MARS ASCENT VEHICLE
CENTENNIAL CHALLENGE

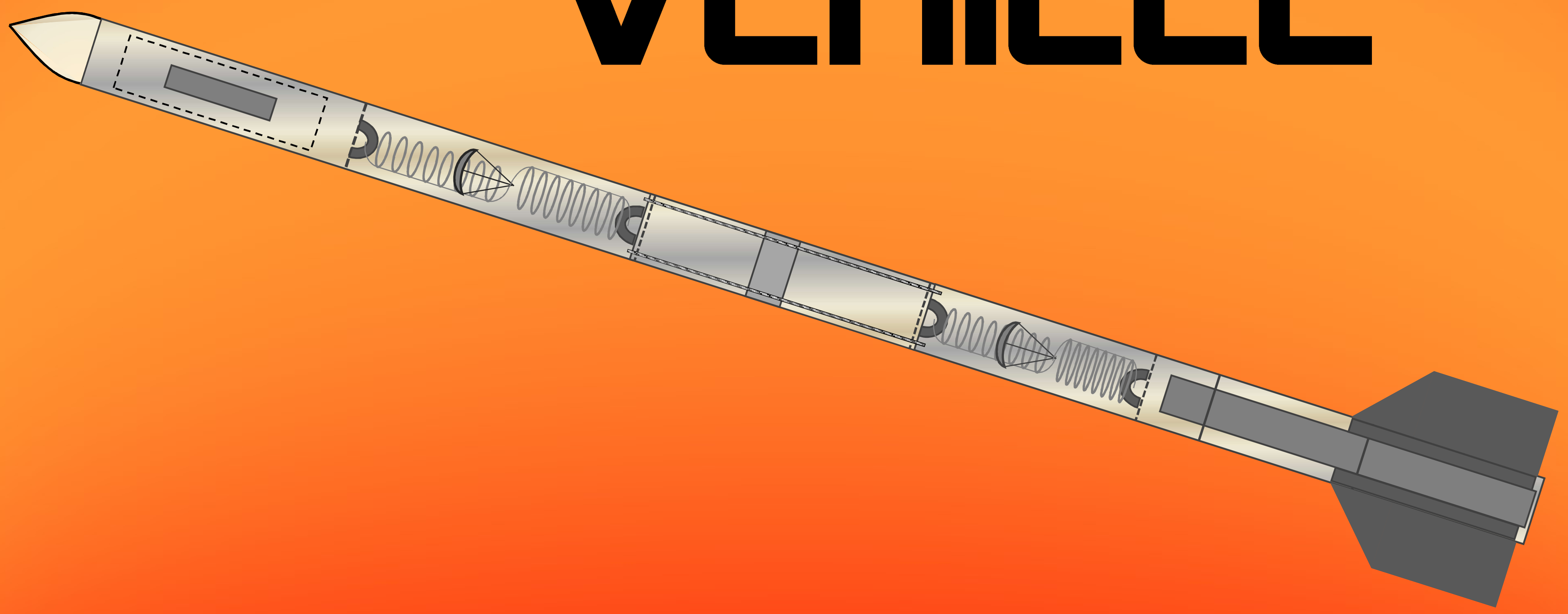
DESIGN, DEVELOPMENT, AND LAUNCH OF A REUSABLE ROCKET AND AUTONOMOUS GROUND SUPPORT EQUIPMENT

