," for the USLI competition, initially the perfect flight data will be weighted moderately by the Kalman filter equations; but as apogee is approach it will be weighted increasingly more heavily. This scheme, to be described in detail later in Section IV of this document, has the effect of making the altimeter the "truth" data for the filter apogee prediction.

III. System Observability

The single altitude measurement has the effect of making all of the state estimates directly observable. This effect can be demonstrated by calculating the system the o observability matrix

$$\tilde{O} = \begin{bmatrix} C \\ CA \\ CA^2 \\ CA^3 \end{bmatrix} \rightarrow \begin{array}{l} C = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix} \\ A = \begin{bmatrix} 0 & r & -q & 0 \\ -r & 0 & p & 0 \\ q & -p & 0 & 0 \\ -M_{13} & -M_{23} & -M_{33} & -\frac{1}{\tau} \end{bmatrix} \end{array}$$

(AJ15

Evaluating the rows of the observability matrix, the corresponding rows are

$$C \cdot A = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 0 & r & -q & 0 \\ -r & 0 & p & 0 \\ q & -p & 0 & 0 \\ -M_{13} & -M_{23} & -M_{33} & -\frac{1}{\tau} \end{bmatrix} = \begin{bmatrix} -M_{13} & -M_{23} & -M_{33} & -\frac{1}{\tau} \end{bmatrix}$$

$$C \cdot A^2 = \begin{bmatrix} -M_{13} & -M_{23} & -M_{33} & -\frac{1}{\tau} \end{bmatrix} \cdot \begin{bmatrix} 0 & r & -q & 0 \\ -r & 0 & p & 0 \\ q & -p & 0 & 0 \\ -M_{13} & -M_{23} & -M_{33} & -\frac{1}{\tau} \end{bmatrix} =$$

$$\begin{bmatrix} \left(r \cdot M_{23} - q \cdot M_{33} + \frac{M_{13}}{\tau} \right) & \left(-r \cdot M_{13} + p \cdot M_{33} + \frac{M_{23}}{\tau} \right) & \left(q \cdot M_{13} - p \cdot M_{23} + \frac{M_{33}}{\tau} \right) & \frac{1}{\tau^2} \end{bmatrix}$$

$$C \cdot A^3 = \left[\begin{pmatrix} r \cdot M_{23} \\ -q \cdot M_{33} \\ +\frac{M_{13}}{\tau} \end{pmatrix} \quad \begin{pmatrix} -r \cdot M_{13} \\ +p \cdot M_{33} \\ +\frac{M_{23}}{\tau} \end{pmatrix} \quad \begin{pmatrix} q \cdot M_{13} \\ -p \cdot M_{23} \\ +\frac{M_{33}}{\tau} \end{pmatrix} \quad \frac{1}{\tau^2} \right] \cdot \begin{bmatrix} 0 & r & -q & 0 \\ -r & 0 & p & 0 \\ q & -p & 0 & 0 \\ -M_{13} & -M_{23} & -M_{33} & -\frac{1}{\tau} \end{bmatrix} =$$

$$\left\{ \begin{pmatrix} -r \cdot \begin{pmatrix} -r \cdot M_{13} \\ +p \cdot M_{33} \\ +\frac{M_{23}}{\tau} \end{pmatrix} \\ +q \cdot \begin{pmatrix} q \cdot M_{13} \\ -p \cdot M_{23} \\ +\frac{M_{33}}{\tau} \end{pmatrix} \\ -\frac{M_{13}}{\tau^2} \end{pmatrix} \quad \begin{pmatrix} r \cdot \begin{pmatrix} r \cdot M_{23} \\ -q \cdot M_{33} \\ +\frac{M_{13}}{\tau} \end{pmatrix} \\ -p \cdot \begin{pmatrix} q \cdot M_{13} \\ -p \cdot M_{23} \\ +\frac{M_{33}}{\tau} \end{pmatrix} \\ -\frac{M_{23}}{\tau^2} \end{pmatrix} \quad \begin{pmatrix} -q \cdot \begin{pmatrix} r \cdot M_{23} \\ -q \cdot M_{33} \\ +\frac{M_{13}}{\tau} \end{pmatrix} \\ +p \cdot \begin{pmatrix} -r \cdot M_{13} \\ +p \cdot M_{33} \\ +\frac{M_{23}}{\tau} \end{pmatrix} \\ -\frac{M_{33}}{\tau^2} \end{pmatrix} \quad -\frac{1}{\tau^3} \right\}$$

(AJ16

Observability in Vertical Flight

One limiting case occurs is for purely vertical flight where the pitch angle approaches 90 degrees. For this case

$$\begin{bmatrix} M_{13} \\ M_{23} \\ M_{33} \end{bmatrix}_{\theta=\frac{\pi}{2}} = \begin{bmatrix} -\sin\frac{\pi}{2} \\ \sin\phi\cos\frac{\pi}{2} \\ \cos\phi\cos\frac{\pi}{2} \end{bmatrix} = \begin{bmatrix} -1 \\ 0 \\ 0 \end{bmatrix},$$ (AJ17

and the observability matrix reduces to

$$\tilde{O}_{\left(\frac{\pi}{2}\right)} = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & -\frac{1}{\tau} \\ -\frac{1}{\tau} & r & -q & \frac{1}{\tau^2} \\ \left(-\left(r^2+q^2\right)+\frac{1}{\tau^2}\right) & \left(-\frac{r}{\tau}+p\cdot q\right) & \left(\frac{q}{\tau}+p\cdot r\right) & -\frac{1}{\tau^3} \end{bmatrix}. \quad \text{(AJ18}$$

Evaluating the determinant of this observability matrix gives

$$\left|\hat{O}\right|_{\theta=\frac{\pi}{2}} = -\left(p\cdot r^2 + p\cdot q^2\right). \quad \text{(AJ19}$$

The observability matrix is non-singular as long as there is some angular motion to the vehicle, and the system will be observable for this limiting case.

Observability in Horizontal Flight

The other limiting case occurs for horizontal flight. Here

$$\begin{bmatrix} M_{13} \\ M_{23} \\ M_{33} \end{bmatrix}_{\phi,\theta=0} = \begin{bmatrix} -\sin 0 \\ \sin 0 \cos 0 \\ \cos 0 \cos 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix} \quad \text{(AJ20}$$

and the observability matrix reduces to

$$\tilde{O}_{\theta,\phi=0} = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & -1 & -1 & -\frac{1}{\tau} \\ r-q & p+\frac{1}{\tau} & -p+\frac{1}{\tau} & \frac{1}{\tau^2} \\ \begin{pmatrix} q\left(-p+\frac{1}{\tau}\right) \\ -r\left(p+\frac{1}{\tau}\right) \end{pmatrix} & \begin{pmatrix} r(r-q) \\ -p(-p+\frac{1}{\tau}) \\ -\frac{1}{\tau^2} \end{pmatrix} & \begin{pmatrix} p(p+\frac{1}{\tau}) \\ -q(r-q) \\ -\frac{1}{\tau^2} \end{pmatrix} & -\frac{1}{\tau^3} \end{bmatrix} \quad \text{(AJ21}$$

Evaluating the determinant of this matrix gives

$$\left|\tilde{O}\right|_{\theta,\phi=0} = q^3 + r^3 + 2\left(p^2 q + p^2 r\right) - \left(q^2 r + r^2 q\right). \quad \text{(AJ22}$$

Similar to the vertical flight condition, in horizontal flight as long as there is angular motion to the vehicle, the system will be completely observable. Since both limiting flight cases produce non-zero determinant values (non-singular observability matrices), one can deduce that each of the intermediate cases for arbitrary flight conditions will also produce non-singular observability matrices; and that the system is in general completely observable and the single altitude measurement will stabilize the integration drift.

