MARS ASCENT VEHICLE
CENTENNIAL CHALLENGE

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

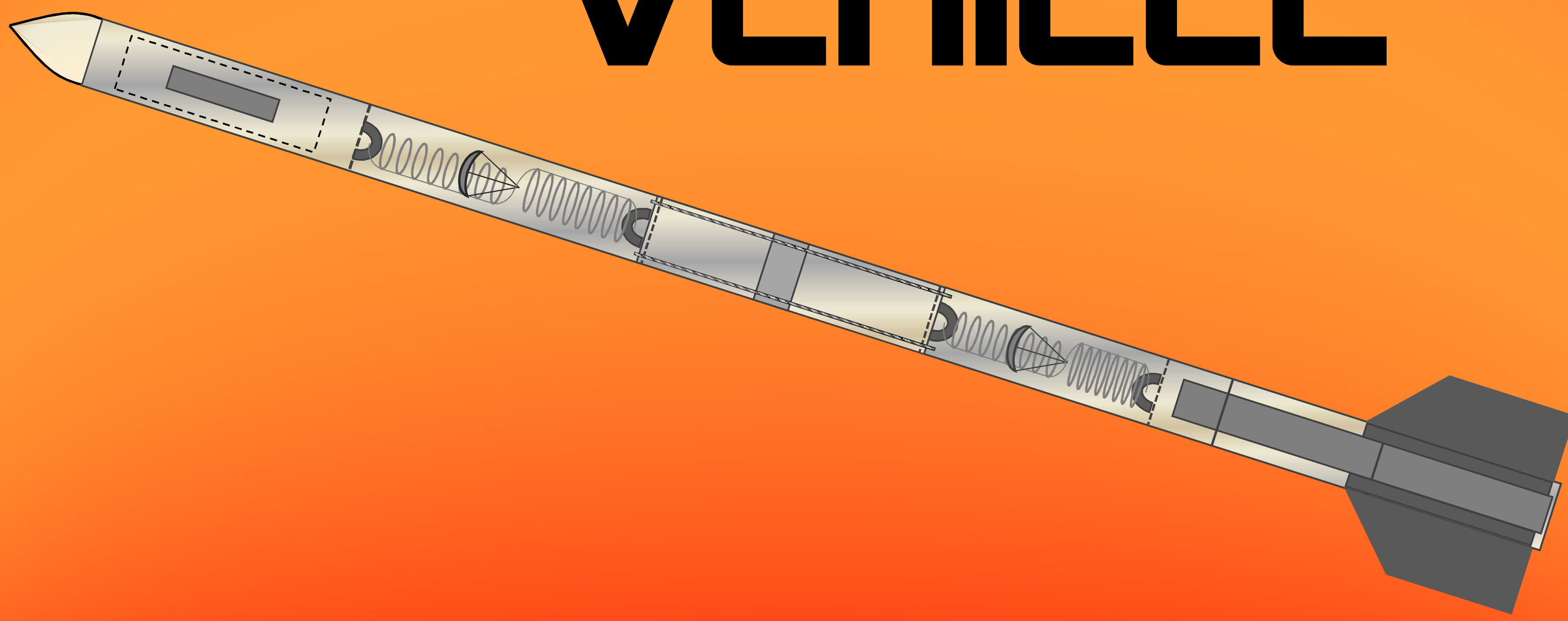
PAYLOAD OPTION 3.1.8 – CENTENNIAL CHALLENGE
NON-ACADEMIC TEAM

MADISON WEST
SL 2016

CRITICAL DESIGN REVIEW

PART 1:

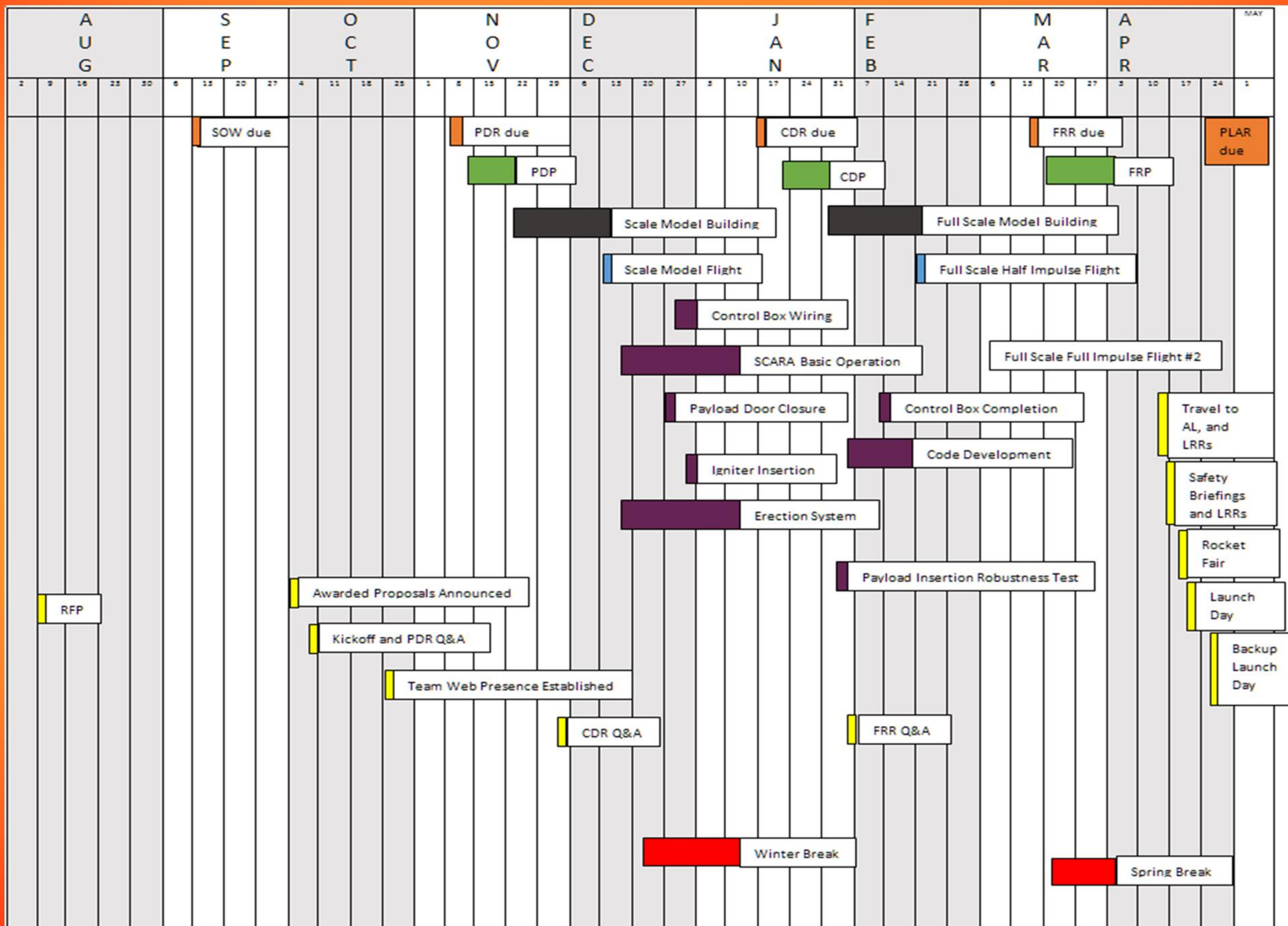
VEHICLE



MAJOR MILESTONE SCHEDULE

Date	Milestone
Nov 21-Dec 11	Scale Model Building
Jan 2	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	Flight Readiness Review due
Mar 17-30	Flight Readiness Presentations
Apr 16	Launch Day in Huntsville
Apr 29	PLAR due

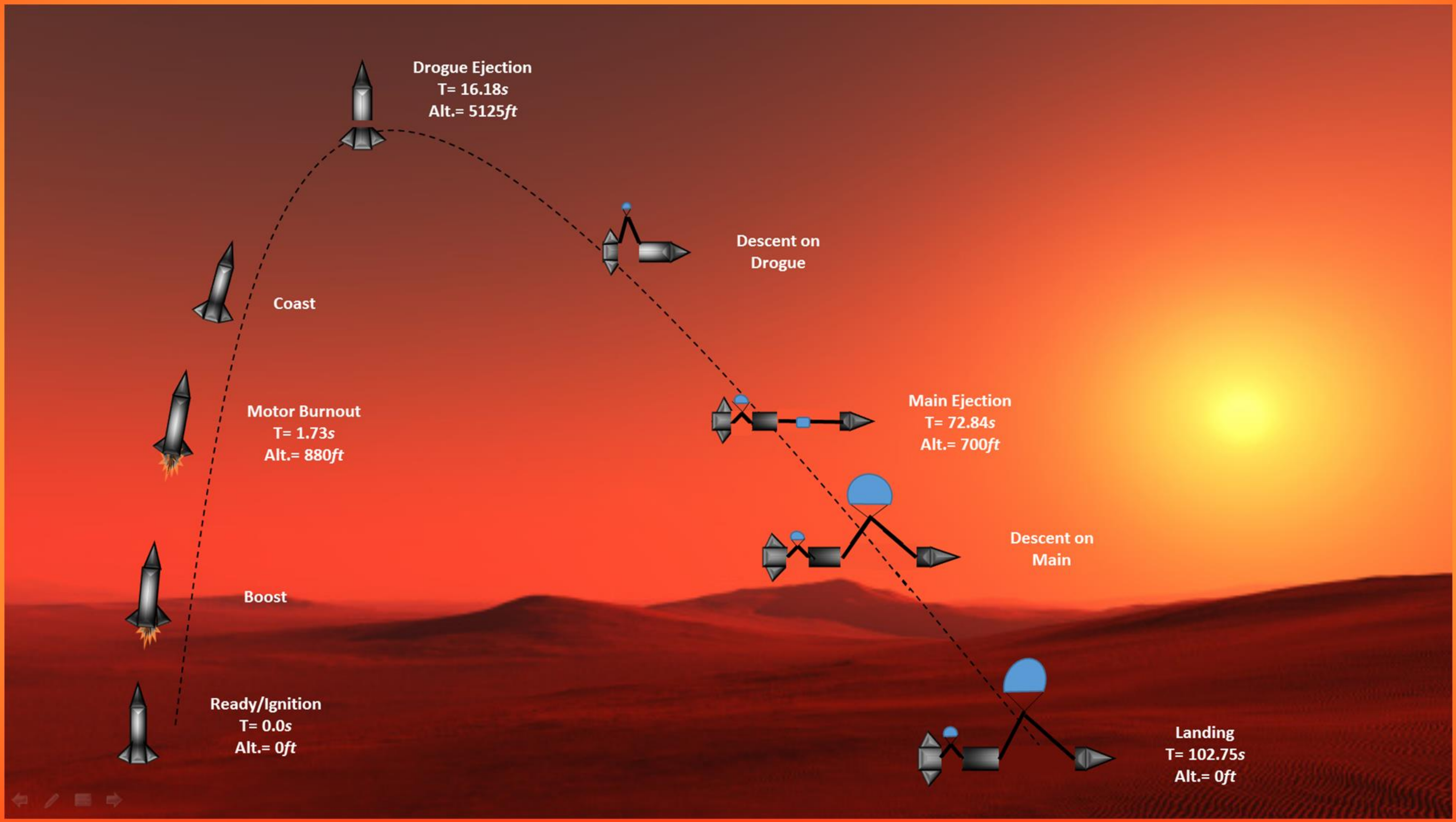
GANTT CHART


AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
SOW due
PDR due
CDR due
FRR due
PLAR due
PDP
CDP
FRP
Scale Model Building
Full Scale Model Building
Scale Model Flight
Full Scale Half Impulse Flight
Control Box Wiring
SCARA Basic Operation
Full Scale Full Impulse Flight #2
Payload Door Closure
Control Box Completion
Travel to AL, and LRRs
Code Development
Igniter Insertion
Safety Briefings and LRRs
Erection System
Rocket Fair
Payload Insertion Robustness Test
Awarded Proposals Announced
Launch Day
RFP
Kickoff and PDR Q&A
Backup Launch Day
Team Web Presence Established
CDR Q&A
FRR Q&A
Winter Break
Spring Break

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



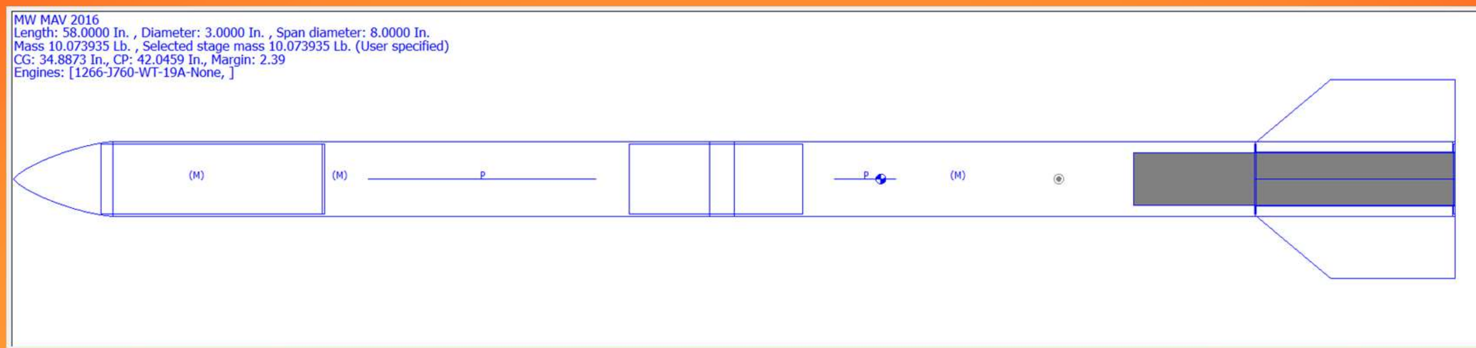
VEHICLE MISSION CRITERIA

- Motor ignition
- Stable flight
- Altitude of 5,280 feet AGL reached <u>but not exceeded</u>
- Deliver standard MAV payload (4oz)
- 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 APPROACH

