MARS ASCENT VEHICLE
CENTENNIAL CHALLENGE

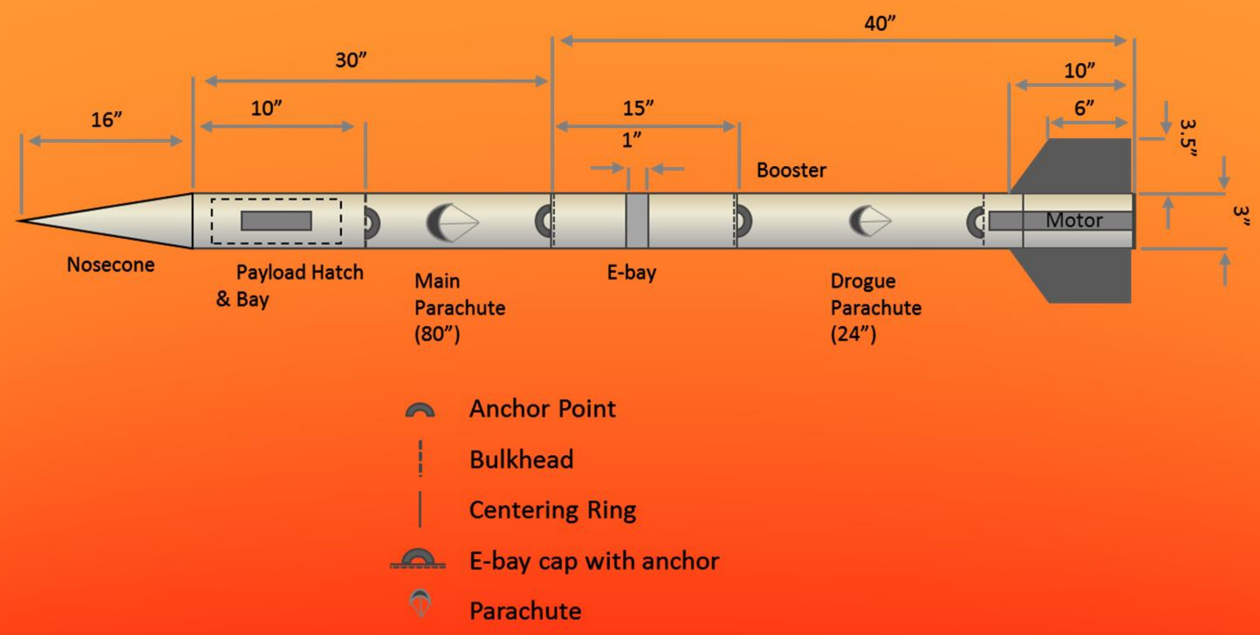
DESIGN, DEVELOPMENT, AND LAUNCH OF A REUSABLE ROCKET AND AUTONOMOUS GROUND SUPPORT EQUIPMENT

PAYLOAD OPTION 3.1.8 – CENTENNIAL CHALLENGE
NON-ACADEMIC TEAM

PRELIMINARY DESIGN REVIEW

http://martians.westrocketry.com/index.php

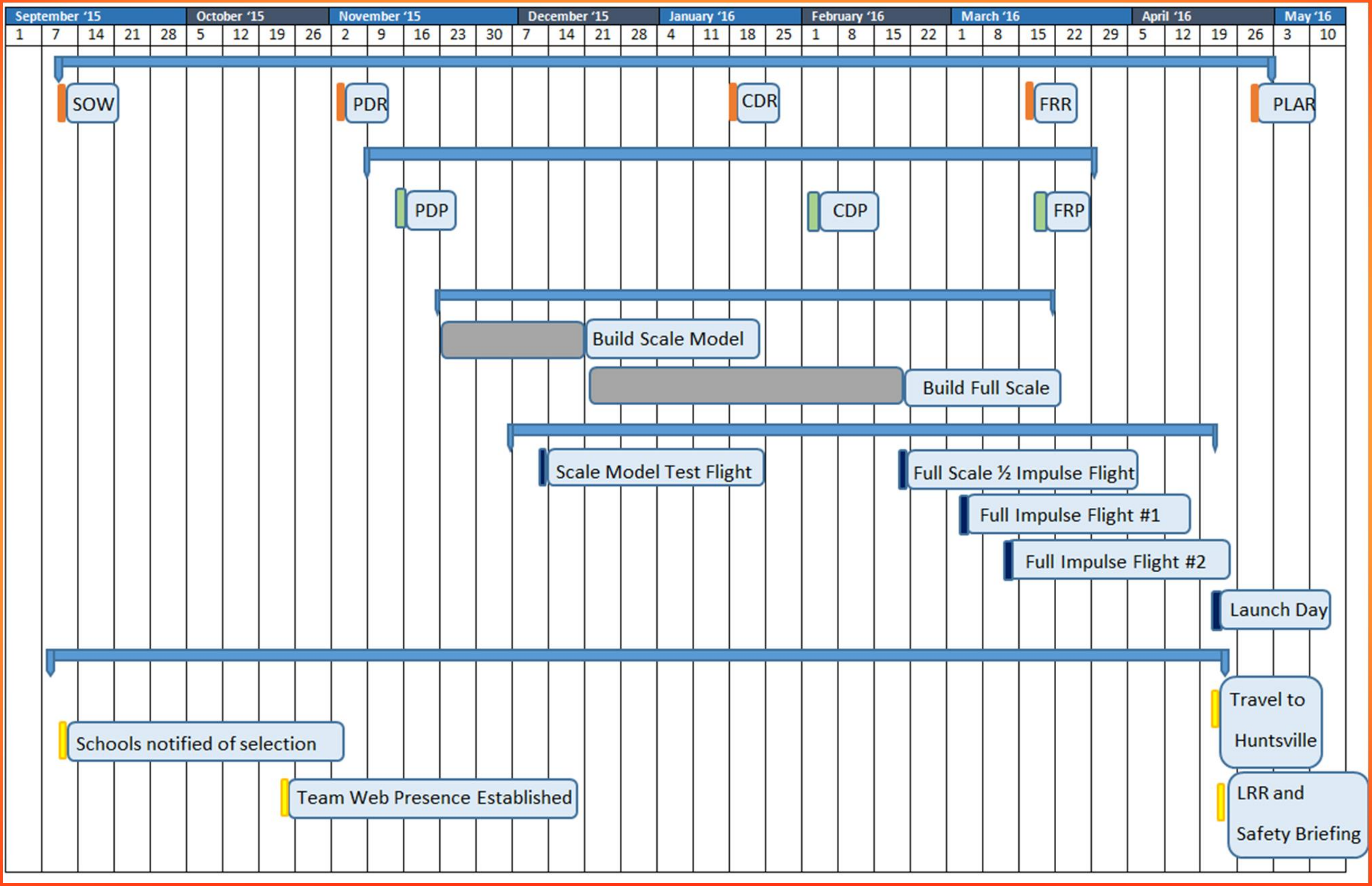
PART 1: VEHICLE



MAJOR MILESTONE SCHEDULE

Date	Milestone
Nov 21-Dec 11	Scale Model Building
Dec 12	Scale Model Flight
Jan 15	Critical Design Review due
Jan 19-29	Critical Design Presentations
Jan 19-Feb 19	Full Scale Building
Feb 20	Full Scale Half Impulse Flight
Feb 27	Full Scale Full Impulse Flight #1
Mar 5	Full Scale Full Impulse Flight #2
Mar 14	FRR due
Mar 17-30	FRP’s
Apr 16	Launch Day in Huntsville
Apr 29	PLAR due

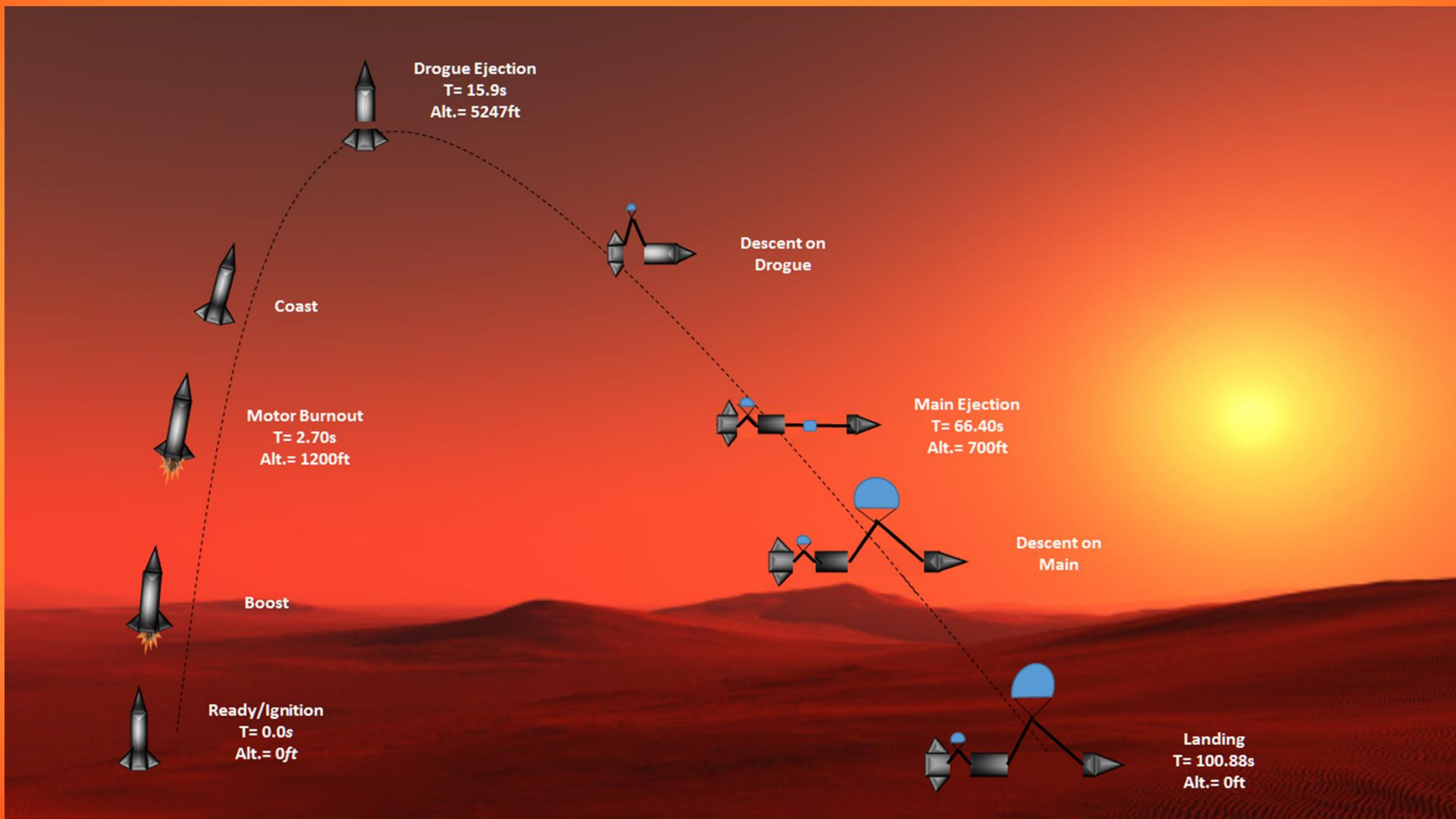
GANTT CHART


September '15
October '15
November '15
December '15
January '16
February '16
March '16
April '16
May '16
1 7 14 21 28 5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 1 8 15 22 1 8 15 22 29 5 12 19 26 3 10
SOW
PDR
CDR
FRR
PLAR
PDP
CDP
FRP
Build Scale Model
Build Full Scale
Scale Model Test Flight
Full Scale ½ Impulse Flight
Full Impulse Flight #1
Full Impulse Flight #2
Launch Day
Travel to Huntsville
Schools notified of selection
Team Web Presence Established
LRR and Safety Briefing

VEHICLE DEVELOPMENT PHASES

Activity	Dates	Time allocated	Time Required
Scale model parts acquisition	11/7-11/21	2 weeks	1 week
Scale model construction	11/21-12/10	3 weeks	2 weeks
Scale model ground tests, verification	12/10, 12/11	2 days	1 day
Scale model test flights (minimum 1 needed)	12/12,12/19, 1/9	3 launch windows	1 windows
Full scale vehicle parts acquisition	1/9-1/23	2 weeks	1 week
Full scale vehicle construction	1/24-2/13	3 weeks	2 weeks
Full scale ground tests, verification	2/14-2/19	1 week	1 day
Full scale test flights (minimum 2 needed)	2/20, 2/27, 3/5	3 launch windows	2 windows
Full scale vehicle final preparations for SL launch in AL	3/6-4/9	5 weeks	1-2 weeks

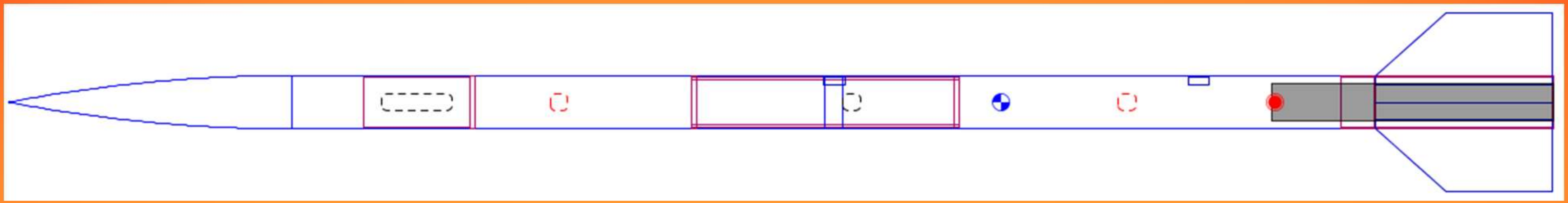
MISSION PROFILE CHART



VEHICLE MISSION CRITERIA

- Motor ignition
- Stable flight
- Altitude of 5,280 feet AGL reached <u>but not exceeded</u>
- Both drogue and main parachute deployed
- Entire vehicle returns to the ground safely with no damage (reflyable on the same day)
- Successful recovery of the rocket