Observability at Launch Condition

At the launch condition, that is when the vehicle is mounted t the launch rail, there will be no actual angular motions to the rocket, and the observability must be evaluated under this condition to insure that the filter calculations will not drift out of bounds. For the launch condition the observability matrix is evaluated with {p, q, r}={0, 0, 0}. For this case the observability matrix reduces to

$$\tilde{O}_{p,q,r=0} = \begin{bmatrix} 0 & 0 & 0 & 1 \\ -M_{31} & -M_{32} & -M_{33} & -\frac{1}{\tau} \\ \frac{M_{31}}{\tau} & \frac{M_{32}}{\tau} & \frac{M_{33}}{\tau} & \frac{1}{\tau^2} \\ -\frac{M_{31}}{\tau^2} & -\frac{M_{32}}{\tau^2} & -\frac{M_{33}}{\tau^2} & -\frac{1}{\tau^3} \end{bmatrix}$$

(AJ23

This matrix is singular and indicates that the *{u,v,w}* states will not be well observed when the vehicle is in the launch condition. Fortunately, these values are known to be *{u,v,w}={0, 0, 0,} when the vehicle is on the rail.* ***Thus a software switch will be necessary to keep the velocity states near zero until the vehicle has left the launch rail. Probably an acceleration switch will be acceptable for this purpose.***

IV. Kalman Filter Equations

The discrete version of the Kalman filter will be implemented. The state equation is discretized using trapezoidal rule. The state noise co-variances are assumed constant. The PerfectFlite measurement noise covariance is scheduled to weight the altitude measurement more heavily as apogee is approached.

State Equation Discretization using Trapezoidal Rule

The continuous-time state equation

$$\begin{bmatrix} \dot{u} \\ \dot{v} \\ \dot{w} \\ \dot{h} \end{bmatrix} = \begin{bmatrix} 0 & r & -q & 0 \\ -r & 0 & p & 0 \\ q & -p & 0 & 0 \\ -M_{13} & -M_{23} & -M_{33} & -\frac{1}{\tau} \end{bmatrix} \cdot \begin{bmatrix} u \\ v \\ w \\ h \end{bmatrix} + g_0 \begin{bmatrix} A_x + \frac{g}{g_0} \cdot M_{13} \\ A_y + \frac{g}{g_0} \cdot M_{23} \\ A_z + \frac{g}{g_0} \cdot M_{33} \\ 0 \end{bmatrix}$$

(AJ24

is written in matrix form as

$$\dot{x} = A \cdot x + B \cdot u$$

$$\rightarrow x = \begin{bmatrix} u \\ v \\ w \\ h \end{bmatrix}, \quad A = \begin{bmatrix} 0 & r & -q & 0 \\ -r & 0 & p & 0 \\ q & -p & 0 & 0 \\ -M_{13} & -M_{23} & -M_{33} & -\frac{1}{\tau} \end{bmatrix}, \quad B \cdot u = g_0 \begin{bmatrix} A_x + \frac{g}{g_0} M_{13} \\ A_y + \frac{g}{g_0} M_{23} \\ A_z + \frac{g}{g_0} M_{33} \\ 0 \end{bmatrix}. \quad \text{(AJ25}$$

The continuous-time equation is discretized via trapezoidal rule where both the current and previous frame IMU data are used to approximate the derivatives

$$x_{k+1/k} = x_{k/k} + \frac{\Delta t}{2}\left(\dot{x}_{k+1} + \dot{x}_k\right) \quad \text{(AJ26}$$

The current time derivative is

$$\dot{x}_k = A_k \cdot x_{k/k} + \left(B \cdot u\right)_k \quad \text{(AJ27}$$

The forward-time derivative term is approximated by

$$\begin{aligned} \tilde{x}_{k+1} &= \left[I + A_k \cdot \Delta t\right] \cdot x_{k/k} + \Delta t\left(B \cdot u\right)_k \\ \tilde{\dot{x}}_{k+1} &= A_{k+1} \cdot \tilde{x}_{k+1} + \left(B \cdot u\right)_{k+1} \end{aligned} \quad \text{(AJ28}$$

and the predicted state etimate is

$$x_{k+1/k} = x_{k/k} + \frac{\Delta t}{2}\left[\left(A_{k+1} \cdot \tilde{x}_{k+1} + \left(B \cdot u\right)_{k+1}\right) + \left(A_k \cdot x_k + \left(B \cdot u\right)_k\right)\right] \quad \text{(AJ29}$$

State Covariance Propagation Using Explicit Euler Rule

A simpler discretization algorithm, better suited to real time calculations uses, only the current IMU data for the covariance propagation. Here the discretization is via the Explicit Euler method. This process allows the covariance update to be performed without requiring that the real time algorithm perform matrix inversions.

$$\begin{aligned} &\frac{x_{k+1} - x_k}{\Delta t} = A_k \cdot x_k + \left(B \cdot u\right)_k \rightarrow x_{k+1} = \left[I + A_{k+1} \cdot \Delta t\right] \cdot x_k + \Delta t\left(B \cdot u\right)_k \\ &\boxed{x_{k+1} = \left[I + A_k \cdot \Delta t\right] \cdot x_k + \Delta t\left(B \cdot u\right)_k} \end{aligned} \quad \text{(AJ30}$$

and the approximate state transition matrix is

$$\Phi_{k+1} = \left[I + A_k \cdot \Delta t\right] = \begin{bmatrix} 1 & r \cdot \Delta t & -q \cdot \Delta t & 0 \\ -r \cdot \Delta t & 1 & p \cdot \Delta t & 0 \\ q \cdot \Delta t & -p \cdot \Delta t & 1 & 0 \\ -M_{13} \cdot \Delta t & -M_{23} \cdot \Delta t & -M_{33} \cdot \Delta t & 1 - \frac{\Delta t}{\tau} \cdot \end{bmatrix}. \quad \text{(AJ31}$$

Following the standard Kalman filter formulation, the resulting transition matrix is used to propagate the state covariance assuming additive state noise whose covariance is defined as $Q_{k+1.}$ The resulting state covariance prediction equations is

$$P_{k+1/k} = \Phi_{k+1} P_{k+1/k} \Phi_{k+1}{}^T + Q_{k+1} \quad \text{(AJ32}$$

Models for the state noise will be developed later in this document.

Kalman Gain Matrix

As described earlier, the measurement equation has the form

$$\left[h_{PerfectFlite}\right] = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u \\ v \\ w \\ h \end{bmatrix}, \quad \text{(AJ33}$$

Thus the measurement matrix, C is invariant and has the form

$$C = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix}. \quad \text{(AJ34}$$

The measurement noise is assumed to have covariance R_{k+1}. Models for the state noise covariance will be developed later in this document. The Standard form of the Kalman gain matrix is

$$K_{k+1} = P_{k+1/k} C^T \left[C P_{k+1/k} C^T + R_{k+1}\right]^{-1}. \quad \text{(AJ35}$$

Substituting in for the actual "C" matrix

$$C P_{k+1/k} C^T + R_{k+1} = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} P_{11} & P_{12} & P_{13} & P_{14} \\ P_{21} & P_{22} & P_{23} & P_{24} \\ P_{31} & P_{32} & P_{33} & P_{34} \\ P_{41} & P_{42} & P_{43} & P_{44} \end{bmatrix} \cdot \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} + R_{k+1} = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} P_{14} \\ P_{24} \\ P_{34} \\ P_{44} \end{bmatrix} + R_{k+1} = P_{44} + R_{k+1},$$

(AJ36

and the Kalman gain becomes

$$K_{k+1} = P_{k+1/k} C^T \left[C P_{k+1/k} C^T + R_{k+1} \right]^{-1} = \begin{bmatrix} \dfrac{P_{14}}{P_{44} + R_{k+1}} \\ \dfrac{P_{24}}{P_{44} + R_{k+1}} \\ \dfrac{P_{34}}{P_{44} + R_{k+1}} \\ \dfrac{P_{44}}{P_{44} + R_{k+1}} \end{bmatrix}_{k+1/k} . \quad \text{(AJ37}$$

Kalman Update Equations

The standard form of the Kalman state update equation is

$$\hat{x}_{k+1/k+1} = \hat{x}_{k+1/k} + K_{k+1} \cdot \left[Z_{k+1} - C \cdot \hat{x}_{k+1/k} \right] . \quad \text{(AJ38}$$