- Minimize vehicle size → smaller AGSE
- Fast liftoff → shorter rail → smaller AGSE
- High velocity → better altitude accuracy
- Fiberglass construction → structural strength
- Minimize impulse needed → lower test flight cost
- Use kinetic energy allowance → smaller parachutes

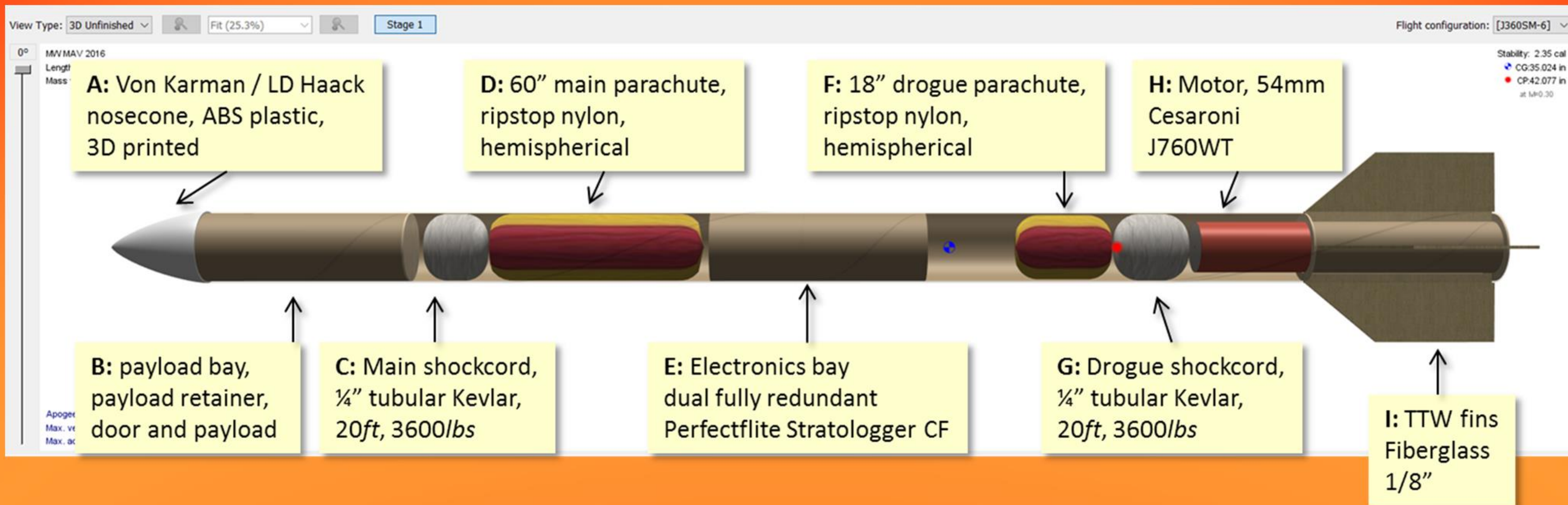
VEHICLE DESIGN



Length	**58”**
Diameter	**3”**
Liftoff Weight	**10.1*lb***
CP	**41.2” from nosecone**
CG	**34.0” from nosecone**
Static margin	**2.4 calibers**
Motor	**CTI J760WT (primary choice)**

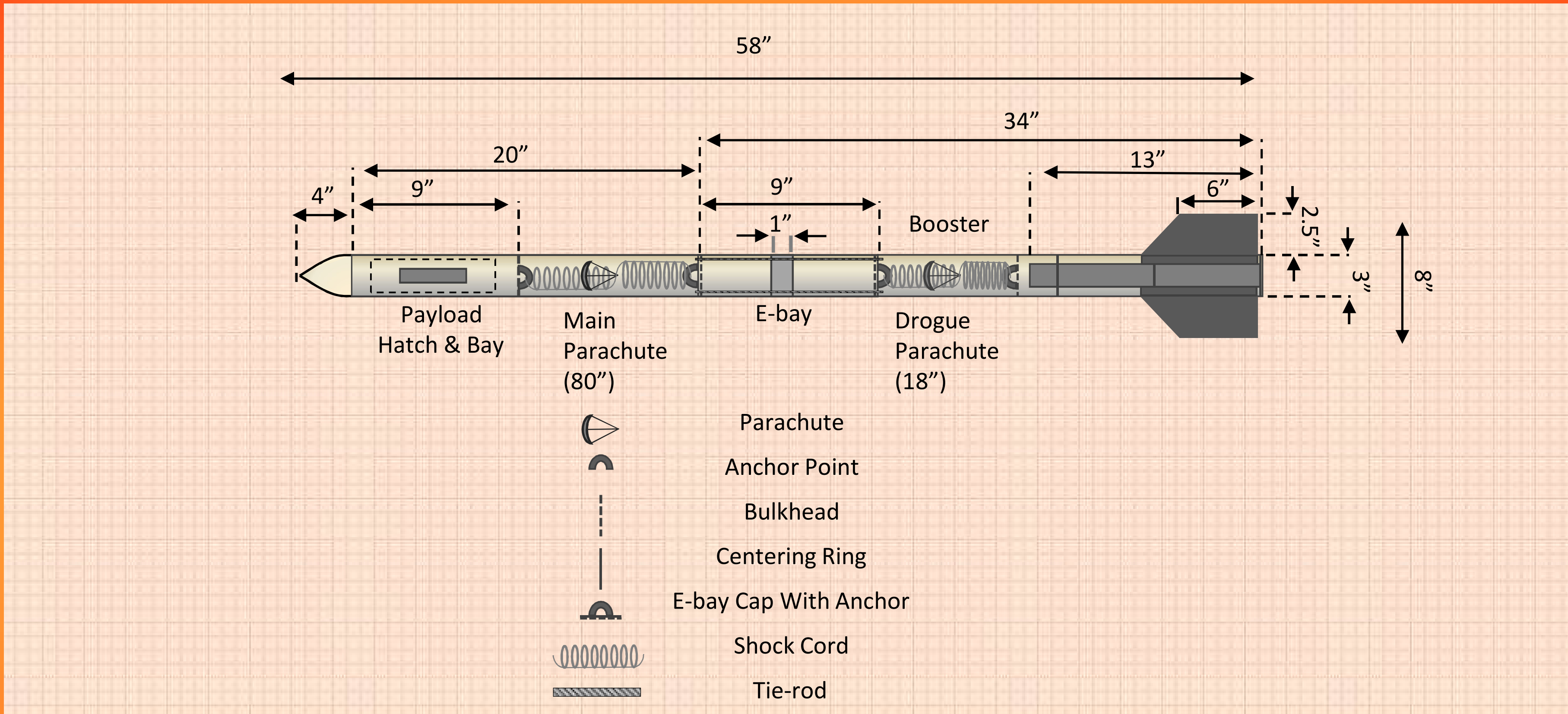
Motor	Diameter *[mm]*	Total Impulse *[Ns]*	Burn Time *[s]*	Stability Margin *[calibers]*	Thrust to weight ratio
CTI J760WT	**54**	**1414**	**1.8**	**2.40**	**20.5**
CTI J449BS	**54**	**1429**	**2.8**	**2.40**	**12.8**

VEHICLE PARTS



Letter	Part	Breaking force *[lbs]*
A	Nosecone (Von Karman, LD-Haack)	
B	Payload bay (section reinforced by coupler)	
C	Main Parachute (8 shroudlines, hemispherical)	400*lbs* per shroudline
D	Deployment E-Bay (2 tie-rods)	800*lbs* per tie-rod
E	Drogue Parachute (8 shroudlines, hemispherical)	400*lbs* per shroudline
F	Motor Mount (54mm)	
G	Fins (4, G10)	

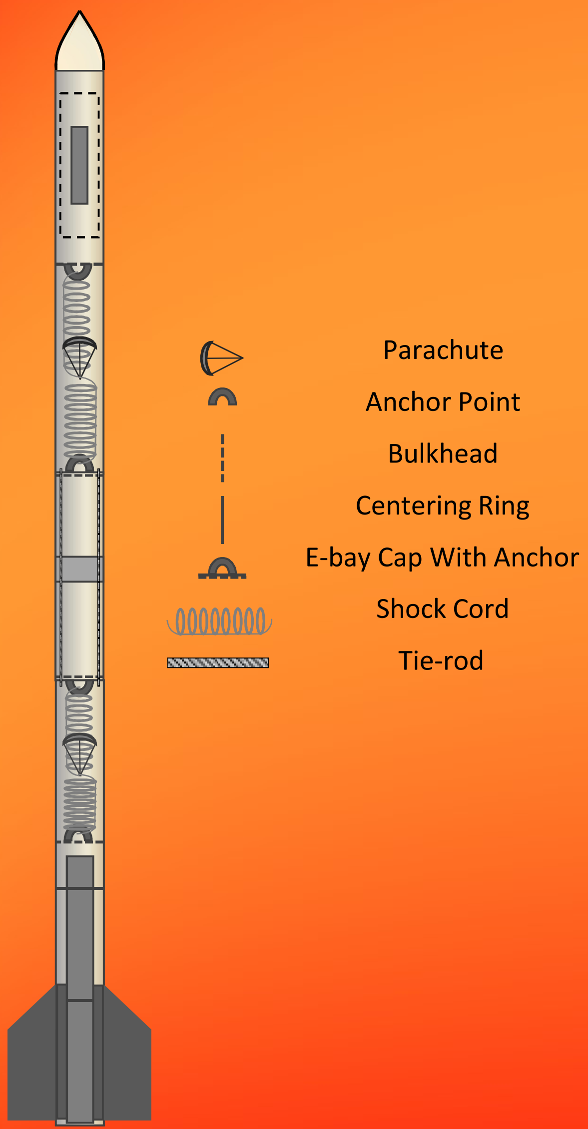
DIMENSIONED DRAWING OF VEHICLE



Nose Cone: ABS 3/32”, Von Karman
Payload Body Tube: Fiberglass 1/8”
Booster Body Tube: Fiberglass 1/8”
Coupler Tubes: Fiberglass 1/8”
Shockcords: ¼” tubular Kevlar, 3600#

Bulkheads: Fiberglass 1/8”
Attachment Points: U-Bolts 1/4”
Tie-rods: #8/32 stainless steel
Fins: Fiberglass 1/8”
Centering Rings: Fiberglass 1/8”

CONSTRUCTION MATERIALS



- **Body:** 3” fiberglass (1/8”) tubing
- **Nosecone:** 3D-printed ABS, Von Karman shape
- **Payload:** PVC tube with dome caps, schedule 40
- **Payload door:** cutout from 1/8” fiberglass tube
- **Payload section reinforcement:** 1/8” fiberglass coupler
- **Shockcords:** 1/4” tubular Kevlar
- **Anchors:** 1/4" stainless steel U-Bolts
- **Bulkheads, centering rings:** fiberglass
- **Motor mount:** 54*mm* Kraft Phenolic
- **Rail buttons:** standard Nylon rail buttons
- **Fins:** 1/8” G10 fiberglass, TTW fins
- **Motor retention system**: Aeropack screw-on motor retainer
- **Epoxy:** West System epoxy, DP420, Loctite

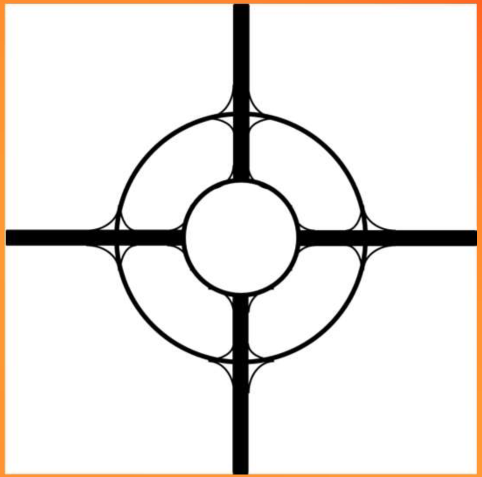
VEHICLE STRENGTH ANALYSIS

Rocket Part	Material	Supplier	Part No.	Strength
Nosecone	3D printed ABS	Madison West	N/A	Flight tested
Tubing	Fiberglass, 75mm tube	Wildman Rocketry	G12-3.0	Flight tested
Fins	1/8" G10 garolite, beveled, TTW	McMaster-Carr	8667K213	Flight tested
Parachutes	Ripstop nylon	Giant Leap	N/A	400lbs shroudlines (8), ripstop nylon
Couplers	Fiberglass	Wildman Rocketry	G12CT-3.0-9	Flight tested
Motor Mount	Fiberglass, 54mm tube	Wildman Rocketry	G12-2.0	Flight tested
Centering Rings, Bulkheads	Fiberglass, 2x1/8"	McMaster-Carr	8667K213	Flight tested
Anchors	¼" stainless steel U-bolts	McMaster-Carr	3201T45	2000lbs
Shockcords	¼" tubular Kevlar	Wildman Rocketry	KEVLAR1/4"	3600lbs
Tie-rods	8/32 stainless steel threaded rods	McMaster-Carr	93250A05	800lbs per tie-rod, 2 tie-rods used

Calculated maximum deployment force: 700*lbs*
Weakest point of rocket: tie-rod connection 1,600*lbs*

CONTRUCTION TECHNIQUES

- All-fiberglass construction
- Fiberglass surfaces sanded prior bonding (penetration)
- West System epoxy for glue bonds (#105/#205, 24hrs)
- Loctite #271 to secure all screws and nuts
- Braided gauge #22 wire for electrical connections
- Through-the-wall fins with root/inner/outer fillets
- #4/40 metal screws for avionics mount
- Rail buttons mounted through-the-wall (screw/nut)



West Epoxy System with appropriate fillers to lighten and strengthen the bonds

Through-the-wall mounted fins with

- Root edge fillets
- Inner fillets
- Outer fillets

VEHICLE 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

SCALE MODEL TEST FLIGHT RESULTS

2/3 Scale Model	
Vehicle Diameter	2.2in
Vehicle Length	40in
Liftoff Weight	2.3lbs
Motor	AT-G339N, 109Ns
Flight Apogee	927ft
Calculated C_d	**0.95**

Low flight (field limitations) might have yielded C_d with significant measurement error (expected value was ~0.70). This will be addressed later during propulsion choice analysis

PROPULSION SELECTION RATIONALE

	Cd = 0.70		Cd = 0.95		Ballast *[lbs]*
Motor	**Apogee** *[ft AGL]*	**v_{exit}** *[mph]*	**Apogee** *[ft AGL]*	**v_{exit}** *[mph]*	
J449BS	5944	40	5134	40	1.4
J295C	5578	37	4876	37	0.3
J355RL	5462	37	4784	37	0.3
J380SS	4570	35	4062	35	N/A
J1520VM	4986	77	4321	77	N/A
J760WT	6009	51	5125	51	1.6

- J760WT and J449BS have sufficient rail exit velocity (v_{exit}) from 5*ft* rail
- J760WT and J449BS have one mile reach even considering C_d = 0.95 (measured)
- J760WT and J449BS can be ballasted to one mile considering C_d = 0.70 (expected)

J760WT is the primary propulsion choice, J449BS is the backup choice

We are considering both C_d = 0.70 and C_d = 0.95 scenarios because we suspect that our scale flight (limited to 1,000ft apogee) might have significant measurement error related to C_d calculation via model anchoring.

