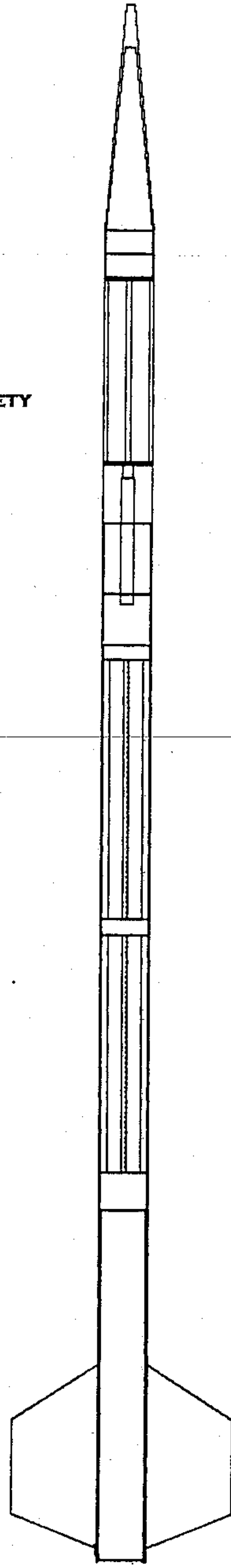
PORTLAND STATE UNIVERSITY

AEROSPACE & ELECTRONIC SYSTEMS SOCIETY



LV-1

TECHNICAL ADVISORY PANEL (TAP) DOCUMENTATION

LAUNCH VEHICLE NO. 1

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General

overview
LV-1 dimension drawing
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Overview

The objective of building LV-1 was to come up with a reliable launch vehicle that could deliver scientific payloads to altitudes of between 10,000 to 50,000 feet.

It is to be a test platform for RF telemetry systems and onboard inertial measurement systems that will hopefully one day lead to an Inertial Navigation System that can drive and actively guided rocket.

The vehicle will also test scratch built avionics and a two stage recovery system. This will be a stepping stone to more advanced onboard electronics and advanced recovery systems.

This vehicle is highly experimental. There are no off the shelf systems anywhere on it. Everything is completely scratch built, even down to the ignitors.

This makes the vehicle more prone to an unknown failure since this will be the first time for using some of the systems but it is also an invaluable learning experience.

A lot of research went into the design of the rocket and payload before anything was assembled. The vehicle was extensively simulated on the ground and components were ground tested as much as possible.

Several computer simulators were used to predict the vehicles flight profile included in the back of the packet are spread sheets from two of them

Rogers Aeroscience ALT 4 software
Stephen Robersons ALTICALC 4.0 software

CP and CD were determined using the following software

Gary Crowells VCP V1.64 CP/CG calculator
Hans Olaf Toff Aerolab CP calculator
ALT 4 CD and CP calculator

Parachute design and descent rates were calculated manually. For reference I used.

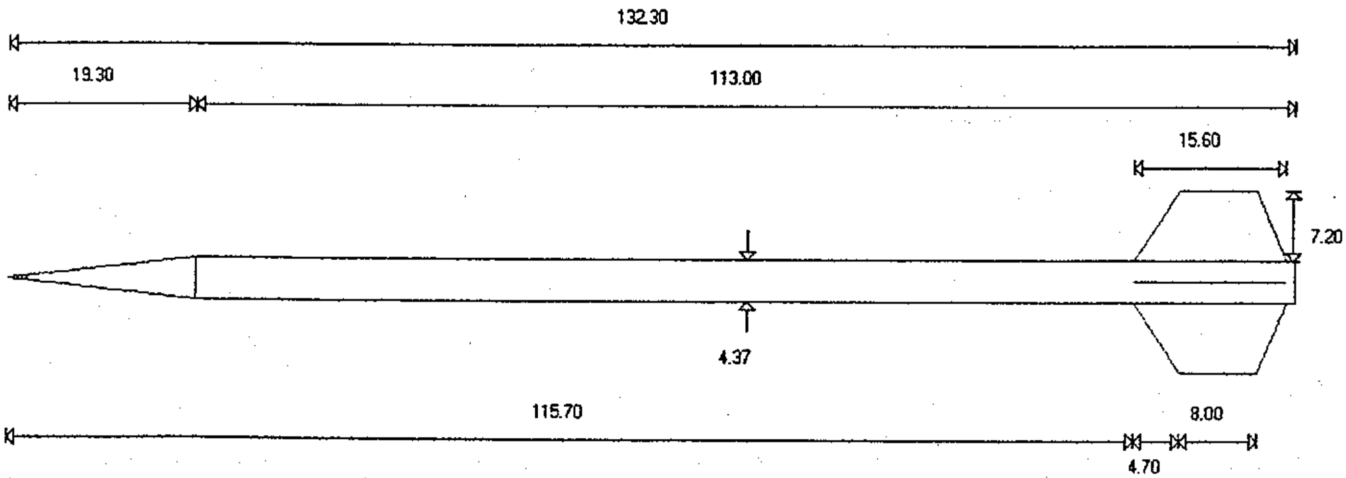
Paratech Technical Report No.1

Other simulations and testing of things like ignitors and ejection charges were done on the ground as well as testing of RF DTMF backup system and dry runs of sequencing electronics.

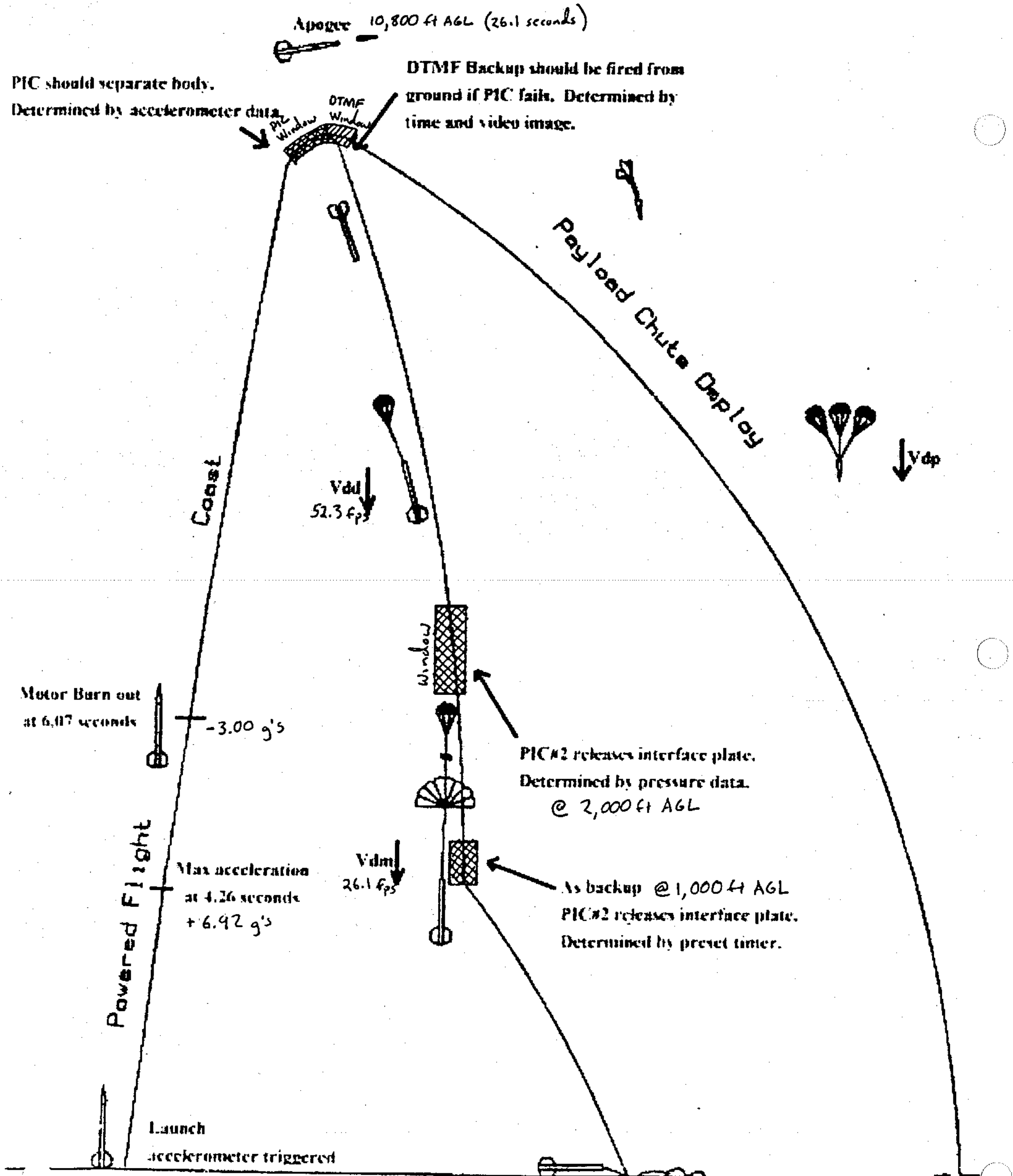
The plan is to try and launch LV-1 on October 25th at the Tripoli launch site in Millican, Oregon. It will be a level 3 certification attempt for me.

I am currently level 2 certified.
The local prefect will require a TAP review.
There will be a TAP committee member on site.
The site has an FAA waiver to 20,000 feet AGL.
It is located in the high desert and is very flat and suitable for a high altitude attempt.

Project: Portland State University AESS LV-1

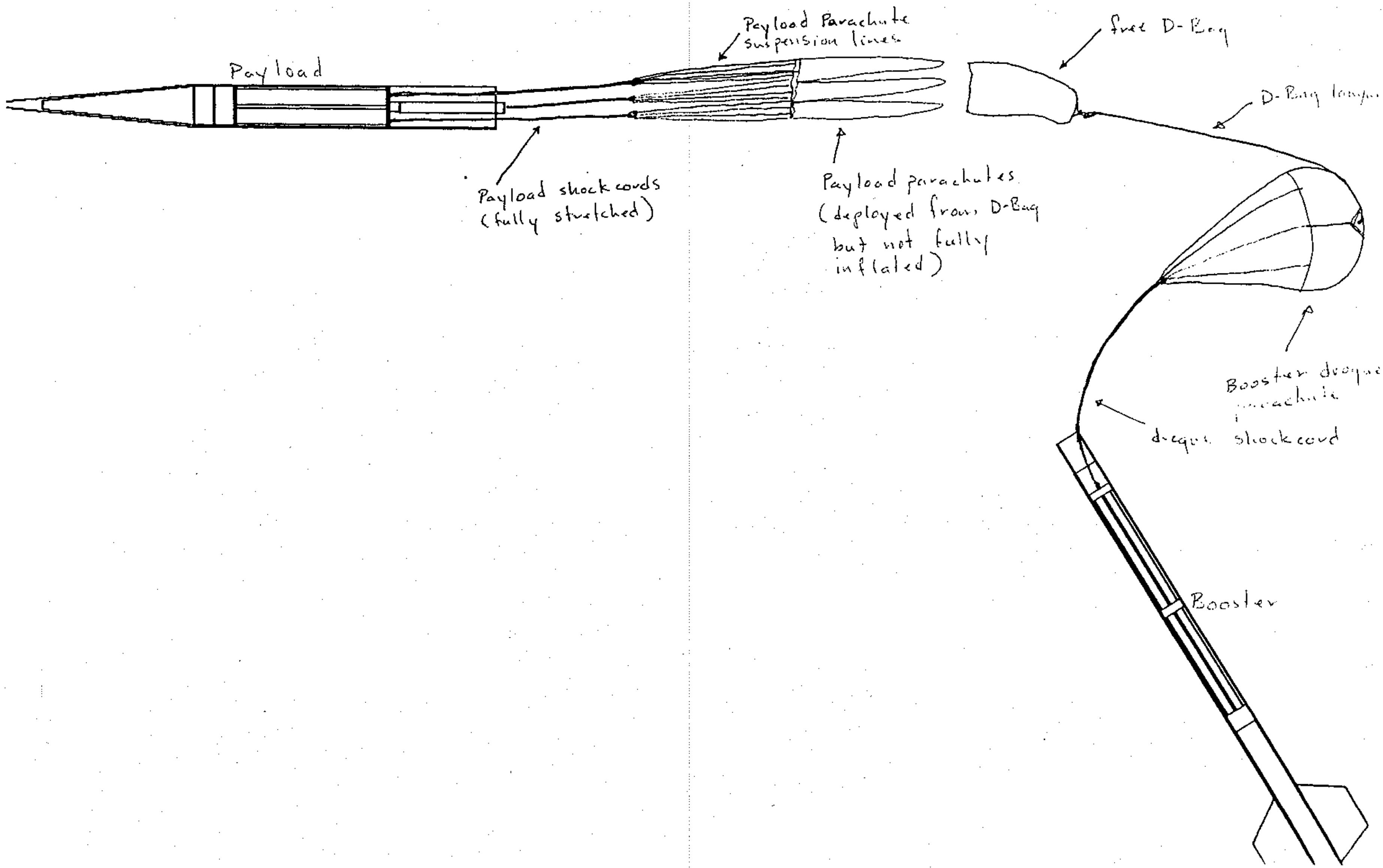


All Dimensions are: in



Apogee 10,800 ft AGL (26.1 seconds)
PIC should separate body.
Determined by accelerometer data.
PIC Window
DTMF Window
DTMF Backup should be fired from ground if PIC fails. Determined by time and video image.
Payload Chute Deploy
Vdp
Coast
Vdd
52.3 fps
Window
PIC#2 releases interface plate.
Determined by pressure data.
@ 2,000 ft AGL
Motor Burn out at 6.07 seconds
-3.00 g's
Powered Flight
Max acceleration at 4.26 seconds
+6.92 g's
Vdm
26.1 fps
As backup @ 1,000 ft AGL
PIC#2 releases interface plate.
Determined by preset timer.
Launch
accelerometer triggered

Deployment Sequence



LVI PAYLOAD MODULE
10/14/98

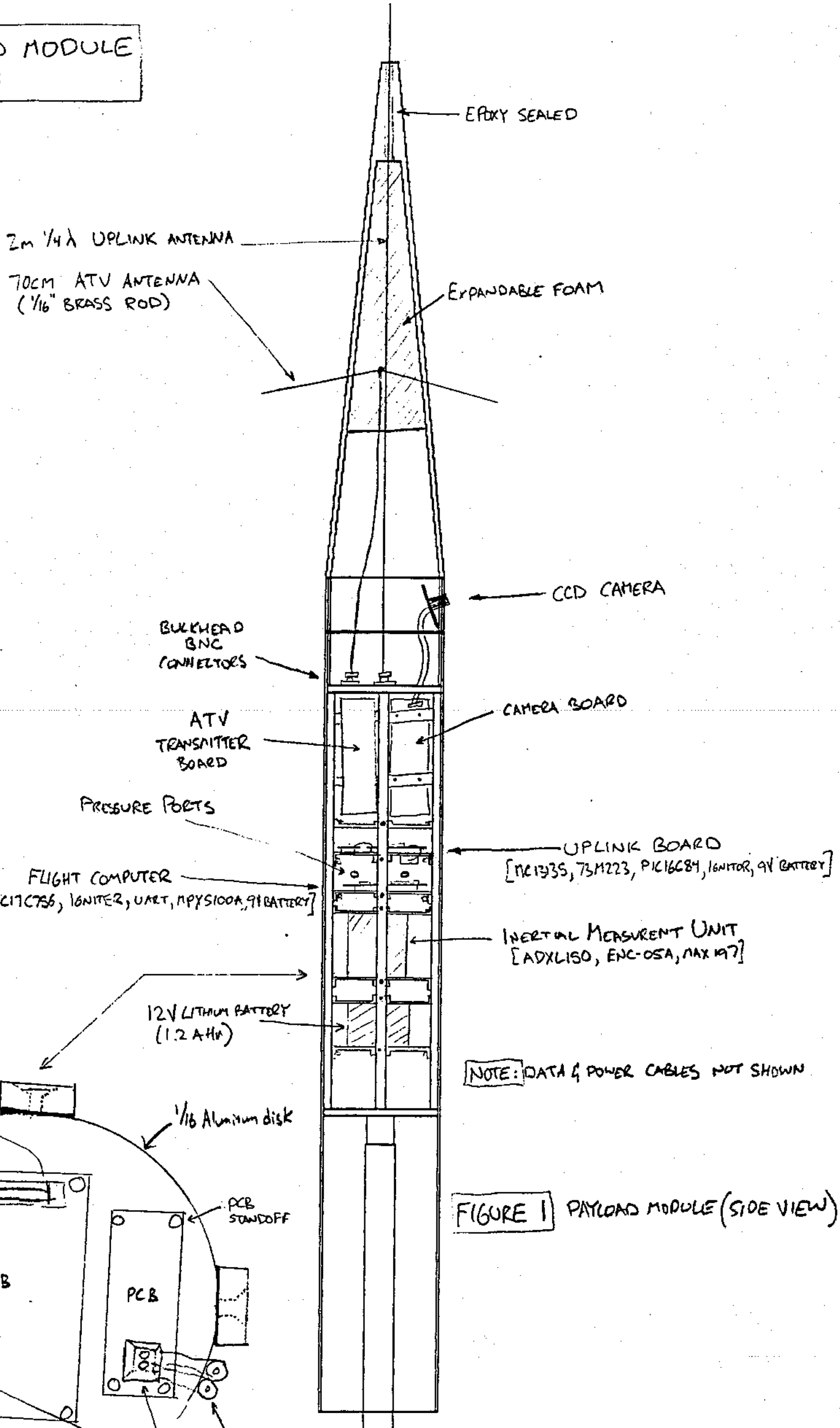


FIGURE 1 PAYLOAD MODULE (SIDE VIEW)