Substituting in for K_{k+1} and C gives

$$\begin{bmatrix} u \\ v \\ w \\ h \end{bmatrix}_{k+1/k+1} = \begin{bmatrix} u \\ v \\ w \\ h \end{bmatrix}_{k+1/k} + \begin{bmatrix} \dfrac{P_{14}}{P_{44} + R_{k+1}} \\ \dfrac{P_{24}}{P_{44} + R_{k+1}} \\ \dfrac{P_{34}}{P_{44} + R_{k+1}} \\ \dfrac{P_{44}}{P_{44} + R_{k+1}} \end{bmatrix}_{k+1/k} \left(h_{PerfectFlite\ k+1} - \hat{h}_{k+1/k} \right) \quad \text{(AJ39}$$

The standard form of the covariance update equation is

$$P_{k+1/k+1} = \left[I - K_{k+1} \cdot C \right] P_{k+1/k} . \quad \text{(AJ40}$$

Substituting in for K_{k+1} and C gives

$$P_{k+1/k+1} = \left[\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} - \begin{bmatrix} \dfrac{P_{14}}{P_{44} + R_{k+1}} \\ \dfrac{P_{24}}{P_{44} + R_{k+1}} \\ \dfrac{P_{34}}{P_{44} + R_{k+1}} \\ \dfrac{P_{44}}{P_{44} + R_{k+1}} \end{bmatrix}_{k+1/k} \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix} \right] P_{k+1/k} = \begin{bmatrix} 1 & 0 & 0 & \dfrac{-P_{14}}{P_{44} + R_{k+1}} \\ 0 & 1 & 0 & \dfrac{-P_{24}}{P_{44} + R_{k+1}} \\ 0 & 0 & 1 & \dfrac{-P_{34}}{P_{44} + R_{k+1}} \\ 0 & 0 & 0 & 1 - \dfrac{P_{44}}{P_{44} + R_{k+1}} \end{bmatrix} P_{k+1/k}$$

(AJ41

State Noise Covariance Model

As described in the Kalman filtering section of this document (Section IV), the state noise (Q_{k+1}) and measurement error *(R_{k+1})* covariance models are necessary to complete the filtering algorithm. The state equation covariance model is derived from errors in the input data from the IMU

$$\begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix}, \begin{bmatrix} \mathrm{p} \\ \mathrm{q} \\ \mathrm{r} \end{bmatrix}, \begin{bmatrix} \mathrm{M}_{31} \\ \mathrm{M}_{32} \\ \mathrm{M}_{33} \end{bmatrix}.$$

The dominant error in the state equation results from the noise inn the accelerometer measurements and the pitch angle errors. Altitude errors due to roll angle are considered t be negligible. Further, cross axis errors are assumed to be negligible and all off-diagonal terms are set to zero.

The parameters $\left\{\sigma^2{}_{A_x}, \sigma^2{}_{A_y}, \sigma^2{}_{A_z}\right\}$ represent the variances due to the IMU accelerometer uncertainties (*g's*^{2}), and the parameter $\sigma^2{}_h$ represents the altitude variance due to the IMU attitude uncertainties. Since

$$\dot{h} = \sin\theta \cdot u - \sin\phi \cos\theta \cdot v - \cos\phi \cos\theta \cdot w \qquad \text{(AJ42}$$

and along a ballistic trajectory $u >> \{v, w\}$, then $u \sim V$ (AJthe total velocity of the vehicle), and the error in altitude rate due to IMU attitude errors can be approximated by

$$\delta\dot{h} = V \cdot \cos\theta \cdot \delta\theta \qquad \textit{(AJ43}$$

The term $V \cdot \cos\theta \approx V_{horizontal}$, and as described earlier the horizontal velocity is constant throughout the flight following motor burnout. The discrete variance is then approximated by

$$\sigma^2 h \approx \Delta t^2 \left(V \cdot \cos\theta\right)^2 \cdot \sigma^2{}_\theta = \Delta t^2 \cdot V_{horizontal}{}^2 \cdot \sigma^2{}_\theta \qquad \text{(AJ44}$$

The resulting state noise covariance model is

$$Q_{k+1} = \left(\Delta t \cdot g_0\right)^2 \begin{bmatrix} \sigma^2{}_{A_x} & 0 & 0 & 0 \\ 0 & \sigma^2{}_{A_y} & 0 & 0 \\ 0 & 0 & \sigma^2{}_{A_z} & 0 \\ 0 & 0 & 0 & \left(\frac{V_{horizontal}}{g_0}\right)^2 \sigma^2{}_\theta \end{bmatrix}. \qquad \text{(AJ45}$$

Open-Loop State-Noise Error Analysis

Eq. 45 the expected horizontal velocity under nominal flight conditions can approximate $V_{horizontal}$. The table below summarizes the expected IMU[4] Accelerometer, pitch attitude, and altitude-rate errors.

Summary of Expected IMU Sensor Errors

$V_{horizontal}$, m/sec	$\{\sigma_{Ax}, \sigma_{Ay}, \sigma_{Az}\}(g's)$	σ_θ $(deg, radians)$	$\frac{V_{horizontal}}{g}\sigma_\theta$ (sec)
0	*±0.10 g's*	*±2 deg. (0.035 rad)*	*0.000 sec*
10	-	-	*0.036 sec*
20	-	-	*0.072 sec*
30	-	-	*0.107 sec*
40	-	-	*0.142 sec*
50	-	-	*0.178 sec*

Figure 3 plots the vertical, horizontal and total velocity components for a nominal launch profile. The mean total velocity for the flight to apogee is *84.4 m/sec* and the mean vertical velocity is *80.3 m/sec*.

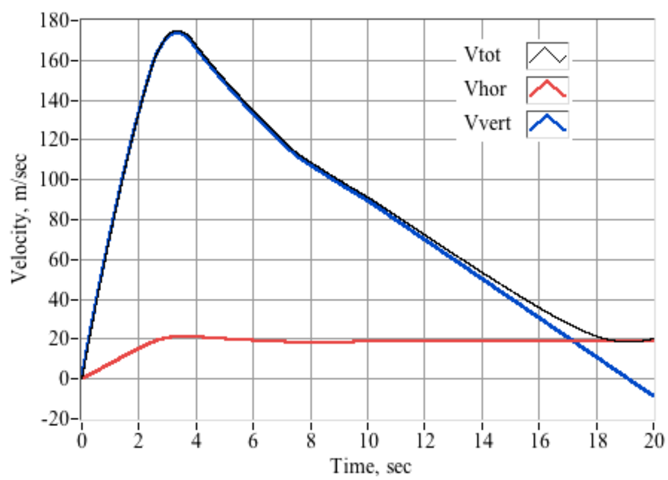


Figure 3. Nominal Velocity Profile for CS -730 Launch

For a ballistic trajectory, the drift due to A_x will be the primary state noise error source. Assuming a approximate major frame rate of 200 samples per seconds, and a 20 second flight to apogee (4000 frames), the collected open-loop state noise drift due to the A_x accelerometer is approximately

$$\left(\Delta t \cdot g_0 \cdot \sigma_{Ax} \cdot N_{frames}\right) = \left(\frac{1}{200_{sps}} \cdot 9.8067_{m/\sec^2} \cdot \left(\pm 0.01_g\right) \cdot 4000_{frames}\right) = \pm 1.96_{m/\sec} \quad \text{(AJ46}$$

Thus the integration should be relatively stable. The total open-loop contribution to the potential altitude error is approximately

$$\left(\delta h_{potential}\right)_{Ax} = \partial\left(\frac{V^2}{2 \cdot g}\right) = \frac{V \cdot \delta V}{g} \approx V_{avg} \cdot \left(\Delta t \cdot g_0 \cdot \sigma_{Ax} \cdot N_{frames}\right) =$$

$$\frac{80.3_{m/\sec} \cdot \left(\pm 1.96_{m/\sec}\right)}{9.8067_{m/\sec^2}} = 16.05_m \quad \text{(AJ47}$$

The nominal trajectory for the Cesaroni L-730 motor with a 33% C-BAS propellant margin, and a launch angle is 85 deg, predicts a terminal horizontal velocity of *18 m/sec*. Thus an expected nominal value for the altitude state-noise parameter is

$$\frac{V_{horizontal}}{g_0} \cdot \sigma_\theta = 0.064_{\sec} \quad \text{(AJ48}$$

The total open loop error contribution for the flight is

$$\left(\Delta t \cdot g_0\right)\frac{V_{horizontal}}{g_0} \cdot \sigma_\theta \cdot N_{frames} =$$

$$\left(\frac{1}{200_{sps}} \cdot 9.8067_{m/\sec^2} \cdot \frac{18_{m/\sec}}{9.8067_{m/\sec^2}}\left(\pm 2^\circ\right) \cdot \frac{\pi}{180} \cdot 4000_{frames}\right) = 12.57_m \quad \text{(AJ49}$$

Thus, root sum squaring the two state noise error sources, the expected IMU total drift for the flight apogee is approximately 20.35 meters. Closing the loop using the perfect flight altimeter should reduce this error significantly.