PROPULSION SELECTION

- We selected the CTI J760WT motor as our primary propulsion choice
- We selected the CTI J449BS motor as our secondary propulsion choice

Length [mm]	Mass [lbs]	Diameter [mm]	Motor Selection	Stability Margin [calibers]	Thrust to weight ratio
321	2.37	54	CTI J760WT	2.4	20.5
321	2.47	54	CTI J449BS	2.4	12.8

FLIGHT SAFETY PARAMETERS MATURITY OF DESIGN

Parameter	Value
Flight Stability Static Margin	**2.4** *calibers*
Thrust to Weight Ratio	**20.5**
Velocity at Launch Guide Departure (5ft launch rail)	**50.2** *mph*

MASS STATEMENT

- **Current Status**
  - Our rocket currently has a mass of 10.1*lb*, which includes a 2.37*lbs* CTI J760WT motor.
  - This is an actual liftoff weight of our rocket, the full scale vehicle construction has been completed.

- **Ballast Impact**
  - The rocket may need 1.6*lbs* of ballast to limit flight apogee to 1*mile* (verification of C_d pending).
  - The rocket would have to gain 30*lbs* for the thrust to weight ratio to drop under 5 (underpowered rocket). Since the rocket has been constructed, this scenario is no longer realistic.

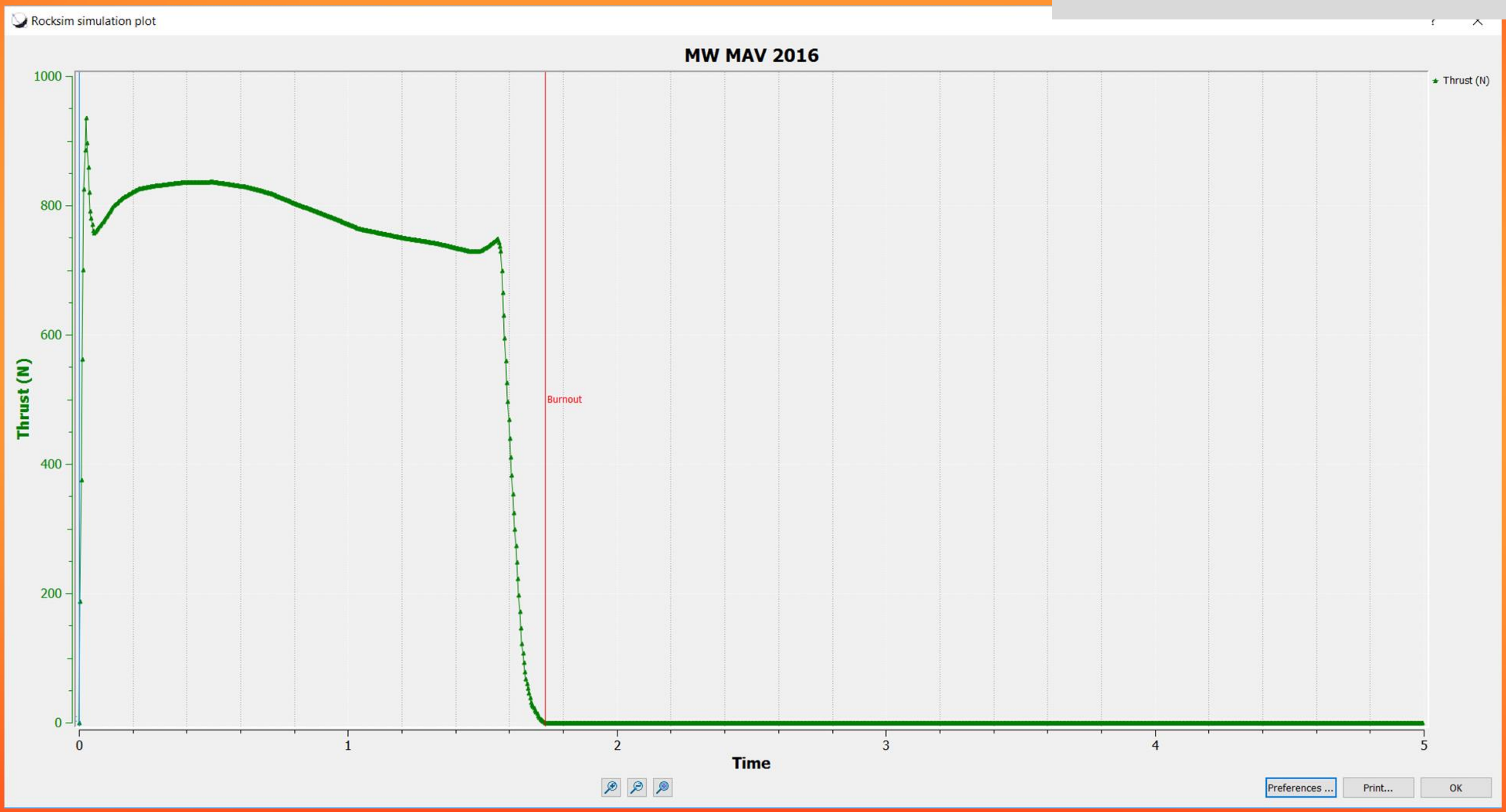
ANCHORED FLIGHT PERFORMANCE PREDICTIONS

Parameter	Value	Source / Justification
Coefficient of drag	0.95	*2/3 scale model fight*
Liftoff weight	10.1*lbs*	*actual weight*
Motor	CTI J760WT	*anchored simulation results*
Wind speed	15*mph*	*expected for AL, April*
Launch rail length	5*ft*	*anchored simulation results*
Launch rail angle	5^{o} downwind	*MAV rules*

THRUST CURVE

Max. Thrust: 937*N*
Burn Time: 1.8*s*

Thrust [*Ns*]



Time [*s*]

ALTITUDE PROFILE

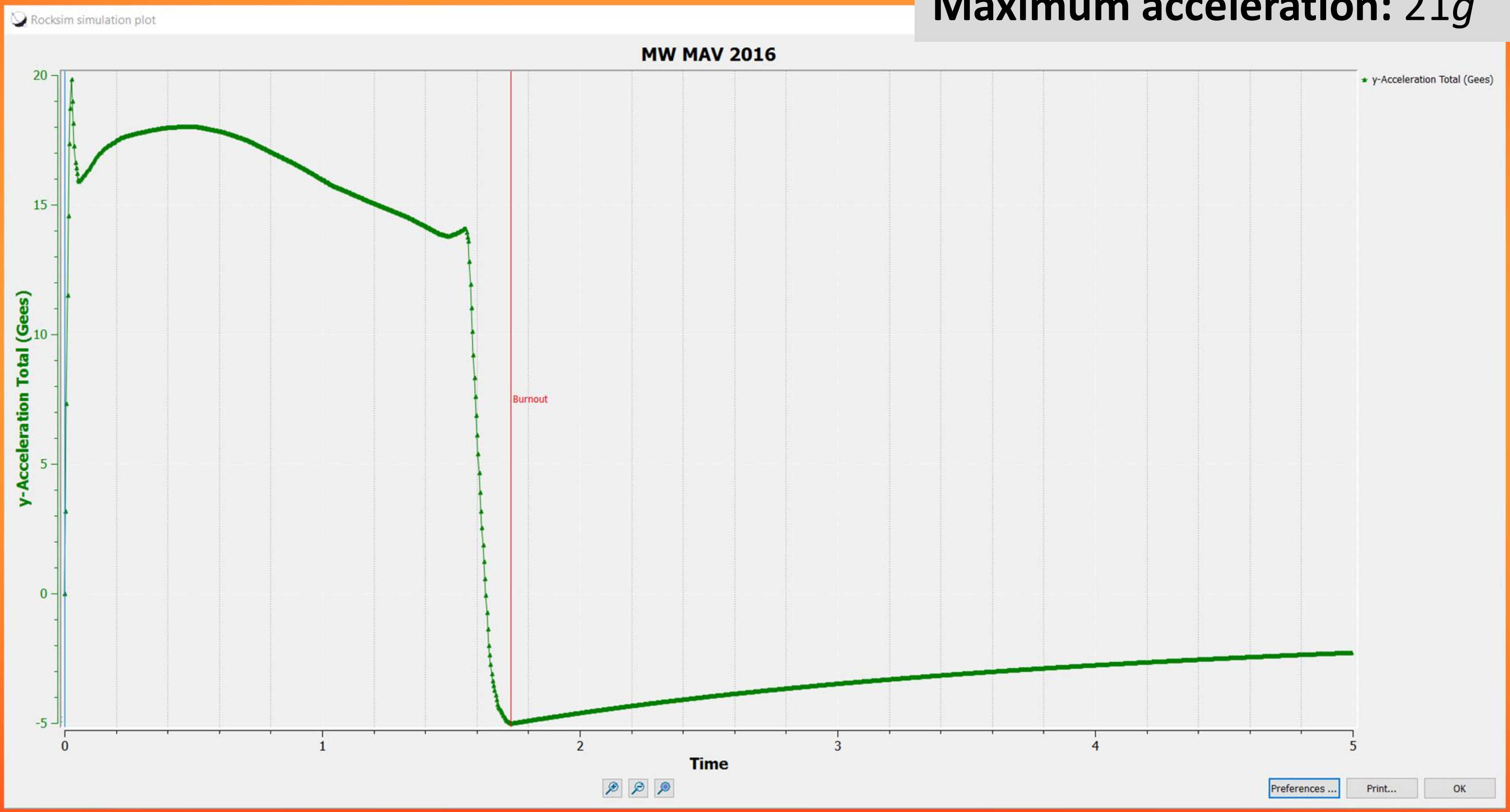
Apogee: $5125ft$, $16s$

Altitude $[ft]$

Time $[s]$

ACCELERATION PROFILE

Maximum acceleration: 21g



Acceleration [g]

Time [s]