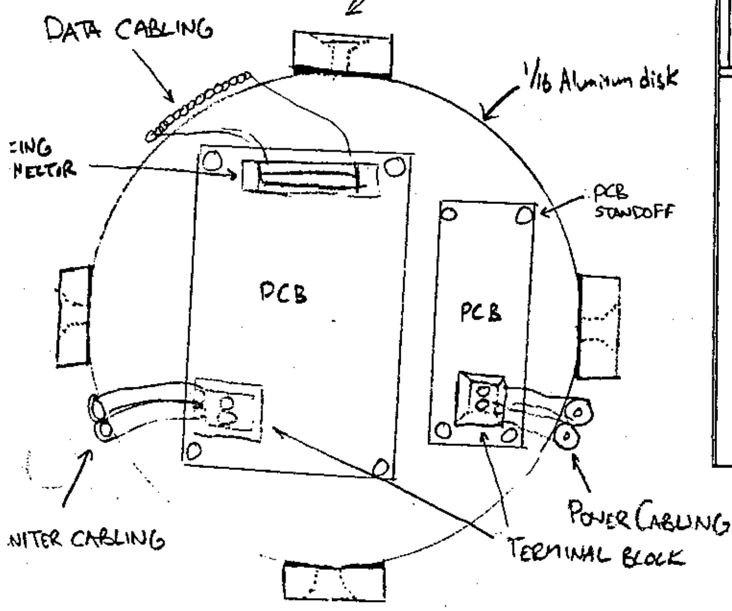
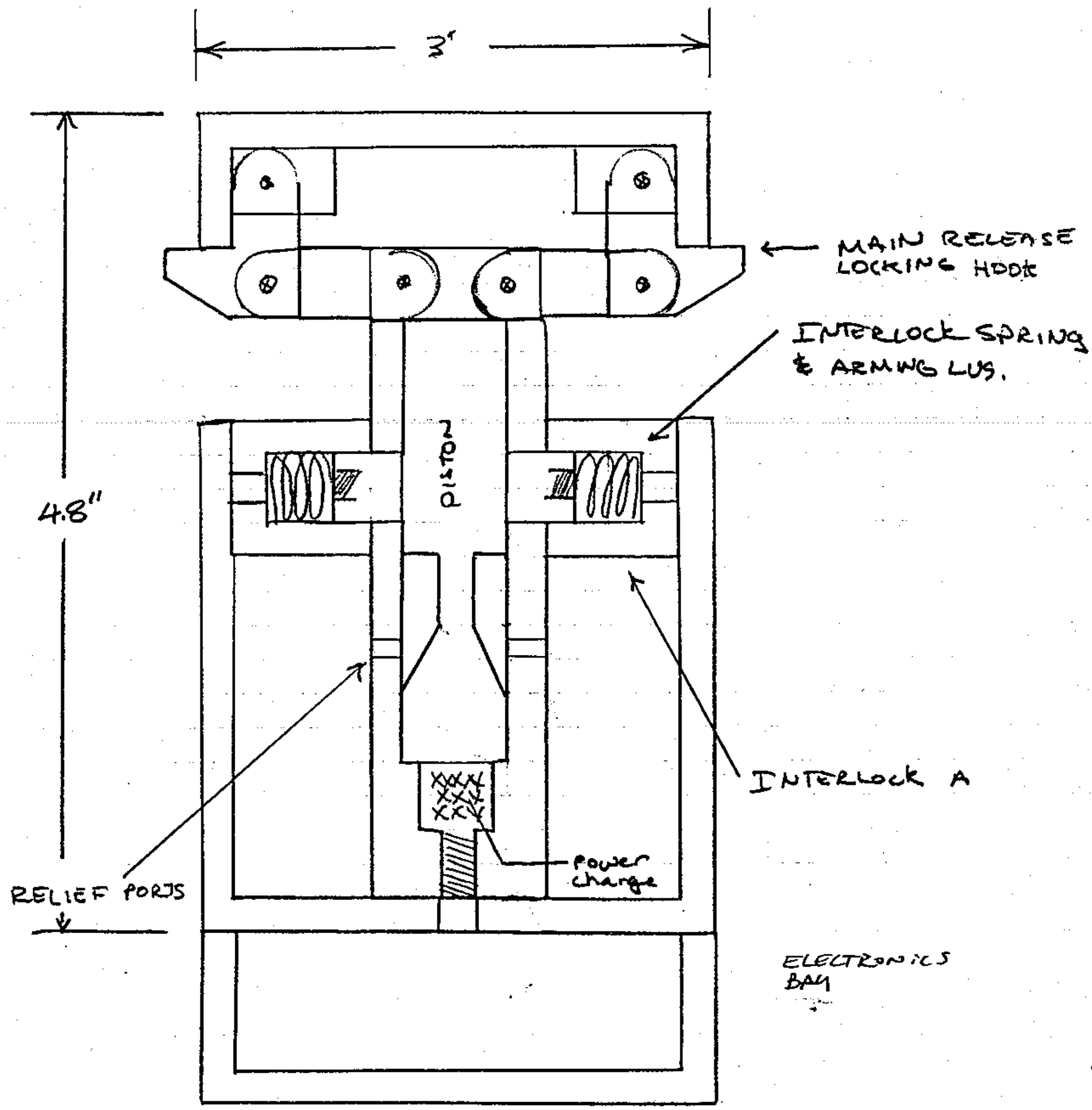
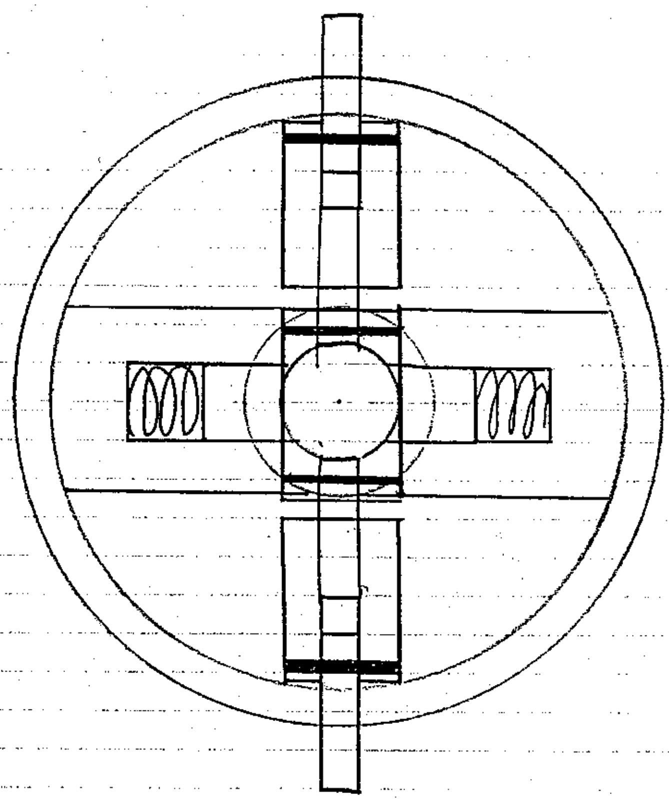


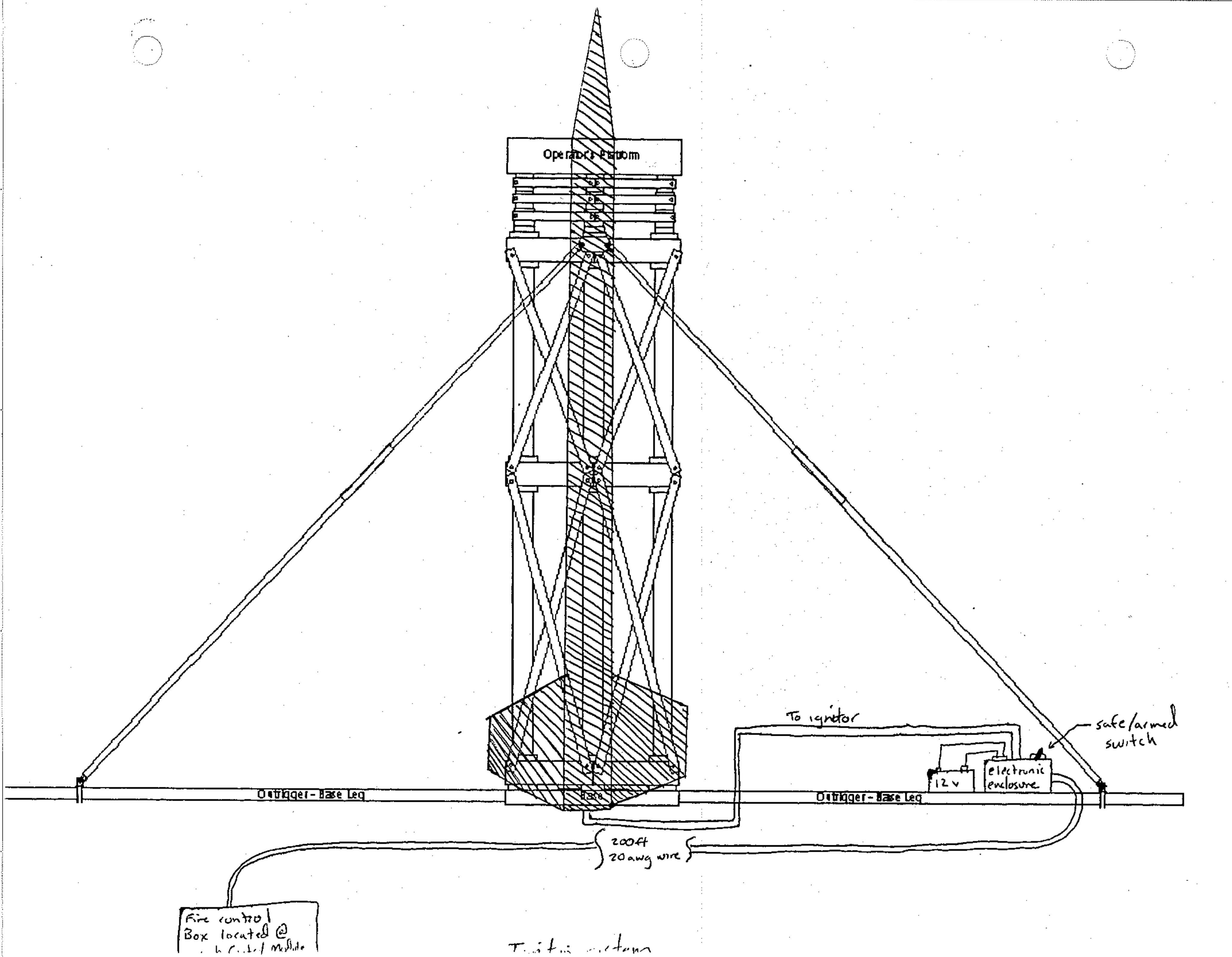
FIGURE 2 PCB CARRIER PLATE (TOP VIEW)

SIDE VIEW

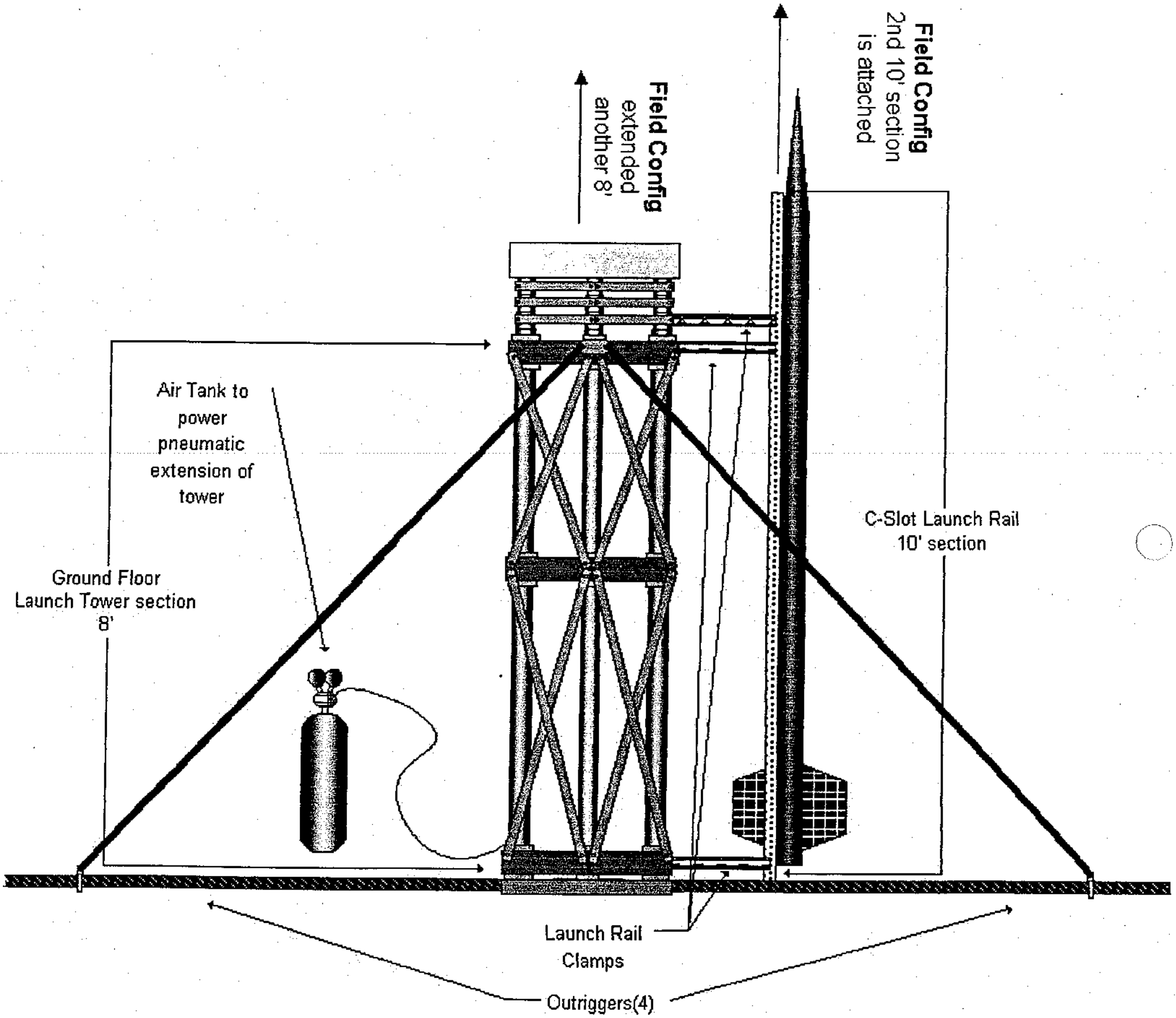

3"
4.8"
MAIN RELEASE LOCKING HOOK
INTERLOCK SPRING & ARMING LUG.
PISTON
INTERLOCK A
RELIEF PORTS
Power charge
ELECTRONICS BAY

TOP VIEW





Operator's Platform
Base
Outrigger - Base Leg
Outrigger - Base Leg
To ignitor
safe/armed switch
electronic enclosure
12 v
200ft 20 awg wire
Fire control Box located @


Field Config
2nd 10' section
is attached
Field Config
extended
another 8'
Air Tank to
power
pneumatic
extension of
tower
C-Slot Launch Rail
10' section
Ground Floor
Launch Tower section
8'
Launch Rail
Clamps
Outriggers(4)

Airframe

Overview
LV-1 drawing
Fin attachment
Motor mount
Internal main body rails
Nose/Payload
Launch lugs

Overview

The airframe of LV-1 can be summed up in one word "beefy". The main body was made around a 4" diameter section of PVC sewer pipe. High performance sewer pipe mind you. The PVC was wrapped in 3 layers of waxed paper then suspended on a longer dowel through the center of the pipe.

The PVC could be rotated as the carbon fiber and epoxy fabric was hand laid up on it. the tube has six layers of fabric.

When almost cured the PVC was knocked out, (PVC would be gripped too tight once epoxy fully shrinks), What is left is a very stout carbon tube. The next step was to trim the tube to desired length 82.0 inches. Once trimmed then the aluminum rail skeleton was installed.

The internal rail system was place in the main body to stiffen it even more, and to create a space for slide in payload modules.

The rails consist of 4 aluminum c channels 90 degrees apart. The rails have holes drilled in them the entire length (48 in) on one inch centers. This is to allow for variable placement of modules (No modules will be flown in this area during the upcoming launch) The 4 rails are held in place by 3 epoxy/fiberglass rings. The rails were screwed to the rings before insertion into main tube. This made the rails a stand alone element. The rail system was then slide into the main body which was coated with fresh epoxy on the inside. This fixed it in place.

The lower ring of the rail system it thicker than the other two and houses the lower spring loaded launch lug. It is essentially a spring loaded "T" that rides in the launch rail and once clear snaps back into the airframe (flush) under about 15lbs of force.

The lower ring also serves as the thrust plate for the motor.

The Motor mount was next. It is built around a 29 inch section of 3.9 inch Phenolic. The Phenolic tube also serves as an anchor point for the fins.

The fins are solid carbon fiber/glass. About 80% carbon fiber, 20% S-2 fiberglass. The fins were fiberglassed onto the Phenolic motor mount making essentially a fin canister. This alone is incredibly strong and I could just about use it as a foot stool. Next I slotted the airframe at the base for the fins and slid the whole canister up till it hit the motor thrust plate (lower rail ring). Once in place I used fiberglass fillets to secure the fins to the carbon fiber body. This method made for a very strong "through wall" fin mount.

Since the rocket is going to be launched on a M1419 this makes the motor bay 5 inches to deep. This was intentionally done so larger M's could be used later. The 5 inches is taken up by a spacer. This spacer is 5 inches in length and 0.5 inches thick. It has two brass pins across its diameter. These 3.9 inch long pins are held strongly in the epoxy, They serve as the anchor point for the main parachute. To fail the 3/8 inch pin would have to snap or pull through the epoxy/phenolic spacer then through the lower rail ring with launch lug in it, then through the entire rail system. This is very unlikely.

There are two last components to the main body.

There is an aluminum ring on the top of the rail section. It rests on top of the top epoxy/fiberglass ring the rails are mounted to. It is screw into to top fiberglass ring then screw are run from the outside of the carbon body into the aluminum ring, holding it fast.

The last thing is a PVC sleeve epoxied on top of the aluminum ring. This provides a 6 inch sleeve for the payload section to slide onto.

The payload section was formed in much the same way as the main body section. A 4 inch PVC mandrel was used and then beaten out. The difference is the payload is made of fiberglass and not carbon fiber. This was done because of electrical conductivity. The Payload team wanted complete electrical insulation for the computer and RF equipment.

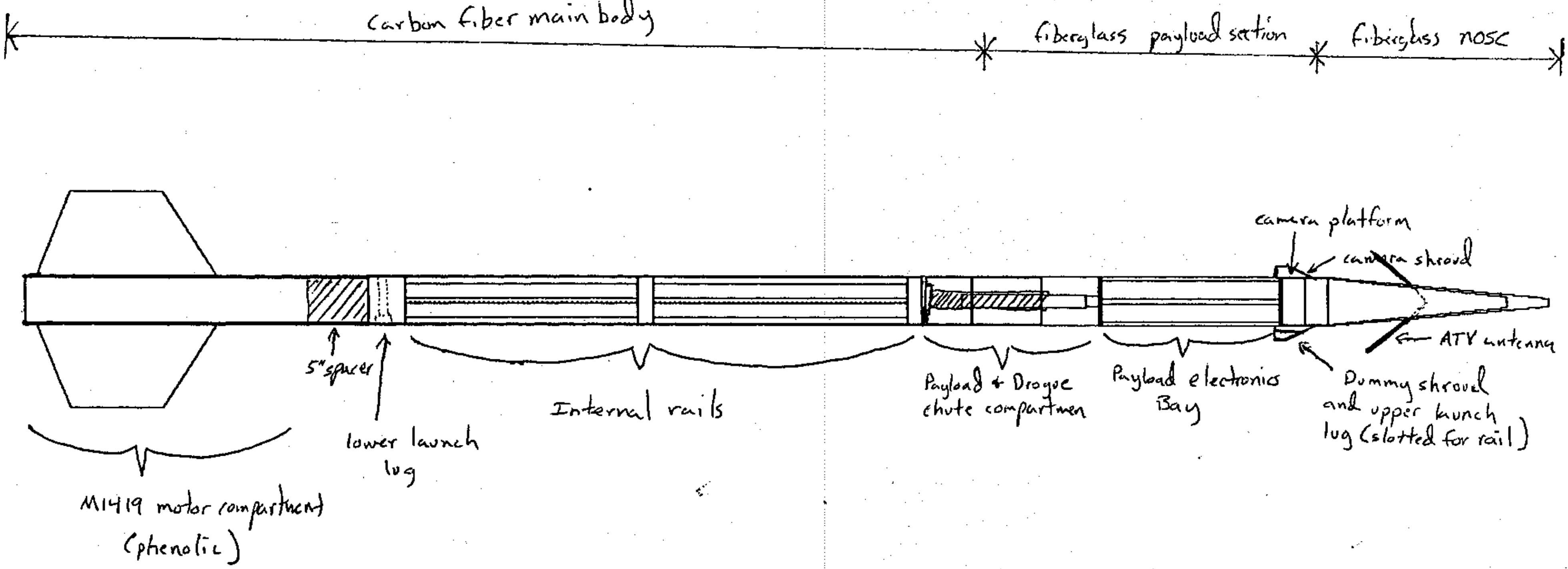
The payload section is just a simple fiberglass tube 29 inches in length. At the end of the payload section there is another PVC sleeve for the nose cone to slide onto. The PVC sleeve is epoxied in and extents 2 inches past the tube and is the home for the ATV camera platform and antenna cable pass through

The payload section acts only as a skin for the payload itself. The g forces experienced by the payload and payload frame are transferred down the piston/cylinder ejection system to the interface plate and the payload rail system.