PAYLOAD OPTION 3.1.8 – CENTENNIAL CHALLENGE
NON-ACADEMIC TEAM

MADISON WEST
SL 2016

FLIGHT READINESS REVIEW

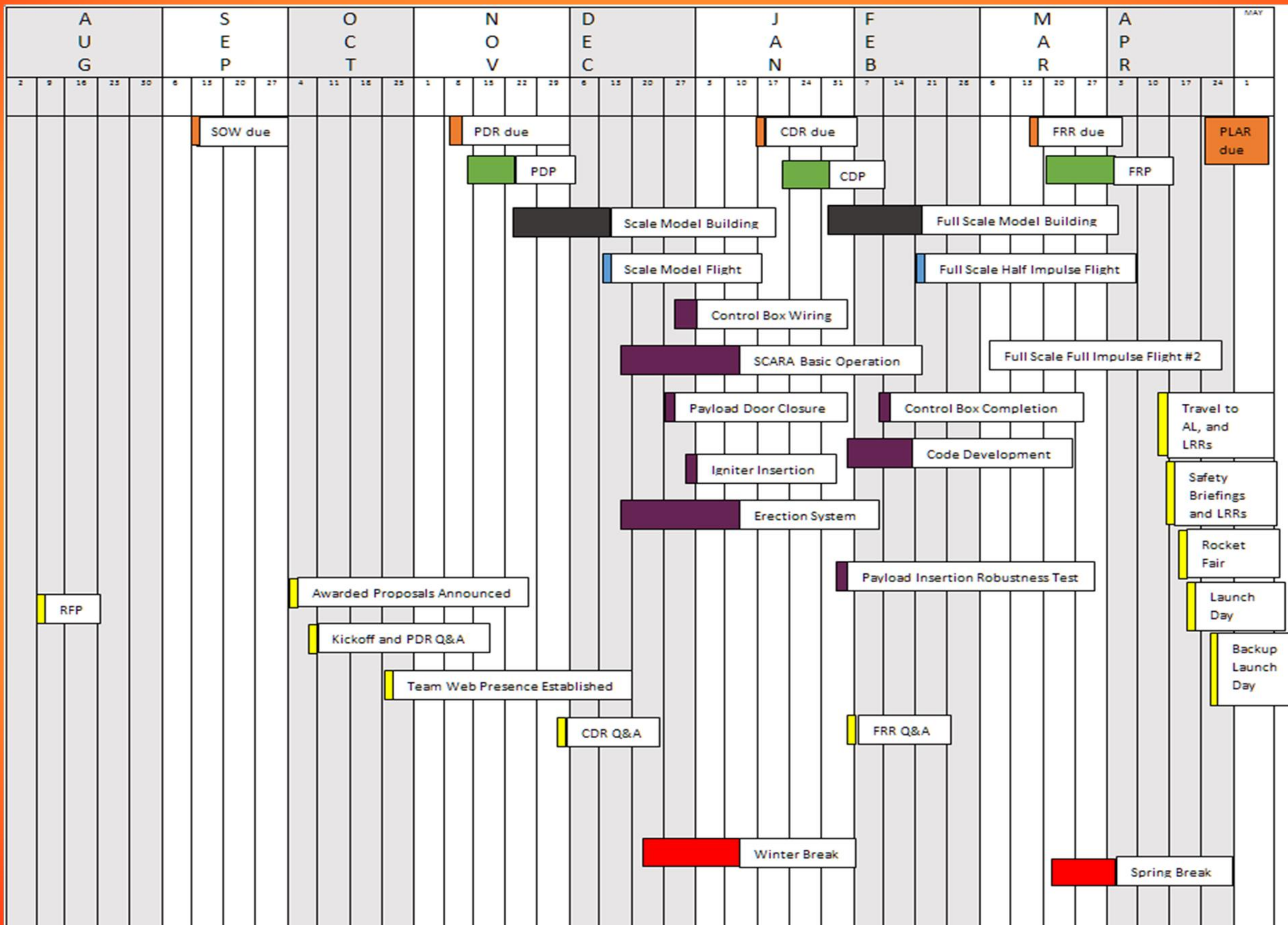
PART 1: VEHICLE



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

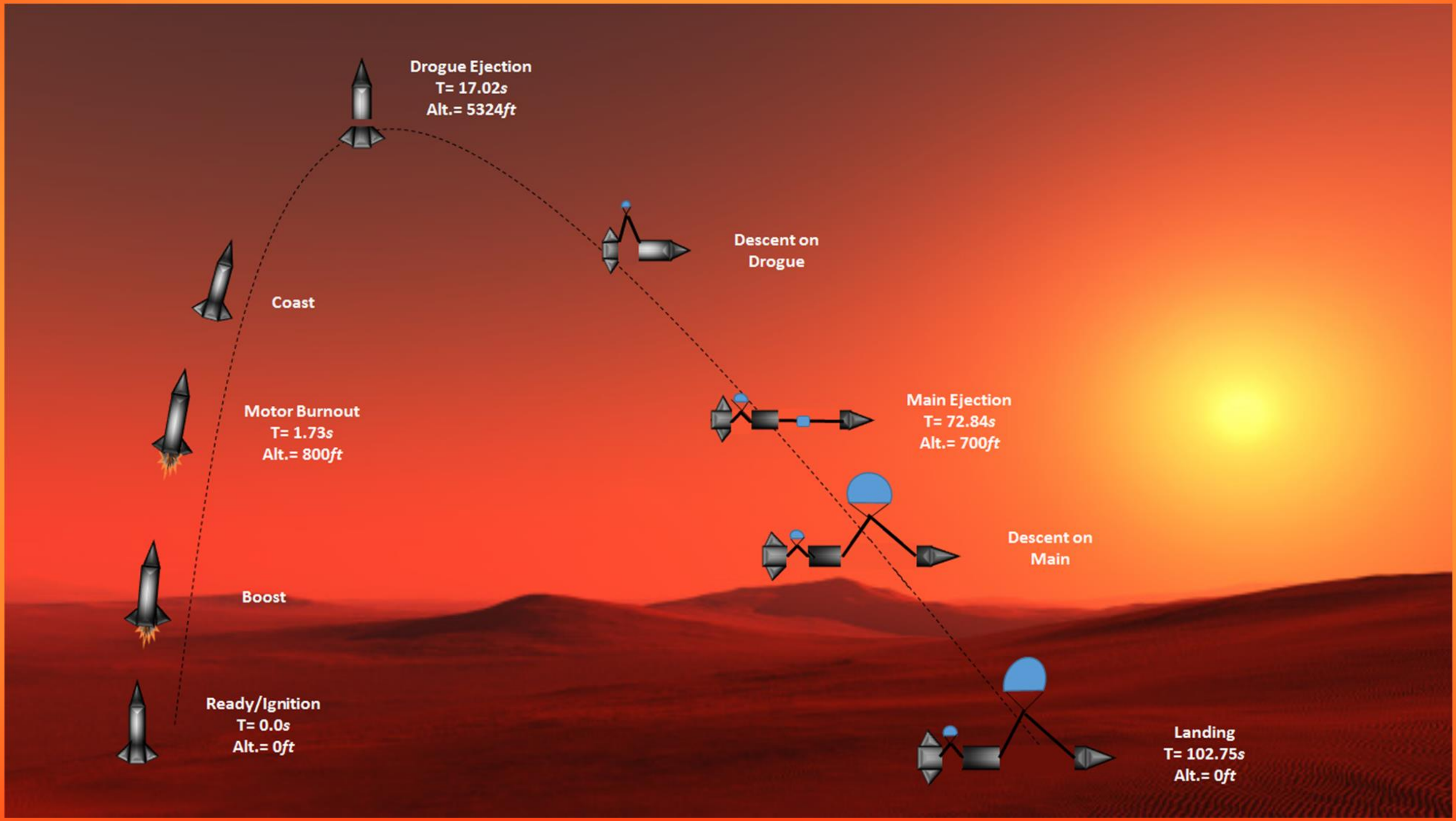


AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
SOW due
PDR due
CDR due
FRR due
PLAR due
PDP
CDP
FRP
Scale Model Building
Full Scale Model Building
Scale Model Flight
Full Scale Half Impulse Flight
Control Box Wiring
SCARA Basic Operation
Full Scale Full Impulse Flight #2
Payload Door Closure
Control Box Completion
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