VELOCITY PROFILE

Max. velocity: 580*mph*
Mach number: 0.756
subsonic

Von Karman nosecone

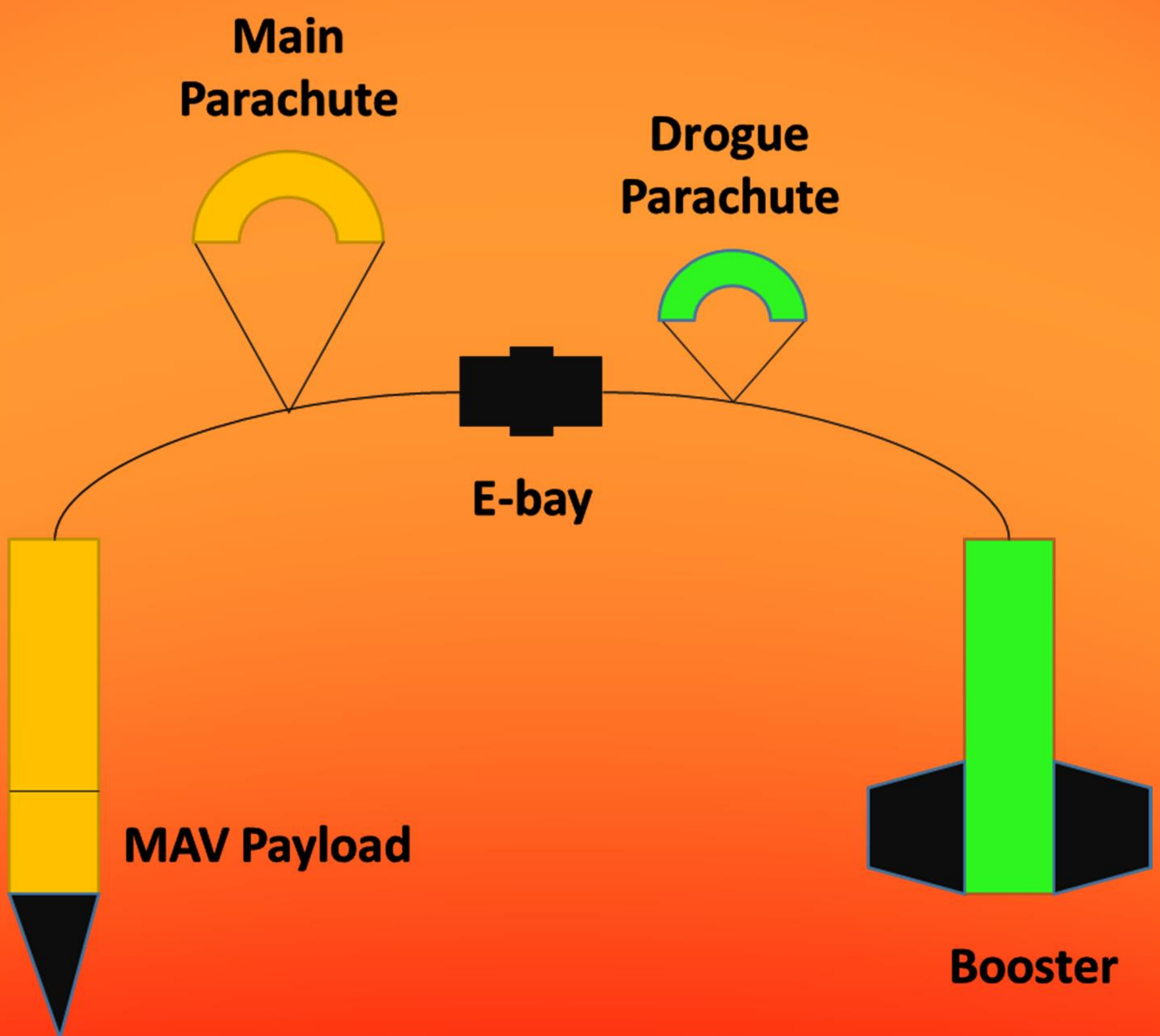
Velocity [*mph*]

Time [*s*]

ALTITUDE VS. WIND SPEED

Wind Speed *[mph]*	**Altitude** *[ft]*	**Change in Apogee** *[%]*
0	5125	0.00
5	5147	0.43
10	5158	0.64
15	5159	0.66
20	5147	0.43

DEPLOYMENT SCHEME



EJECTION CHARGE CALCULATIONS

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

- *Wp* - ejection charge weight *[g]*
- *dP* - ejection pressure (15 *[psi]*)
- *V* - pressurized volume *[in^3]*
- *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	0.93* / 1.50†
Main	0.83* / 1.50†

* **Calculated ejection charge** – serves a base value for static tests

† **Final ejection test size** (as determined by static tests, using two #2/56 nylon shear pins)

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

PDR Feedback
Item #1

PARACHUTE SIZE

Parachute	Diameter *[in]*	Descent Rate *[fps]*	Ejection Charge *[g]*	Deployment Altitude *[ft]*	Descent Weight *[lbs]*	Impact Energy *[ft.lb-f]*
Drogue	18	78.1	1.50†	5125	8.8	--
Main	60	23.4	1.50†	700	0.9 2.6 5.3	7.5* 22.5* 45.0*

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

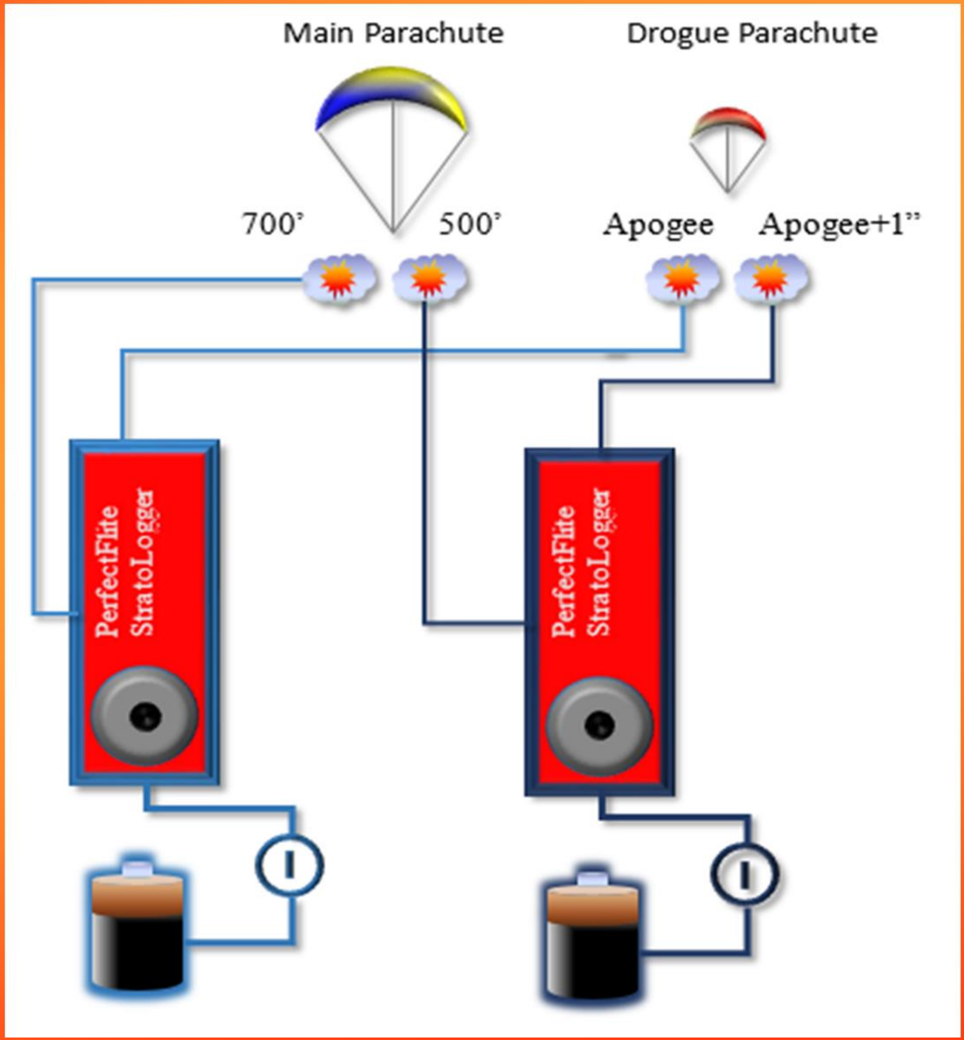
† Ejection charge sizes listed are results of static testing (the charge size was precalculated and then adjusted during static ejection tests on the ground).

DEPLOYMENT SYSTEM STRENGTH

Component	Material	Breaking force
Shockcords	¼" tubular Kevlar	3,600*lbs*
Thermal protectors	Nomex sheets	N/A
Parachutes	Rip-stop nylon, 8 nylon shroudlines, SpheraChute	400*lbs* per shroudline (× 8)
Anchors	¼" stainless steel U-bolts	2,000*lbs*
Bulkheads (anchor hosts)	½" G10FR fire retardant garolite	
Tie-rods	#8 stainless steel threaded rods	800*lbs* (× 2)
Tie-rod nuts	#8 brass knurled nuts	N/A
Electrical matches	M-tek, electrical current 0.3*A* no-fire, 0.7*A* all-fire	N/A
Terminal blocks	Nylon screw terminals	N/A

Recovery system can withstand forces of 1,600*lbs,* maximum calculated load is 700*lbs*

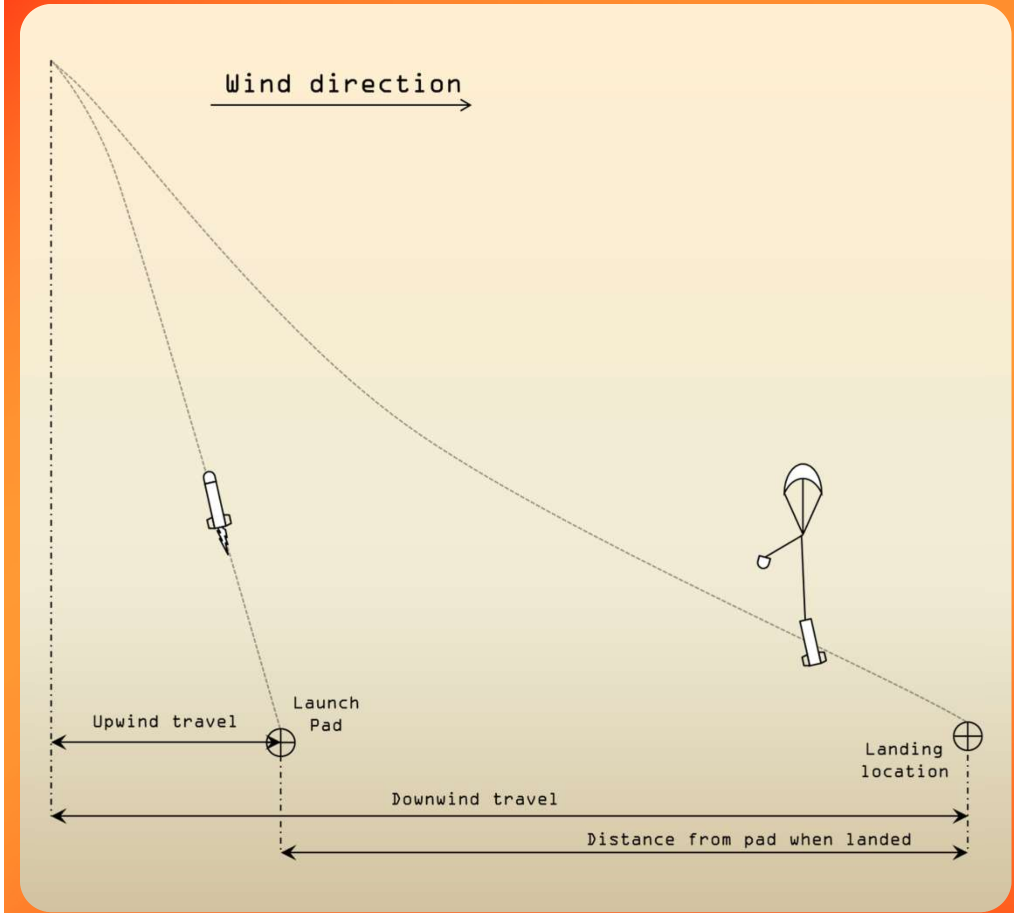
REDUNDANT DEPLOYMENT



All active avionics is **fully redundant**. Each Perfectflite Stratologger CF altimeter has a dedicated *battery*, set of *ejection charges* and arming *switch*.

All barometric devices are equipped with automatic **Mach delay** feature to prevent false detection of apogee in transonic regime.

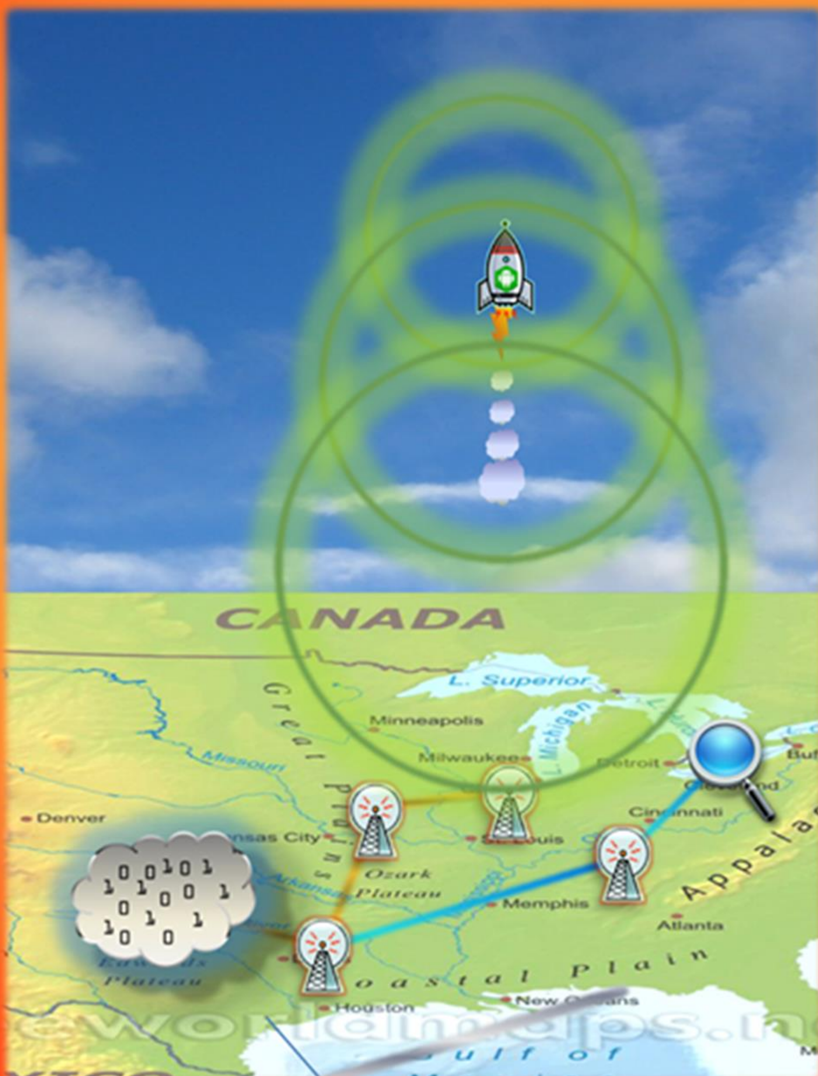
VEHICLE DRIFT PREDICTIONS



The distance from launch pad to the landing location is a sum of upwind travel (negative value, if rocket travels against wind) and downwind travel (positive value, if rocket drifted downwind). Due to the mandated 5° downwind launch angle, most upwind travel values (except one for 20mph wind speed) are positive for our project (weathercocking is compensated by launch rail angle).