Measurement Noise Covariance Model

The measurement error covariance model is derived from errors in the PerfectFlite altitude measurements, $h_{PerfectFlite}$. The nominal measurement error variance is calculated directly from the expected uncertainty in the *PerfectFlite* altitude measurement. The state accuracy of the altitude measurement is +0.5% of reading.[5] This value equates to approximately *±8 meters* measurement uncertainty at apogee. Because the PerfectFlite reading is judged to be the "truth" metric for altitude in the competition, the variance will be linearly diminished with time so that the filter weights the sensor altitude reading more and more heavily as apogee is approached. Thus the potential altitude output used to control the vehicle's energy level will be strongly tied to the perfect flight altitude reading. The prescribed adaptive weighting function for the PerfectFlite measurement noise is

$$\sigma_{h_{PerfectFlite}} = \pm 0.005 \cdot \hat{h}_{k/k} \cdot \left(1 - \frac{\hat{h}_{k/k}}{h_{target}}\right) + \varepsilon \quad \text{(AJ50}$$

In Eq. 50 h_{target} ids the target altitude of 1609.32 meters, and $h_{k/k}$ is the current altitude estimate of the Kalman filter. The parameter "epsilon" is a small factor to insure that the measurement noise covariance does not go to *exactly zero*. This event could cause stability problems with the Kalman filter covariance propagation. Figure 4 plots this function for a nominal flight trajectory, along with the expected ground-level altitude profile. The minimum weighting (inverse of the error function) occurs shortly after motor burn out and approaches its maximum value just prior to reaching apogee. The "epsilon" safety-factor was set to 0.1 meter for this calculation.

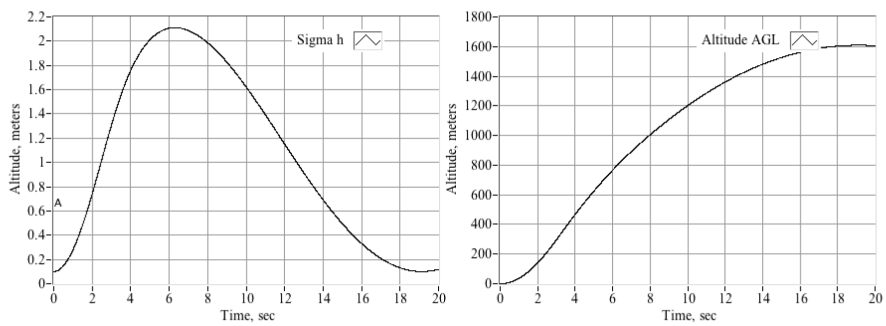


Figure 4. PerfectFlite Measurement Noise Weighting Function Profile,

V. Energy Management Algorithm

The energy management algorithm uses a balance of potential and kinetic energy to predict the vehicle apogee altitude based on Kalman filter estimates of velocity (*kinetic energy per unit mass*) and altitude (*potential energy per unit mass*). The feedback algorithm checks calculated potential altitude against a target reference and if the energy state of the vehicle is low, activate the C-BAS system by opening the feed-gas solenoid valve. When the energy state climbs to the prescribed value, the solenoid valve is closed.

Potential Altitude

The potential altitude can be calculated using the body axis velocity and altitude estimates. From conservation of energy, since the vertical velocity of the vehicle is zero at apogee, the total energy (*per g*) at apogee can be calculated from the total energy (*per g*) at any point following motor burnout by

$$h_{apogee} + \frac{V^2{}_{horizontal}}{2 \cdot g} = h_{(t)} + \frac{V^2{}_{(t)}}{2 \cdot g} - \int_{t}^{t_{apogee}} \frac{\rho \cdot V^3}{2 \cdot \beta} d\tau \qquad \text{(AJ51}$$

Since the early flight path is near vertical, and energy losses due to drag diminish as apogee is approached, the horizontal velocity at motor burnout remains nearly constant through out the ballistic portion of the flight. This effect is directly verified by flight simulation (see Figure 3) Thus

$$h_{apogee} = \frac{V^2_{(t)} - V^2_{horizontal}}{2 \cdot g} - \int_{t}^{t_{apogee}} \frac{\rho \cdot V^3}{2 \cdot \beta} d\tau = h_{(t)} + \frac{V^2_{(t)_{vertical}}}{2 \cdot g} - \int_{t}^{t_{apogee}} \frac{\rho \cdot V^3}{2 \cdot \beta} d\tau \quad \text{(AJ52}$$

Near apogee the drag term in Eq. 12 diminishes and potential altitude can be calculated directly using the $\{h \quad \dot{h}\}$ outputs from the Kalman filter,

$$\left(\hat{h}_{potential}\right) = h + \frac{\dot{h}^2}{2 \cdot g} \quad \text{(AJ53}$$

C-BAS Activation Criterion

It can be shown that the C-BAS system is most effective in changing potential altitude of the vehicle when initiated very early in flight. Approximately, the change in potential altitude is given by

$$\Delta h_{potential} = \left(V_{active} + \Delta V\right) \cdot \frac{\Delta V}{g} \quad \text{(AJ54}$$

In Eq. (54) V_{active} is the velocity at which the C-BAS system is first activated. Clearly, activation soon after motor burnout provides for the best propellant efficiency. However, during the ballistic phase of flight the vehicle is continually decelerating (due to the vehicle drag), and the C-BAS working fluid (CO_2) will be pinned against the front end of the tank. This event would result in only vapor leaving the exhaust port at the bottom end of the tank. The exiting vapor has the effect of rapidly cooling the tanks; causing reduced internal pressure, and eventually freezing the working fluid. To insure that only liquid and not vapor exits the tank, the C-BAS system will not be activated until the vehicle drag, measured by the IMU's longitudinal accelerometer, drops below the anticipated thrust level of the C-BAS exit steam.

Figure Figure 5 compares the anticipated vehicle drag against the C-BAS momentum flux level. Both deceleration due to drag and the axial acceleration due to the C-BAS are plotted as absolute values. For a nominal flight profile, the drag force magnitude drops below the C-BAS longitudinal force level at approximately 950 ft AGL, or about 7 seconds after launch. Here the net forward axial acceleration of the vehicle will keep mostly fluid at the bottom of the tank near the exit port. This IMU deceleration point will be set once the vehicle drag coefficient and C-BAS acceleration levels are refined.

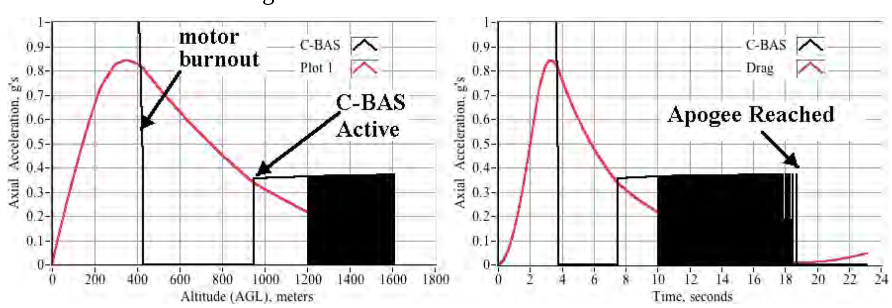


Figure 5. Comparison of the Vehicle Drag and C-BAS Acceleration Levels.