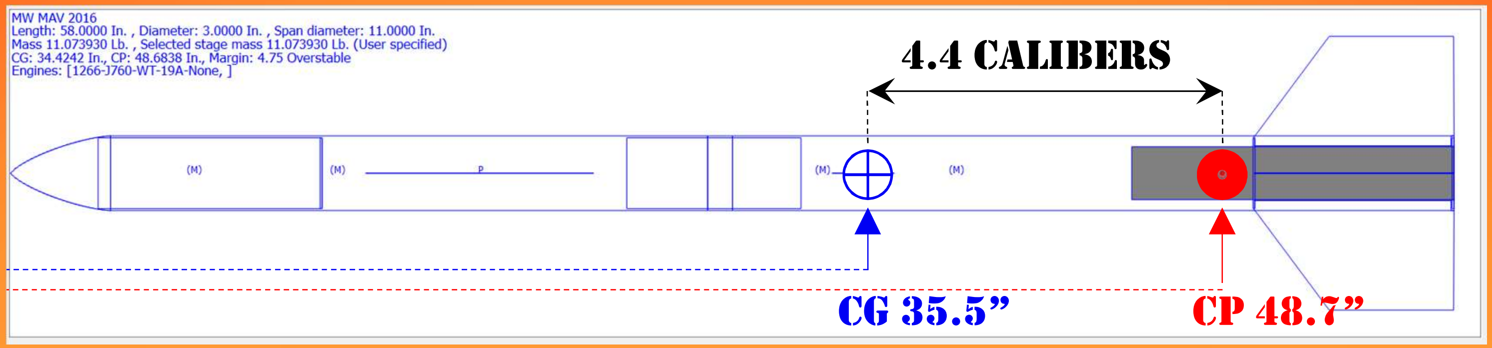
VEHICLE MISSION CRITERIA

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

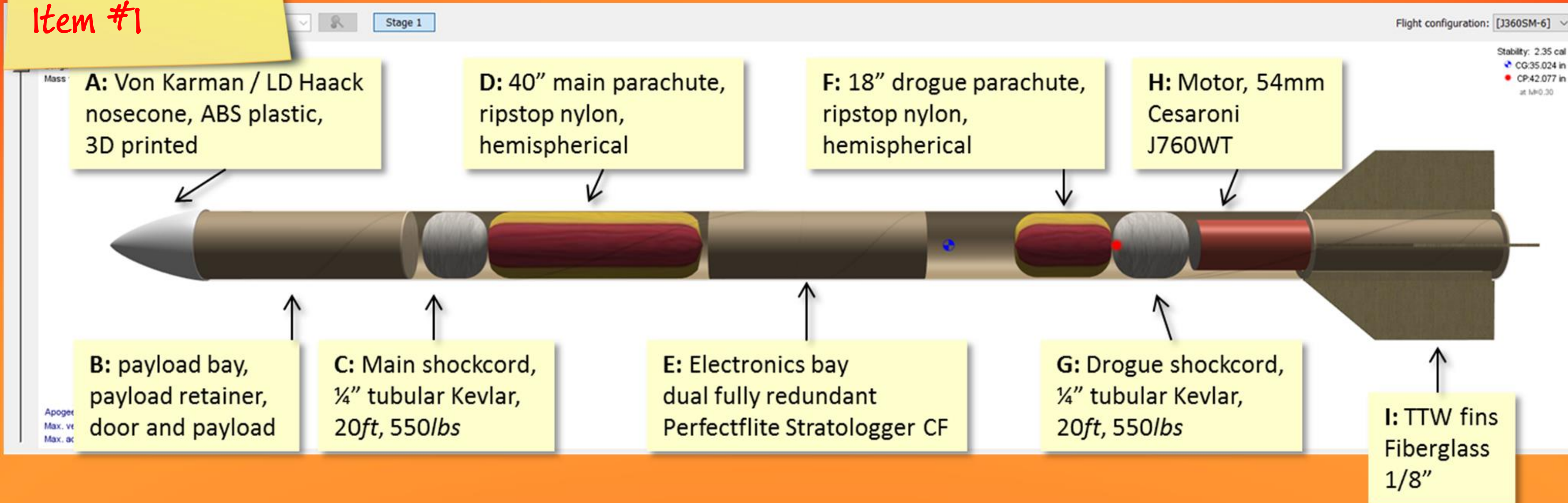


Length	58”
Diameter	3”
Liftoff Weight	10.1*lb*
CP	48.7” from nosecone
CG	35.5” from nosecone
Static margin	4.4 calibers
Motor	CTI J760WT (primary choice)

Motor	Diameter *[mm]*	Total Impulse *[Ns]*	Burn Time *[s]*	Stability Margin *[calibers]*	Thrust to weight ratio
CTI J760WT	54	1414	1.8	4.40	18.7
CTI J449BS	54	1429	2.8	4.40	11.7