Wind speed [mph]	Upwind Travel [ft]	Downwind Travel [ft]	Distance from pad when landed [ft]	Distance from pad when landed [mile]
0	760	0	760	0.144
5	542	635	1177	0.223
10	338	1272	1610	0.305
15	136	1908	2044	0.387
20	-66	2539	2473	0.468

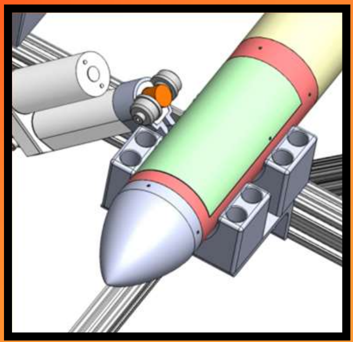
TRACKING AND TELEMETRY



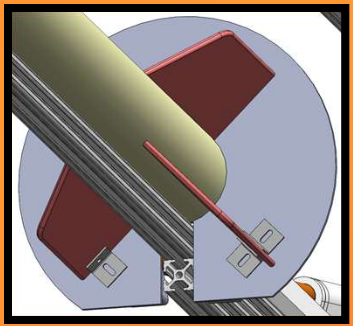
CLOUD AIDED TELEMETRY : Cloud-Aided-Telemetry (CAT) system uses an on-board Android device and app to transmit flight, tracking and payload data from an airborne rocket using any available cellular network. The data travel along orange route to our data cloud (located in Houston, TX) from where they 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 TO AGSE INTERFACES

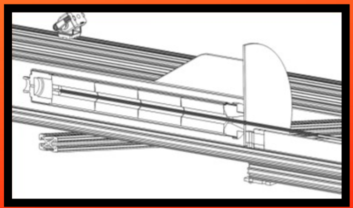


The *front cradle* is used to support the rocket during payload insertion and payload door operation.



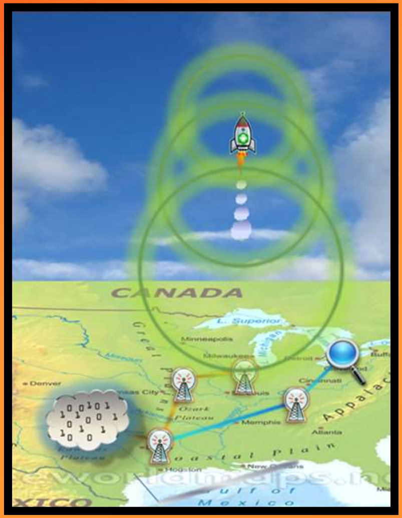
The *aft stabilization* system is used to prevent rocket from rolling off the rail during payload insertion and rail erection

Rail buttons guide the rocket along the launch rail.

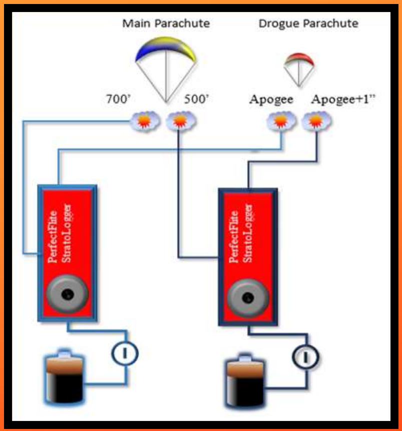


Igniter insertion system inserts an igniter into motor bore

OTHER INTERFACES



Both *tracking* systems (radio beacons and CAT tracker) are *vehicle to ground* interface (both are wireless)



***Internal interface*: deployment electronics and ejection charges**

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

Verifications

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.

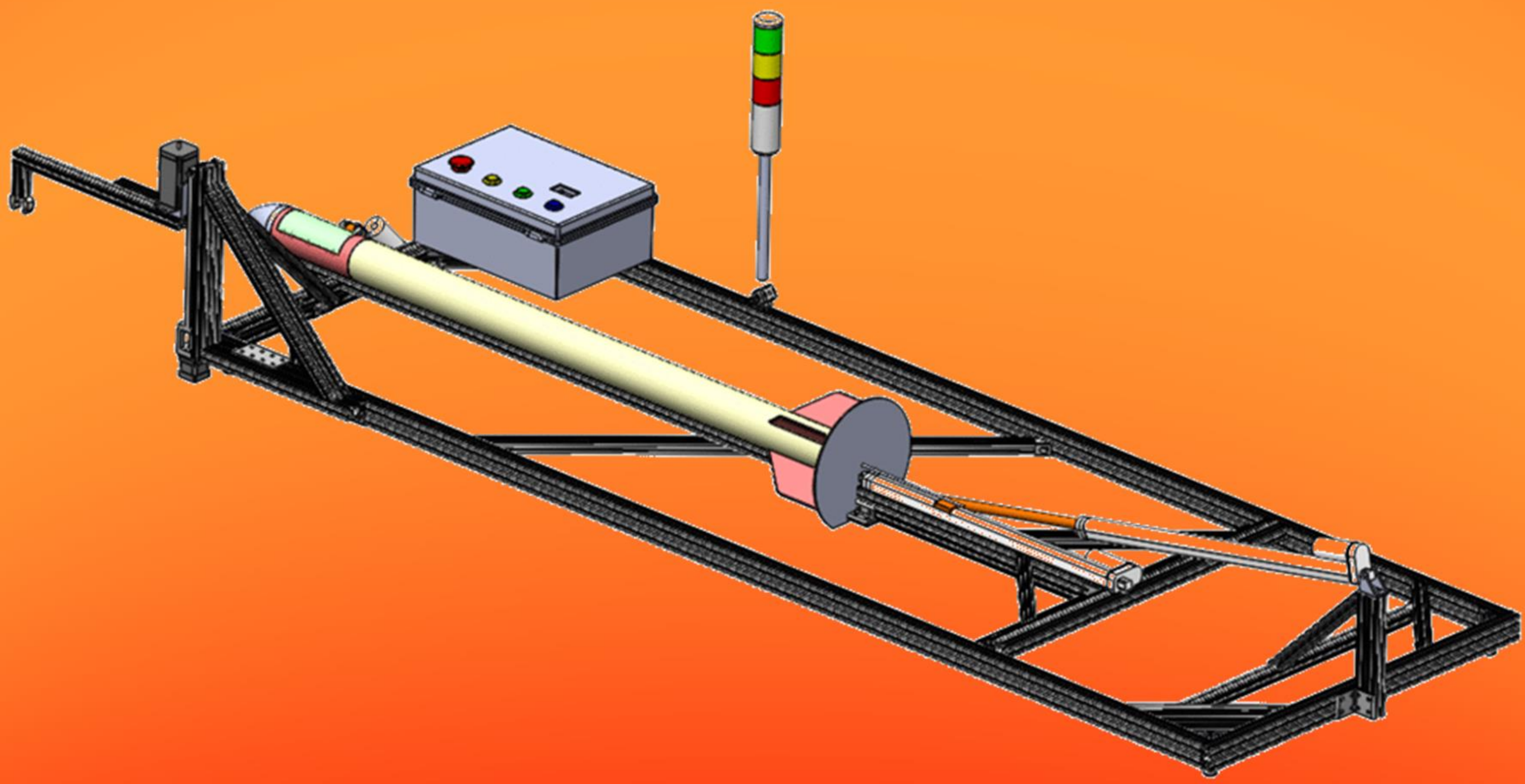
V5: Full Scale Vehicle: verifies the vehicle performance

VERIFICATION MATRIX

	V1	V2	V3	V4	V5
C1	1.2	2.5	2.4	1.2	1.2
C2	2.5	1.3	1.4	1.4	1.4
C3	1.5	2.5	1.12	1.2	1.2
C4	1.7	1.7	1.12	1.7	1.7
C5	2.2	2.5	1.12	1.13.1	1.13.1
C6	2.11	2.5	2.11	2.11	2.11
C7	1.8	2.5	1.8	1.8	1.8

P = planned, C = successfully completed
Status: Verification is in progress

PART II: AGSE

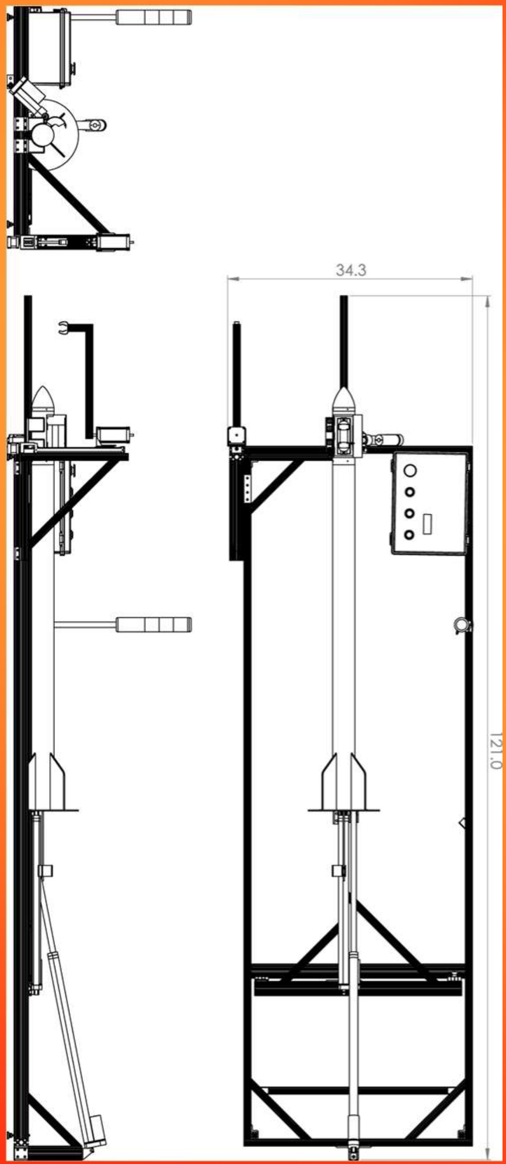


AGSE TASKS

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

AGSE SUPERSTRUCTURE

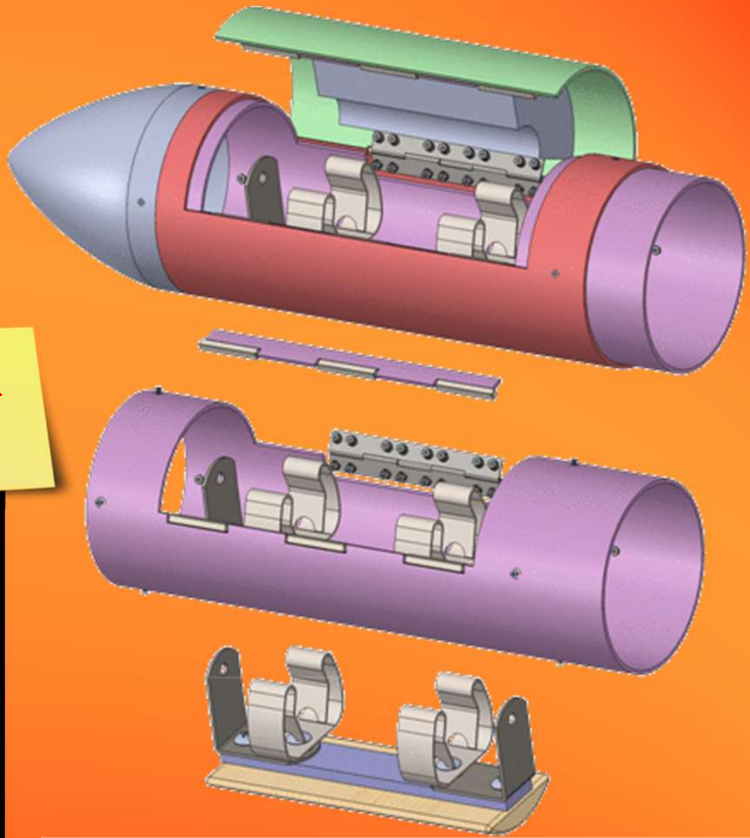
- Meets volume, mass, and performance requirements
- Envelope approximately 10 x 3 x 2 *ft*^{3} closed, 9 x 8 x 2 *ft*^{3} in launch configuration
- Full system (with rocket) weighs less than 90 *lbs*



PAYLOAD SECUREMENT SYSTEM

The payload securement system uses a set of passive grippers to secure the payload. Magnets are used to secure the door with ***30lbs*** of force.