The rocket nose was a pain to construct. It had to be custom made and be 4.37 inches in diameter.

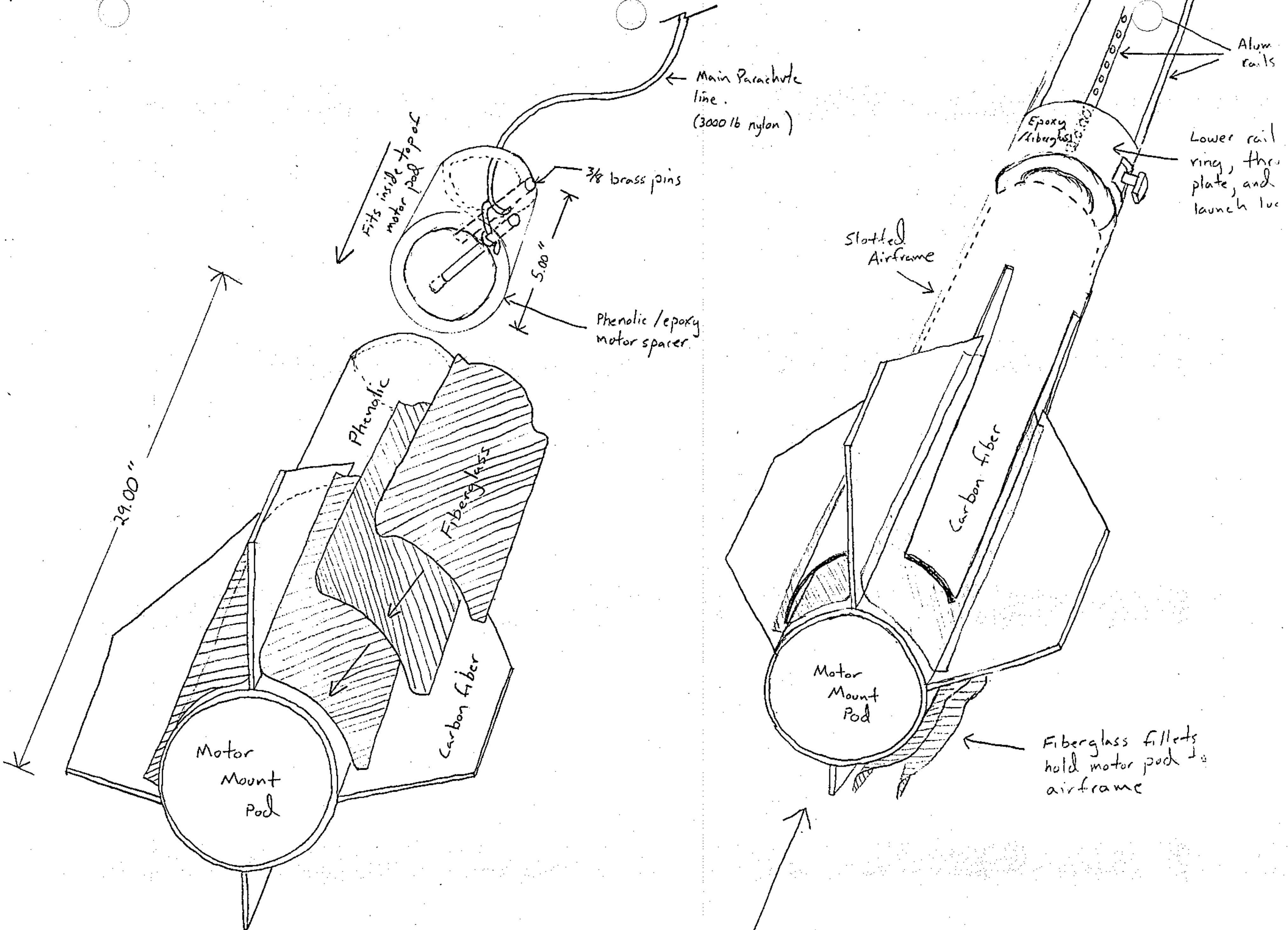
I made a conical Styrofoam replica with two inch long cylindrical base, this entire piece was filled, sanded, and sprayed with mold release. This Styrofoam "male" was thin inserted into a cylinder of plaster of Paris to make a female impression. Once the plaster had set the Styrofoam male had to be dissolved with acetone. The female nose mold was then cleaned, sealed, and sprayed with mold release. Fiberglas could then be laid up inside the mold.

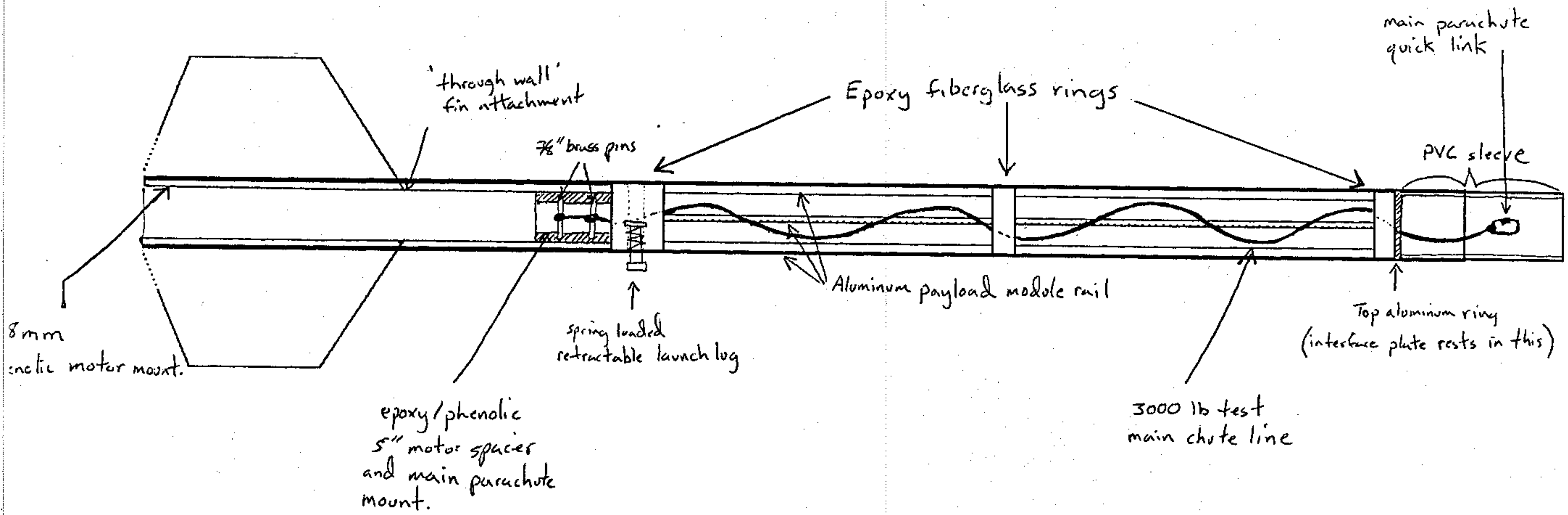
That is a basic overview of the construction of the airframe. If you have any questions please feel free to contact me.



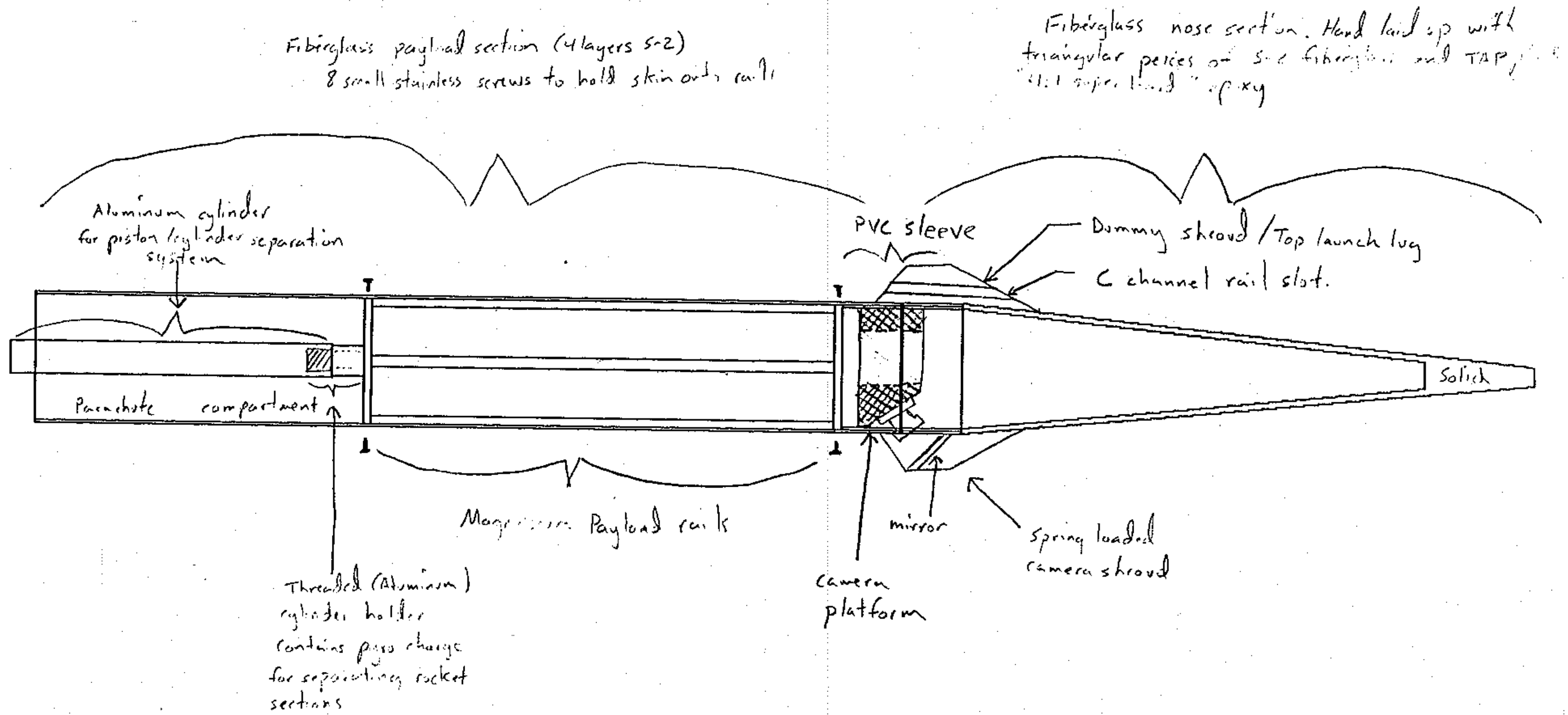
Carbon fiber main body
fiberglass payload section
fiberglass nose
camera platform
camera shroud
ATV antenna
Dummy shroud and upper launch lug (slotted for rail)
5" spacer
lower launch lug
Internal rails
Payload & Drogue chute compartmen
Payload electronics Bay
M1419 motor compartment (phenolic)

Fin attachment and Motor mount





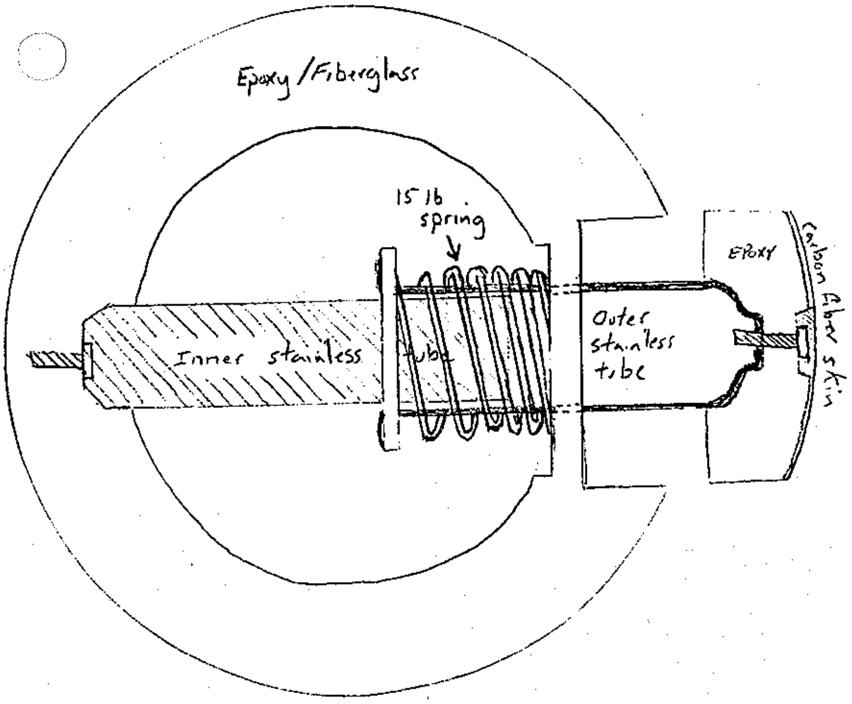
main parachute quick link
'through wall' fin attachment
Epoxy fiberglass rings
7/8" brass pins
PVC sleeve
Aluminum payload module rail
8mm
nolic motor mount.
spring loaded retractable launch lug
Top aluminum ring (interface plate rests in this)
epoxy/phenolic 5" motor spacer and main parachute mount.
3000 lb test main chute line



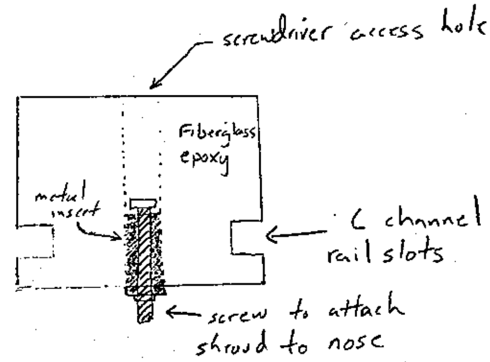
nose - payload

Bottom Retractable Lug — Top Lug

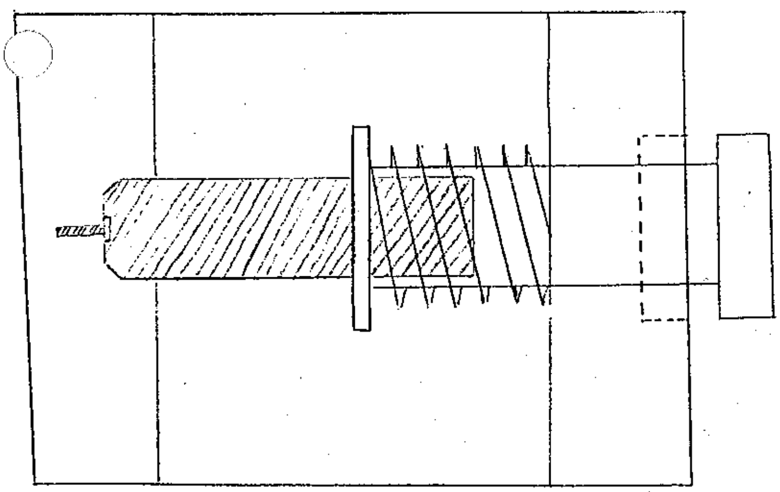
(dummy camera shroud 180° opposite mirror shroud. To balance aerodynamic drag.)



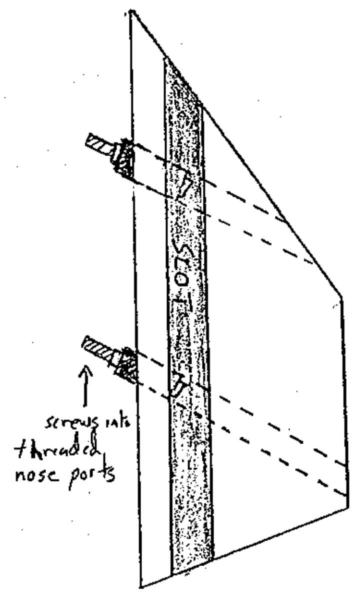
Top View



Top View



Side View



Side View

Recovery System

Overview
System attachment points
Descent rate spreadsheet

Overview

The recovery system of LV-1 is two systems.

The payload system. Which includes three, simultaneously opening chutes.
The Main body system. Which includes a two-stage deployment arrangement. Drogue then main chute.

Upon apogee detect (flight sequencer sampling the accelerometer) a pyrotechnic charge is blown in the piston/cylinder assembly. This forces the two halves of the rocket apart (main body and payload section). This separation will pull the drogue chute and payload chutes out of their compartment that lies between the top of the interface plate and the bottom of the payload bay. The two system will extract due to the fact they are physically linked. They will pull out as the body halves move away form one another. This physical linking which mandates extraction is broken once the payload chutes are pulled from their deployment bag (see illustration). The deployment system then becomes two separate systems.

The payload has three 3.5ft flat circular ripstop nylon chutes with nylon suspension lines. Using the standard drag equation compensated for altitude and temperature this will yield a descent rate of 18 fps. this will allow for a very long descent time to optimize the ATV video coverage. The three parachutes are attached to the magnesium base plate of the payload module with u-bolts run through the plate. each chute has 5 ft of bungee chord sewn inside of a 7ft scrunched length of tubular nylon tape. This will allow for shock absorption and energy dissipation but also be a 'hard stop' if the bungee exceeds its point of elasticity (you know.....breaks!). The parachutes are simple 'flat-circulars' and are not purchased but scratch built. All attachment points are reinforced with nylon tape for extra safety.

The main body upon apogee separation has a 4.0 ft drogue deploy. The drogue has the same construction as the payload chutes except it has a nylon tape/ bungee shock chord only 3 feet long. The descent rate of the main body with fuel expended motor is 52 fps. A nice quick drop rate to get the body down .