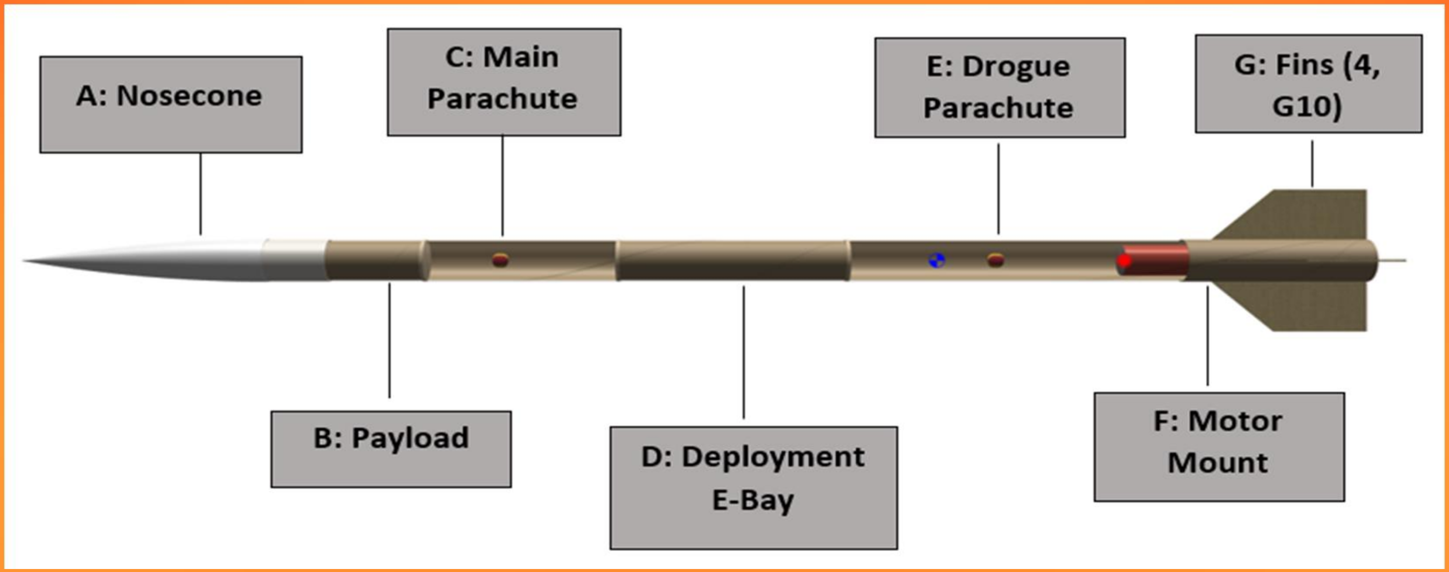
VEHICLE DESIGN



Length	**87”**
Diameter	**3”**
Liftoff Weight	**13.4*lb***
CP	**71” from nosecone**
CG	**59” from nosecone**
Static margin	**4.02 calibers**
Motor	**CTI K530SS (primary choice)**

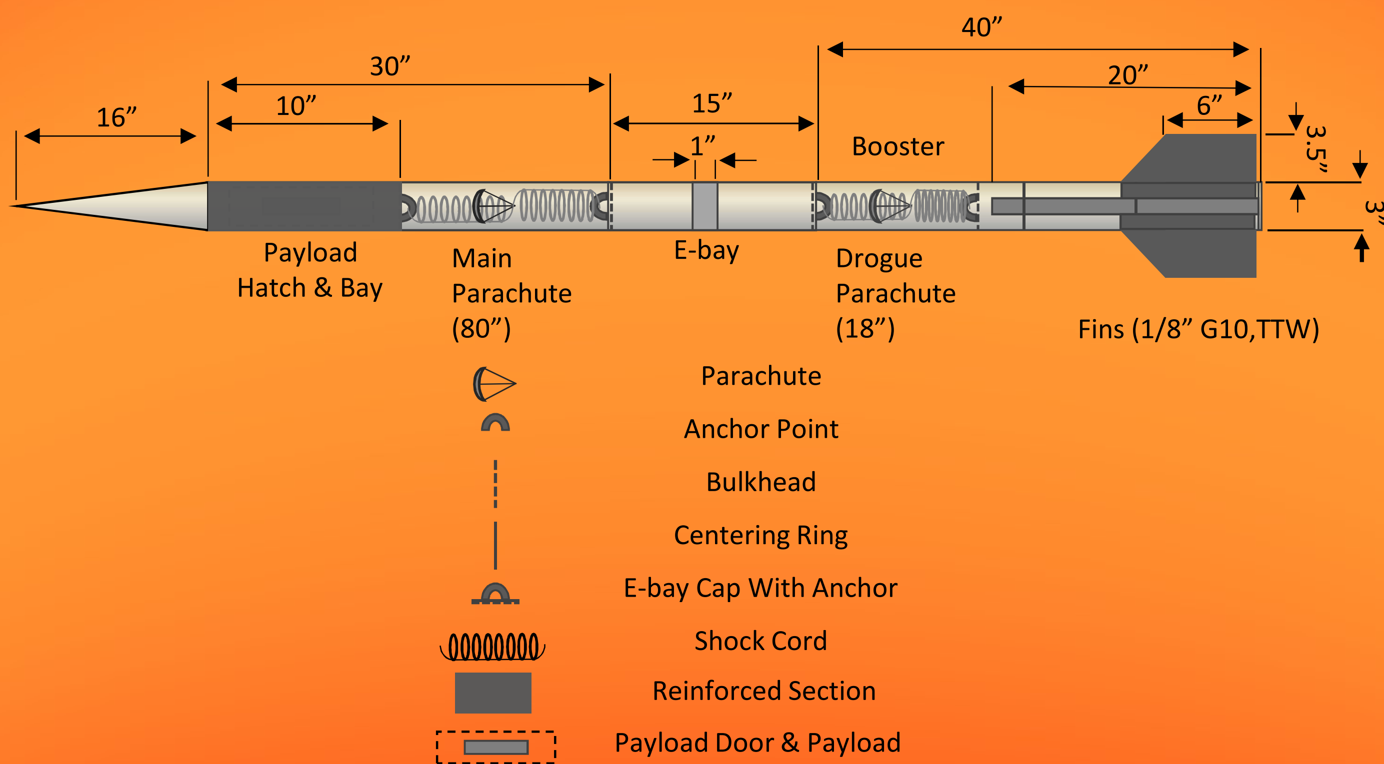
Motor	Diameter *[mm]*	Total Impulse *[Ns]*	Burn Time *[s]*	Stability Margin *[calibers]*	Thrust to weight ratio
CTI K530SS	54	1414	2.7	4.02	10.0
AT K535	54	1429	2.8	4.03	11.7

VEHICLE PARTS



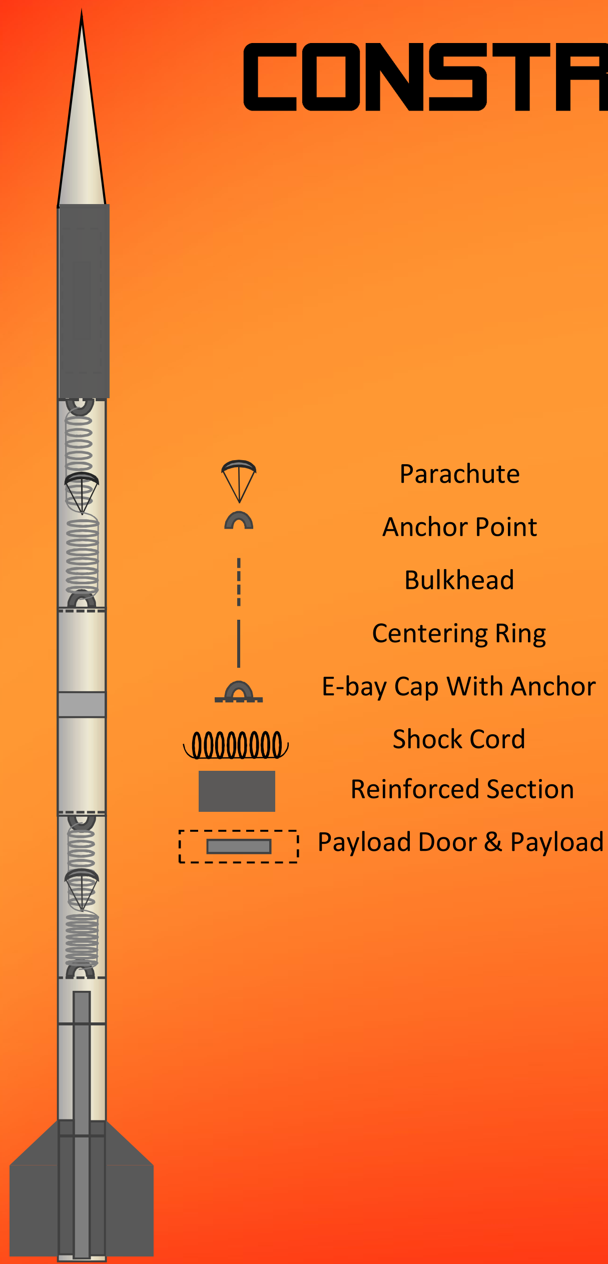
Letter	Part
A	Nosecone
B	Payload(section reinforced by coupler)
C	Main Parachute
D	Deployment E-Bay
E	Drogue Parachute
F	Motor Mount (75mm)
G	Fins (4, G10)

DIMENSIONED DRAWING OF VEHICLE



Nose Cone: Fiberglass 3/32”
Payload Body Tube: Fiberglass 1/8”
Booster Body tube: Fiberglass 1/8”
Coupler Tubes: Fiberglass 1/8”
Payload Door: Fiberglass 1/8”
Bulkheads: Fiberglass 1/8”
Attachment Points: U-Bolts 1/4”
Fins: Fiberglass 1/8”, TTW
Centering Rings: Fiberglass 1/8”
Payload: PVC pipe schedule 40

CONSTRUCTION MATERIALS



- **Nosecone:** fiberglass nose cone
- **Body:** 3” fiberglass (1/8”) tubing
- **Bulkheads, centering rings:** fiberglass
- **Motor mount:** 54*mm* Kraft Phenolic
- **Rail buttons:** standard Nylon rail buttons
- **Shockcords:** ½” tubular Kevlar
- **Fins:** 1/8” G10 fiberglass, TTW fins
- **Payload:** PVC tube with dome caps, schedule 40
- **Payload door:** cutout from 1/8” fiberglass tube
- **Payload section reinforcement:** 1/8” fiberglass coupler
- **Motor retention system**: Aeropack screw-on motor retainer
- **Anchors:** 1/4" stainless steel U-Bolts
- **Epoxy:** West or Loctite epoxy

MOTOR SELECTION

- We selected the CTI K530SS 54mm motor to propel our rocket to out target altitude (5247ft).
- The CTI K530SS motor provides an appropriate thrust to weight ratio for our vehicle (10).

Length *[mm]*	**Mass** *[lbs]*	**Diameter** *[mm]*	**Motor Selection**	**Stability Margin** *[calibers]*	**Thrust to weight ratio**
404	3.62	54	CTI K530SS	4.02	10

FLIGHT SAFETY PARAMETERS MATURITY OF DESIGN

Parameter	Value
Flight Stability Static Margin	**4.02 *calibers***
Thrust to Weight Ratio	**10**
Velocity at Launch Guide Departure (5ft launch rail)	**41.2 *mph***

MASS STATEMENT

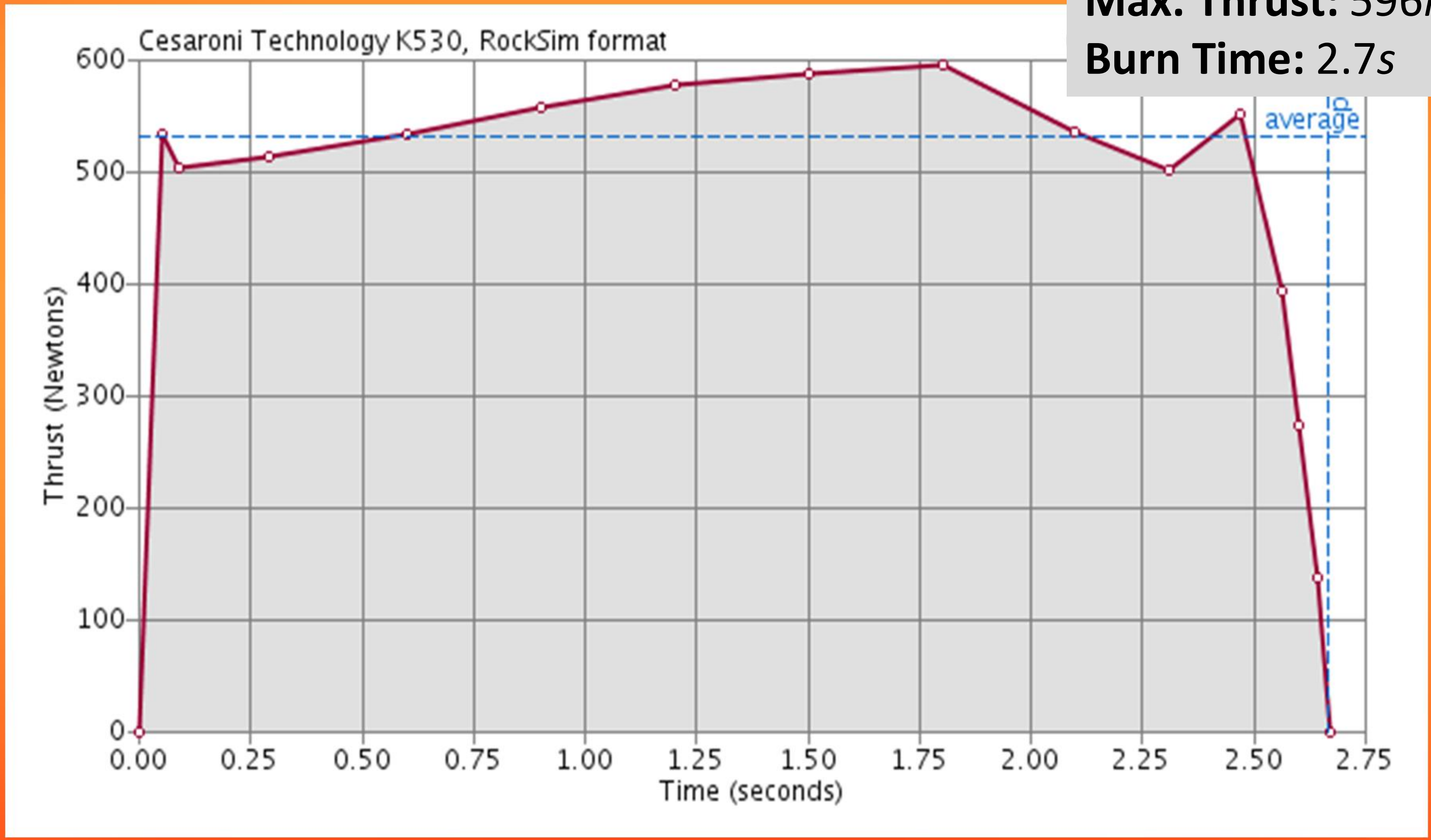
- **Current Status**
  - Our rocket currently has a mass of 13.4*lb*, which includes a 3.62*lb* CTI K530-SS motor.
  - This estimate of the mass comes from the OpenRocket database where our rocket is being designed.