PDR Feedback Items #3, #4



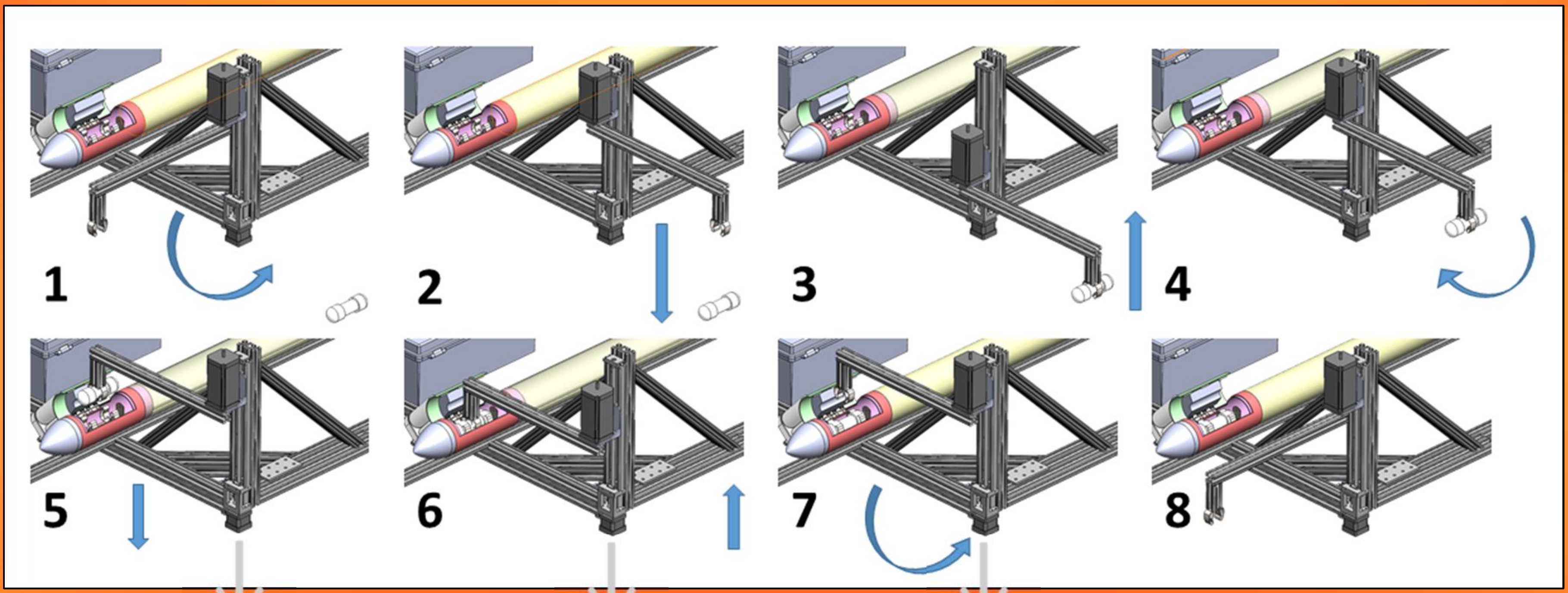
Coupler reinforces payload compartment to compensate for weakened structure.

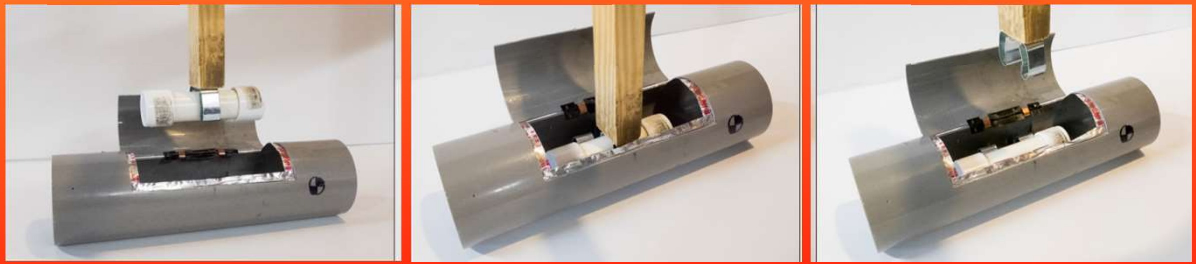
PDR Feedback Item #2

PAYLOAD RETRIEVAL AND INSERTION

Payload placement guide (laser mark)

1-8 RETRIEVAL AND INSERTION SEQUENCE

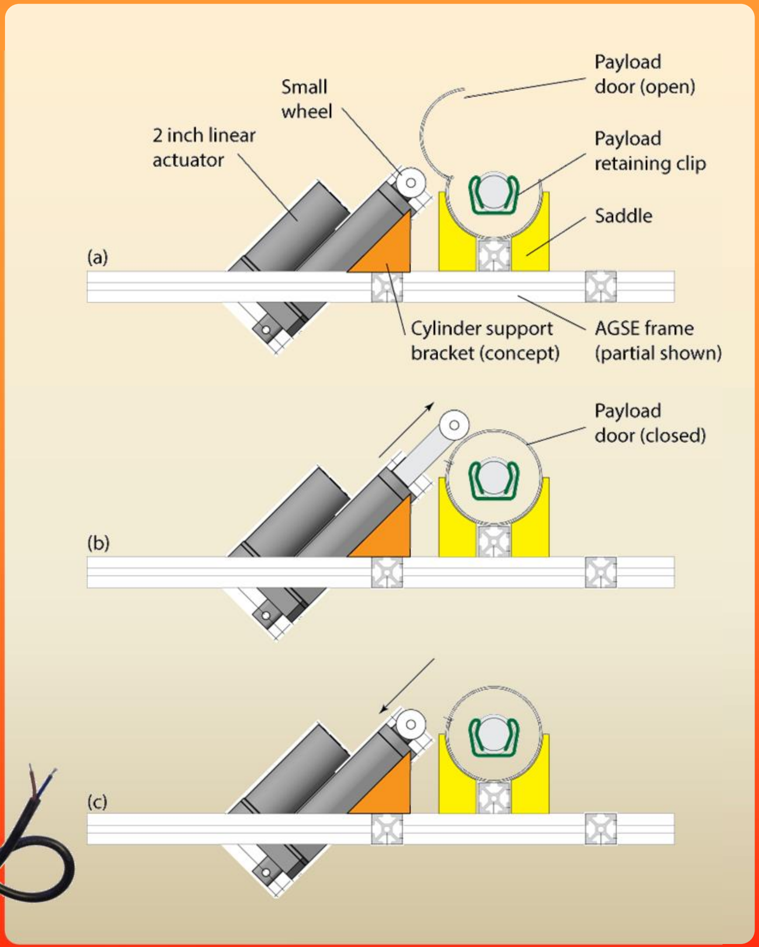




Pretotype demonstration of payload insertion and retention utilizing 2:1 grip:retain force ratio

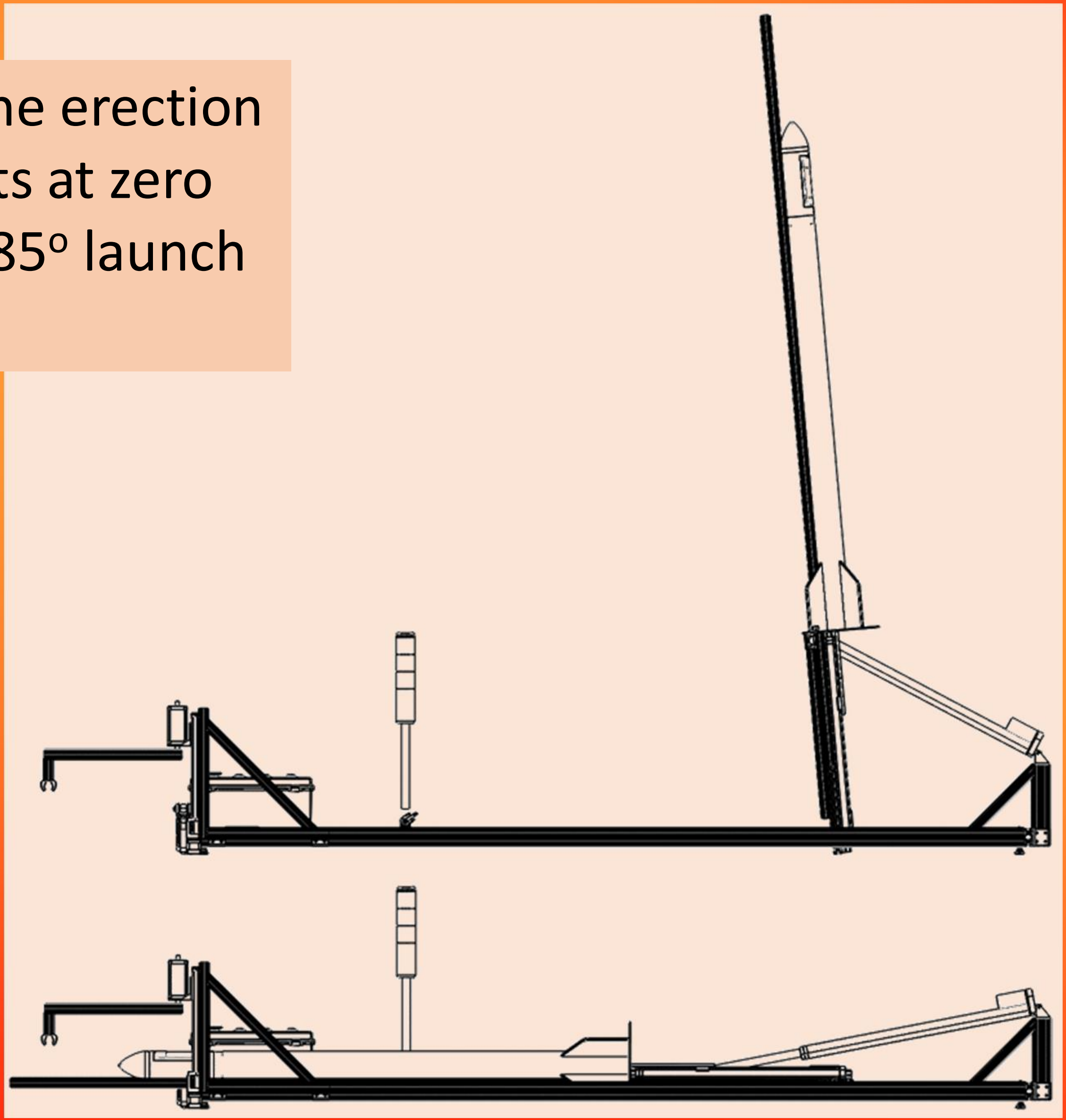
DOOR CLOSURE SYSTEM

Door is held open for loading by oversprung hinge. Linear actuator closes the door. Oversprung hinge and magnets (30*lbs* of force) hold the door closed during flight.

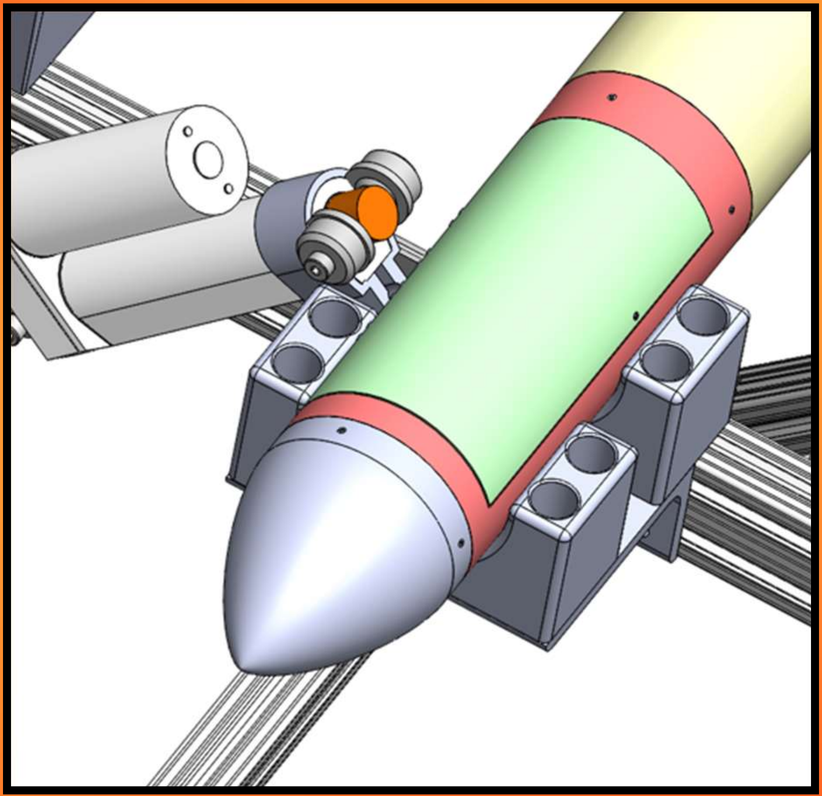


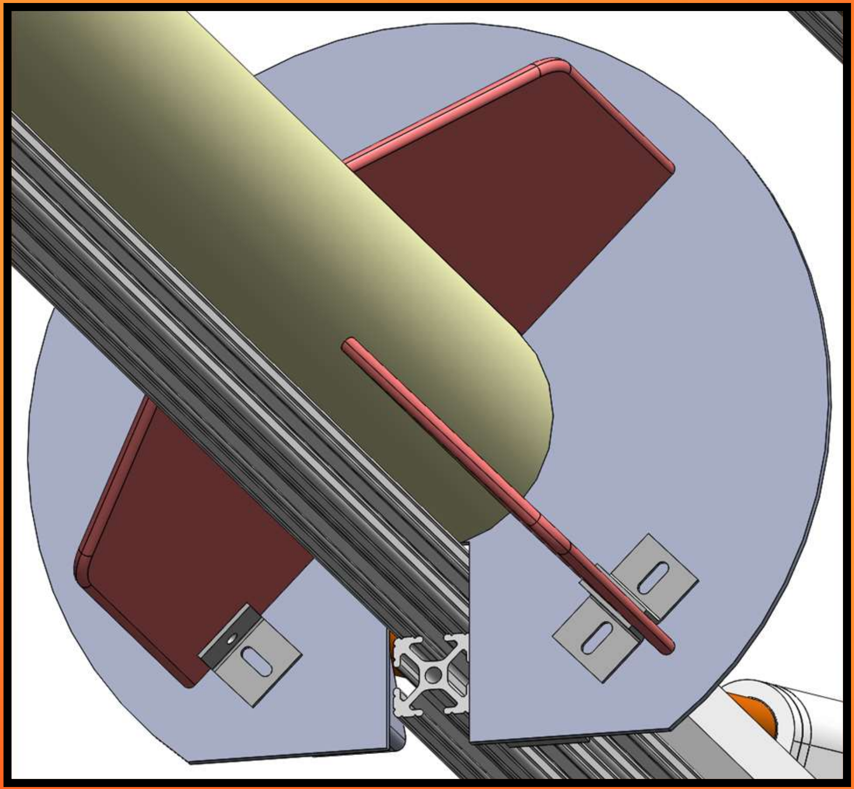
THE ERECTION SYSTEM

Linear actuator is used for the erection system. Linear actuator starts at zero angle and pulls the rail to a 85° launch position.