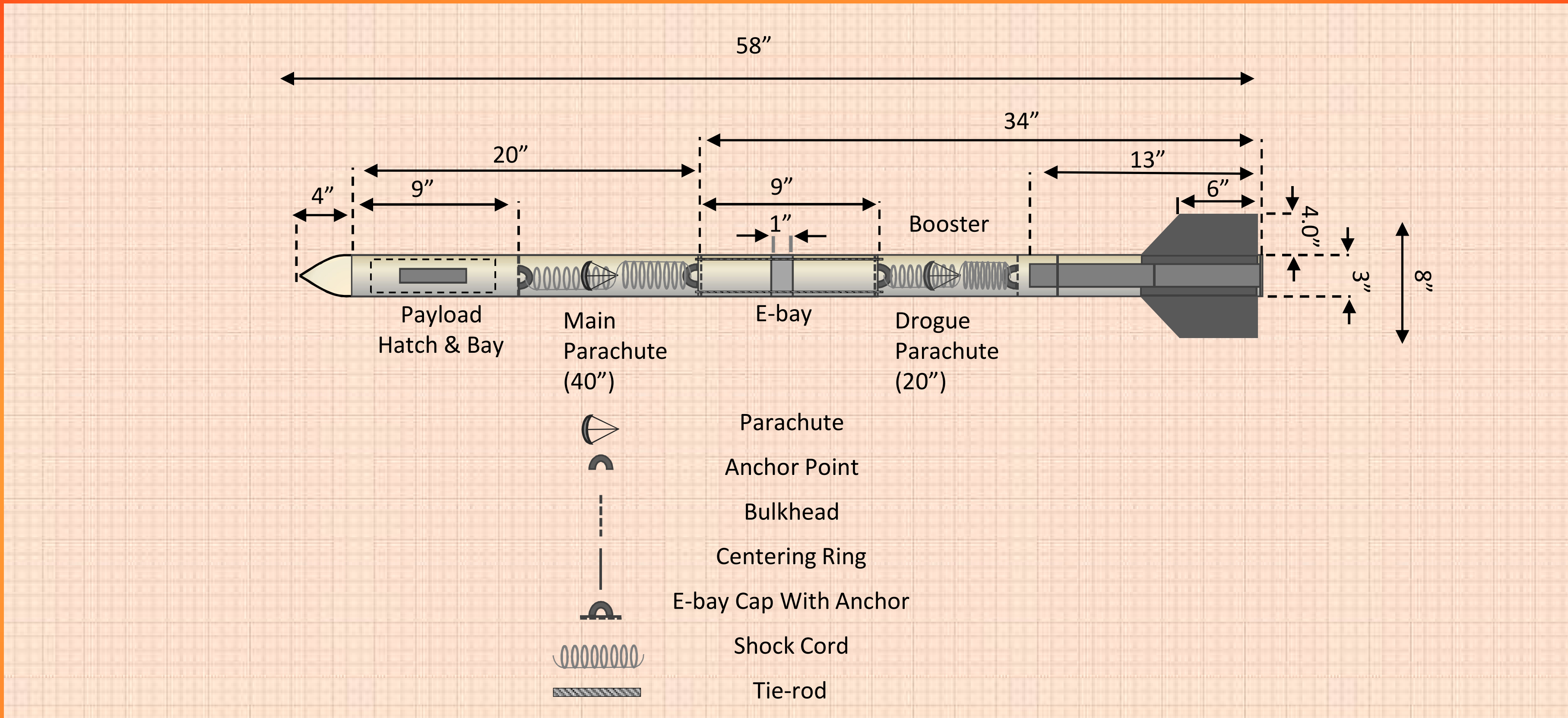
VEHICLE PARTS

CDR Feedback Item #1



Letter	Part	Breaking force *[lbs]*
A	Nosecone (Von Karman, LD-Haack)	
B	Payload bay (section reinforced by coupler)	
C	Main Parachute (8 shroudlines, hemispherical)	320*lbs* per shroudline
D	Deployment E-Bay (2 tie-rods)	1000*lbs* per tie-rod