The recovery system is very strong and will have no problem if deployed at apogee. In the event of computer or sensor failure the rocket separation has a back up DTMF system (2m HAM radio) which is a ground based, manually controlled, signal sent to the rocket to blow the pyro's. This system has been ground tested but in the event that it has to be used in flight there is one big question. When will we know when to fire it. From computer simulations we will know approximately when the rocket should hit apogee. We will determine a specific time after that event the backup DTMF should be fired. There are a couple of indicators we have to know when to fire. 1) time simulations to apogee. 2) Visual appearance from ground (can be deceptive) 3) Live video signal from rocket. In an earlier flight (that of LV-0) we noticed you could see a very distinct 'hang time' at apogee. If the main computer system does not fire the pyrotechnic separation charge in the time window that was simulated then we will have to go off of these three queues to fire the backup system.

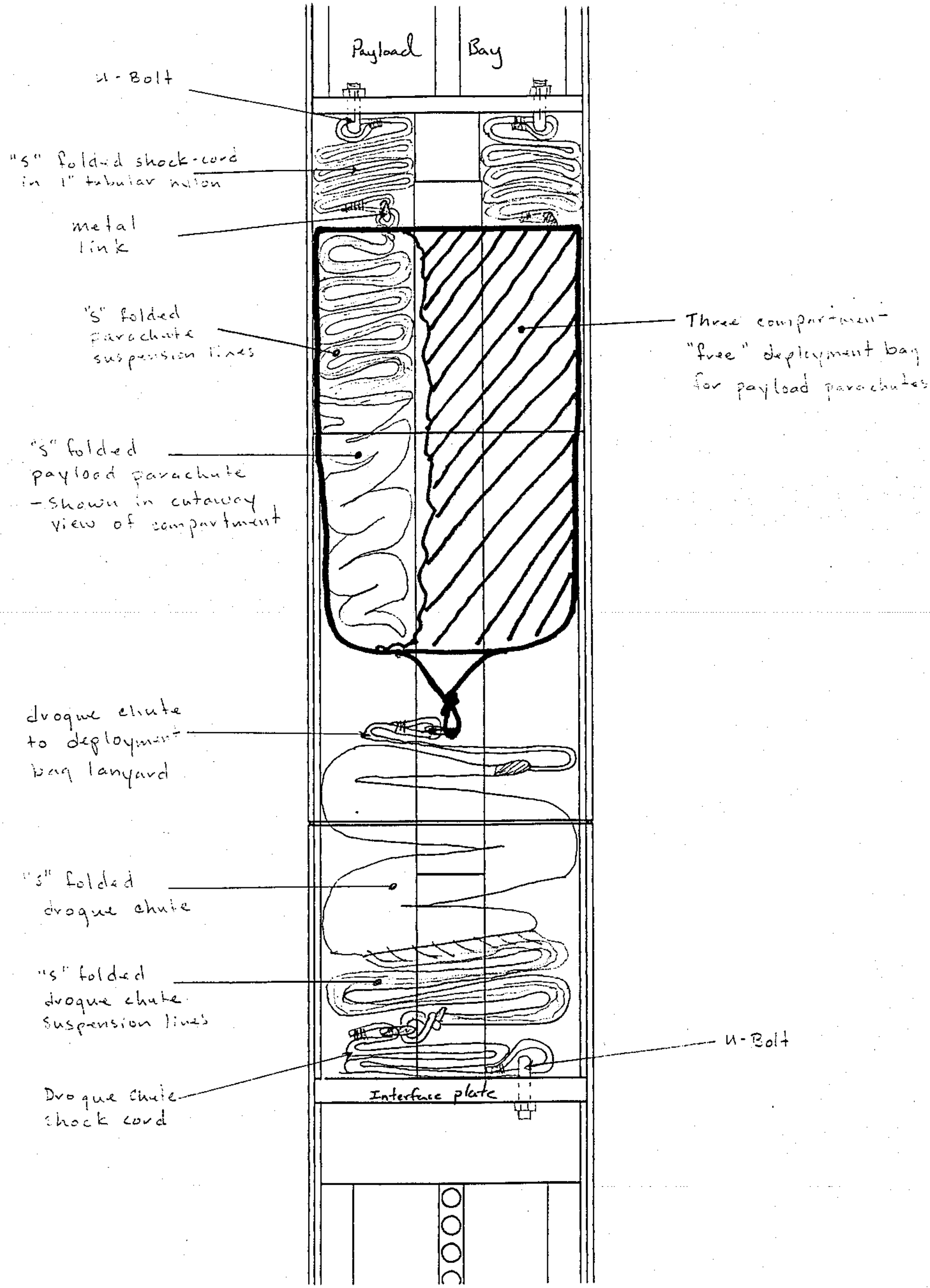
Worst case scenario, if the computer fails, there will be a short delay firing the back up system because we will probably hesitate , waiting for the software algorithm to sense apogee. If the back up is fired late hopefully the strength and elasticity built into the recovery system should save it from a destructive relatively high speed opening.

After the main body (on the drogue) has fallen within 2,000 feet of the ground. determined by altimeter. the interface plate PIC microcontroller with pressure sensor will give the signal to fire a pyrotechnic charge to release the interface plate that is being held into the main body. Once the interface plate has let go, the force of the drogue will extract the main parachute.

The main parachute is 'flat-circular' also and made of ripstop nylon with a small shock chord. Not much shock resistance has been built into the main parachute because we know exactly how fast it should be falling on the drogue, assuming the drogue is deployed and functioning correctly.

The main parachute is 8 feet in diameter (the material sheet says 7ft. ignore this.) this will cause a descent rate of 26 feet per second. This is a bit high but the airframe is VERY strong and should survive it fine.

If the interface plate electronics fails to read the pressure correctly to know when it is time to release the interface plate, a backup timer will fire the charge to separate the plate. The timer is set for 20 seconds after the time the rocket should be at 2,000 feet.



Payload
Bay
u-Bolt
"S" folded shock-cord in 1" tubular nylon
metal link
"S" folded parachute suspension lines
Three compartment "free" deployment bag for payload parachutes
"S" folded payload parachute - shown in cutaway view of compartment
drogue chute to deployment bag lanyard
"S" folded drogue chute
"S" folded drogue chute suspension lines
u-Bolt
Drogue chute shock cord
Interface plate

Recovery System

Materials list:

Payload Parachutes

Dim: 3 X 3.5 ft flat circular design
Const: ripstop nylon w/ nylon suspension lines.

Deployment Bag:

Dim: 1 x 4 in dia x 8 in long w/ 3 compartments
const: Cotton w/ nylon lanyard

Booster Parachute

Dim: 1 x 4 ft drogue
1 x 7 ft Main
const: ripstop nylon w/ nylon suspension lines

Shock-Cords

Dim: 3 x 5 ft (Payload), 1 x 3 (drogue), and 1 x 5 (Booster Main)
const: 1 inch nylon tubular tape w/ 1/4 inch bungee cord core. Nylon tape is as long as bungee may stretch.

Descent Rate Calculations

Target Range :

Drogue chute	50 - 55 fps
Main chute	20 - 25 fps
Payload chutes	15 - 20 fps

Given :

Main body section 27.5 lbs
Payload section 7.5 lbs
Cd = 0.80 (for flat circular chutes)
rho = .00238 slugs/ft^3 (standard conditions @ sealevel)
Launch site conditions : 2,500 MSL @ 65 F.
rho correction factor for altitude = 0.915
rho correction factor for temperature = 0.920

Equations :

D = .5A(Cd)(rho)V^2
Terminal velocity occurs when D = W (Drag = Weight)

Therefore :
Vt = sqrt[2W / A(Cd)(rho)]

Variables :

A = Area
Cd = drag coefficient
rho = air density (cirrected rho = .0020035)
Vt = terminal velocity
W = weight (mg)

Data :

Payload weight (lbs)	Parachute diameter(x3) (ft)	Parachute area (total) (ft^3)	Descent rate (ft/sec)	time to ground from 10,800 ft * (seconds)
7.5	2.0	9.4	31.5	343
	2.5	14.7	25.2	428
	3.0	21.2	21.0	514
	3.5	28.9	18.0	600
	4.0	37.7	15.8	685
	4.5	47.7	14.0	771
	5.0	58.9	12.6	857

Body weight (lbs)	Drogue chute diameter (ft)	Parachute area (ft^3)	Descent rate (ft/sec)	Time from apogee to 2K ft * (seconds)
27.5	2.0	3.1	104.5	84
	2.5	4.9	83.6	105
	3.0	7.1	69.7	126
	3.5	9.6	59.7	147
	4.0	12.6	52.3	168
	4.5	15.9	46.5	189
	5.0	19.6	41.8	210

Body weight (lbs)	Main chute diameter (ft)	Parachute area (ft^3)	Descent rate (ft/sec)	Time from 2K to ground * (seconds)
27.5	6.0	28.3	34.8	57
	7.0	38.5	29.9	67
	8.0	50.3	26.1	77
	9.0	63.6	23.2	86
	10.0	78.5	20.9	96
	11.0	95.0	19.0	105
	12.0	113.1	17.4	115

* Does not take into account density change with altitude.

Avionics

Overview

Block diagram (separation system and interface plate release system)

Schematics (separation system and interface plate system)

Overview of LV1's Avionics Package

10/15/98

Overview

Although many of these systems could have been bought commercially, most commercial packages (Black Sky, Emmanuel Avionics, etc.) do not fit the needs of LV1. There are four main parts to LV1's custom avionics package:

1. CCD camera and Amateur TV transmitter
2. The Flight Computer and Science Payload
3. The Backup Separation System
4. The Interface Plate Release System

1. CCD Camera and Amateur TV Transmitter

LV1 has a color video camera with NTSC output which transmits it's video through a commercially purchased (PC Electronics) Amateur TV transmitter (Figure 1). Running at 426.250MHz, the unit transmits real time video and sound through an inverted "V" antenna. The audio channel of the ATV transmitter is used as a data channel using audio frequency shift keying (via commercially available 2400bps modem chip).

2. The Flight Computer and Science Payload

The Flight Computer (FC) is a Microchip, Inc. PIC17C756 microcontroller (Figure 2). It has two primary functions: gather data from the science sensors (3 accelerometers, 3 gyroscopes, pressure and temperature), transmit this data to ground (using the ATV audio channel), and use the data to do the flight sequencing of the rocket. In this case, flight sequencing means using a combination of the Z axis accelerometer and the pressure sensor to determine apogee. At apogee, the FC fires a separation charge which separates the upper payload section from the main body section, releasing the body drogue and payload main chutes.

3. The Backup Separation System

In case the FC either doesn't correctly determine apogee, or the FC controlled igniter fails to ignite the separation charge, we have a backup separation system which can fire a backup igniter in the separation charge from a command on the ground (Figure 3). Using an amateur hand held transceiver, we can dial DTMF tones at 144.455MHz (ATV coordination frequency). These tones are picked up by the backup system on the rocket, decoded by a DTMF decoder chip, and send to a PIC16C84 microcontroller. The microcontroller decodes the tone sequence, looking for a password plus command. The password seeking algorithm is immune to drop outs and noise from the DTMF decoder chip, ensuring that the backup system won't accidentally fire. Once the password is decoded, the chip follows the next tone as a command: it can fire the separation charge using it's backup igniter, or it can send a 3bit message to the FC. These 3bit messages can be used as a test "feedback" system for the entire system: dialing in a test command through the backup separation system should send test data down through the ATV audio data stream, ensuring that everything is working correctly.

4. The Interface Plate Release System

After the main body and payload sections have separated, the main body falls on a small drogue parachute. In order to release the main body parachute only a few thousand feet above ground level (to minimize drifting), the Interface Plate Release System measures pressure to determine when to fire the pyrotechnics for the release the plate (Figure 4). In case the pressure sensor fails, there is also a timer backup on the system. Each system, the pressure sensor and the timer, has its own igniter, making the system almost completely redundant.