ROCKET STABILIZATION



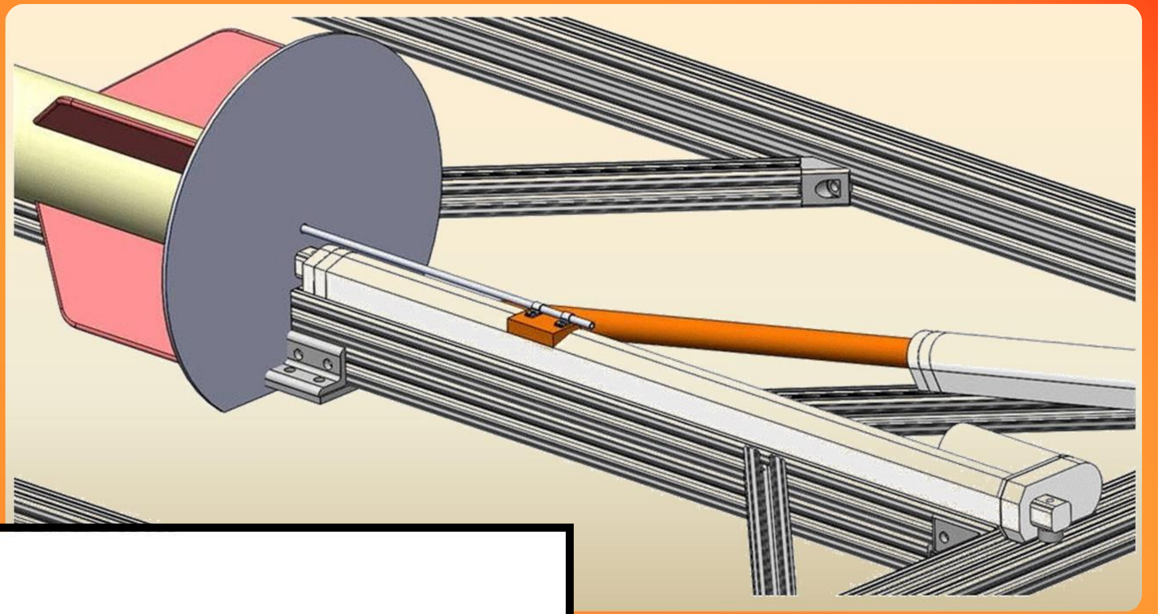


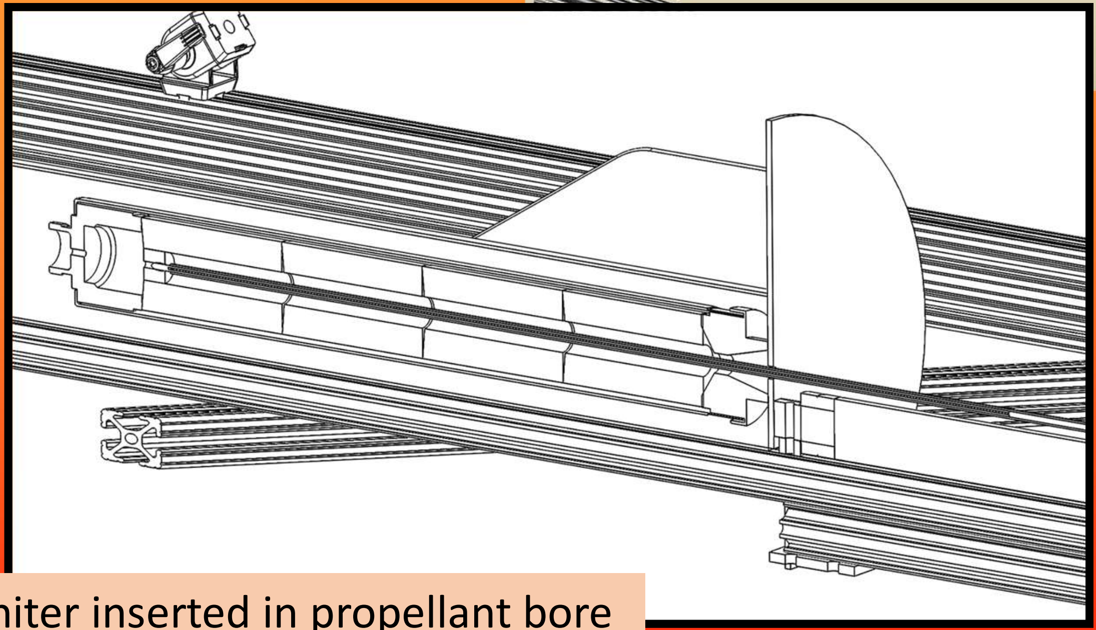
The front cradle is used to support the rocket during payload insertion and payload door operation.

The aft stabilization system is used to prevent rocket from tilting the rail (damaging rail buttons) during payload insertion and rail erection

THE IGNITER INSERTION SYSTEM

Linear actuator is used to insert igniter into the motor. The igniter is housed in a single use carbon tube to avoid problems with igniter wire crumpling.

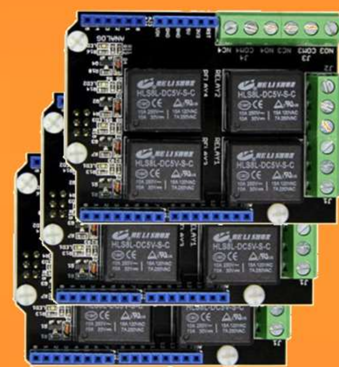




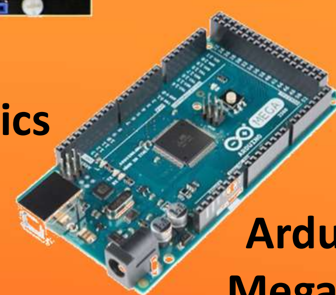
Igniter inserted in propellant bore

CONTROL DRIVER

Information display



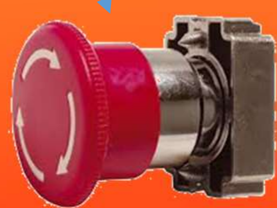
Driver electronics



Arduino Mega2560

Stack lights (information)

Control panel

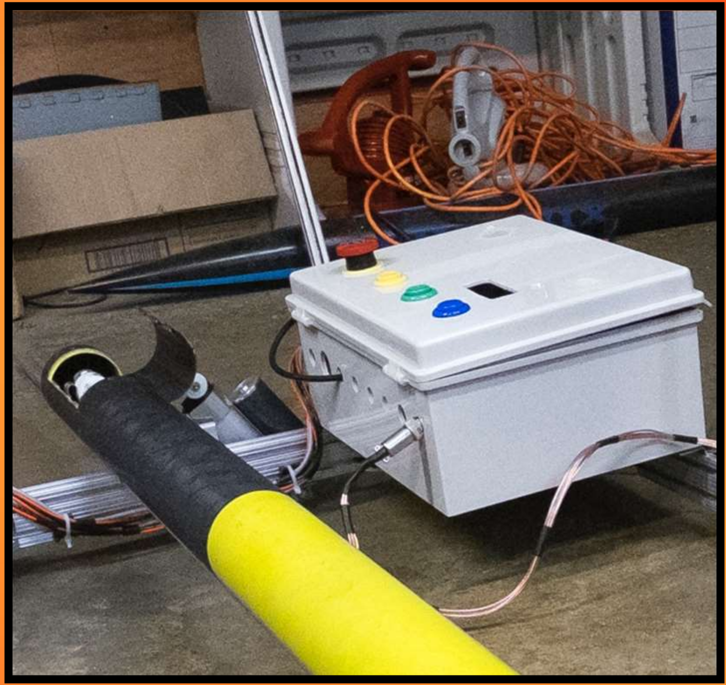


E-stop button

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

Power source (battery)

CONTROL PANEL



Returns AGSE to <u>HOME</u> position

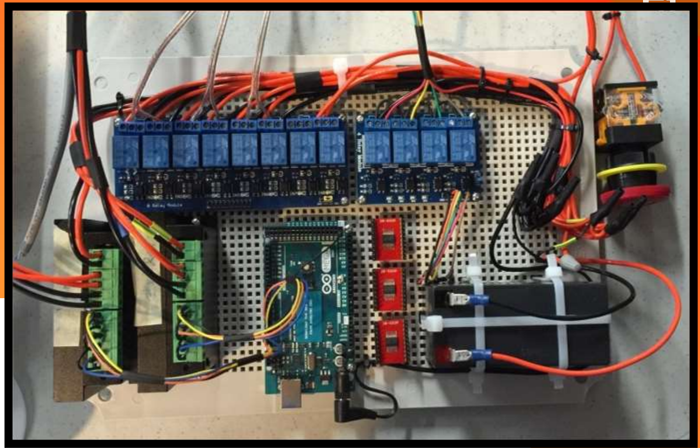
<u>START</u>s/resumes autonomous operation of AGSE

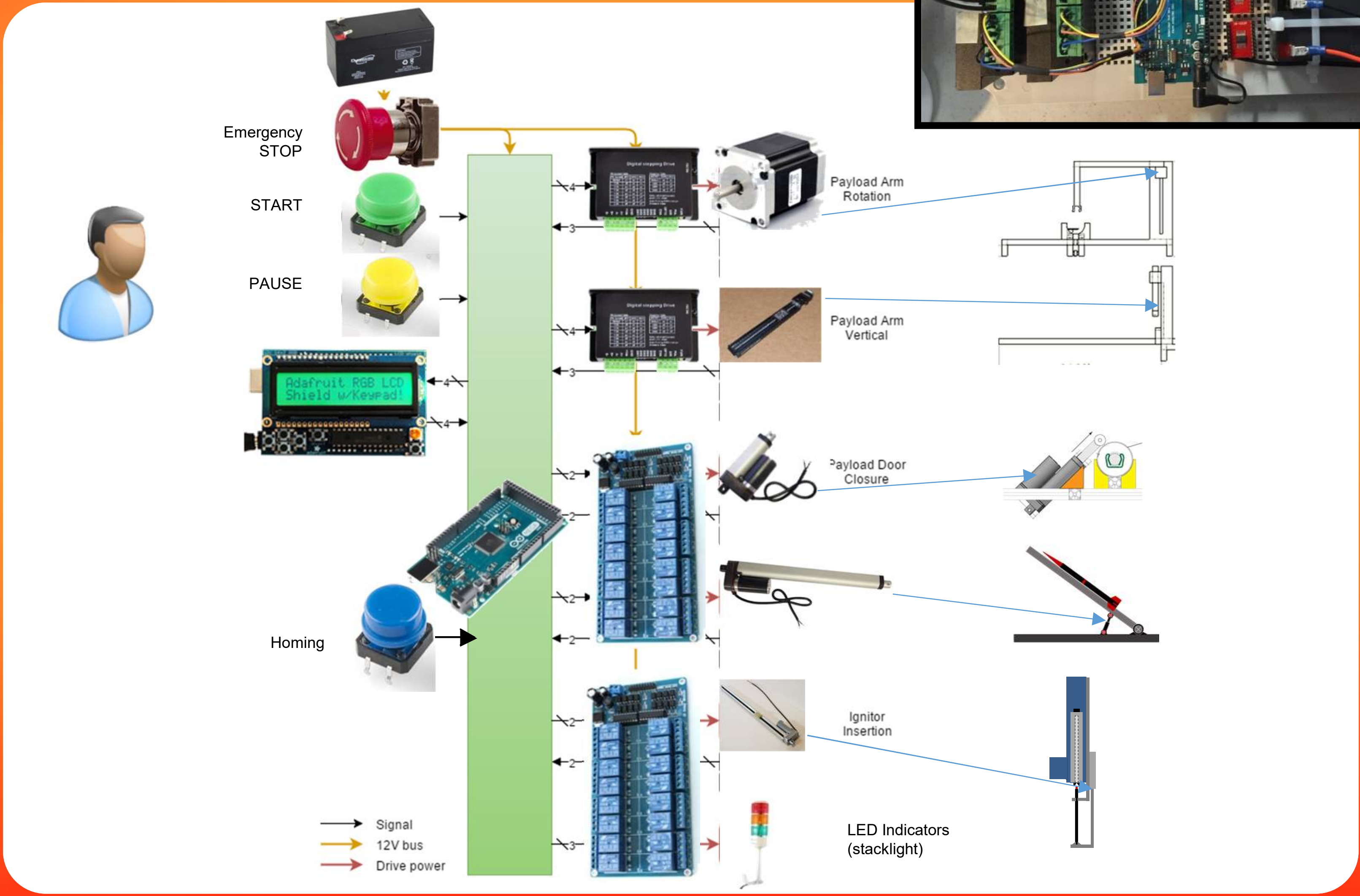
<u>PAUSE</u>s autonomous operation of AGSE

Physically disconnects power (emergency <u>STOP</u>)