- **Design Changes Impact**
  - If the rocket gains 5*lb* of weight it will only reach an altitude of 4,361*ft* which we consider *unacceptable performance*.
  - The rocket would have to weigh 26.8*lb* for the thrust to weight ratio to drop under 5 (underpowered rocket).

THRUST CURVE

Max. Thrust: 596*N*
Burn Time: 2.7*s*

Thrust [*Ns*]



Time [*s*]

ALTITUDE PROFILE

Apogee: 5247ft, 16s

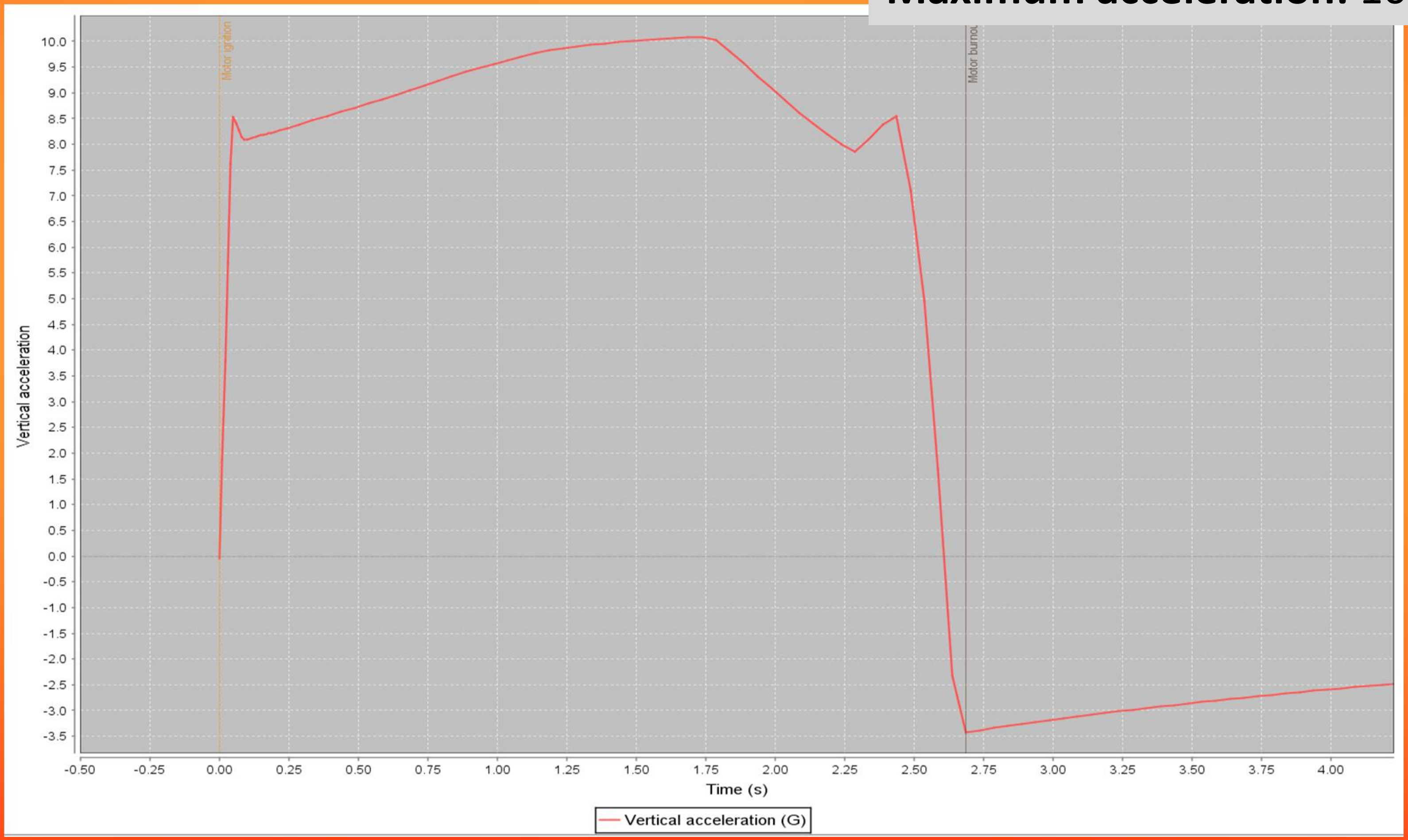
Altitude [ft]

Time [s]

ACCELERATION PROFILE

Maximum acceleration: $10G$

Acceleration $[m/s^2]$

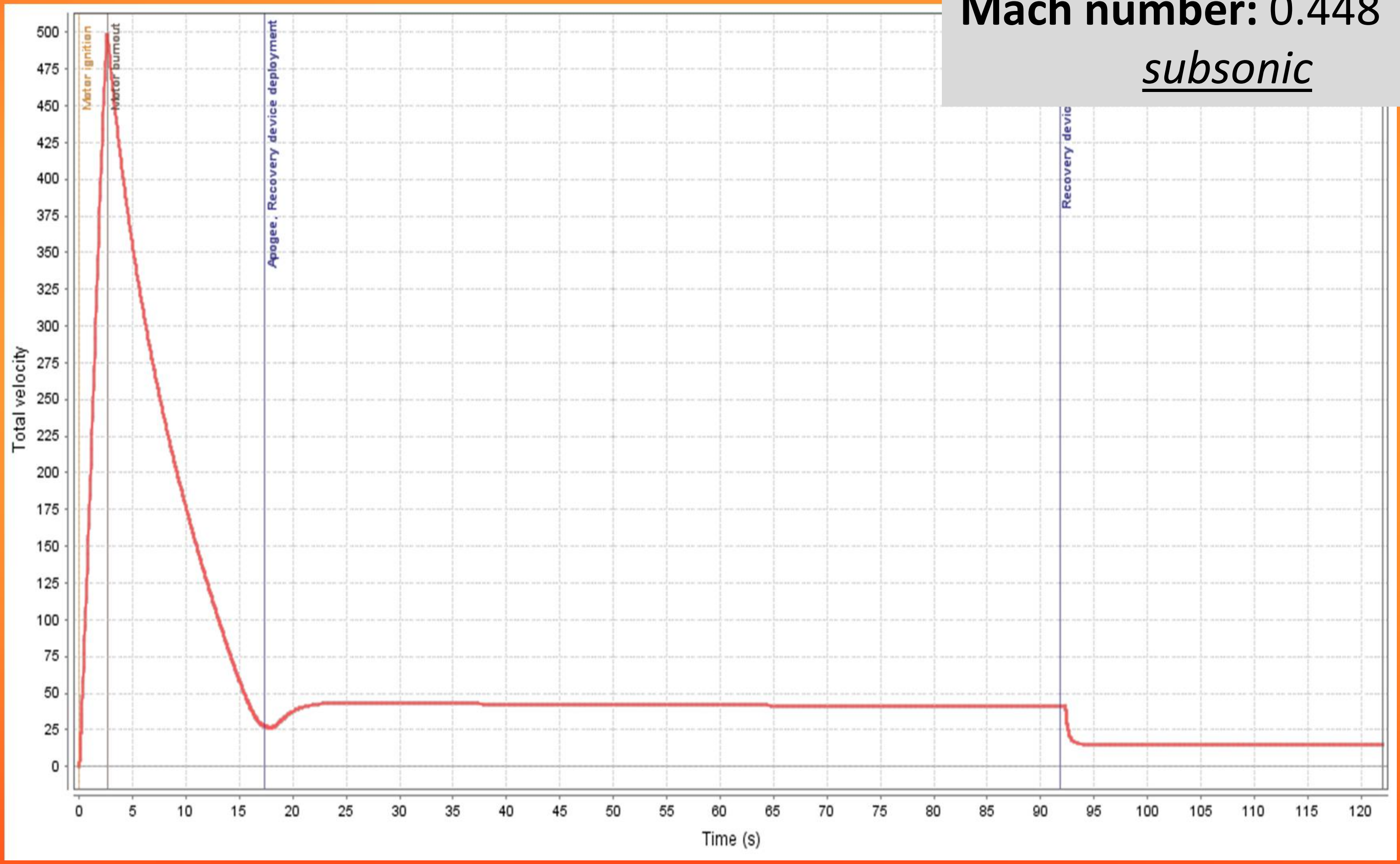


Time $[s]$

VELOCITY PROFILE

Max. velocity: 498*fps*
Mach number: 0.448
subsonic

Velocity [*ft/s*]

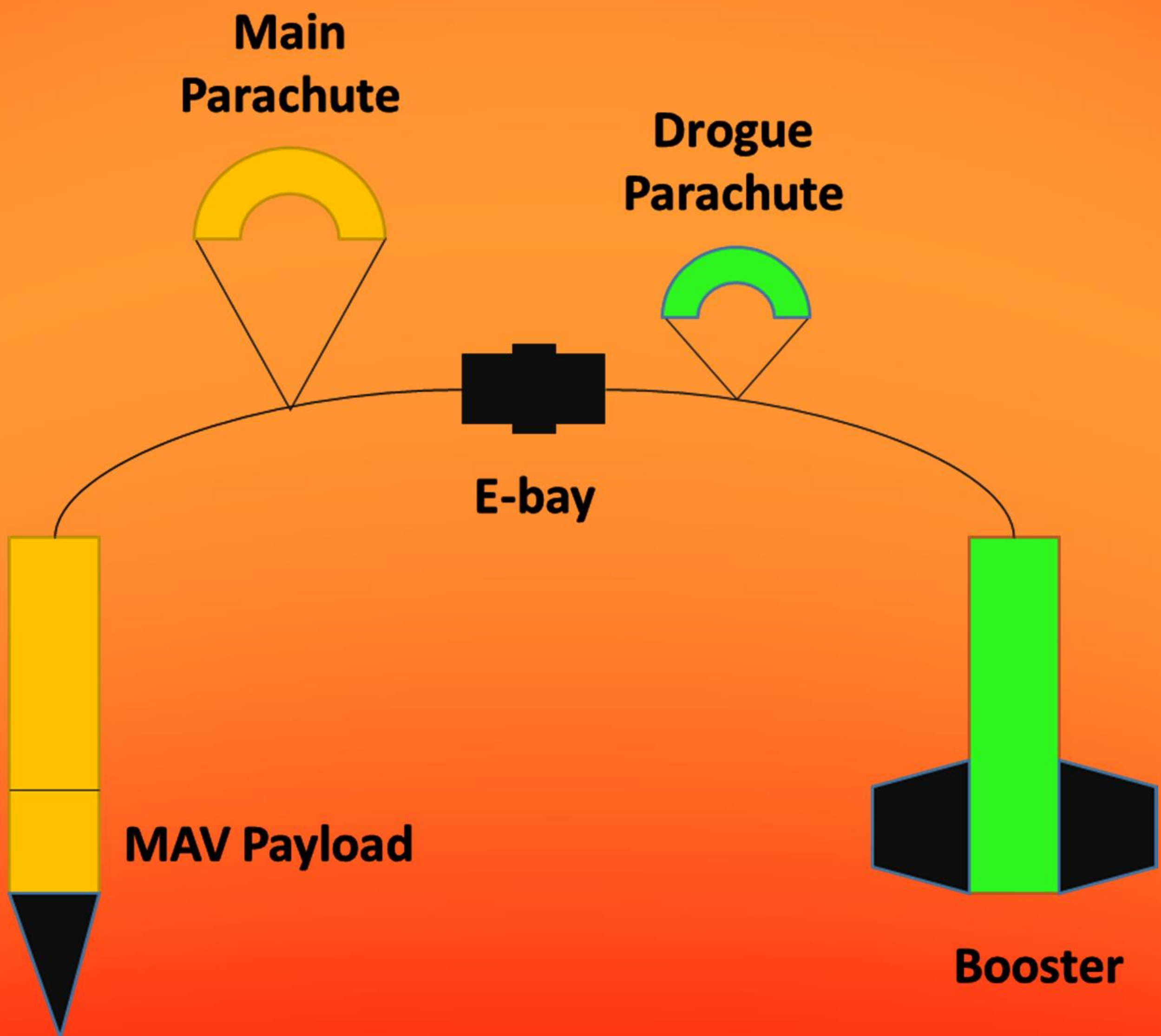


Time [*s*]

ALTITUDE VS. WIND SPEED

Wind Speed *[mph]*	Altitude *[ft]*	Change in Apogee *[%]*
0	5247	0.00
5	5188	-1.12
10	5122	-2.38
15	5061	-3.53
20	5024	-4.23