Target Altitude Scheduling

The drag loss term in Eq. 52 is path dependent and will be difficult to accurately calculate in flight with the C-BAS augmentation thrusters firing. The drag-loss parameter is best calculated pre-flight for a nominal trajectory and then used to schedule the "target altitude" as a function of the flight altitude. This approach allows the targeting algorithm to "aim high" to account for the anticipated energy losses due to drag along the flight path. The accumulated drag loss, which diminishes with the starting altitude

$$\int_{t}^{t_{apogee}} \frac{\rho \cdot V^3}{2 \cdot \beta} d\tau$$

is added to the target altitude – nominally 1609.32 meters – to derive a target altitude schedule. Figure 6 shows the potential altitude loss due to drag along the flight path, and compares the target altitude to the potential altitude calculated using Eq. 53. The true altitude is also plotted for comparison purposes. The plotted data are for a representative trajectory using approximately 2/3rd's of the available C-BAS impulse. The assumed maximum C-BAS thrust level is 40 Newtons.

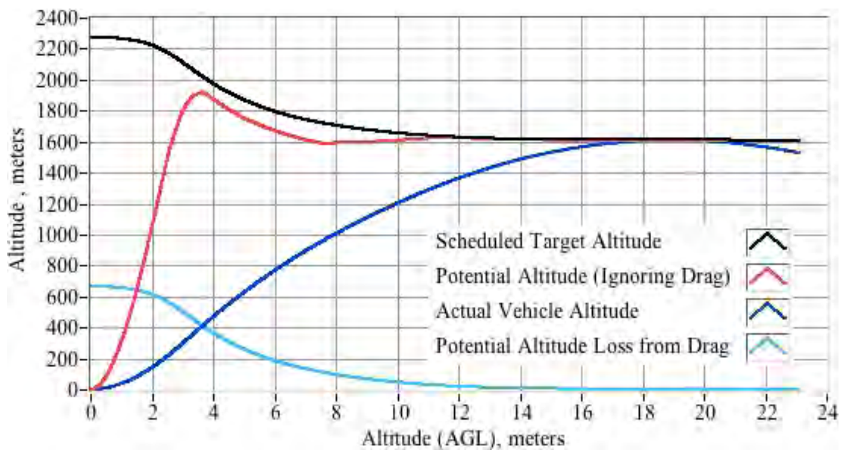


Figure 6. Potential Altitude Loss due to Drag and Target Altitude Schedule.

Pre-scheduling the target altitude improves the algorithm efficiency and has the effect of requiring less "toggling" on the C-BAS impulse to achieve the desired altitude. Figure 7 compares the C-BAS control activity with and without target altitude pre-scheduling. In this figure the 0.5 g's have been added to the fixed-target C-BAS acceleration data to allow the two curves to be distinguished. The fixed target control algorithm requires constant activity from approximately 10 seconds to apogee. The algorithm with the pre-scheduled target altitude "hedges the bet" by aiming slightly higher and allowing the natural altitude decay due to drag the bring the vehicle energy state to the proper level. Compares the propellant mass consumptions for the two approaches. Pre-scheduling the target altitude results in approximately a 10% cold-gas propellant savings.

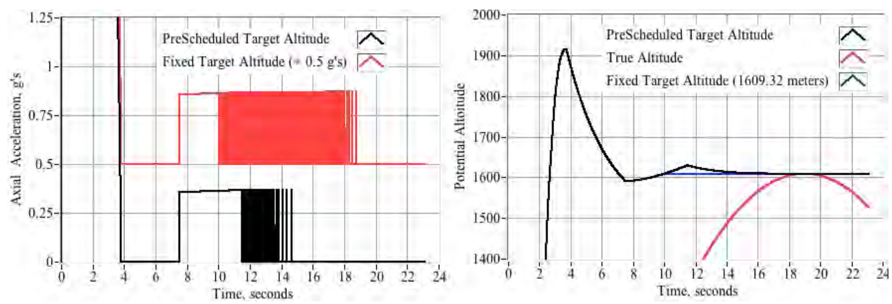


Figure 7. Effect of Target Altitude PreScheduling on C-BAS Control Activity.

The current target altitude schedule is listed as a function of time of flight and altitude (AGL) in the table below.

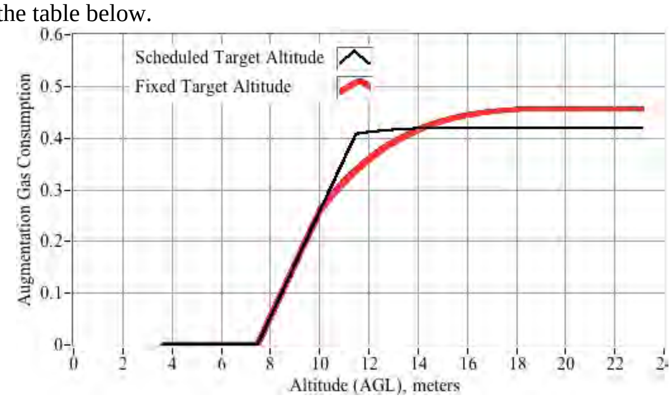


Figure 8. Effect of Target Altitude Pre-Scheduling on CO_2 Propellant Consumption.

Target Altitude Schedule

Time of Flight (sec)	Flight Altitude, AGL (meters)	Target Altitude (meters)
0.00	0.00	2273.71
1.00	36.86	2263.13
2.00	140.38	2220.41
3.00	296.03	2110.21
4.00	467.71	1972.55
5.00	625.11	1868.03
6.00	766.07	1793.77
7.00	892.10	1741.07
8.00	1004.78	1703.54
9.00	1107.49	1675.24
10.00	1201.24	1653.78
11.00	1285.83	1637.98

12.00	1360.62	1626.96
13.00	1425.58	1619.59
14.00	1480.73	1614.92
15.00	1526.07	1612.15
16.00	1561.59	1610.64
17.00	1587.30	1609.89
18.00	1603.18	1609.54
19.00	1609.25	1609.34
19.12	1609.32	1609.32
20.00	1605.51	1609.32

C-BAS Augmentation Algorithm

The collected C-BAS Augmentation algorithm is

$$\left(\hat{h}_{potential}\right)_t = h_t + \frac{\dot{h}_t}{2 \cdot g_t}$$

$$h_{target} \rightarrow lookup\left[h_t\right]$$

$$\begin{array}{l} if \ldots \left\{ \left(\hat{h}_{potential}\right)_t < h_{target} \ldots and \ldots A_x \leq \left(\frac{F_{C-BAS}}{M \cdot g_0}\right)_{nominal} \right\} \\ \qquad \rightarrow C-BAS \ \text{"on"} \\ else \\ \qquad \rightarrow C-BAS \ \text{"off"} \end{array}$$

(AJ55

VI. 3DM-GX3 Communications

The 3DM-GX3®-25 IMU is a high-performance, miniature Attitude Heading Reference System (AHRS), utilizing MEMS sensor technology. It combines a triaxial accelerometer, triaxial gyro, triaxial magnetometer, temperature sensors, and an on-board processor running a sophisticated sensor fusion algorithm to provide static and dynamic orientation, and inertial measurements.

The system offers a range of output data quantities, including fully calibrated inertial measurements: acceleration, angular rate, and magnetic field; or deltaAngle & deltaVelocity vectors. It can also output computed orientation estimates: pitch, roll, and heading (yaw) or rotation matrix. All quantities are fully temperature compensated and are mathematically aligned to an orthogonal coordinate system. The angular rate quantities are further corrected for G-sensitivity and scale factor non-linearity to third order. For this project we are using the Original Equipment Manufacture (OEM) version of the IMU.