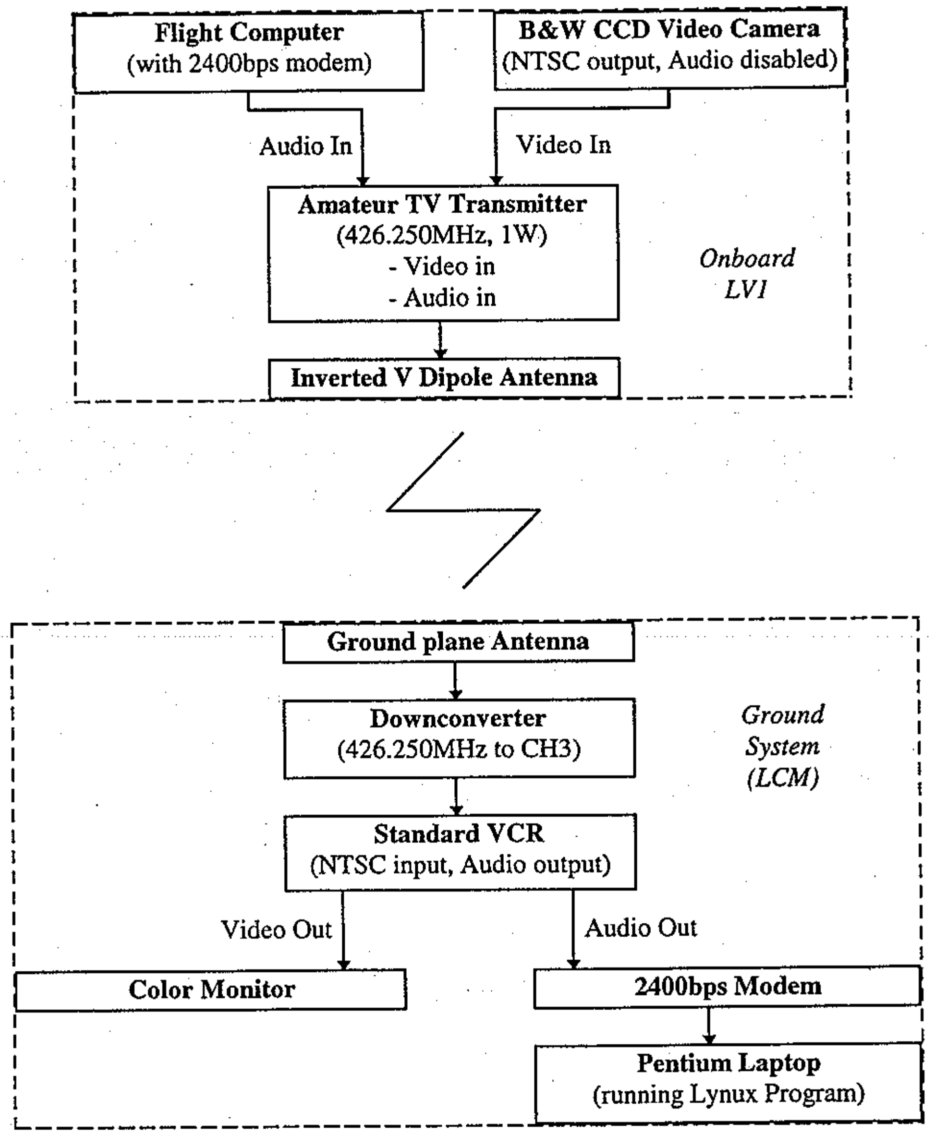


Figure 1: CCD camera and Amateur TV transmitter

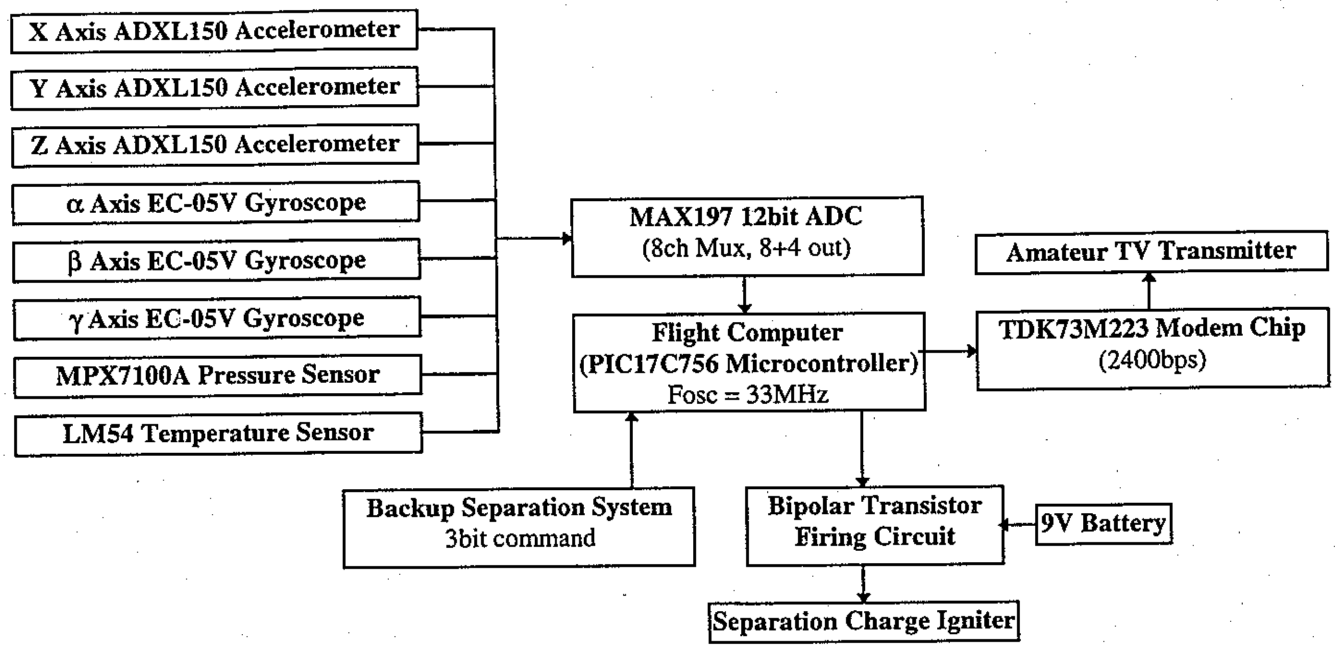


Figure 2: The Flight Computer and Science Payload

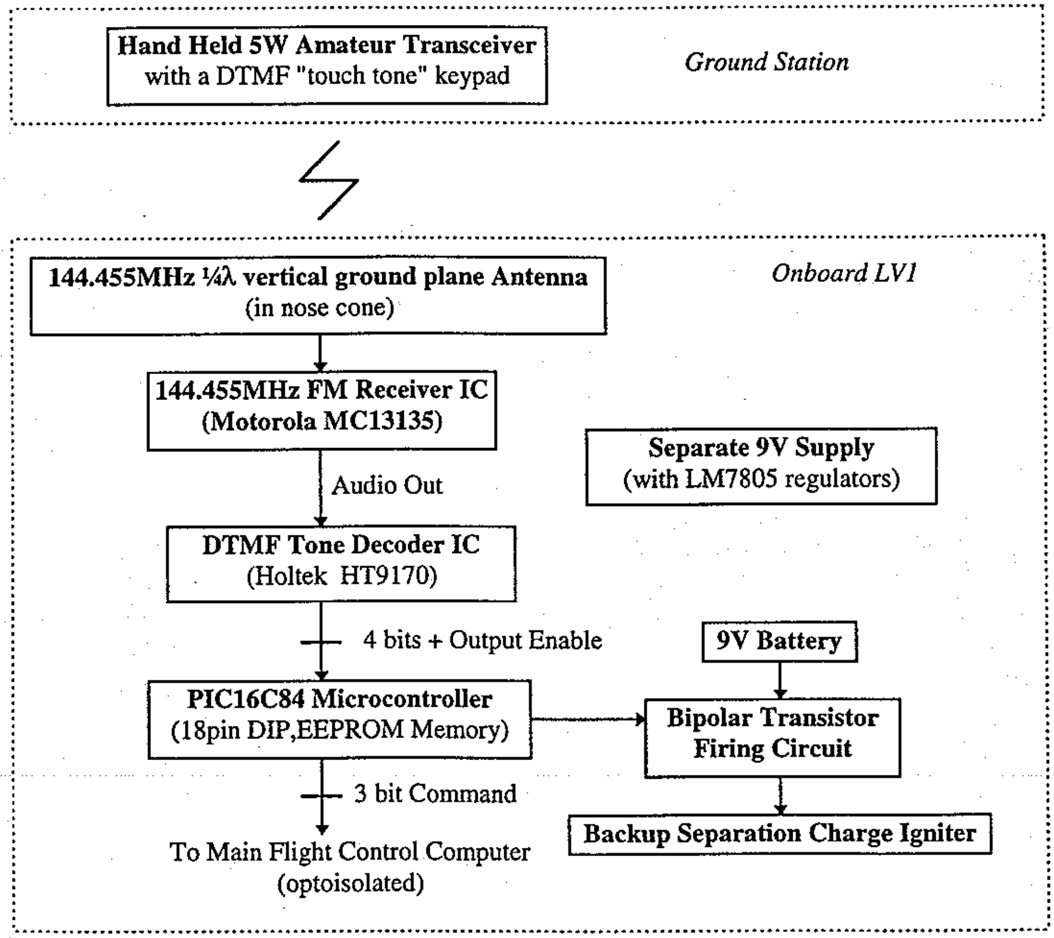


Figure 3: The Backup Separation System

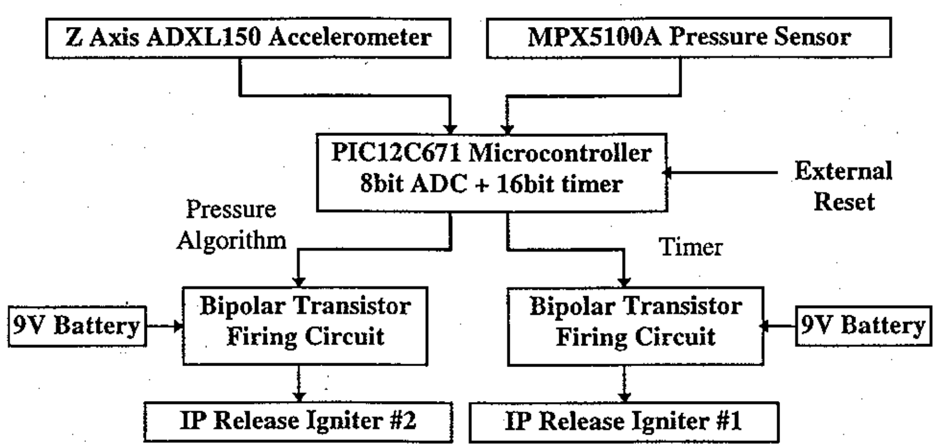


Figure 4: The Backup Separation System

PSU AESS LV1 Backup Separation System

10/15/98

Introduction

The Backup Separation System (BSS) is the backup ignition system for the pyrotechnic charge which separates the payload and body sections at apogee. Since it is possible for the Flight Computer (FC) to fail to sense apogee (and thus fail to fire the separation charge), the backup system was implemented to have manual control over the separation. A hand-held amateur band radio transceiver is used to send DTMF tones at 144.455MHz to the BSS. The BSS decodes the DTMF tones, and looks for a password plus command sequence.

2m Receiver and DTMF Decoder:

The 144.455MHz signal is picked up by a 2m band ¼ wavelength ground plane antenna. the signal is demodulated by a Motorola MC13135 FM Receiver IC. The demodulated audio signal (DTMF tones, noise, perhaps other signals from other amateurs) is then send to a Holtek HT9170 DTMF decoder chip. The HT9170 outputs a 4bit DTMF code, plus an output enable. The HT9170 is extremely resistant to spurious noise and non-DTMF tones on the incoming audio signal; traffic on the 144.455MHz frequency will not accidentally trigger it.

PIC Microcontroller - Password:

A PIC16C84 microcontroller continuously monitors the HT9170 chip's outputs. The PIC looks for a series of nibbles (4bits from the DTMF decoder) that match a stored password and command code. To execute any command, the PIC must first read a specified password sequence. A password may be any 4 consecutive DTMF tones - for example, "123#" would be a valid password. Due to the high probability of dropouts, the PIC will ignore repeated tones. For example, "1111223#" would be a acceptable password. Given the robust filtering capabilities of the HT9170, it is far more likely that the signal will "chop" up, than spurious nibbles will be sent. In the event of a mis-keyed password, the entire password sequence is reset and the user must start over from the beginning.

PIC Microcontroller - Command:

After the password has been successfully received by the PIC chip, the next DTMF tone is interpreted as the system command. There are 11 possible tones, of which only 8 are currently assigned commands:

0. (Do nothing)
1. Tell the FC to send a test signal
2. Tell the FC to reset itself
3. Tell the FC to fire the main separation igniter
4. **Fire backup separation igniter**
5. Tell the FC to go into Coast Mode
6. Tell the FC to go into Launch Detected mode
7. (Do nothing)

Only command number 4 will cause the BSS to fire its backup igniter in the separation charge. the rest of the commands are sent in a opto-isolated 3bit command signal to the FC. This "feedback" connection lets launch control test both the BSS and the FC before flight; for example, sending a "Password + 1" signal will cause test data to stream from the FC. This "launch stand" test is crucial in determining if LV1 is "good to go".

Backup Separation Charge Firing Circuitry:

The igniters are fired by a NTE264 (TIP127) PNP-Darlington (I_C = 10A) bipolar transistor with bypass resistors to guarantee transistor turn off during a microcontroller reset or sleep. The PNP-Darlington will have no problem handling a high current igniter, especially given the short duty cycle (5 seconds). The PIC's outputs are rated at 25mA source per pin; due to the PNP power Darlington, only 1mA is actually necessary to fire the circuit.

Note that "European style" terminal blocks are used to connect the igniters, and that each igniter system has it's own 9V battery. This separates the microcontroller's power system from the firing circuits, eliminating the a reset generated by a voltage drop during firing.

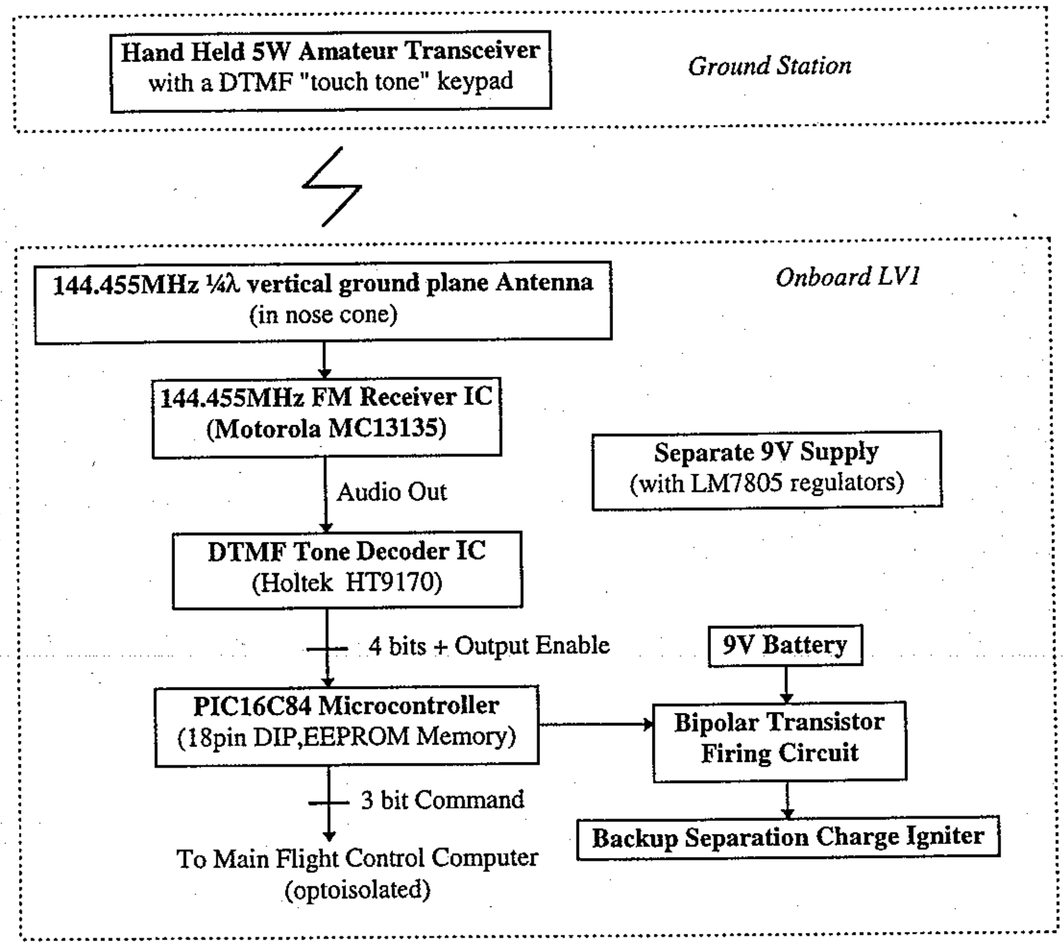
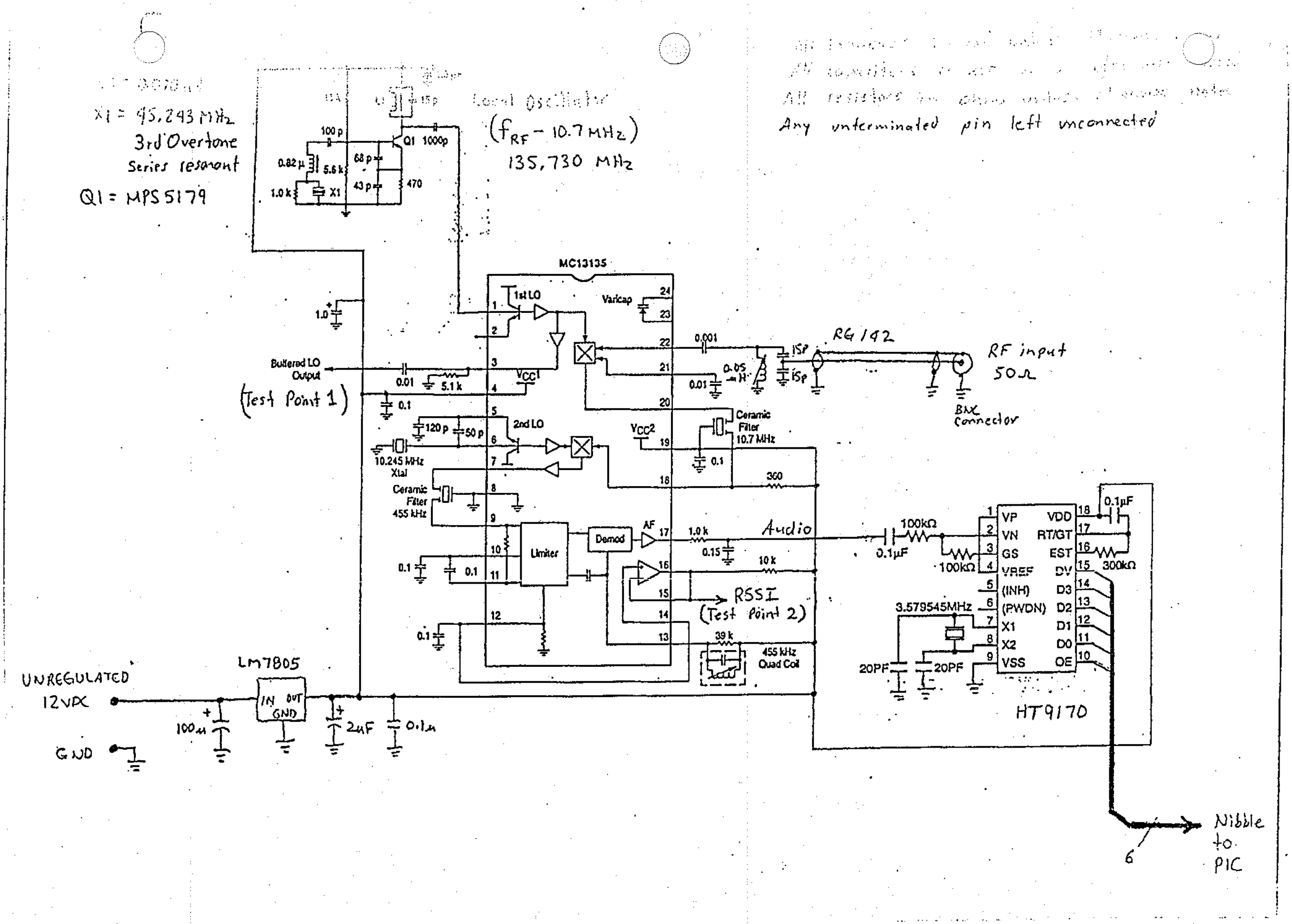


Figure 1: Block Diagram of the Backup Separation System


X1 = 45.243 MHz
3rd Overtone
Series resonant
Q1 = MPS5179
Local Oscillator
(f_RF - 10.7 MHz)
135,730 MHz
Any unterminated pin left unconnected
MC13135
1st LO
Varicap
2nd LO
Limiter
Demod
AF
Vcc1
Vcc2
Buffered LO Output
(Test Point 1)
10.245 MHz Xtal
Ceramic Filter 455 kHz
Ceramic Filter 10.7 MHz
RG 142
RF input 50Ω
BNC Connector
Audio
RSSI
(Test Point 2)
455 kHz Quad Coil
UNREGULATED 12VDC
GND
LM7805
IN
OUT
GND
VP
VN
GS
VREF
(INH)
(PWDN)
X1
X2
VSS
VDD
RT/GT
EST
DV
D3
D2
D1
D0
OE
3.579545MHz
HT9170
Nibble to PIC

PSU AESS LV1 Interface Plate Release System

10/15/98

Introduction

The Interface Plate Release Ignition System ("system") is responsible for releasing the interface plate in the main body of the rocket. Releasing the interface plate allows the body's drogue parachute to pull out the body's main parachute, thereby lessening the impact of the body on the ground. The system is redundant in the two most common failure areas: The altitude sensor is backed up by an onboard timer, and the altitude sensor and backup timer have separate ignition systems (igniters, firing circuits, and batteries). The system integrates both release algorithms in a single microcontroller, Microchip's PIC12C671. The microcontroller ("PIC") is run off an internal factory-calibrated oscillator, with 2 out of 6 I/O pins being used for A/D conversions and 4 out of 6 pins being used for digital I/O.

On Power-up or Reset:

Upon Reset, either from a power-up or an external Reset signal, the PIC clears the external ports, resets its internal state, and waits for 5 seconds for power supply noise and other transients to die down. Then the PIC starts a 30 second running average on the pressure sensor (a Motorola MPX5100A which is signal-conditioned and temperature compensated) which becomes the "ground level" reading necessary for altitude determination. After this initialization process, the buzzer is sounded for 1 second.

Note that the PIC can be reset through a hole in the body tube. Inserting a metal rod will short out two PCB traces which will pull the MCLR* signal of the PIC to ground, forcing a reset. This way, the PIC can be reset just before launch to get a more accurate ground level determination.

Launch Detect:

The PIC then waits for a launch detect: a 2g acceleration for at least 2 seconds, based off the A/D conversion of an Analog Device's ADXL150 accelerometer. 2g's for more than 2 seconds is extremely hard to reproduce without the help of an actual rocket motor, since most throwing, dropping, or bumping occurs in the less than 1 second regime. Upon launch detect, the backup timer is started, and the buzzer is pulsed at 0.5 Hz to indicate the system is armed. The PIC then waits for the theoretical time to apogee (based on computer simulations) to enhance the accuracy of the pressure sensor data.

Altitude Determination:

The PIC then begins sampling pressure data. If the pressure data indicates a height above the ground level of more than 2,000ft for more than 2 seconds, then the system produces a rapid 0.1 Hz pulsing on the buzzer to indicate it's now armed status. As soon as the pressure sensor detects a height of less than 2,000ft for more than 2 seconds, the altitude igniter is ignited for 5 seconds. If the back up timer igniter has not yet been fired, the PIC continues sounding the buzzer at the 0.1Hz to indicate the "armed status" of the timer igniter. Otherwise, if the timer igniter has already fired, the buzzer is turned off to indicate an "all clear" status.

Backup timer:

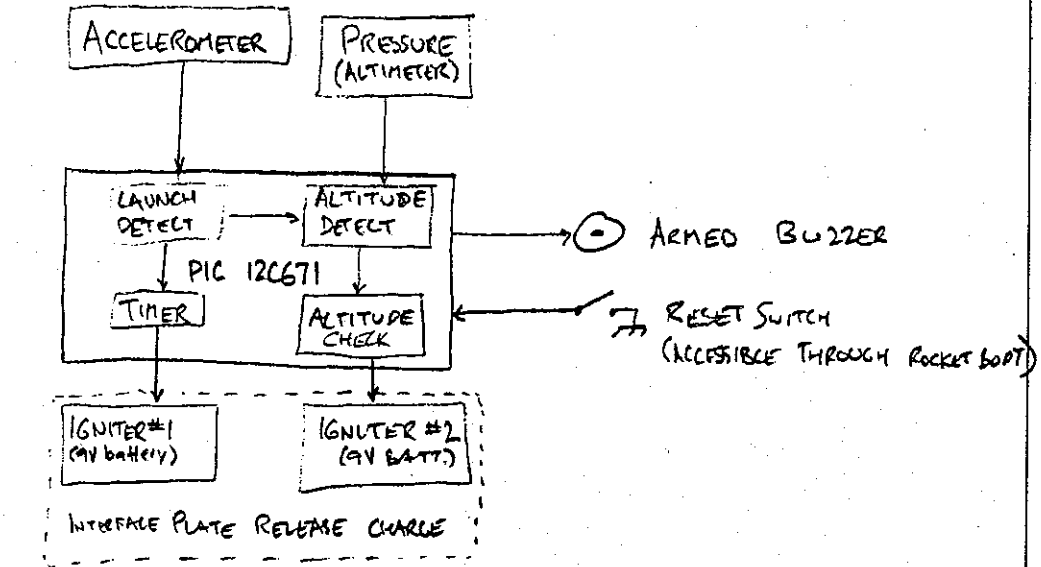
The PIC has an onboard timer which begins a countdown from the launch detect. After the theoretical burn time, coast, and float time on the body drogue (calculated by computer simulations), the backup timer will fire the timer igniter (igniter #1) for 5 seconds. If the altitude igniter has already been fired, the PIC will shut down into sleep mode, turning off the buzzer to indicate an "all clear" status. If the pressure sensor has still not fired, then the PIC will keep the buzzer going at the 0.1Hz "armed status" rate. In the case where the altitude determination never fires it's igniter, the backup timer will count to a "maximum" time value (based on maximum conditions in the computer simulations) and then put the PIC into sleep mode. The buzzer will stop, indicating an "all clear" status and the altitude igniter will never be fired.