DEPLOYMENT SCHEME



PARACHUTE SIZE

Parachute	Diameter *[in]*	Descent Rate *[fps]*	Ejection Charge *[g]*	Deployment Altitude *[ft]*	Descent Weight *[lbs]*	Impact Energy *[ft-lbf]*
Drogue	18	90.0	2.43	5247	13.51	--
Main	80	20.3	2.53	700	1.68 3.50 8.33	9.5 19.9 47.7

Impact energies and descent weights under main parachute listed in *payload section, electronics bay and booster section* order

EJECTION CHARGE CALCULATIONS

$$Wp = dP * V / (R * T) * (454/12)$$

- *Wp* - ejection charge weight *[g]*
- *dP* - ejection pressure (15 *[psi]*)
- *V* - pressurized volume *[in³]*
- *R* - universal gas constant (22.16 *[ft-lb $^oR^{-1}$ lb-mol^{-1}]*)
- *T* - combustion gas temperature (3,307 *[^oR]*)

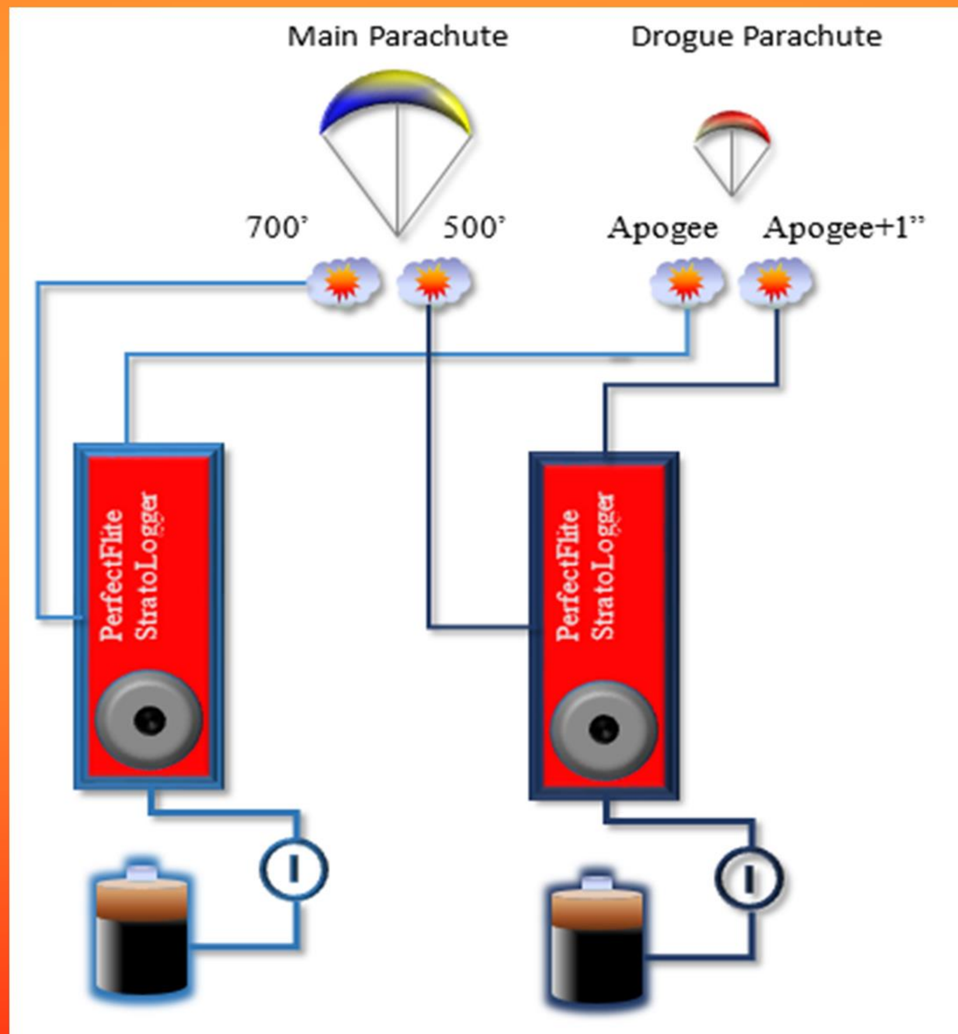
CALCULATED EJECTION CHARGES *

Parachute	Charge *[g]***
Drogue	2.43
Main	2.53

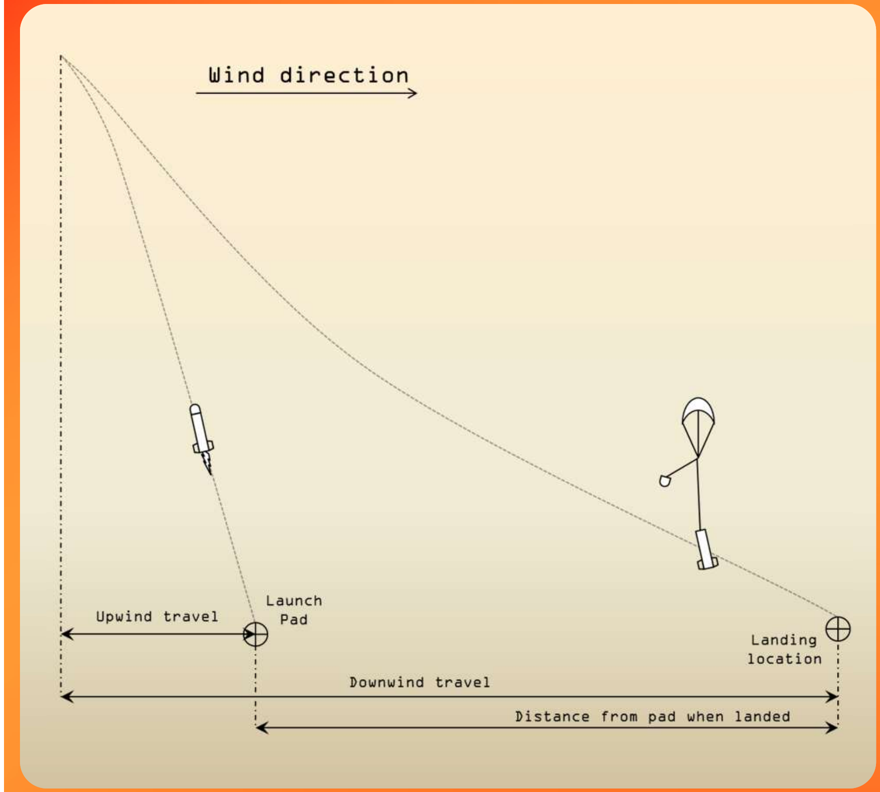
*   Ejection Charges will be finalized during static testing

** Primary charges shown. Secondary charges will be 25% larger (Jeffries' backup scheme).

REDUNDANT DEPLOYMENT

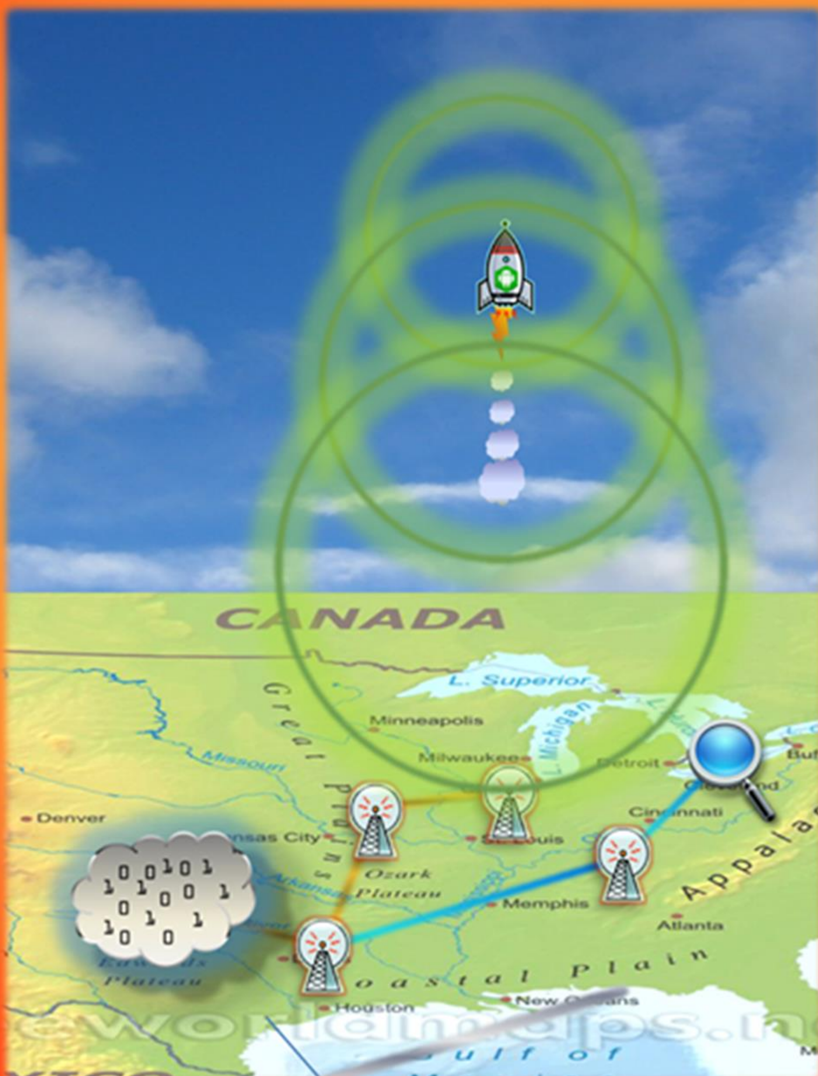


VEHICLE DRIFT PREDICTIONS



Wind speed [mph]	Upwind Travel [ft]	Downwind Travel [ft]	Distance from pad when landed [ft]	Distance from pad when landed [mile]
0	25	0	25	0.005
5	1350	621	729	0.138
10	1550	1242	308	0.058
15	1700	1863	163	0.031
20	1750	2484	1234	0.234

TRACKING AND TELEMETRY



CLOUD AIDED TELEMETRY : Cloud-Aided-Telemetry (CAT) system uses an on-board Android device and app to transmit flight, tracking and payload data from an airborne rocket using any available cellular network. The data travel along orange route to our data cloud (located in Houston, TX) from where they can be retrieved via blue route by any connected device (such as cell phone) and aid the search for the rocket and payload. CAT is an 'opportunistic uploader' and can store gigabytes of data on-board while searching for available connection.

This system has been succesfully tested at LDRS 33 launch during 8K+ flight.

VEHICLE SAFETY VERIFICATION

Phase	Method	Verifies/Provides
SOW **PDR**	**Computer simulations (OpenRocket, RockSIM)**	• Vehicle stability • Preliminary performance predictions
CDR	**Half-scale model**	• Vehicle stability/design • Coefficient of drag • Deployment scheme
FRR	**Full scale/half impulse flight**	• Vehicle stability • Vehicle robustness • Recovery system reliability • Improved performance predictions
FRR	**Full scale/full impulse flight**	• Vehicle performance • Vehicle robustness • Flight constraints compliance

VERIFICATION PLAN

Tested Components

C1: Flight Electronics

C2: Recovery Systems

C3: Motor

C4: Power Supply

C5: Ejection Charges

C6: Tracking and Telemetry

C7: Launch System

VERIFICATION PLAN

<u>Verifications</u>

V1: Functionality: Ensure satisfactory performance of components.

V2: Integrity: Application of force to verify durability.

V3: Integration: Ensures proper fit of each component within its assigned compartment, free of interference of other components.

V4: Scale Model: Verifies the predicted performance of the vehicle.

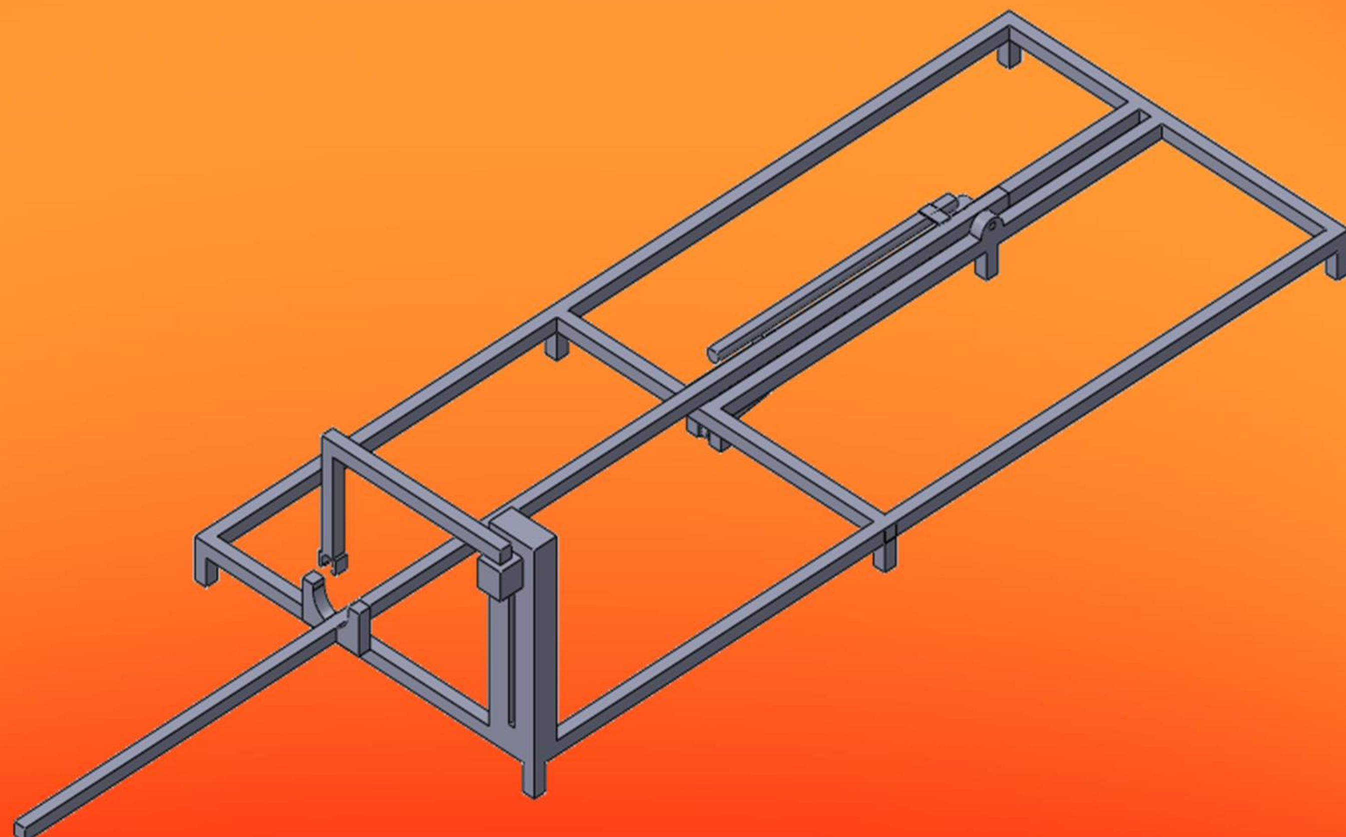
VERIFICATION MATRIX

	V1	V2	V3	V4
C1	1.2	2.5	2.4	1.2
C2	2.5	1.3	1.4	1.4
C3	1.5	2.5	1.12	1.2
C4	1.7	1.7	1.12	1.7
C5	2.2	2.5	1.12	1.13.1
C6	2.11	2.5	2.11	2.11
C7	1.8	2.5	1.8	1.8