IMU Serial Port Default Settings

COM Port Default Serial Settings	Baud Rate **115.2K**
Parity: **None**	Data Bits: **8**
Stop Bits: **1**	RTS/CTS: **Disabled**
COM Port Default Serial Settings	Baud Rate **115.2K**

All communications with IMU sensors are accomplished via a real (RS-232 or UART) or virtual (USB) serial port.

Required IMU Data Message

Acceleration, Angular Rate & Orientation Matrix

Function: 3DM-GX3 outputs 67-byte data record with Acceleration and Angular Rate Vectors and the Orientation (Direction Cosine) Matrix.

Command:
Byte 1 0xC8

Response:
Byte 1 0xC8

Bytes 2-5	*AccelX (IEEE-754 Floating Point)*
Bytes 6-9	*AccelY (IEEE-754 Floating Point)*
Bytes 10-13	*AccelZ (IEEE-754 Floating Point)*
Bytes 14-17	*AngRateX (IEEE-754 Floating Point)*
Bytes 18-21	*AngRateY (IEEE-754 Floating Point)*
Bytes 22-25	*AngRateZ (IEEE-754 Floating Point)*
Bytes 26-29	*M1,1 (IEEE-754 Floating Point)*
Bytes 30-33	*M1,2 (IEEE-754 Floating Point)*
Bytes 34-37	*M1,3 (IEEE-754 Floating Point)*
Bytes 38-41	*M2,1 (IEEE-754 Floating Point)*
Bytes 42-45	*M2,2 (IEEE-754 Floating Point)*
Bytes 46-49	*M2,3 (IEEE-754 Floating Point)*
Bytes 50-53	*M3,1 (IEEE-754 Floating Point)*
Bytes 54-57	*M3,2 (IEEE-754 Floating Point)*
Bytes 58-61	*M3,3 (IEEE-754 Floating Point)*
Bytes 62-65	*Time Tag (32 bit unsigned int)*
Bytes 66-67	*Checksum*

Time Tag
• *Time since system power-up or timer set command.*
•*To convert the time tag value to seconds, divide by 62,500.*

Checksum
The 16 bit checksum is equal to the sum of all preceding 65 bytes with rollover from 65535 to 0.
• *Used the check message validity*
• *16-bit unsigned int*

Accel – (X, Y, Z components)
Body Axis Acceleration Vector components (per IMU axis alignment).
• *Fully temperature compensated*
• *Scaled into physical units of g's (1 g = 9.80665 m/sec^2).*

$$\begin{bmatrix} A_x / g_0 \\ A_y / g_0 \\ A_z / g_0 \end{bmatrix} \rightarrow g_0 = 9.80665 \; \tfrac{m}{\sec^2}$$

AngRate – (X, Y, Z components)
Body axis angular rate vector (per IMU axis alignment).
• *Fully temperature compensated*
• *Scaled into units of radians/second.*

$$\begin{bmatrix} p \\ q \\ r \end{bmatrix} \rightarrow \tfrac{radians}{\sec}$$

Orientation (Direction Cosine) Matrix – (M)
9-component coordinate transformation matrix that orients the IMU body-axis with respect to the (North, East, Down) fixed-earth coordinate system.

$$\ddot{M} = \left\{ M_{ij} \right\} =$$

$$\begin{bmatrix} \cos\theta\cos\psi & \cos\theta\sin\psi & -\sin\theta \\ \sin\phi\sin\theta\cos\psi - \cos\phi\sin\psi & \sin\phi\sin\theta\sin\psi + \cos\phi\cos\psi & \sin\phi\cos\theta \\ \cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi & \cos\phi\sin\theta\sin\psi - \sin\phi\cos\psi & \cos\phi\cos\theta \end{bmatrix}$$

OEM IMU Connector and Pinouts

The connector used on the 3DM-GX3-25 OEM module is a *Samtec* fine pitch (0.050") 5 x 2 (10 pin) keyed header connector. Cables are IDC ribbon cables. Connectors and cables in any length can be ordered directly from Samtec. Refer to the Samtec website for specific order information. Figure 5 below shows the OEM connector pinouts.

Connector: Samtec FTSH-105-01-F-D-K.

Mates with Samtec FFSD-05-D-xx.xx-01-N (where xx.xx is length of cable in inches)

Pin	Name	Type	Description
1	USBDM	BiDir	USB D- Signal
2	USBDP	BiDir	USB D+ Signal
3	VBUS	Power	Power – Minimum 3.1 volts, Maximum 5.5 volts DC
4	UARTRX	Input	LVTTL (5V Tolerant) Serial UART receive (connect to host Transmit)
5	UARTTX	Output	LVTTL (5V Tolerant) Serial UART transmit (connect to host Receive)
6	NC		not connected
7	GPIO1	I/O	General purpose I/O
8	GND	Ground	Power and signal ground
9	GPIO2	I/O	General purpose I/O
10	nENABLE	Input	Module enable. LVTTL low enables. LVTTL high disables

Figure 9. OEM Connector Pinouts for 3DM-GX3-25 IMU.

VII. PerfectFlite Communications

The altimeter can be connected to a computer via the appropriate cable kit and interface software. This connection will allow you to access the advanced features of the altimeter. Connection to the altimeter must be established before the continuity beep phase or after the flight. Connection is not allowed once the continuity beep phase has begun in order to keep any possible spurious input on the serial data line from terminating the flight (and deployment) sequence. The figure below shows the serial connector pins

The PerfectFlite altimeter has an option for streaming data during the flight. The “T1” command signals the device to output the data during flight. The communication data rate for commands is 38,400 baud. Telemetry altitude data is streamed at 9600 baud. The Serial port format has no parity, 8-bit word with 1 stop bit. Xon/Xoff is enabled. The altitude telemetry streams ASCII character data with up 5 altitude characters followed by two characters <CR> <LF>. Figure 6 shows the major components of the altimeter and serial connector pinouts,

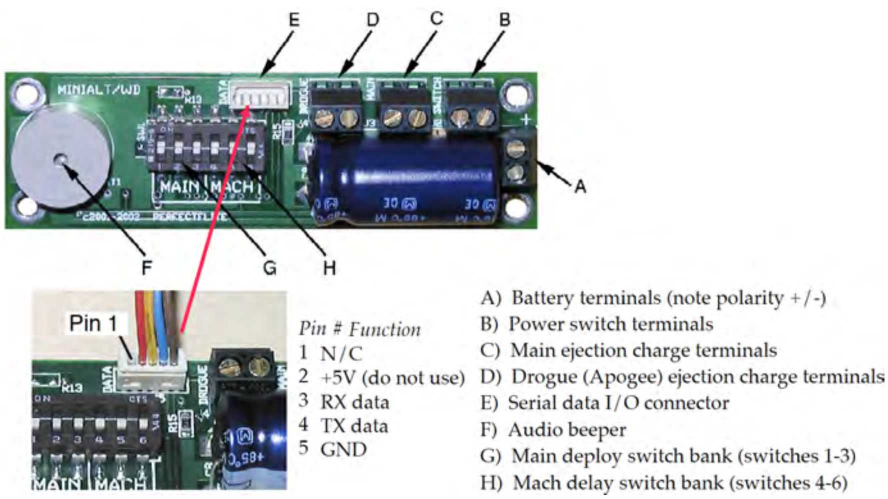


Figure 10 Major PerfectFlite Components and Serial I/O Connector Pinouts

VIII. Collected Estimation and Control Algorithms

Prescribed Inputs:

State and Measurement Noise Covariances: Q_{k+1}, R_{k+1}

Initial Conditions:

Current State Vector and Covariance Matrix: $x_{k/k}$, $P_{k/k}$

Input Data:

Current Acceleration (corrected to *cg* of the vehicle), Angular Velocity, Direction Cosine, and Altitude Measurements

$$\left(\begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix}_{k+1}, \begin{bmatrix} M_{31} \\ M_{32} \\ M_{33} \end{bmatrix}_{k+1}, \begin{bmatrix} \mathrm{p} \\ \mathrm{q} \\ \mathrm{r} \end{bmatrix}_{k+1}, \mathrm{h}_{k+1} \right)$$