Firing Circuitry:

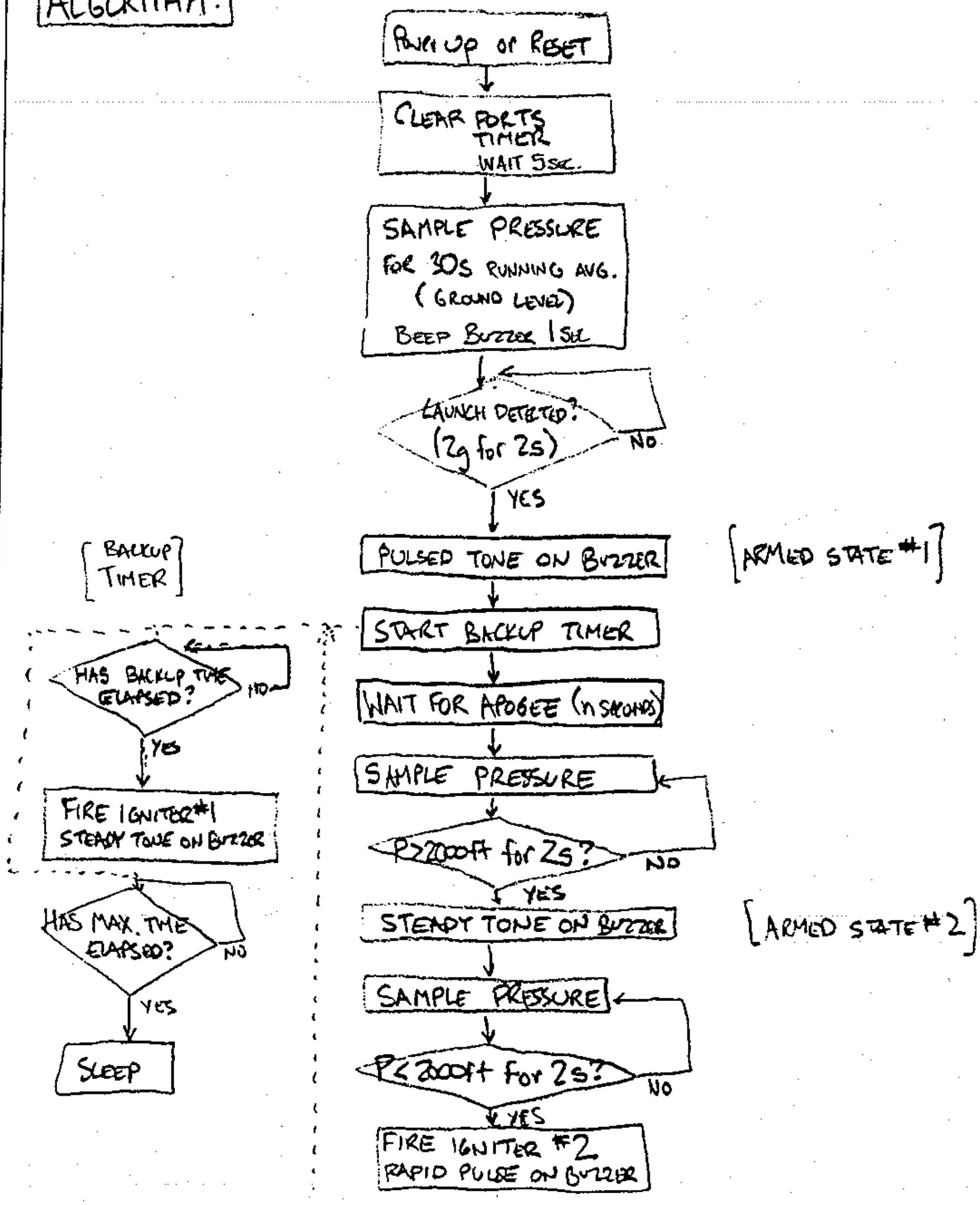
The igniters are fired by a NTE264 (TIP127) PNP-Darlington ($I_C = 10A$) bipolar transistor with bypass resistors to guarantee transistor turn off during a microcontroller reset or sleep. The PNP-Darlington will have no problem handling a high current igniter, especially given the short duty cycle (5 seconds). The PIC's outputs are rated at 25mA source per pin; due to the PNP power Darlington, only 1mA is actually necessary to fire the circuit.

Note that "European style" terminal blocks are used to connect the igniters, and that each igniter system has it's own 9V battery. This separates the microcontroller's power system from the firing circuits, eliminating the a reset generated by a voltage drop during firing.

BLOCK DIAGRAM

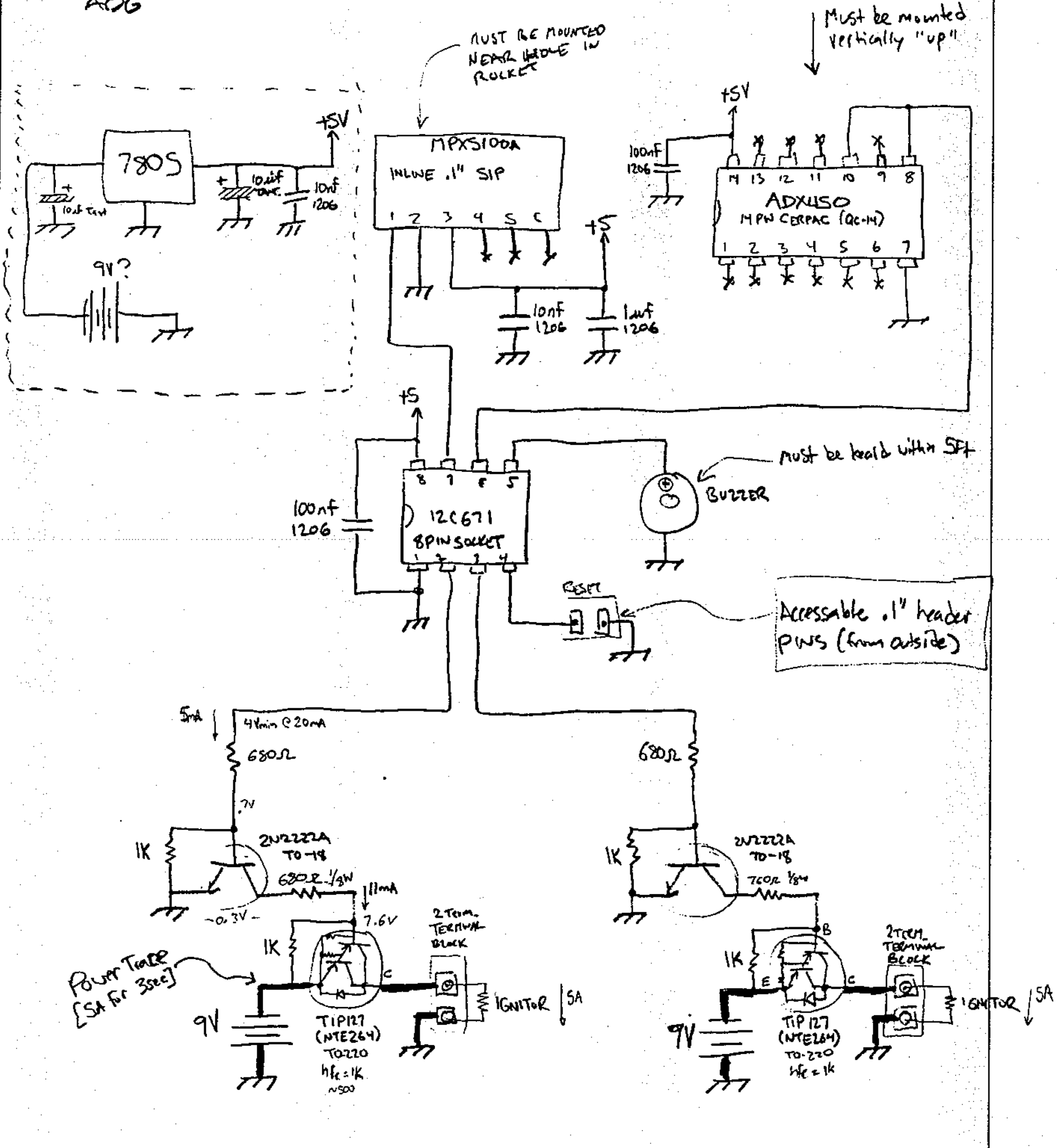


ALGORITHM:



INTERFACE PLATE SYSTEM

10/11/98
ADG



Note: • Resistors not marked with wattage are < 1/10 W
• PNP Darlingtons (NTE264) should be bent over & screwed down: Tab = Collector
So it should be potted to avoid shorts to the ignitor

Motor

Overview

Thrust curve and data

Overview

Motor selection was pretty straight forward. A Tripoli certified motor was needed for the launch. The rocket was built to accommodate a 10,000 Ns. "M" motor. A reload of that size was a little more than could be afforded, and someone locally had an M1419 for sale. Since I have my Low Explosive Users Permit I am able to consume such a motor on site.

From the Tripoli Motor Testing Committee results, the motor has an average thrust of about 246 lbs and burns progressively for about 3.5 sec, then begins to drop off (see illustration) This would give us a thrust to weight ration of 5.7 to 1.

Using some simple math and neglecting drag.

$$V^2 = V_o^2 + 2a(X-X_o)$$

and assuming the launch rail is 20 feet in length. Our exit velocity should be.

85 fps or 58 mph.

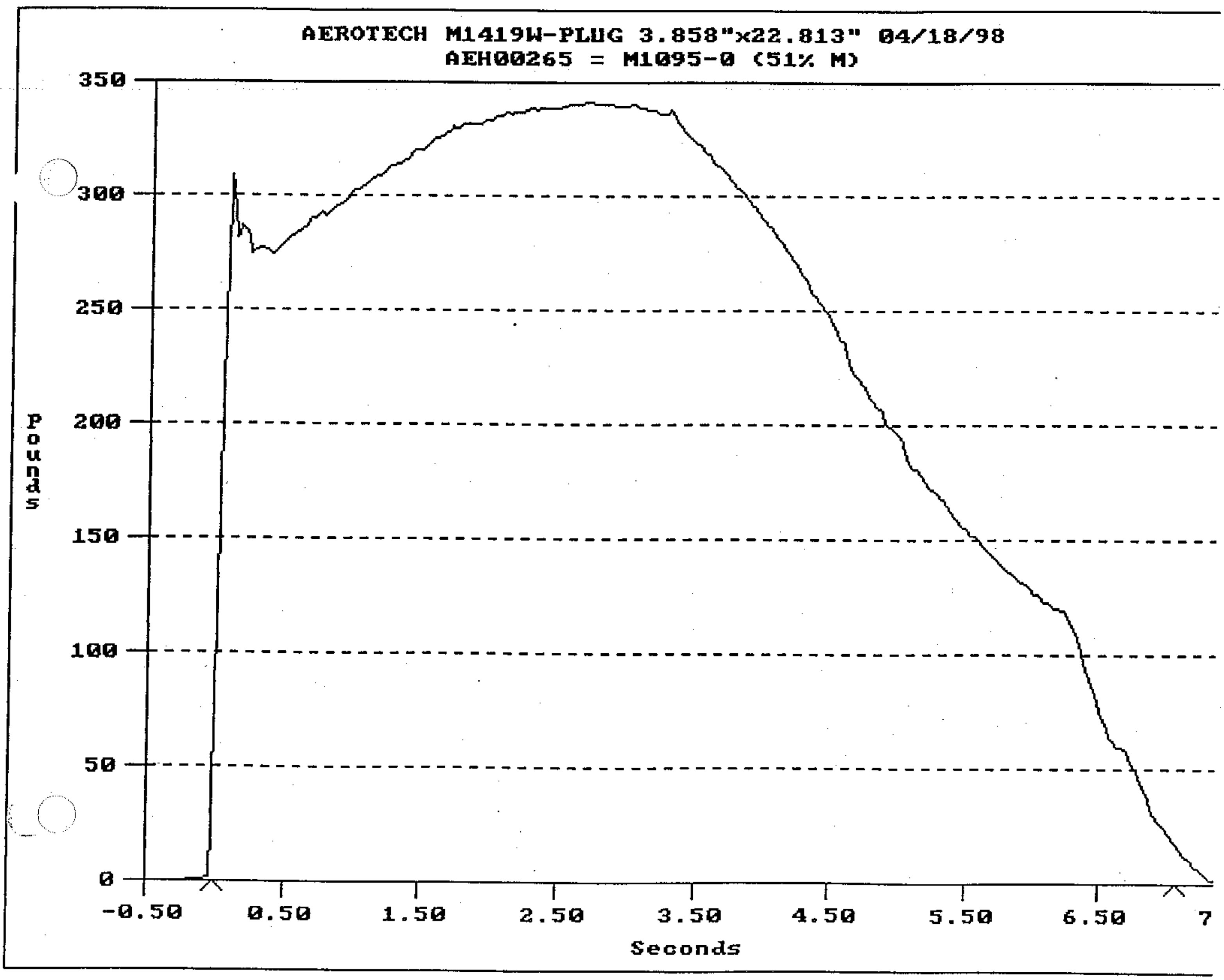
The motor will be fired using a scratch built nichrome/pyro composition ignitor.

M1419W AeroTech

Motor Manufacturer	AeroTech	Nozzle Throat dia(in)	0.734
Manuf Metric Designation	M1419W-PLUG	Exit Cone diameter(in)	1.4
TMT Metric Designation	M1095-0 (51% M)	Samples per sec	480
Testing Date	04/18/98	Burntime eval (%)	5
Certified Until	04/31/01	Calculated burntime(s)	7.07708
Motor diam(in)	3.858	Total Impul lbs-s (N-s)	1742.78 (7755.37)
Motor length(in)	22.813	Max Thrust lbs (N)	357.514 (1590.94)
Propellant Wt. lbs (g)	9.00	Ave Thrust lbs (N)	246.257 (1095.84)
Motor Wt. Lbs	15.438	Isp lbs-s/lbs	193.643

Representative TMT Thrust Curve

Back to Motor Testing Page



Launcher

Overview
Ignition system schematic
Rail system
Clamp

Overview

The launcher is based around a pneumatic manlifter. It was used at one time by the Tacoma School District to change gymnasium light bulbs. By some strange twist of fate it ended up in a military surplus yard and then as a rocket launch tower.

The tower itself is a telescoping aluminum platform that has been retrofitted to work of a 40 cu.ft. tank of CO2 to raise it instead of an air compressor.

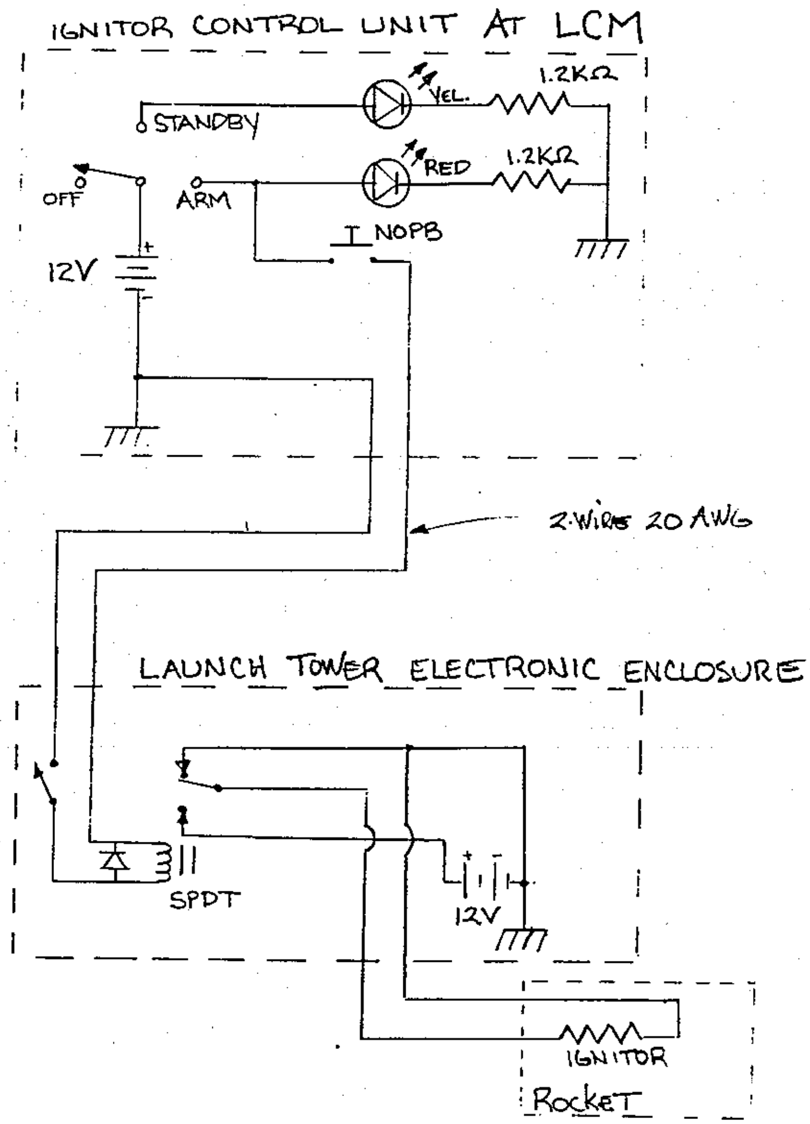
The tower can go as high as 40 feet, but we will only be using 20 feet for the upcoming launch. The tower has a base footprint of about 3.5 feet which is not much. That is why it was built to take 4 outriggers. These had to be custom made out of mild steel since the originals did not come with the tower. With the outriggers on, the tower has a footprint of 25 feet. VERY stable. It is also not adjustable for angle. We are locked in at a 0 degree angle. this makes it difficult to launch in any kind of wind.

The tower, while it is erected, is loaded with 10 foot sections of rail. 10 feet are added on the ground then the tower is raised 10 feet and so on. The rail slips into clamps on the side of the tower. These clamps come out from the tower quite a ways because of the clearance needed so that the rocket fins do not hit the 45 deg. uprights that go from the tower to the outriggers.

On this flight the lowest 10 feet will not be added until the rocket is loaded onto the rail.