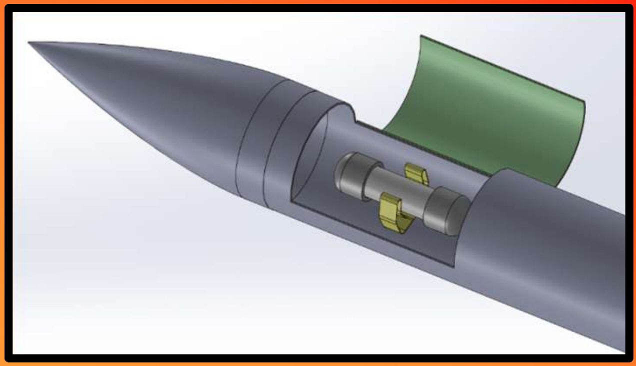
P = planned, C = successfully completed

Status: Verification will begin after PDR conference.

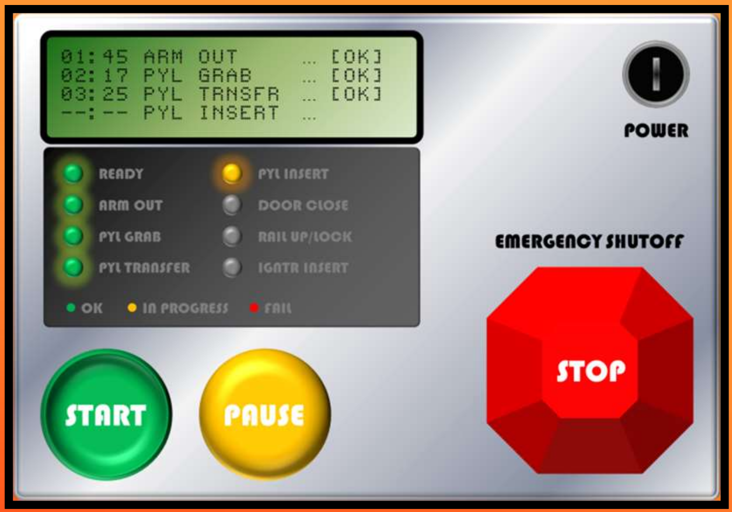
PART II: AGSE

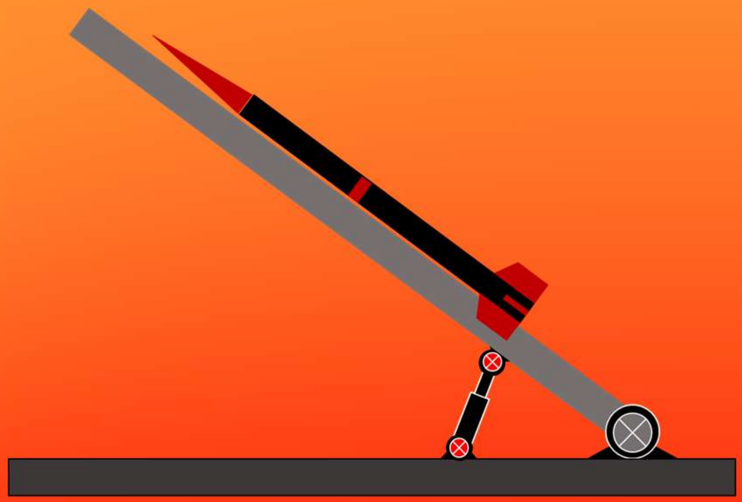


AGSE TASKS

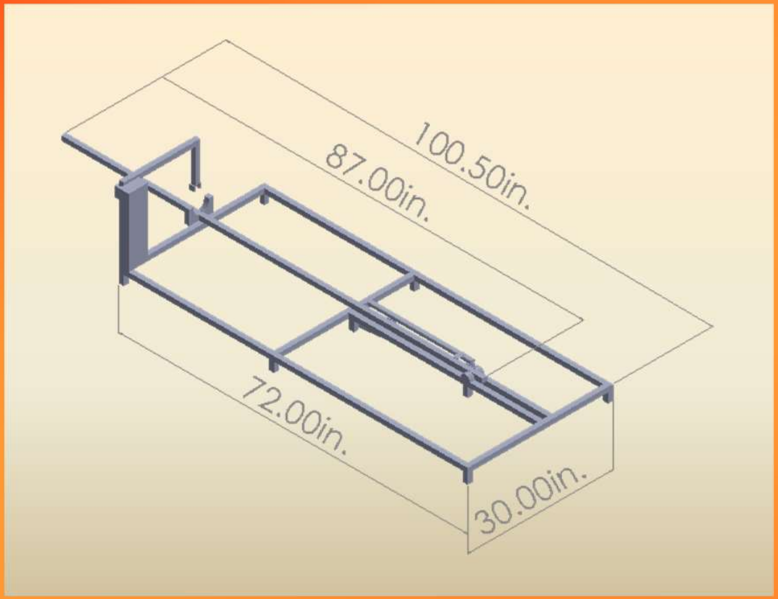


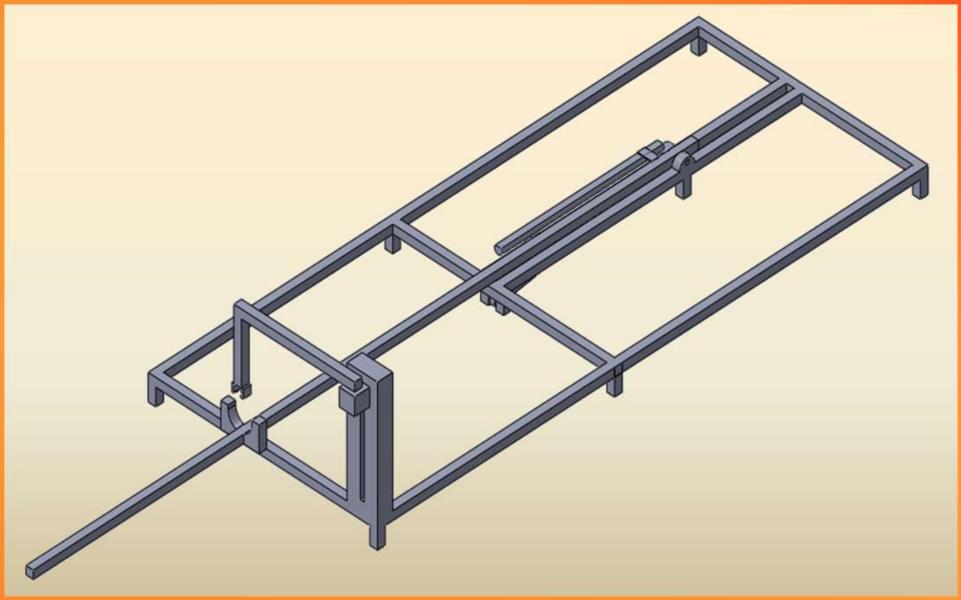
- Acquire payload container
- Insert container into payload bay
- Close the bay door
- Raise rocket into launch position
- Insert igniter into motor





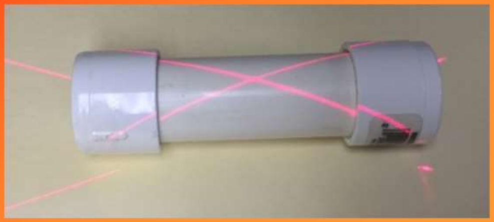
AGSE SUPERSTRUCTURE



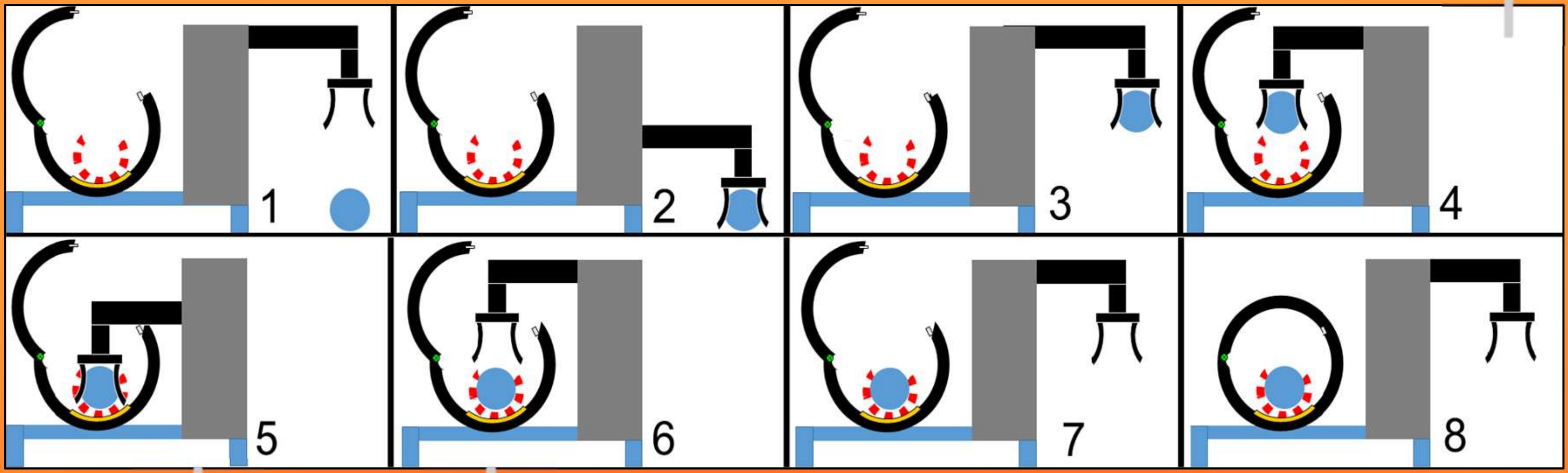


- Concept structure anticipates meeting volume, mass, and performance requirements
- Envelope approximately 8.5 x 3 x 3 ft^3 closed, 8 x 3 x 8 ft^3 in launch configuration
- Full system (with rocket and all aspects) anticipated to be <120 *lbs*

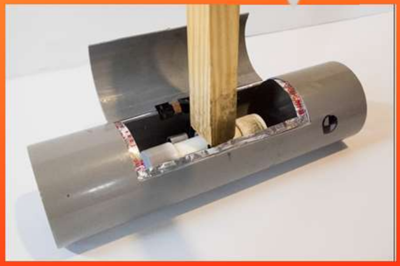
PAYLOAD RETRIEVAL AND INSERTION

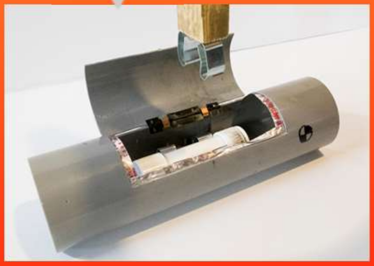


Payload placement guide (laser mark)