Previous Frame Acceleration, Angular Velocity, Direction Cosine, and Altitude Measurements

$$\left(\begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix}_{k}, \begin{bmatrix} M_{31} \\ M_{32} \\ M_{33} \end{bmatrix}_{k}, \begin{bmatrix} \mathrm{p} \\ \mathrm{q} \\ \mathrm{r} \end{bmatrix}_{k}, \mathrm{h}_{k} \right)$$

Current Sample Interval:

$$\Delta t = t_{k+1} - t_k$$

State Prediction:

$$\tilde{x}_{k+1} = \left[I + A_k \cdot \Delta t\right] \cdot x_{k/k} + \Delta t \left(B \cdot u\right)_k$$

$$x_{k+1/k} = x_{k/k} + \frac{\Delta t}{2}\left[\left(A_{k+1} \cdot \tilde{x}_{k+1} + \left(B \cdot u\right)_{k+1}\right) + \left(A_k \cdot x_k + \left(B \cdot u\right)_k\right)\right]$$

$$\rightarrow x = \begin{bmatrix} u \\ v \\ w \\ h \end{bmatrix}, \quad A = \begin{bmatrix} 0 & r & -q & 0 \\ -r & 0 & p & 0 \\ q & -p & 0 & 0 \\ -M_{13} & -M_{23} & -M_{33} & -\frac{1}{\tau} \end{bmatrix}, \quad B \cdot u = g_0 \begin{vmatrix} A_x + \frac{g}{g_0} M_{13} \\ A_y + \frac{g}{g_0} M_{23} \\ A_z + \frac{g}{g_0} M_{33} \\ 0 \end{vmatrix}$$

$$g = 9.780318_{\frac{m}{\sec^2}} \times \left[1 + 0.0053024 \cdot \sin^2(\lambda) + 0.0000058 \cdot \sin^2(2\lambda)\right] - 3.086 \cdot 10^{-6}{}_{\frac{1}{\sec^2}} \cdot \left(h_{k/k} + h_{launch}\right)$$

Covariance Prediction:

$$Q_{k+1} = \left(\Delta t \cdot g_0\right)^2 \begin{bmatrix} \sigma^2{}_{A_x} & 0 & 0 & 0 \\ 0 & \sigma^2{}_{A_y} & 0 & 0 \\ 0 & 0 & \sigma^2{}_{A_z} & 0 \\ 0 & 0 & 0 & \left(\frac{V_{horizontal}}{g_0}\right)^2 \sigma^2{}_{\theta} \end{bmatrix}$$

$$\Phi_{k+1} = \left[I + A_k \cdot \Delta t\right] = \begin{bmatrix} 1 & r \cdot \Delta t & -q \cdot \Delta t & 0 \\ -r \cdot \Delta t & 1 & p \cdot \Delta t & 0 \\ q \cdot \Delta t & -p \cdot \Delta t & 1 & 0 \\ -M_{13} \cdot \Delta t & -M_{23} \cdot \Delta t & -M_{33} \cdot \Delta t & 1 - \frac{\Delta t}{\tau} \cdot \end{bmatrix}_k$$

$$P_{k+1/k} = \Phi_{k+1} P_{k+1/k} \Phi_{k+1}{}^{T} + Q_{k+1}$$

Kalman Gain Calculation:

$$R_{k+1} = \left(0.005 \cdot \hat{h}_{k/k} \cdot \left(1 - \frac{\hat{h}_{k/k}}{h_{target}}\right) + \varepsilon\right)^2$$

$$K_{k+1} = P_{k+1/k} C^T \left[C P_{k+1/k} C^T + R_{k+1} \right]^{-1} = \begin{bmatrix} \frac{P_{14}}{P_{44} + R_{k+1}} \\ \frac{P_{24}}{P_{44} + R_{k+1}} \\ \frac{P_{34}}{P_{44} + R_{k+1}} \\ \frac{P_{44}}{P_{44} + R_{k+1}} \end{bmatrix}_{k+1/k}$$

State Update:

$$\hat{x}_{k+1/k+1} = \hat{x}_{k+1/k} + K_{k+1} \cdot \left[Z_{k+1} - C \cdot \hat{x}_{k+1/k} \right]$$

$$\begin{bmatrix} u \\ v \\ w \\ h \end{bmatrix}_{k+1/k+1} = \begin{bmatrix} u \\ v \\ w \\ h \end{bmatrix}_{k+1/k} + \begin{bmatrix} \frac{P_{14}}{P_{44} + R_{k+1}} \\ \frac{P_{24}}{P_{44} + R_{k+1}} \\ \frac{P_{34}}{P_{44} + R_{k+1}} \\ \frac{P_{44}}{P_{44} + R_{k+1}} \end{bmatrix}_{k+1/k} \left(h_{PerfectFlite\ k+1} - \hat{h}_{k+1/k} \right)$$

Covariance Update

$$P_{k+1/k+1} = \left[I - K_{k+1} \cdot C \right] P_{k+1/k}$$

$$P_{k+1/k+1} == \begin{bmatrix} 1 & 0 & 0 & \frac{-P_{14}}{P_{44} + R_{k+1}} \\ 0 & 1 & 0 & \frac{-P_{24}}{P_{44} + R_{k+1}} \\ 0 & 0 & 1 & \frac{-P_{34}}{P_{44} + R_{k+1}} \\ 0 & 0 & 0 & 1 - \frac{P_{44}}{P_{44} + R_{k+1}} \end{bmatrix} P_{k+1/k}$$

Potential Altitude

$$\left(\hat{h}_{potential} \right)_t = h_t + \frac{\dot{h}_t}{2 \cdot g_t}$$

C-BAS Control Algorithm

$$h_{target} \rightarrow lookup\left[h_t\right]$$

$$\left| \begin{array}{l} if \ldots \left\{ \left(\hat{h}_{potential}\right)_t < h_{target} \ldots and \ldots A_x \le \left(\dfrac{F_{C-BAS}}{M \cdot g_0}\right)_{nominal} \right\} \\ \qquad \rightarrow C-BAS \text{ "}on\text{"} \\ else \\ \qquad \rightarrow C-BAS \text{ "}off\text{"} \end{array} \right.$$

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K. Solenoid Valve Data Sheet

H40 Series

G C VALVES

- High Pressure
- 1/4" NPT
- Stainless Steel Body
- 2-Way Piloted Piston
- Normally Closed

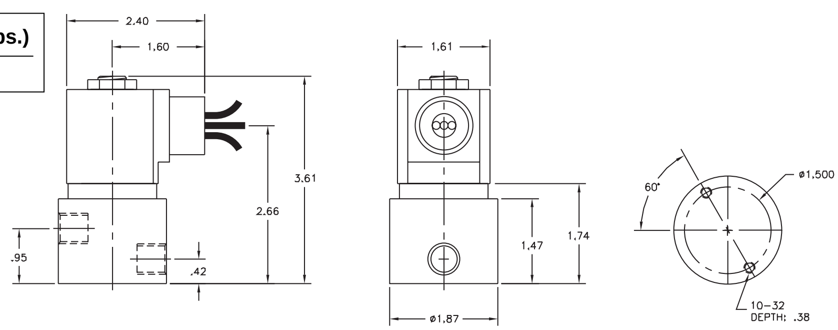
Materials	Seals:	Viton® and Teflon®
	Orifice: Pilot Main	Stainless Steel Stainless Steel Ø 3/8"
Electrical	Standard Housing:	Encapsulated Waterproof Conduit (NEMA 4/4X)
	Optional Housings:	Metallic Conduit, Explosion-proof (NEMA 7), Grommet, Open Frame, Junction Box (single or dual knockouts), DIN; Contact GC Valves Customer Service for others.
	Standard Voltages:	24, 120, 240 AC 60 Hz; 50 Hz available 6, 12, 24 DC; Contact GC Valves Customer Service for Additional Voltages.
	Voltage Tolerance:	±10% of applicable voltage
	Coil Classes:	F, H, N
	Standard Lead Length:	24 inch
Operating Temperature	Ambient (Nominal):	32°F to 125°F
Mounting	Position:	Any
Approvals*	Agency:	UL Recognized

* Not available for all variations

® Registered Trademark of DuPont Co.