When the rocket is loaded and on the pad we will use a scratch built fire control system. The system has the required safety interlocks and send a signal from the launch control module, (Portable launch center in the back of a pickup truck), down 200 feet of wire to the launch electronics box mounted at the tower. The signal kicks over a relay and dumps current through the ignitor from a 12 volt battery located at the tower. Then the rest is history.

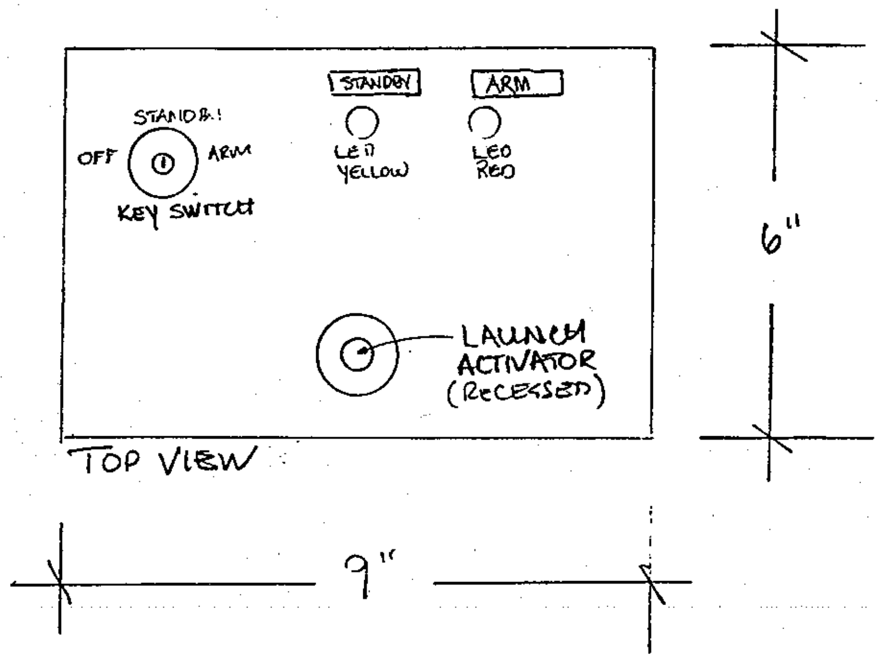
LV-1 IGNITOR SCHEMATIC

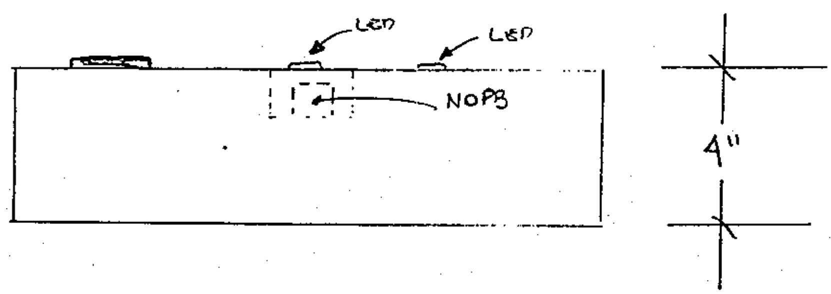


PARTS LIST

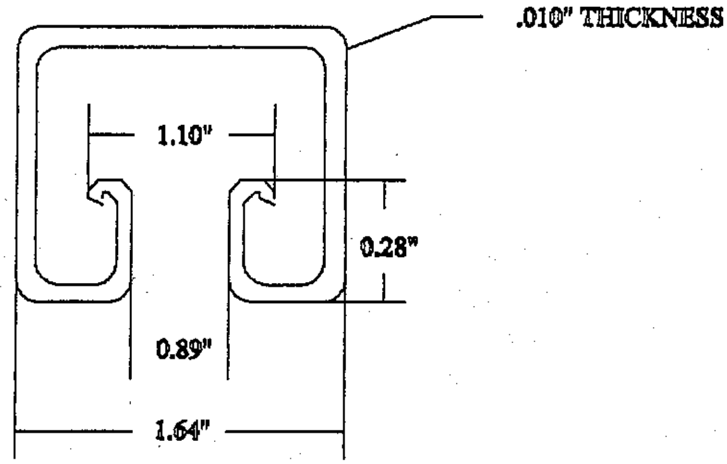
1 - LED YELLOW
1 - LED RED
1 - 12V SPDT RELAY
1 - DIODE
1 - NOPB SWITCH
1 - SPST SWITCH
1 - KEYED AUTO SWITCH (ROTARY)
2 - 12 V DC BATTERY
2 - 1.2KΩ STANDARD RESISTOR

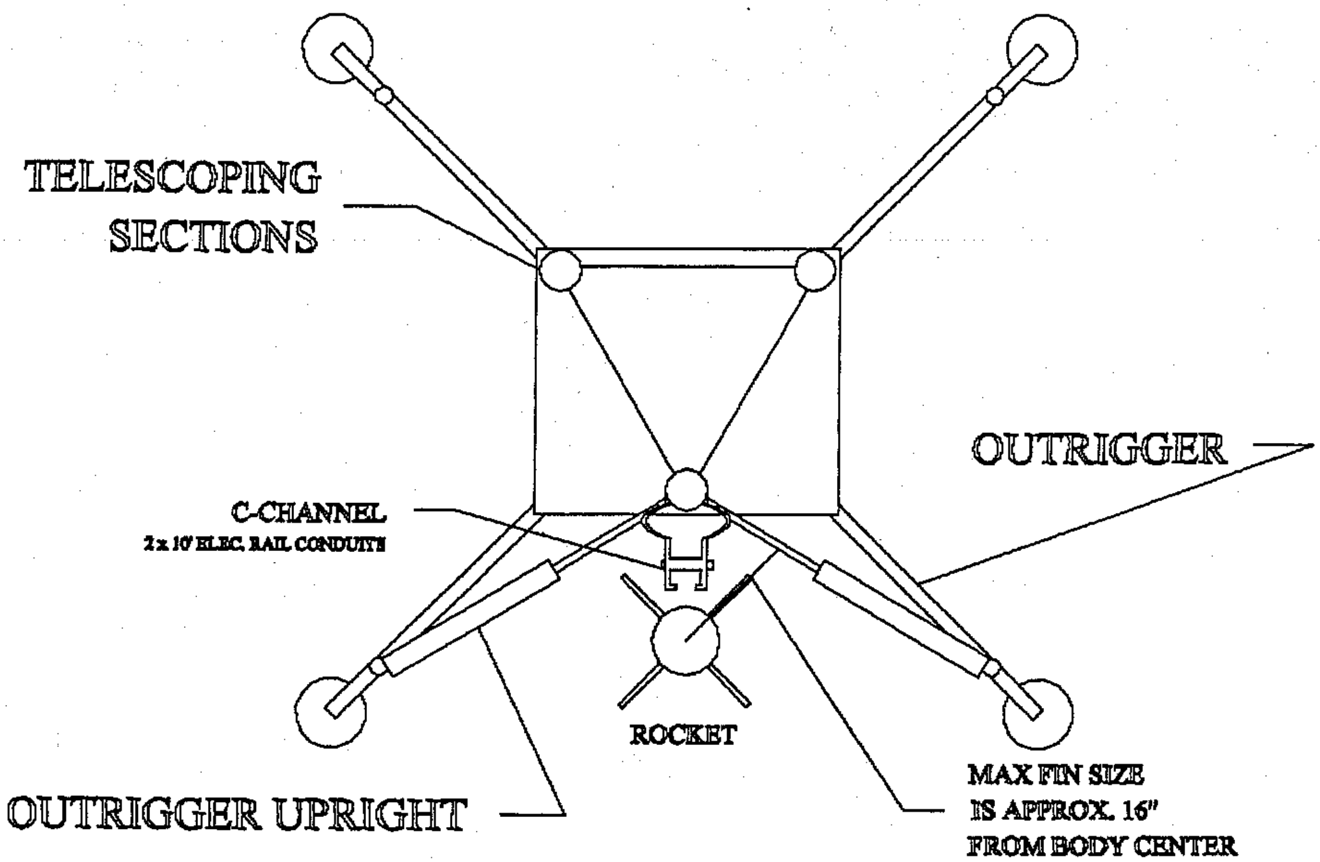
LAUNCH CONTROL UNIT





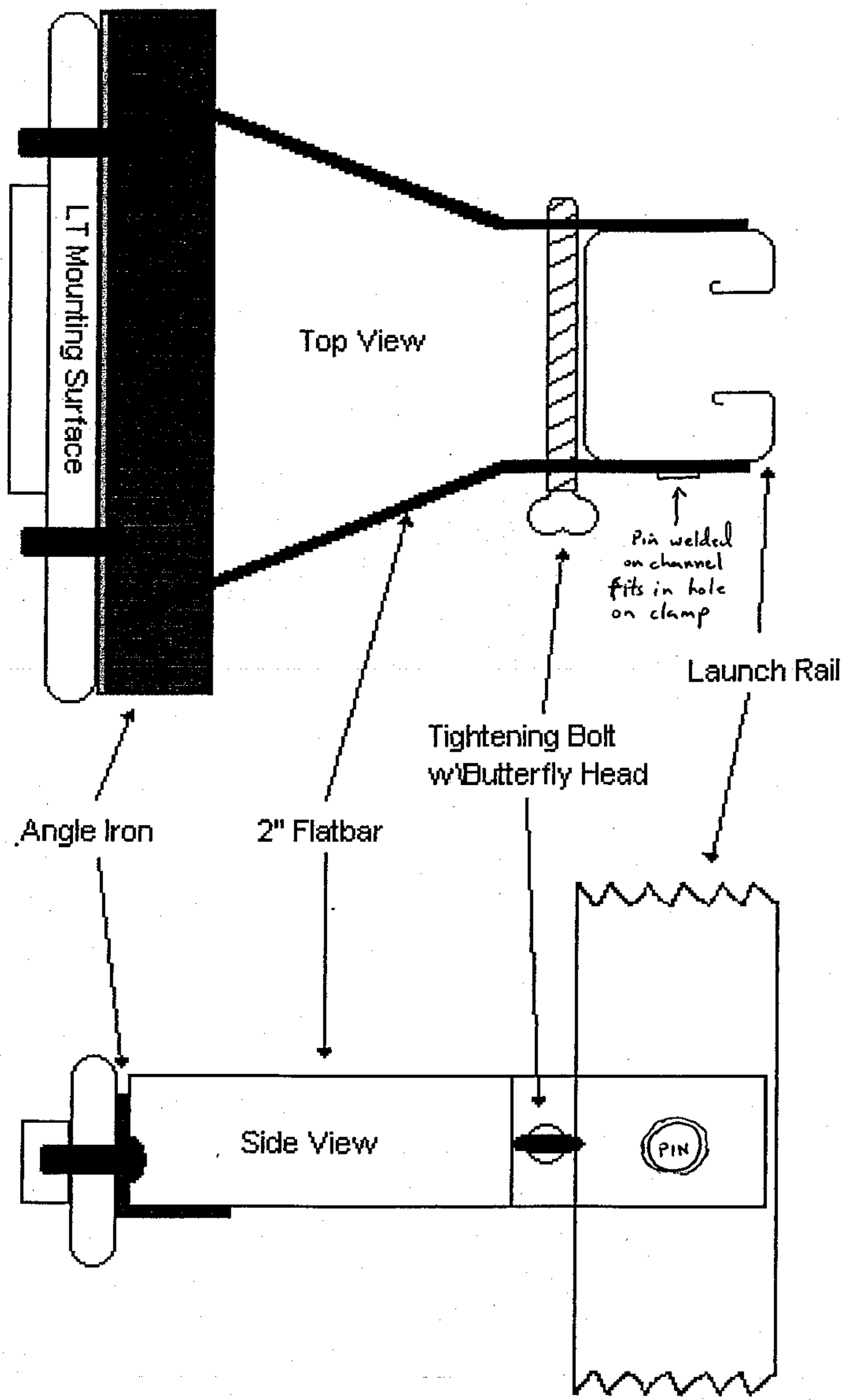
C-CHANNEL CROSS-SECTION





PLAN VIEW
LAUNCH TOWER
NOTE: DRAWINGS NOT TO SCALE

LT Launch Rail Bracket



Operations

Sequence of Setup
Pre-flight checklist

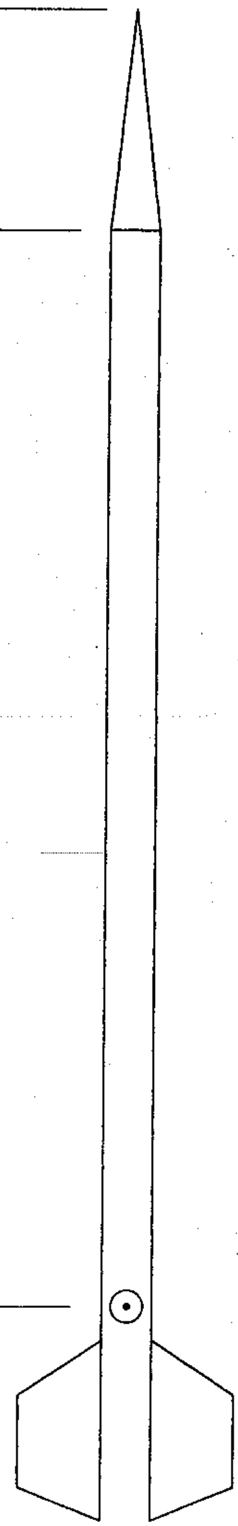
Performance

VCP1.64	CP analysis
CPcalc4.0	CP analysis
Aerolabs	CP analysis
ALT4 CD	CD analysis
Altcalc4.0	Flight simulation
Altcalc4.0	Spreadsheet
ALT4	Flight data
ALT4	Flight simulation
ALT4	Flight simulation
ALT4	Spreadsheet

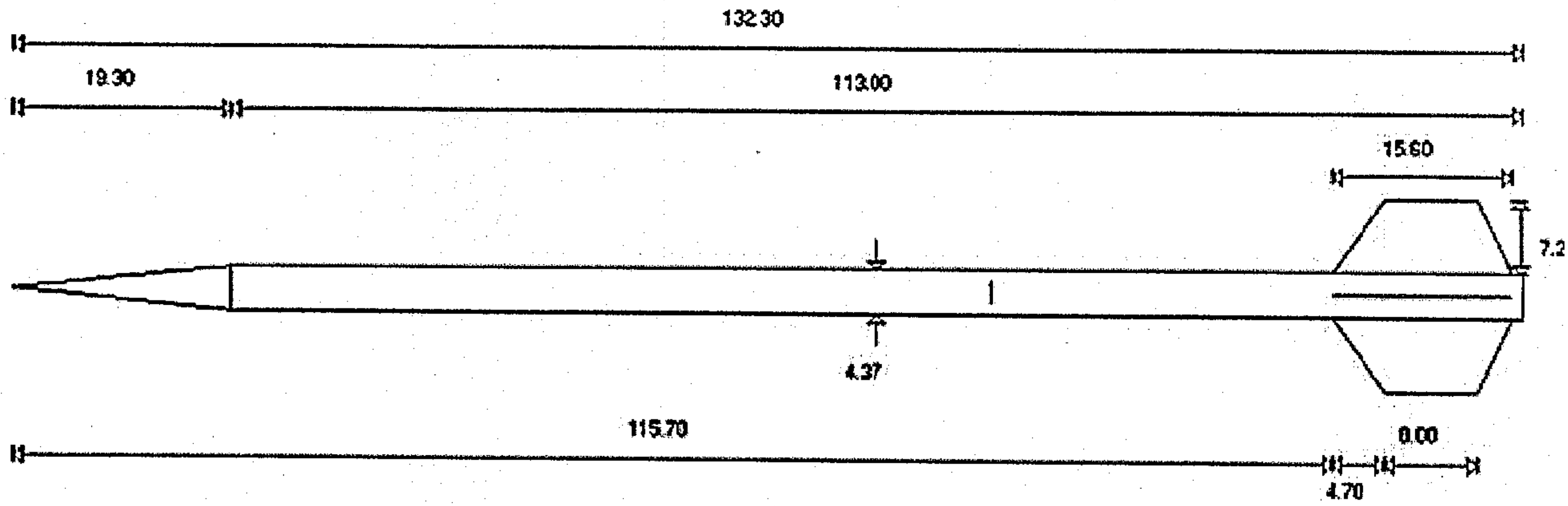
Vehicle Description: LV-1

Equation Mode: Extd Barrowman   Units: in/oz

item	station	data: (d=dia / m=margin / w=weight / f=#fins)
TIP	132.300	
NC	113.000	4.370 d
CP ST	19.560	-19.560 m
FU 1	1.000	4 f
0 Datum		

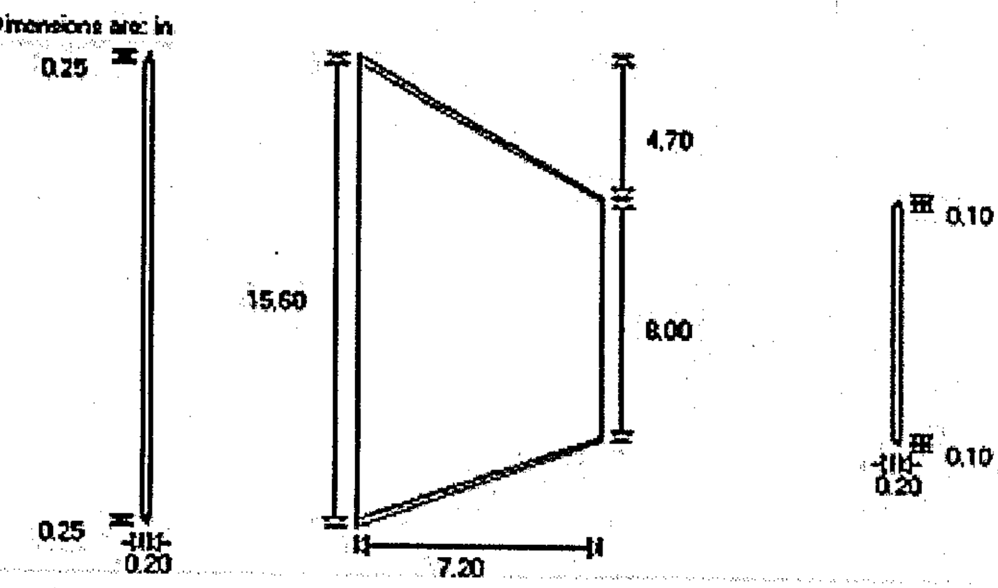


VCP1.64 Stability Analysis - VCP ©1996, Gary A. Crowell Sr.