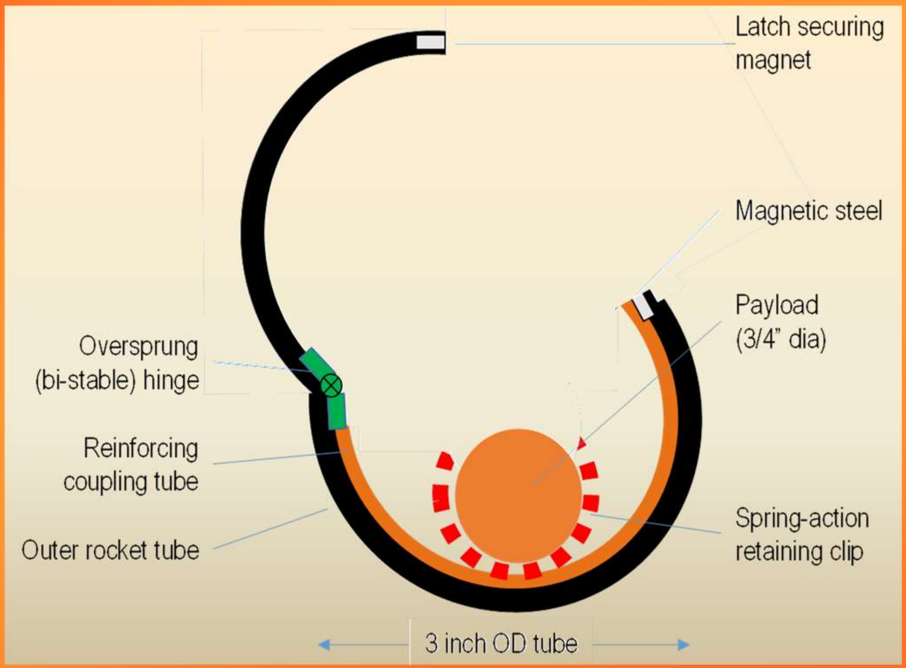


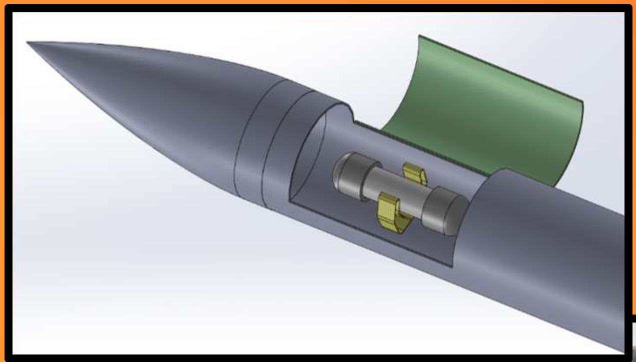
1-8 RETRIEVAL AND INSERTION SEQUENCE

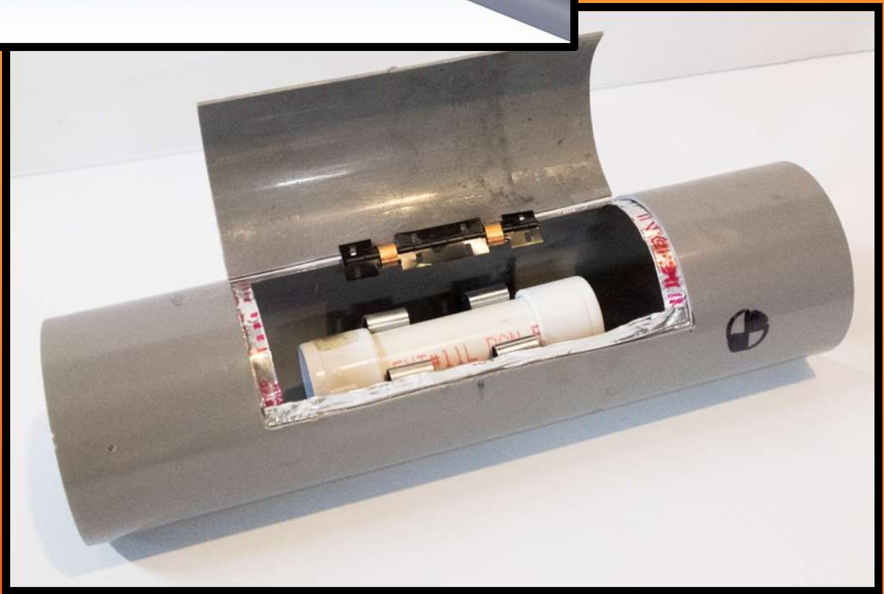




PAYLOAD SECUREMENT SYSTEM

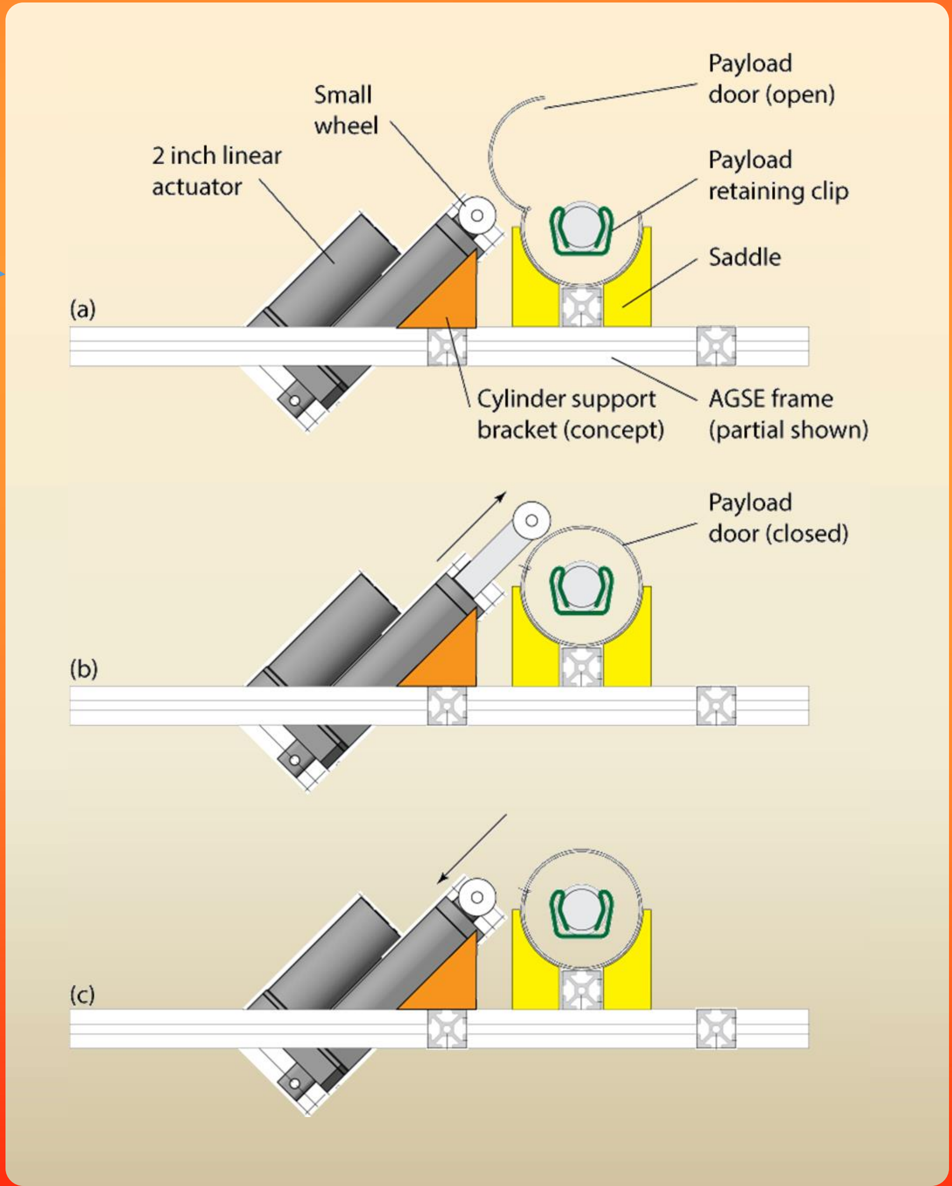




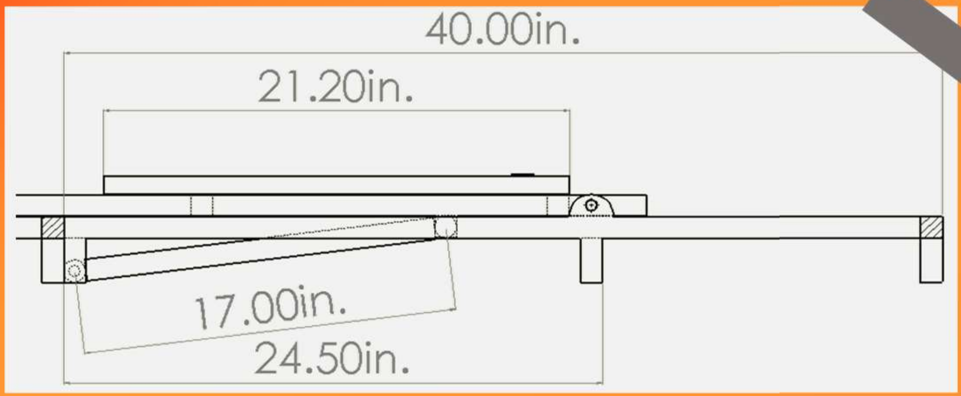


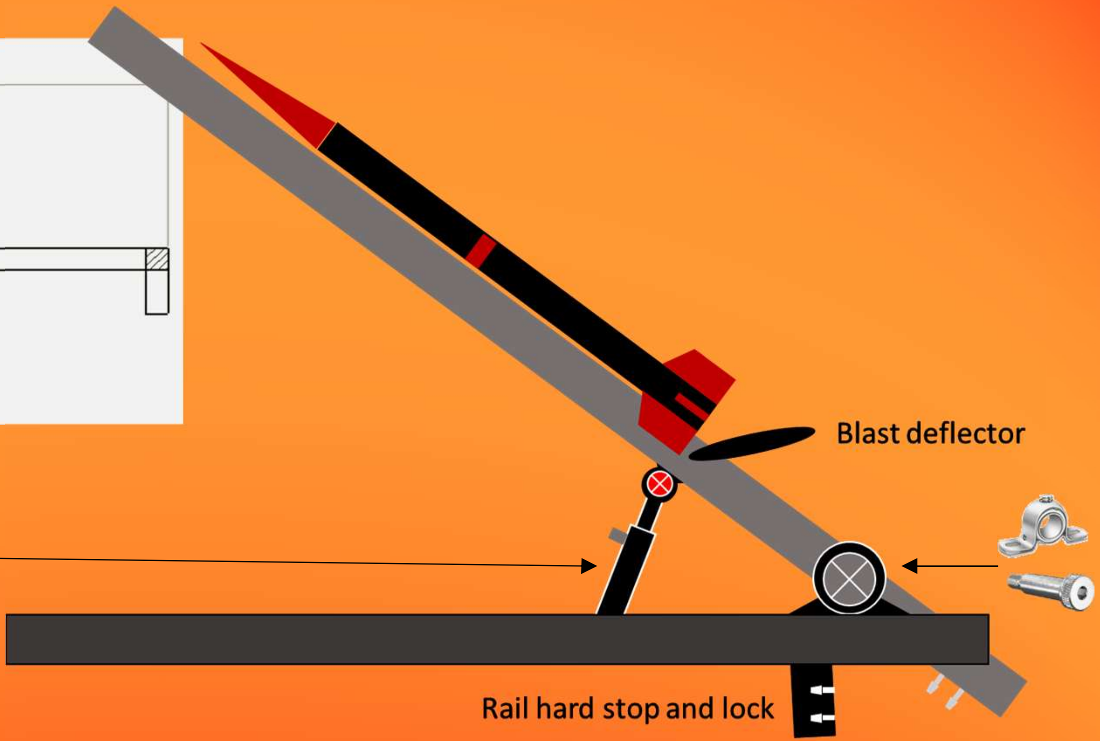
The payload securement system uses a set of passive grippers to secure the payload. Magnets will be used to secure the door.