Dimensions/Weight

Weight (lbs.)
1.8

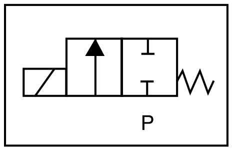


GC Valves Customer Service: 800-828-0484 (7:30am to 4pm ET) or 800-582-4232 (7:30am to 4pm PT)

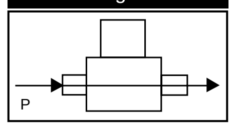
H401 – High Pressure, 1/4" NPT, Stainless Steel Body, Normally Closed

Valve Selection List

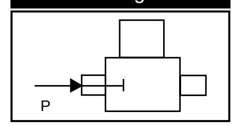
Normally Closed



Energized



De-Energized



Pipe Size NPT	Orifice Size IN	C_V	Operating Pressure Differential (psi) Minimum	Maximum Air/Gas AC	Maximum Air/Gas DC	Maximum Water AC	Maximum Water DC	Maximum Light Oil AC	Maximum Light Oil DC	Max Fluid Temp. °F	Seal Material	Power Consumption (Watts) AC	Power Consumption (Watts) DC	Model Code (120V/60HZ — 110V/50HZ Shown) Stainless Steel Body
1/4	3/8	1.1	0	2200	2200	2200	2200	2200	2200	230	Viton/ Teflon	10	10	H401GF02Z1BF5

Part Numbering

1 2 3	4	5	6	7 8	9	10	11	12 13
H 4 0	1	G	F	0 2	Z	1	B	F 5
Series	Operating Mode	Housing*	Coil Class*	Voltage*	Seal Material	Body Material	Pipe Connection	Orifice Size
H40	1: Normally Closed	G: Conduit	F: Class F	02: 120/60 110/50	Z: Viton/ Teflon	1: Stainless Steel	B: 1/4" NPT	F5: 3/8"

* See the "Engineering Guide" for additional voltages, variations and options.

Coil Data

Coil Family

Type	Size
All	S4

Frequency (Hz)		60	50
Nominal Power (VA)	Inrush	46	46
	Holding	20	21

GC Valves Customer Service: 800-828-0484 (7:30am to 4pm ET) or 800-582-4232 (7:30am to 4pm PT)

L. Student Prototype Lab/Shop Rules

Student Prototype Lab Users, All!!!

Some items may require consultation from our Department Head etc. which could take a bit.

The Phone number for the SPL is 797-3820

Please note the following Student Prototype Lab Policies as of 11-03-2010. SUBJECT TO CHANGE

3 strikes and you are out! COULD BE ON FIRST OFFENSE IF OBVIOUSLY DANGEROUS!

Buddy System. A minimum of TWO people per project group will be in the lab at the same time! NO EXCEPTIONS! SPL personnel should always be present when working with machinery or welders.

Safety glasses will be worn over your eyes. Not on top of your head. Please bring your own if you have some.

Hearing protection should be worn when high noise levels are present in the lab. We have some of the overhead types and some small personal in ear types available

Dust masks should be worn whenever grinding. We have these items available also.

No Jewelry will be permitted in the lab. This includes rings, watches and necklaces.

Please bring a padlock and use a locker in the hallway to store these items to avoid loss. We have permission to use the lockers which are nearest to the SPL. You will be required to furnish your name and locker number to SPL personnel before attaching any locks.

If your hair is longer than shoulder length, you will need to tie it up prior to working with machinery.

No shorts or sandals will be allowed in the SPL.

No long sleeves will be allowed when using machinery. Rolled sleeves are ok.

Cover skin when welding to avoid burns. Always use welding curtains around the welding area to help protect the eyes of other lab users. You are responsible to chisel or grind welding spatter from the welding table and sweep under the table also.

Beware of fuel from buggies and batteries which are being charged prior to welding. CHECK FOR THESE ISSUES BEFORE WELDING TO AVOID EXPLOSIONS!

You will be responsible to furnish a current MSDS for all chemicals that you bring into the lab.

No horseplay!

Leave the area cleaner than you found it! Your working area will be swept and or vacuumed prior to leaving the lab! DO NOT USE AIR HOSE TO BLOW OFF AREA! All chips will be discarded in appropriate trash containers! Area will be left in a ready condition for the next user! Wipe down machinery.

When using grinders or cut-off saws, it is your responsibility to sweep or vacuum a minimum 20 square foot area. EVEN IF IT LOOKS CLEAN! AGAIN, DO NOT USE AIR HOSE!! Wipe down Machinery. Do NOT leave the lab before cleaning around the grinders which you have used!!

Never walk up to a machine operator or welder from behind and touch them. If you need their attention, wait until they stop, then approach them from front or sides.

If you need to hammer or make loud noises, please inform all other users when this will happen and only after they have stopped their process.

No ear buds or headphones will be allowed in the SPL. All music should be at an acceptable level as decided by Mike Morgan. No offensive lyrics will be tolerated.

No personal projects allowed in the SPL Facility. Equipment and Supplies are to be used for USU projects only!

No personal vehicles allowed in SPL.

Project areas will be assigned as needed. Ask first. No Materials will be left in walking paths as designated by yellow lines. No materials will be stored around equipment.

All materials will be clearly marked indicating group of origin. Marked items will not be used by other groups.

Always sign in before and after hours using sheet near main door! A list indicating equipment used will also appear there shortly.

ALL broken Equipment, Tooling and ALL Injuries will be reported to Mike Morgan in person or mail to mike.morgan@usu.edu. Personal injuries call my cell #435-770-8528.

If an EMERGENCY arises, please use a USU phone and dial 911 so USU can respond. If this is not possible, use any working phone and dial 911. This is the Technology building #45.Building code is TECH.

It appears as though the SPL has been available for very limited use on Saturdays from 9:00am to 6:00pm. We can try this out and see how it works, but only after approval has been granted. Please plan SPL usage for weekdays. The lab is currently available Monday through Friday from 8:00 am until 9:00 pm with SPL personnel support.

No Access to the SPL on SUNDAYS!

Please send an e-mail to me indicating odd hours or days needed.

There will be times when conflicts arise concerning specific equipment needs and schedules. We will possibly need to alternate times or see if we can perform other procedures until the equipment becomes available. Some deadlines will have higher priorities than others. We can all minimize this issue by planning in advance and not wait until due dates. We will work through these situations separately as needed in an attempt to avoid barriers which could produce negative results for all. Please inform me of your specific equipment needs with approximate dates and daily timeframe as well as total hours needed. I understand that this can be very difficult to assess but a best guess will work. If your time allotment changes please notify me so that others can use open times. Once again, let's work on these projects continuously with goals being set and monitored to help avoid the crunch time bottleneck.

We are sharing the SPL with many other groups. We need to show them the same respect that we would want. We can all work together to have a fun time and learn some great skills.

I feel that we can all challenge each other to do better and remind each other when things are not quite up to par. Continuous improvement is a wonderful tool for us and our workmanship.

We all have strong points and areas for growth. As a TEAM we can be unstoppable. LET'S ALL WORK AS A LARGE TEAM!!

Please note that the building access code may change in the near future.

Please pass this on to all members.

Thanks, Mike Morgan Revision 5 11-03-2010

M. UROC Contact Information

Rachel Curry	Chemical Hygienist	(435) 797-7423	rachell.curry@usu.edu
Eric Jorgensen	Asst. Director, Environmental Affairs (DOT Issues)	(435) 797-2856	ericj@cc.usu.edu
Raymond Cartee	Director of Research Farms	(435) 797-2209	
Tim Boschert	Tripoli Utah Prefect	(801) 274-8076	tboschert@utah.gov

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