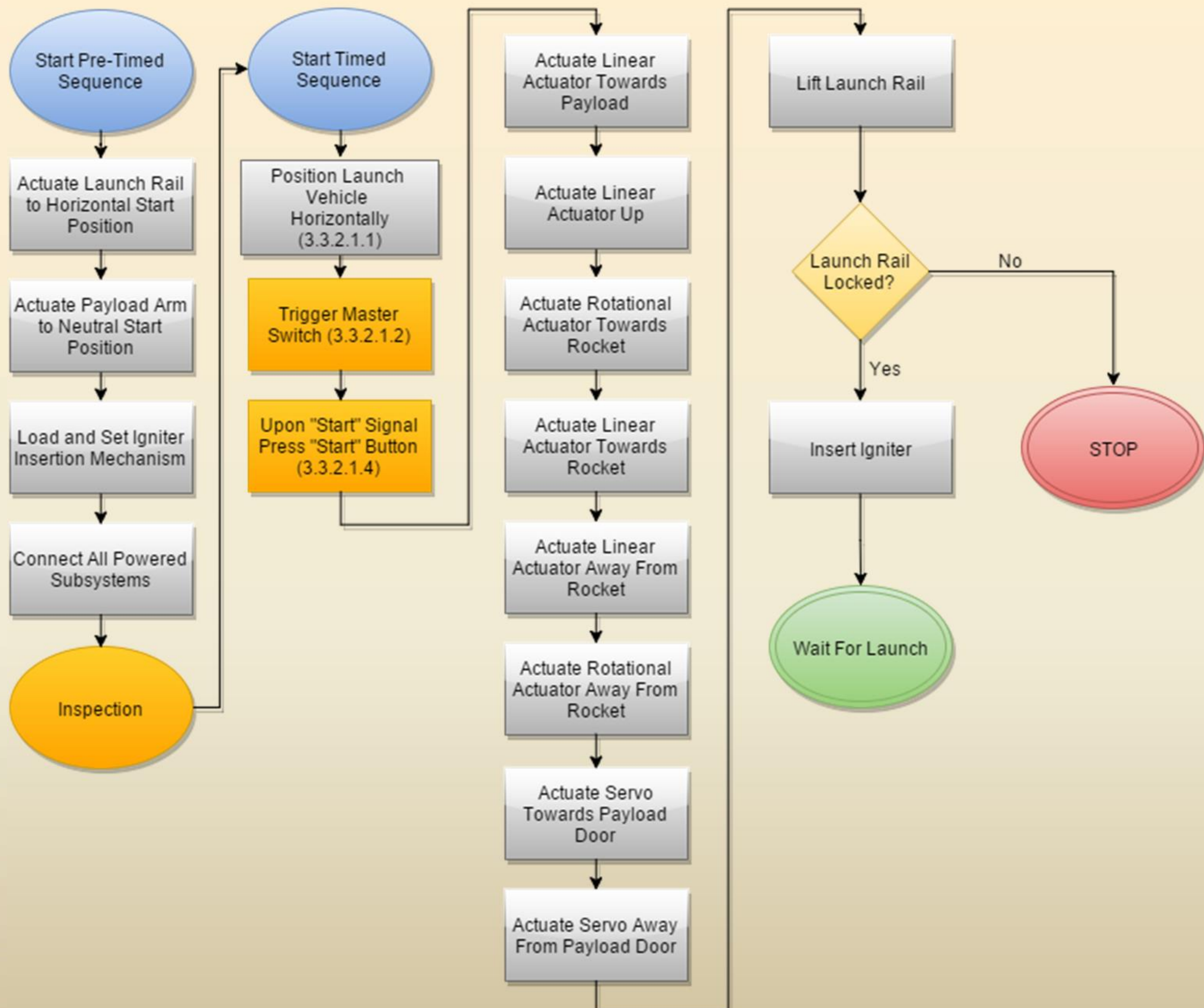
Information display

AGSE BLOCK DIAGRAM





PROCESS FLOW



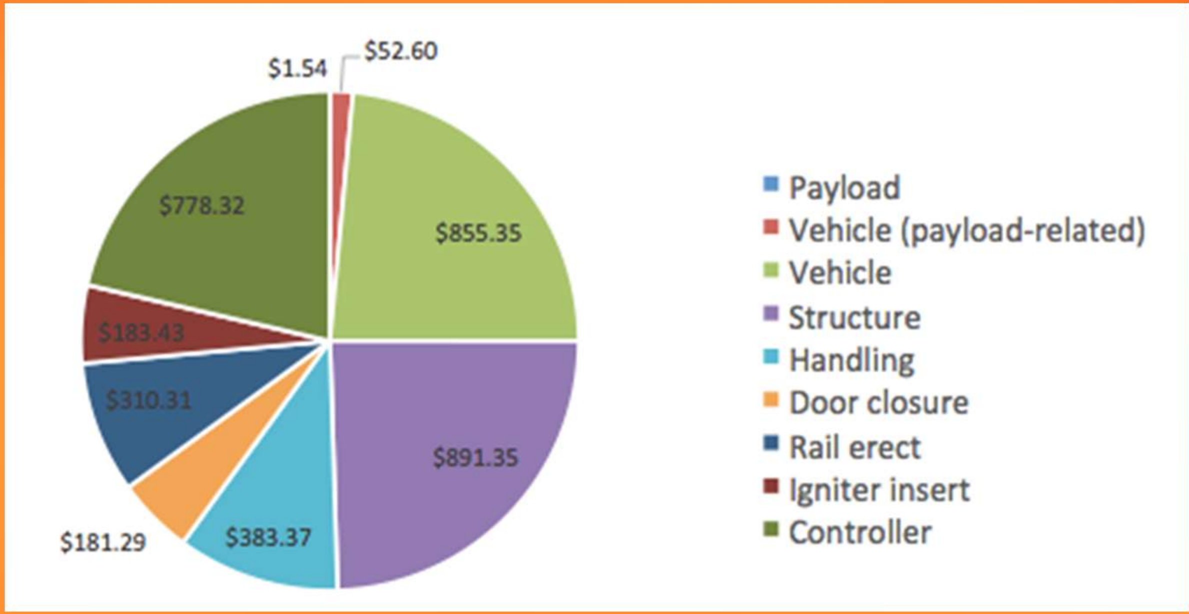
TIME TO COMPLETE SEQUENCE

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	15	
9	Push door closed	10	
9b	Check microswitches	1	
10	Retreat door push plunger	10	
10b	Check microswitches	1	
11	Erect launch rail	90	
11b	Check microswitches	1	
12	Insert igniter	30	
12b	Check microswitches	1	
13	Signal "complete"	2	
		279	sec
		4.7	**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

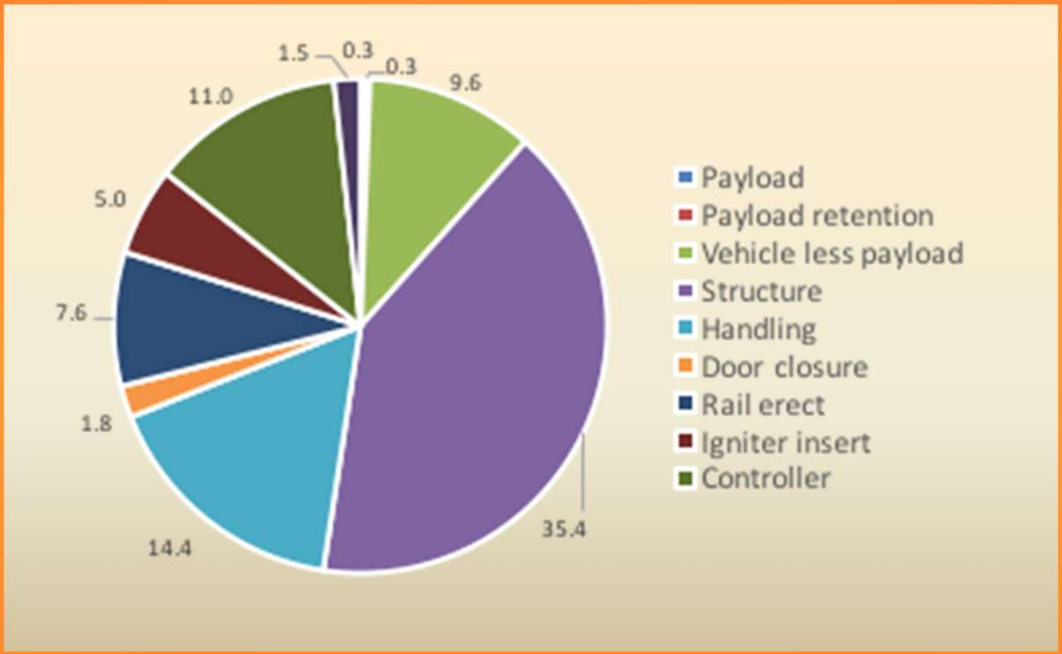
BUDGET



Subsystem	Cost	Comment
Payload	$1.54	just the PVC payload and weighting
Vehicle (payload-related)	$52.60	includes items required to retain and secure the payload
Vehicle	$855.35	all aspects of the rocket including structure, propulsion, recovery, telemetry
Structure	$891.35	the static superstructure of the ASGE
Handling	$383.37	the robotic motion control for acquiring and depositing the payload
Door closure	$181.29	means for closing door and holding rocket
Rail erect	$310.31	lifting the launch rail into a near-vertical position
Igniter insert	$183.43	insertion of the igniter into the engine
Controller	$778.32	all aspects of control including microcontroller, drivers, indicators, safety lights, housing, and power
	$3,637.55	

The Vertical Motion Stage was a surplus purchase for $117.95 but the fair market value was $1200.00, therefore the total should be $4719.60.

MASS ALLOCATION ESTIMATE



Subsystem	Mass (lbs)	Comment
Payload	0.3	just the PVC payload and weighting
Payload retention	0.3	includes items required to retain and secure the payload
Vehicle less payload	9.6	all aspects of the rocket including structure, propulsion, recovery, telemetry
Structure	35.4	the static superstructure of the ASGE
Handling	14.4	the robotic motion control for acquiring and depositing the payload
Door closure	1.8	means for closing door and holding rocket
Rail erect	7.6	lifting the launch rail into a near-vertical position
Igniter insert	5.0	insertion of the igniter into the engine
Controller	11.0	all aspects of control including microcontroller, drivers, indicators, safety lights, housing, and p
Remote	1.5	remote control dongle
TOTAL	**86.8**	

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				3.3.3.2		3.3.4		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	
C3	3.1				3.3.3.2		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	
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	
C6	3.1				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		3.3.4		3.3.3.3	
C8	3.1				3.3.3.2		3.3.4		3.3.3.3	

P = planned, C = successfully completed

Status: Verification will begin after PDR conference.

PAYLOAD COMPARTMENT FLIGHT STRESS TEST

We have launched the payload compartment using auxiliary booster (Competitor kit) and CTI J1520VM motor. The payload door remained closed during flight and landing, however the payload has shifted forward and dislodged from the front clip. The shift forward indicates that the payload retention failed during deployment or landing, not during boost. A design modification will be made and the test will be repeated.

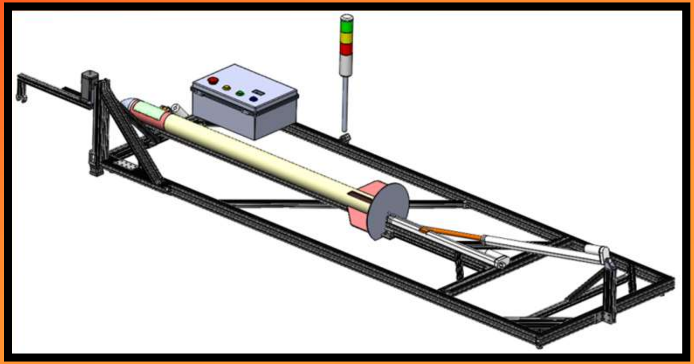
AGSE LAUNCH TESTS

INITIAL: F-class TARC rockets, 650g, to verify rail and blast deflector functionality

ADVANCED: H-class fiberglass/Blue Tube rockets, 1500g, to further test the blast deflector and to uncover possible stability problems

FINAL: J-class fiberglass rockets, 4500-5000g, to test AGSE robustness and launch capability under full intended load (1000N thrust). AGSE was tested up to 1700N thrust.

AGSE STATUS



AGSE STATUS

Superstructure: completed.

Movements: all linear actuators and stepper motors were tested and are suitable for the tasks assigned to them. All AGSE movements can be executed via manual activation of actuator/motors.

End switches: microswitches for detection of movement completion were tested and are being integrated with the superstructure.

Firmware: code has been developed for each AGSE movement, however the final code integration is not completed yet.

Controller: the design was finalized and the controller is in production.

Launch capability: AGSE is launch capable and has been tested using various rockets of gradually increasing size (up to 170% of maximum intended thrust).

OUTREACH PLAN

	Date	School	Outreach	# of People
✓	**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, Payload Displays	3,070
	Jan. 31, 2016	Science Bowl	Pneumatic Rockets, SLI projects	250
	Feb. 20, 2016	Physics Open House	Pneumatic Rockets, Displays, presentations	300
	Mar. 12, 2016	Franklin 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: 4,100

OUTREACH EVENTS FOR JAN, FEB, MAR

Science Bowl is a regional science contest for middle schools. As a break from fierce competition rounds, Madison West Rocketry will provide a hands-on activity (pneumatic rockets) and several displays of current and past SLI projects, including MAV AGSE. ***250 participants***

Physics Fair (accompanied by annual Wonders of Physics show) is an established event (9^{th} season this year) organized by Physics Dept. of UW Madison. Madison West Rocketry participated first time last year and we will be coming back this year as well. ***300 participants***

Several elementary and middle schools in Madison Metropolitan School District hold annual Super Science Saturday events where participants meet scientists from different fields and explore scientific topics via interactive displays and hands-on displays. ***180 participants***


QUESTIONS?