DOOR CLOSURE SYSTEM



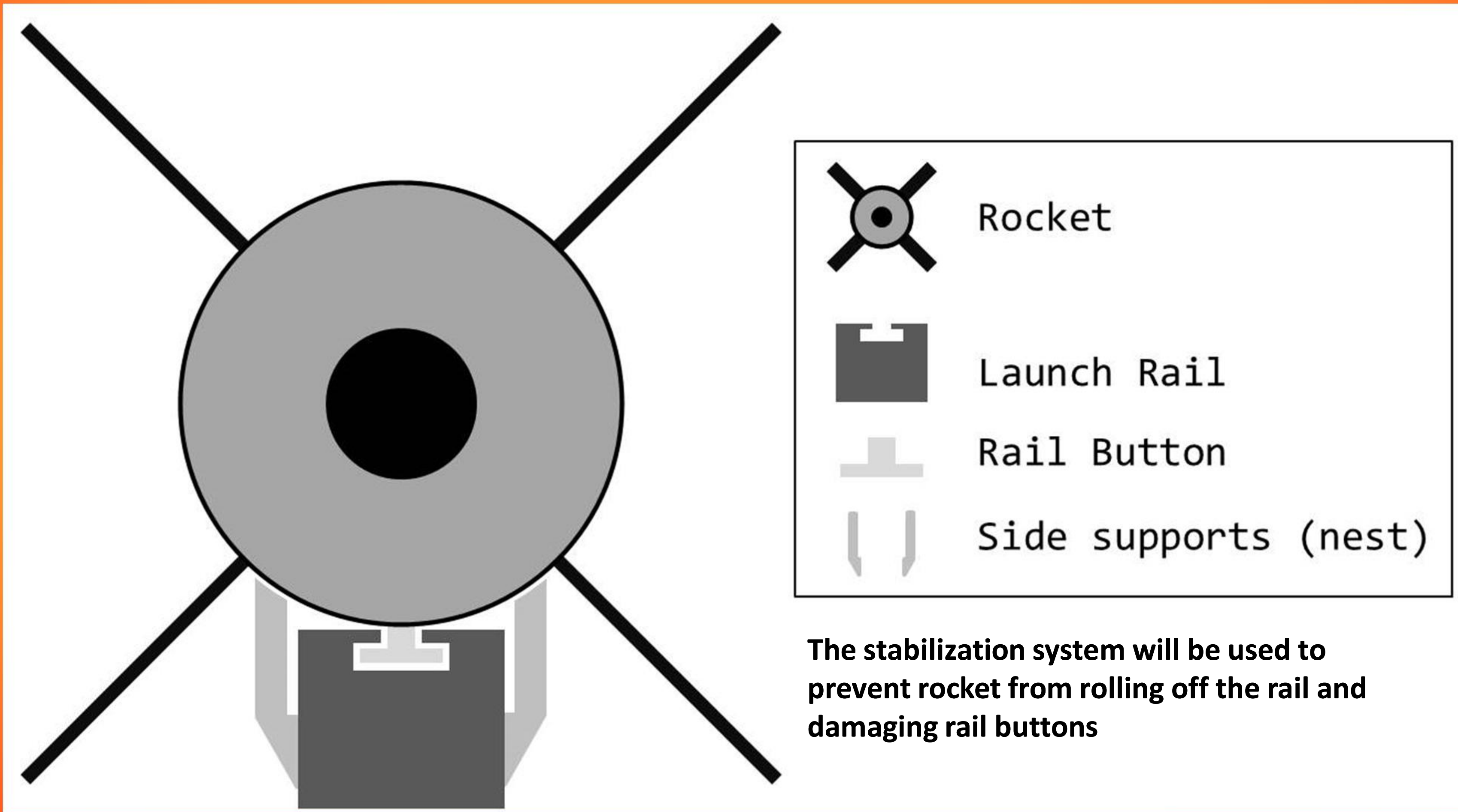
THE ERECTION SYSTEM





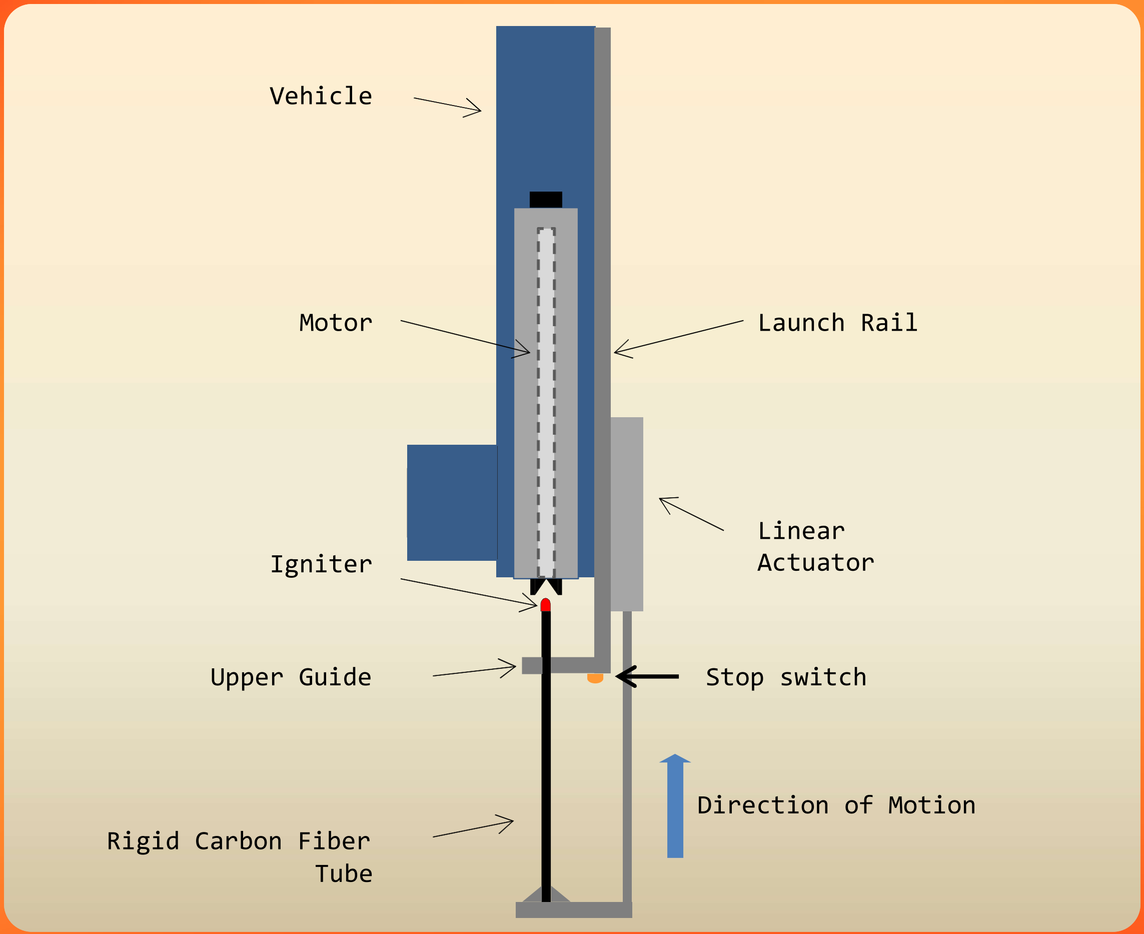
We will be using a linear actuator for the erection system. Linear actuator will start at an angle and push the rail to a 85° launch position. After reaching the hard stop rail will be lock itself using the spring loaded snap-in pins (similar to Pogo™ pins).

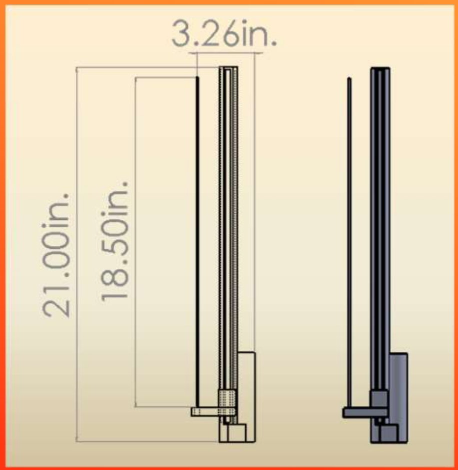
ROCKET STABILIZATION



The stabilization system will be used to prevent rocket from rolling off the rail and damaging rail buttons

THE IGNITER INSERTION SYSTEM

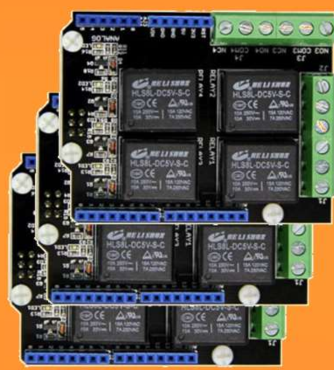


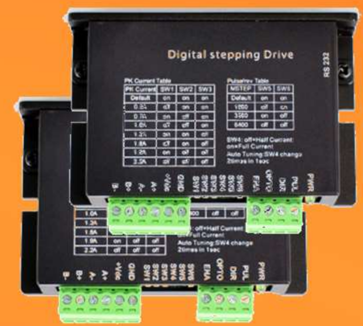


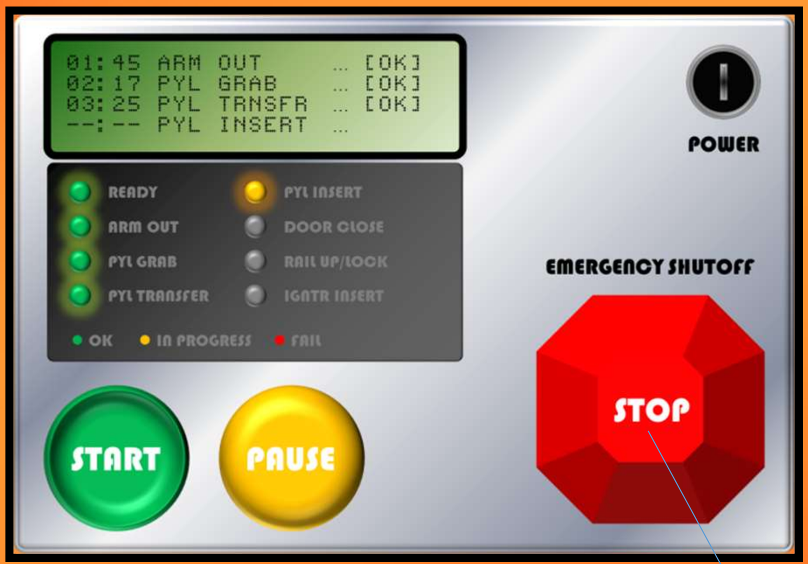
We are also using a linear actuator, of the same type as the erection system, for the igniter insertion system. It will push the igniter a set distance into the motor.

CONTROL DRIVER

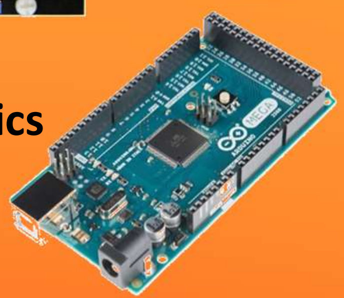
Information display





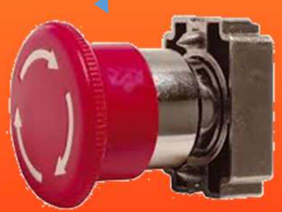


Driver electronics



Stack lights (information)

Control panel

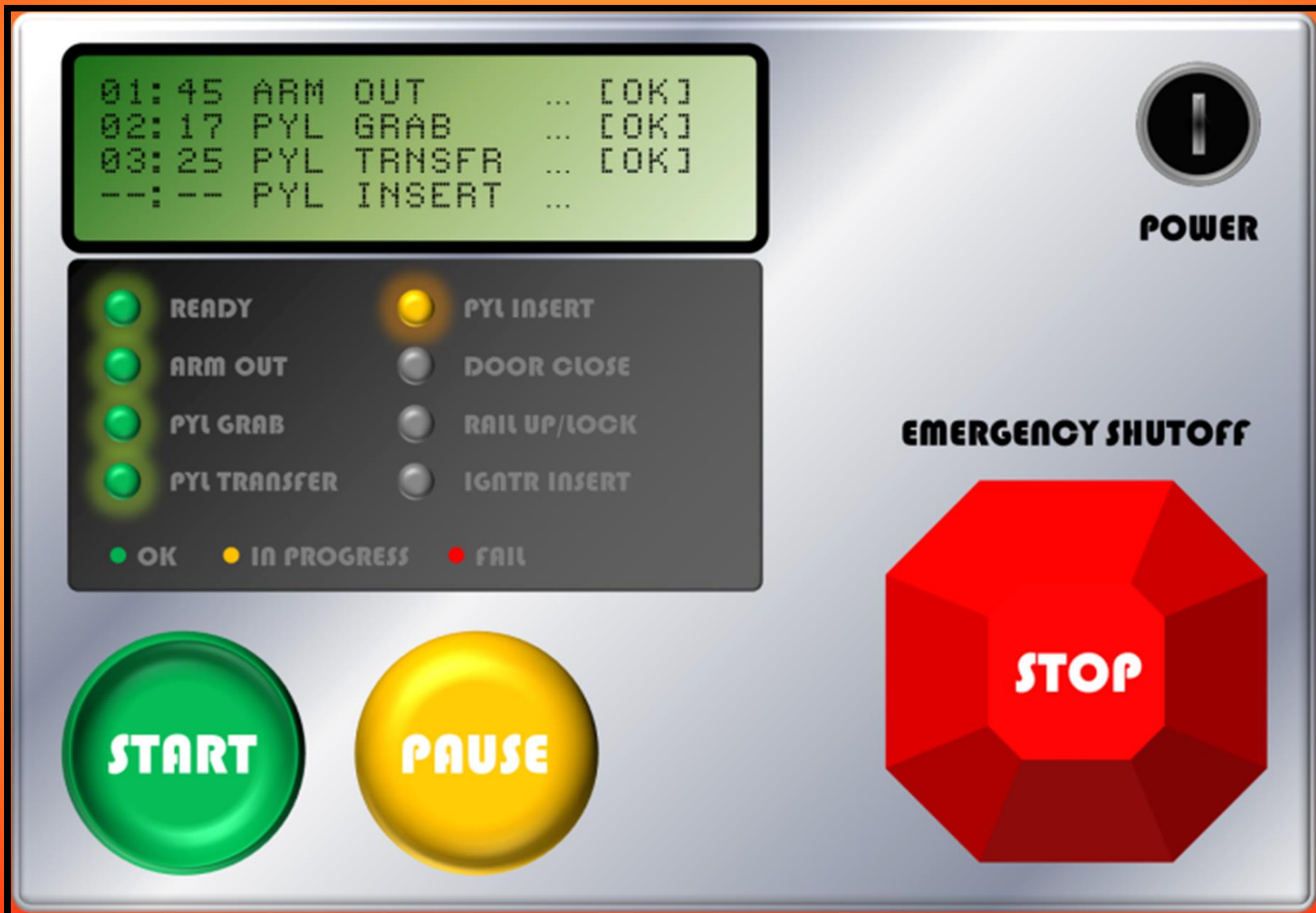


There will be LED display designed to communicate the conditions and progress of the AGSE

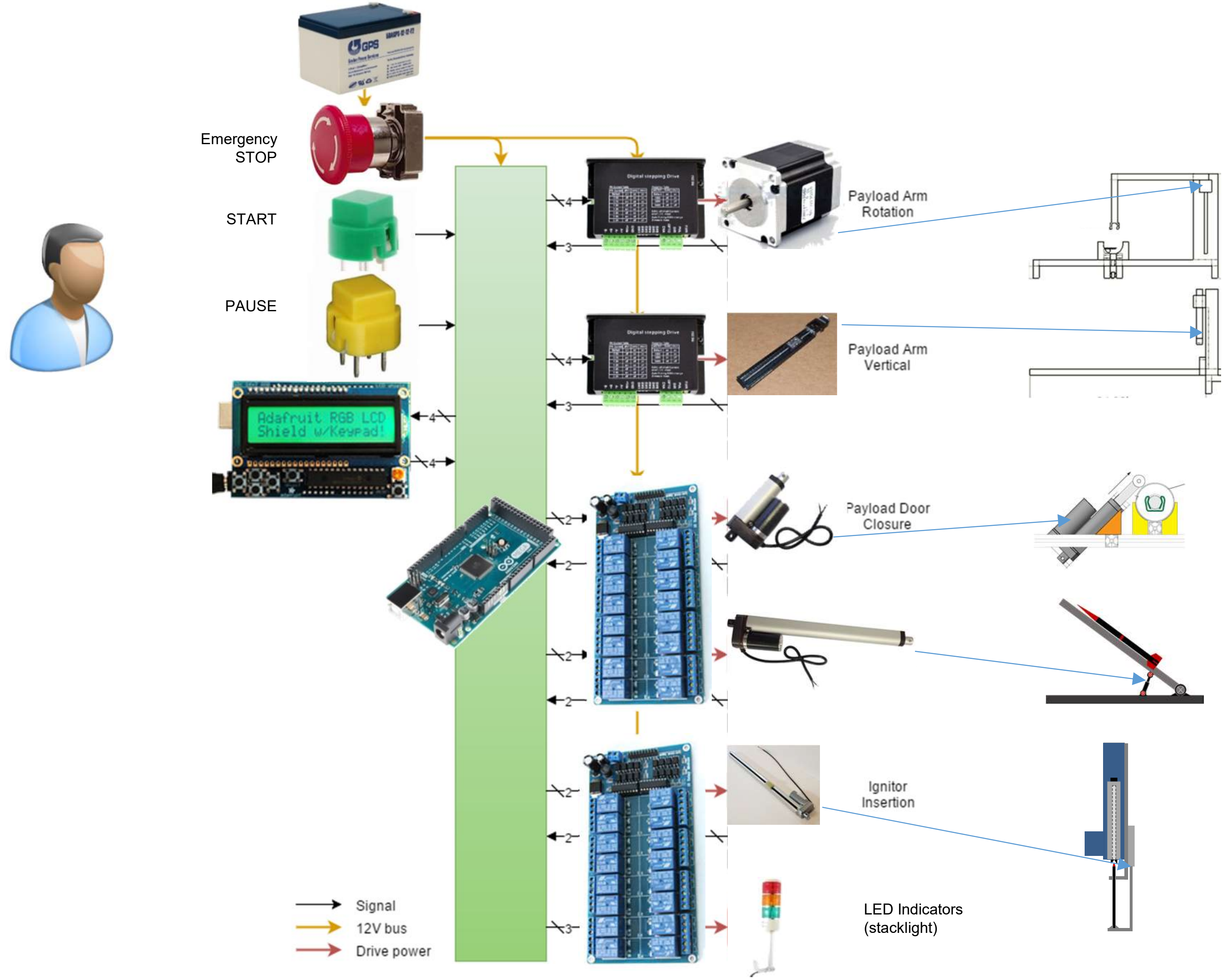
E-stop button

Power source (battery)