Number of Finns: 4
Finn Aspect Ratio: 2.759
Finn Taper Ratio: 0.513
Finn Thickness Ratio: 1.89 %
Finn Leading Edge Sweep: 26.57 deg
Finn Trailing Edge Sweep: 2.86 deg
Finn midchord Sweep: 7.13 deg
Profile: Hexagonal

Barrowman Center of Pressure: 112.74001
Barrowman Cna: 26.630576



cd2

Auto

CD 4.05f

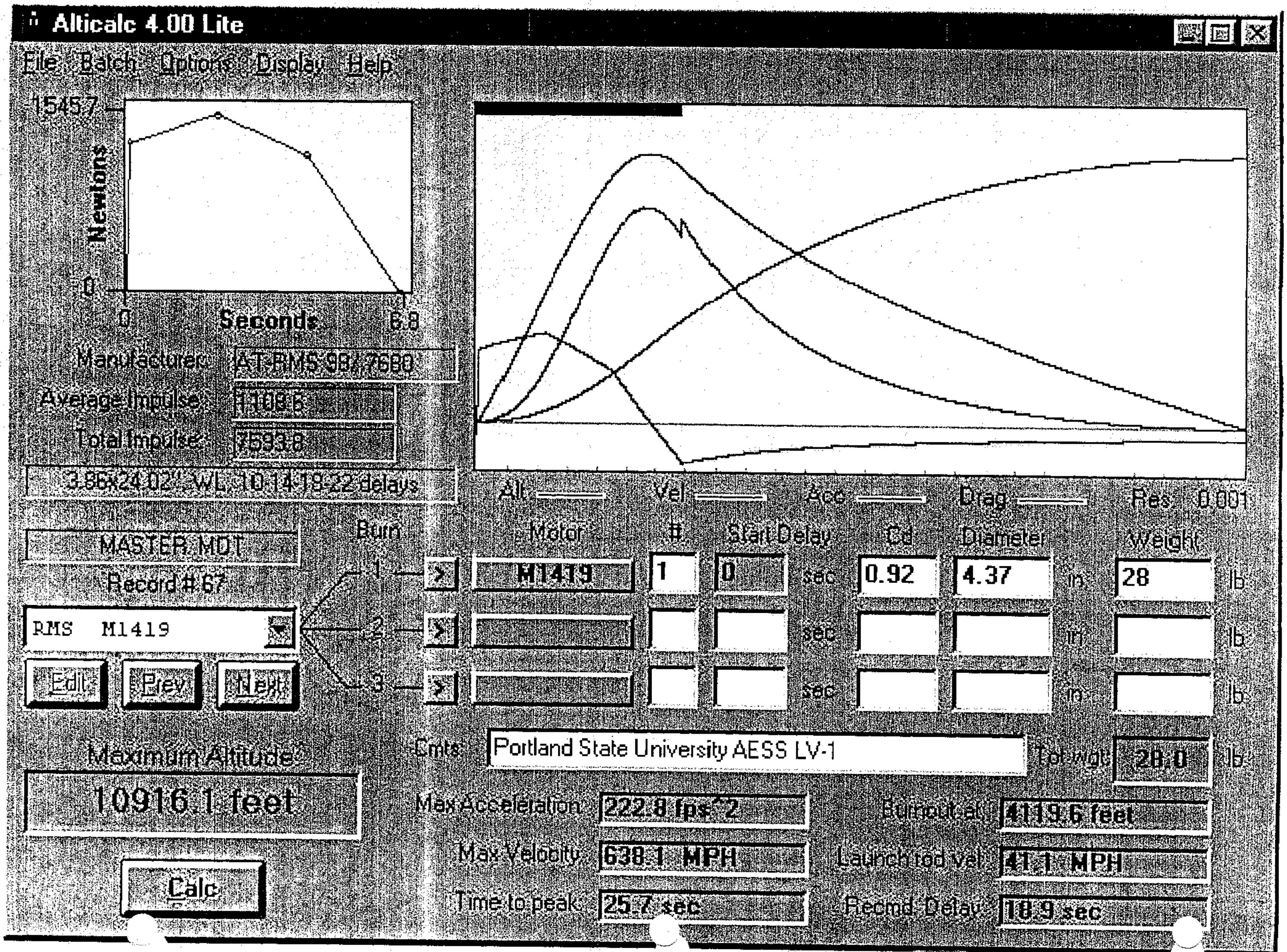
New Run   Edit Current   Printspooler   Quit   Storage

```
NAME: LV-1
DESC: PORTLAND STATE LAUNCH VEHICLE1
BODY: Maximum diameter.: 4.37       NOSECONE TYPE...........: C
      Overall length...: 132.3         Length...............: 19.3

FINS: Number of........: 4          LAUNCH LUG. outside dia.: 1.0
            Area method.: S
    Root chord.........: 15.6       BOATTAIL: Base diameter.: ______
    Tip  chord.........: 8                    length......: ______
    Dist to front of Tc: 4.7
    Fin span ..........: 7.2        NOZZLE exit diameter....: 1.4


    Exposed area.......: 84.96        Overall representative subsonic CD
    Total equiv area...: 121.5657     (Avg of CD at RN of 10^6 and 10^7)
    Leading edge sweep.: 33.13659                          .9247327

    Airfoil section ...: H
    Diamond airfoil len: .1
    Fin thickness......: .20
```



Alticalc 4.00 Lite
File Batch Options Display Help
15457
Newtons
0
0
Seconds
6.8
Manufacturer: AT-RMS 98/7680
Average Impulse: 1108.6
Total Impulse: 7593.8
3.86x24.02" WL 10-14-18-22 delays
Alt Vel Acc Drag Res: 0.001
MASTER.MOT
Record # 67
RMS M1419
Edit Prev Next
Burn
1
2
3
Motor # Start Delay Cd Diameter Weight
M1419 1 0 sec 0.92 4.37 in 28 lb
sec in lb
sec in lb
Cmts: Portland State University AESS LV-1
Tot wgt: 28.0 lb
Maximum Altitude
10916.1 feet
Calc
Max Acceleration: 222.8 fps^2
Max Velocity: 638.1 MPH
Time to peak: 25.7 sec
Burnout at: 4119.6 feet
Launch rod vel: 41.1 MPH
Recmd. Delay: 18.9 sec

Alticalc Simulations

.nicle weight **Wg** (lbs)	Drag Coefficient **Cd** (dimensionless)	Max. pos. accel. **g+** (g's)	Max. neg. accel. **g-** (g's)	Max. Velocicty **Vmax** (mph)	Time to Apogee **Ta** (seconds)	Time dtmf backup **Tdtmf** (seconds)	Max. Altitude **Ymax** (feet)
41 lbs	0.80	7.34		677.5	26.8		11976
	0.82	7.33		675.6	26.6		11857
	0.84	7.31		673.7	26.4		11741
	0.86	7.3		671.7	26.3		11627
	0.88	7.29		669.8	26.1		11514
	0.90	7.28		667.7	26		11401
	0.92	7.26		665.4	25.8		11284
	0.94	7.25		663	25.7		11168
	0.96	7.24		660.6	25.5		11055
	0.98	7.23		658.3	25.3		10945
	1.00	7.22		656	25.2		10838
42 lbs	0.80	7.16		665.7	26.8		11840
	0.82	7.14		663.3	26.6		11708
	0.84	7.13		660.9	26.4		11580
	0.86	7.12		658.5	26.3		11455
	0.88	7.11		656.2	26.1		11334
	0.90	7.1		653.9	25.9		11216
	0.92	7.09		651.6	25.8		11101
	0.94	7.08		649.3	25.6		10990
	0.96	7.06		647.1	25.5		10881
	0.98	7.05		644.9	25.3		10775
	1.00	7.04		642.7	25.2		10672
43 lbs	0.80	6.98		651.5	26.7		11623
	0.82	6.97		649.2	26.5		11497
	0.84	6.96		647	26.3		11374
	0.86	6.95		644.7	26.2		11255
	0.88	6.94		642.5	26		11139
	0.90	6.93		640.3	25.9		11026
	0.92	6.92		638.1	25.7		10916
	0.94	6.91		636	25.5		10809
	0.96	6.9		633.9	25.4		10705
	0.98	6.89		631.8	25.3		10603
	1.00	6.88		629.7	25.1		10504
44 lbs	0.80	6.82		637.7	26.8		11405
	0.82	6.81		635.5	26.4		11284
	0.84	6.8		633.4	26.2		11167
	0.86	6.79		631.1	26.1		11053
	0.88	6.78		629.2	25.9		10942
	0.90	6.77		627.1	25.8		10834
	0.92	6.76		625.1	25.6		10729
	0.94	6.75		623	25.5		10626
	0.96	6.74		621	25.3		10526
	0.98	6.73		619.1	25.2		10428
	1.00	6.72		617.1	25.1		10332
45 lbs	0.80	6.66		624.3	26.5		11186
	0.82	6.65		622.2	26.3		11071
	0.84	6.64		620.2	26.1		10959
	0.86	6.63		618.2	26		10850
	0.88	6.62		616.2	25.8		10743
	0.90	6.61		614.3	25.7		10640
	0.92	6.6		612.3	25.5		10539
	0.94	6.59		610.4	25.4		10441
	0.96	6.58		608.5	25.3		10345
	0.98	6.57		606.6	25.1		10251
	1.00	6.56		604.8	25		10159

alt4

Auto

```
   Rocket Name: AESSLV1
       Remarks: Portland State Launch Vehicle1        #    Motor
                                                     1    M1419-RM
  Max Diameter: 4.37
Overall Length: 132.3
 Len/Dia ratio: 30.27

   Drag method: F CD File: LV-1
   Launch Lug?: N Rcht  CD:(.604)        Launch wgt: 43
      Average Subsonic CD: .92                  Max: ________
                                               Incr: ______
 Launch site conditions
 Elevation(ft): 2500       Ground launch ? (Y/N)  : Y
 Air press(Hg): _______       air start altitude  : _______
 Air temp. (F): 65            air start velocity  : ________

 Enter number of this type of motor
       ESC = MENU
```

alt4

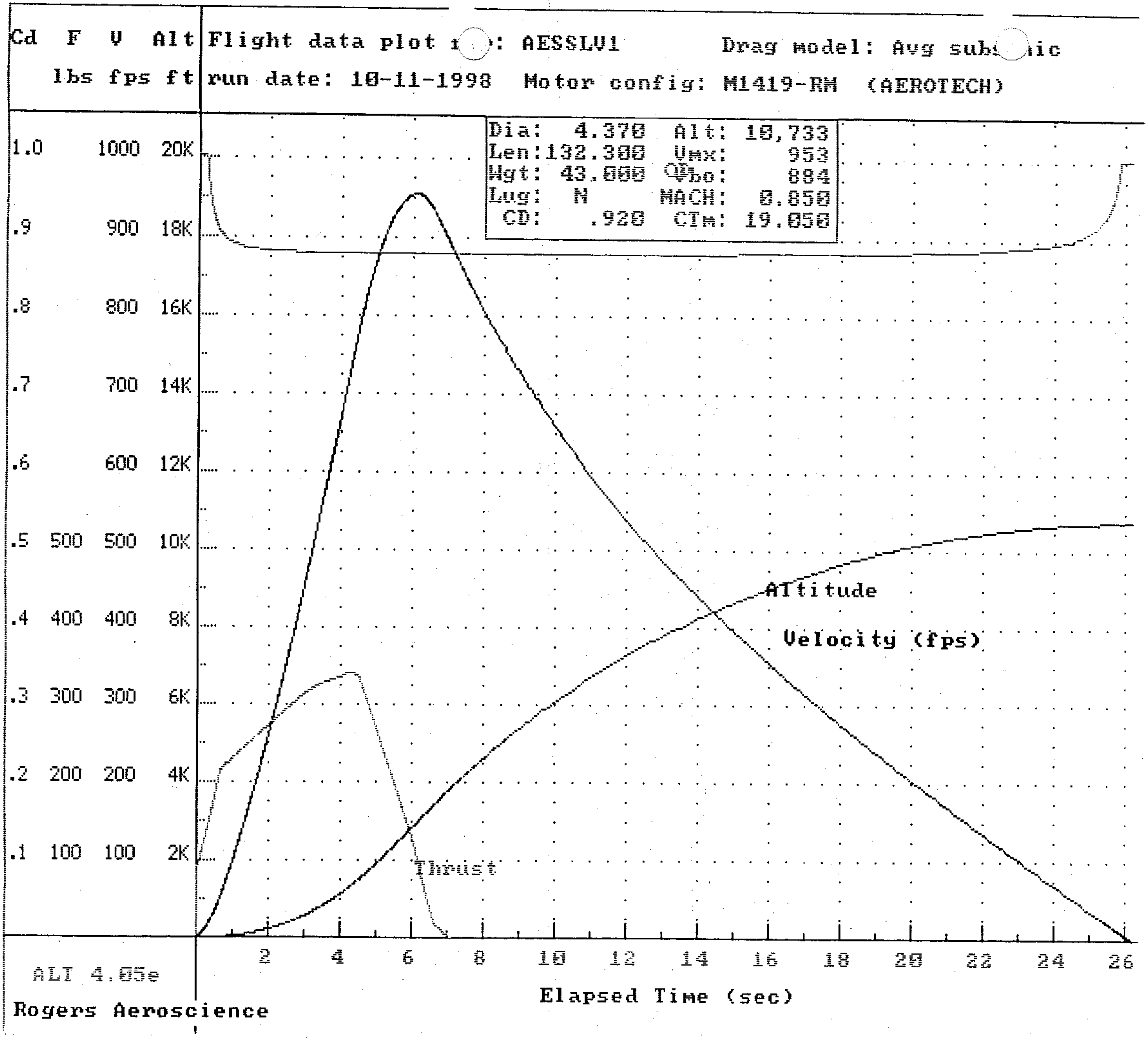
Auto

ALT 4.05e by ROGERS AEROSCIENCE Flight report for: AESSLV1

TIME (sec)	Thrust (lbs)	Drag Coeff.	Accel. (ft/sec2)	Velocity (ft/sec)	Speed of Sound	Mach No.	Velocity (mph)	Altitude (feet)
26.14	0.00	99.999	-32.141	-0.138	1080.727	-.000	-0.1	10733.036

```
Lift-off weight ..        43.00 lbs
Max altitude .....    10,733.04 ft.        2.03 miles
max mach number ..         0.86
max velocity .....       952.72 ft/sec. at    6.07 sec. (  649.58 mph)
  x acceleration .         6.92 G's     at    4.26 sec.
max deceleration .        -3.00 G's     at    7.10 sec.
     burnout alt .     3,857.80 ft      at    7.09 sec. (calc step: 0.01 sec.)
burnout velocity .       883.69 ft/sec (local Mach  0.798) ( 602.52 mph)
      coast time .        19.05 seconds
```

Return = data browser;   Q = quit:



Cd F V Alt
lbs fps ft
Flight data plot : AESSLV1
Drag model: Avg subsonic
run date: 10-11-1998
Motor config: M1419-RM (AEROTECH)
Dia: 4.370
Len: 132.300
Wgt: 43.000
Lug: N
CD: .920
Alt: 10,733
Vmx: 953
Vbo: 884
MACH: 0.850
CTm: 19.050
1.0 1000 20K
.9 900 18K
.8 800 16K
.7 700 14K
.6 600 12K
.5 500 500 10K
.4 400 400 8K
.3 300 300 6K
.2 200 200 4K
.1 100 100 2K
Altitude
Velocity (fps)
Thrust
2 4 6 8 10 12 14 16 18 20 22 24 26
Elapsed Time (sec)
ALT 4.05e
Rogers Aeroscience

Alt 4 Simulations

Vehicle weight Wg (lbs)	Drag Coefficient Cd (dimensionless)	Max. pos. accel. g+ (g's)	Max. neg. accel. g- (g's)	Max. Velocicty Vmax (mph)	Time to Apogee Ta (seconds)	Time dtmf backup Tdtmf (seconds)	Max. Altitude Ymax (feet)
41 lbs	0.80	7.41	-3.10	693.10	27.30		11,868
	0.82	7.38	-3.13	690.90	27.13		11,738
	0.84	7.34	-3.17	688.70	26.95		11,612
	0.86	7.31	-3.20	686.50	26.78		11,489
	0.88	7.28	-3.23	684.30	26.61		11,367
	0.90	7.25	-3.26	682.00	26.45		11,247
	0.92	7.22	-3.29	679.70	26.28		11,127
	0.94	7.19	-3.31	677.30	26.12		11,010
	0.96	7.16	-3.34	675.00	25.96		10,897
	0.98	7.13	-3.37	672.80	25.81		10,786
	1.00	7.10	-3.39	670.50	25.66		10,679
42 lbs	0.80	7.24	-2.97	678.00	27.24		11,669
	0.82	7.21	-3.00	675.70	27.06		11,537
	0.84	7.19	-3.03	673.40	26.88		11,409
	0.86	7.16	-3.06	671.10	26.71		11,285
	0.88	7.13	-3.09	668.90	26.54		11,164
	0.90	7.10	-3.11	666.60	26.38		11,046
	0.92	7.07	-3.14	664.40	26.22		10,932
	0.94	7.04	-3.17	662.20	26.06		10,820
	0.96	7.02	-3.19	660.10	25.91		10,711
	0.98	6.99	-3.22	657.90	25.76		10,606
	1.00	6.96	-3.24	655.80	25.61		10,502
43 lbs	0.80	7.08	-2.84	662.30	27.13		11,436
	0.82	7.06	-2.87	660.20	26.96		11,311
	0.84	7.03	-2.90	658.00	26.78		11,189
	0.86	7.00	-2.92	655.90	26.62		11,070
	0.88	6.98	-2.95	653.80	26.46		10,955
	0.90	6.95	-2.98	651.70	26.30		10,842
	0.92	6.92	-3.00	649.80	26.14		10,733
	0.94	6.90	-3.03	647.50	25.99		10,626
	0.96	6.87	-3.05	645.50	25.84		10,522
	0.98	6.85	-3.08	643.50	25.69		10,421
	1.00	6.82	-3.10	641.50	25.55		10,322
44 lbs	0.80	6.93	-2.72	647.20	27.01		11,201
	0.82	6.90	-2.75	645.10	26.84		11,082
	0.84	6.88	-2.77	643.10	26.67		10,966
	0.86	6.85	-2.80	641.10	26.51		10,853
	0.88	6.83	-2.83	639.10	26.36		10,743
	0.90	6.81	-2.85	637.10	26.20		10,636
	0.92	6.78	-2.88	635.20	26.05		10,532
	0.94	6.76	-2.90	633.20	25.90		10,430
	0.96	6.73	-2.92	631.30	25.76		10,330
	0.98	6.71	-2.95	629.40	25.62		10,234
	1.00	6.68	-2.97	627.60	25.48		10,139
45 lbs	0.80	6.78	-2.61	632.40	26.88		10,965
	0.82	6.76	-2.63	630.50	26.71		10,852
	0.84	6.73	-2.66	628.60	26.55		10,742
	0.86	6.71	-2.68	626.70	26.40		10,634
	0.88	6.69	-2.71	624.90	26.25		10,530
	0.90	6.66	-2.73	623.00	26.10		10,428
	0.92	6.64	-2.76	621.20	25.95		10,328
	0.94	6.62	-2.78	619.40	25.81		10,231
	0.96	6.60	-2.80	617.60	25.67		10,136
	0.98	6.57	-2.83	615.80	25.53		10,044
	1.00	6.55	-2.85	614.00	25.40		9,953