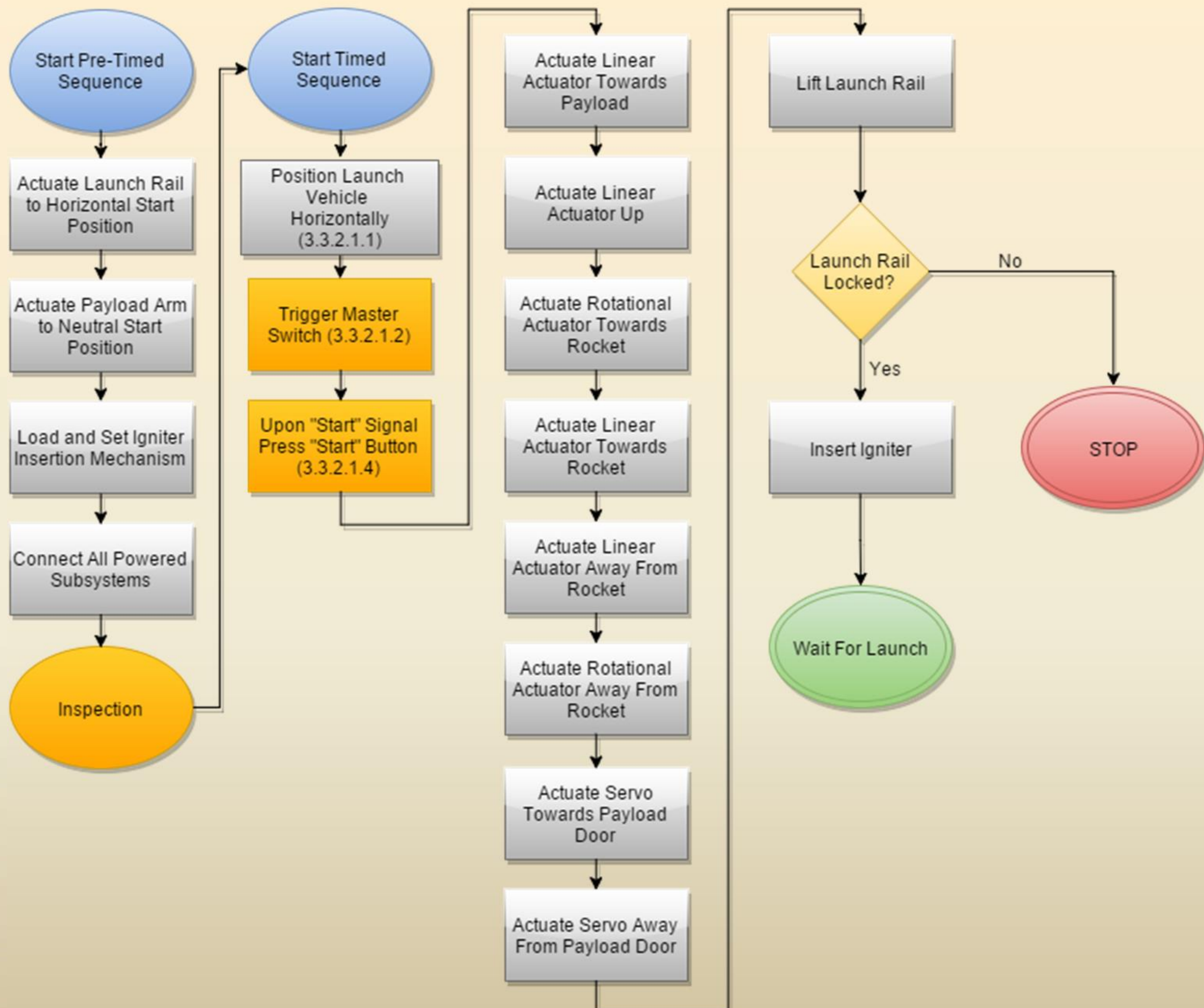
CONTROL PANEL



AGSE BLOCK DIAGRAM



PROCESS FLOW



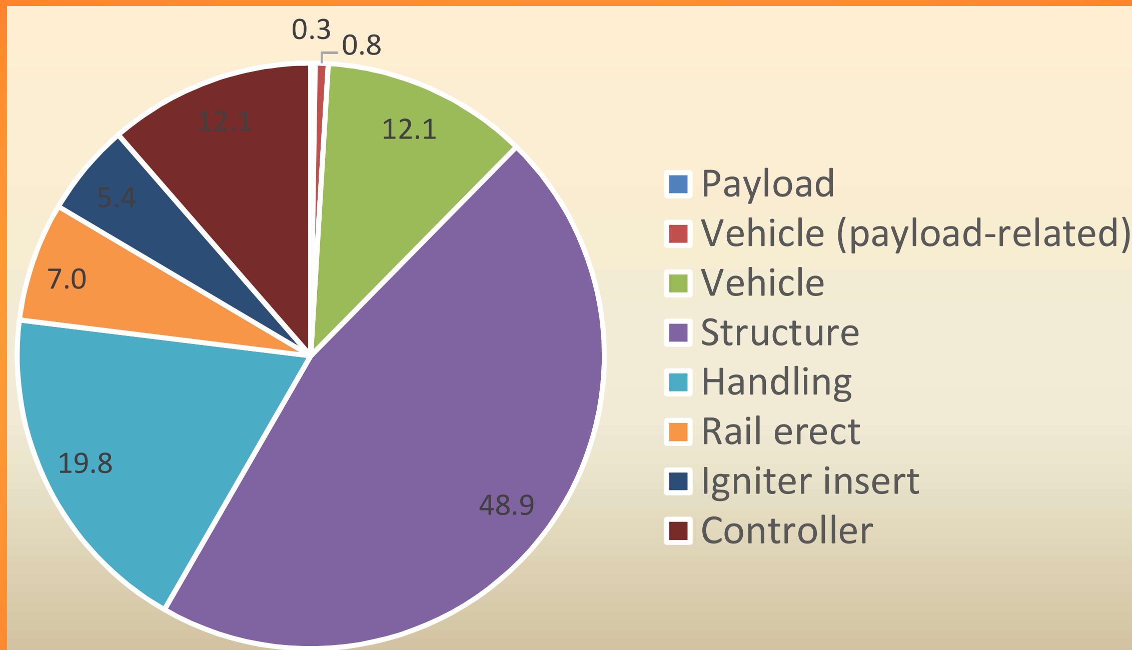
TIME TO COMPLETE SEQUENCE

Step #	Action	Duration *[sec]*	
1	Press button to start sequence	2	
2	Rotate arm 90° over payload	15	
3	Lower arm to engage payload	20	
4	Raise arm with payload	20	
5	Rotate arm 180° over vehicle	30	
6	Lower arm to push in payload	10	
7	Retreat vertically	10	
8	Rotate arm 90° to neutral position	10	
9	Push door closed	8	
9b	Check microswitches	1	
10	Retreat door push plunger	8	
10b	Check microswitches	1	
11	Erect launch rail	30	
11b	Check microswitches	1	
12	Insert igniter	18	
12b	Check microswitches	1	
13	Signal "complete"	1	
		186	**sec**
		3.1	**min**

KEY COMPONENTS AND SUBSYSTEMS

Subsystem	Description	Manufacturer/Supplier	Model
Payload retention	Dowel holder / spring steel clip	True value	
Payload retention	Eyeglass case spring hinge	Donation from local Costco	n/a
Payload retention	Magnet	KH magnetics	
Structure	8020 rail	club inventory, McMaster-Carr	
Structure	8020 assembly hardware	McMaster-Carr	
Handling	Laser line generator	Craftsman/Amazon	
Handling	Gripper	True value	
Handling	Linear motor stage (8") / vertical	THK/eBay	N/A
Handling	Stepper motor with encoder	StepperOnline (NEMA 17/23 size)	N/A
Handling	Linear actuator (2") / door closer	Everest Supply or Firgelli	
Erection	Linear actuator (18")	Everest Supply or Firgelli	N/A
Erection	Pillow sleeve bearing	McMaster-Carr	
Erection	Shoulder bolt	McMaster-Carr	
Insertion	Linear actuator with track mount	Firgelli	
Insertion	Carbon-fiber tube	McMaster-Carr	
Controller	Microcontroller	Sparkfun	Arduino Uno R3
Controller	Relay shield	Sparkfun	
Controller	Stepper driver with microstep	TBD	
Controller	Battery, 12 Pb-acid/gel	Tenergy or similar	e.g., TB12120
Controller	Indicator tower	uxcell/Amazon	12V tricolor

MASS ALLOCATION ESTIMATE



Subsystem	Mass (lbs)	Comment
Payload	0.3	just the PVC payload and weighting
Vehicle (payload-related)	0.8	includes items required to retain and secure the payload
Vehicle	12.1	all aspects of the rocket including structure, propulsion, recovery, telemetry
Structure	48.9	the static superstructure of the ASGE
Handling	19.8	the robotic motion control for acquiring and depositing the payload
Rail erect	7.0	lifting the launch rail into a near-vertical position
Igniter insert	5.4	insertion of the igniter into the engine
Controller	12.1	all aspects of control including microcontroller, drivers, indicators, safety lights, housing, and pc
TOTAL	**106.4**	

VERIFICATION PLAN

Tested Components

- **C1:** AGSE Frame
- **C2:** Rail Erection System
- **C3:** End Effector
- **C4:** Payload Retrieval System
- **C5:** Igniter Insertion System
- **C6:** Control Panel
- **C7:** Emergency Stop Button
- **C8:** Power Source

VERIFICATION PLAN

Verifications

- **V1 Integrity Test:** applying force to verify durability.
- **V2 Force Stall Test:** applying force to verify stall force of motor.
- **V3 Holding Force Test:** applying force to verify holding force of motor.
- **V4 Time Test:** verifying time taken for action.
- **V5 Functionality Test:** test of basic functionality of a device on the ground.
- **V6 Power Draw Test:** determining the amount of power required to sustain this component for a certain amount of time.
- **V7 Conditions Test:** verifying that components will function in launch conditions.
- **V8 Hard Stop Test:** verifying that all hard stops function.
- **V9 Weight Test:** verifying that the AGSE remains under 150 pounds
- **V10 Volume Test:** verifying that the AGSE does not surpass the allowable volume

VERIFICATION MATRIX

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
C1	3.1	3.3.2.1.3	3.3.2.1.3		3.3.3.2	3.3.6.1.1	3.3.4	3.3.2.1.3	3.3.3.3	3.3.3.3
C2	3.1	3.3.2.1.3	3.3.2.1.3	3.3.5.6	3.3.3.2	3.3.6.1.1	3.3.4	3.3.2.1.3	3.3.3.3	3.3.3.3
C3	3.1	3.3.2.1.3	3.3.2.1.3		3.3.3.2	3.3.6.1.1	3.3.4	3.3.2.1.3	3.3.3.3	
C4	3.1	3.3.2.1.3	3.3.2.1.3	3.3.5.6	3.3.3.2	3.3.6.1.1	3.3.4	3.3.2.1.3	3.3.3.3	3.3.3.3
C5	3.1	3.3.2.1.3	3.3.2.1.3	3.3.5.6	3.3.3.2	3.3.6.1.1	3.3.4	3.3.2.1.3	3.3.3.3	3.3.3.3
C6	3.1	3.3.2.1.3	3.3.2.1.3		3.3.3.2	3.3.6.1.1	3.3.4	3.3.2.1.3	3.3.3.3	
C7	3.1	3.3.2.1.3	3.3.2.1.3		3.3.2.1	3.3.6.1.1	3.3.4	3.3.2.1.3	3.3.3.3	
C8	3.1	3.3.2.1.3	3.3.2.1.3		3.3.3.2	3.3.6.1.1	3.3.4	3.3.2.1.3	3.3.3.3	

P = planned, C = successfully completed

Status: Verification will begin after PDR conference.

OUTREACH PLAN

Date	School	Outreach	# of People (estimate)
Oct. 8, 2015	Cub Scouts	Pneumatic Rockets, Displays, Q&A	50
Oct. 16, 2015	Randall Elementary	West High Homecoming Parade	200
Oct. 24 & 25, 2015	Wisconsin Science Festival	Pneumatic Rockets, Rocket and Payload Displays	3070
Feb. 13, 2016	Physics Open House	Pneumatic Rockets, Displays, presentations	300
Mar. 12, 2016	Franklin and Randall Elementary Super Science Saturday	Pneumatic Rockets, Displays	100
Mar. 19, 2016	O'Keefe Middle School Super Science Saturday	Pneumatic Rockets, Displays	80
Apr. 1, 2016	Kids' Express	Pneumatic Rockets	50
			Total: 3850

OUTREACH AND COMMUNITY

MCC Grant Acceptance Ceremony

Wisconsin Science Festival

Homecoming Parade

Painting at Madison Science Museum


QUESTIONS?