E	Drogue Parachute (8 shroudlines, hemispherical)	320*lbs* per shroudline
F	Motor Mount (54mm)	
G	Fins (4, G10)	

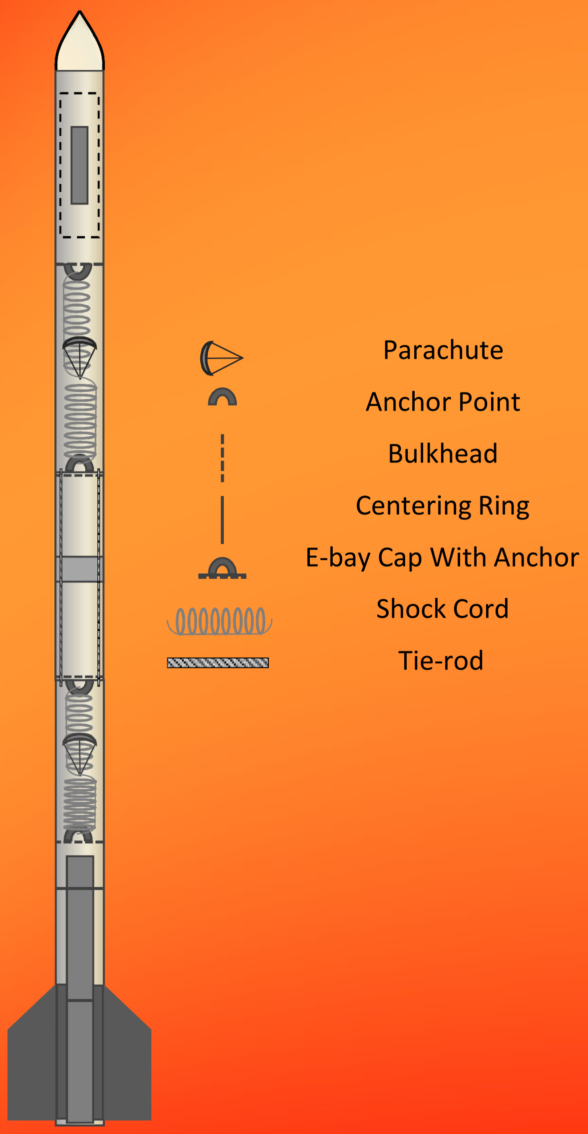
DIMENSIONED DRAWING OF VEHICLE



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, 540#

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 VERIFICATION SCHEDULE

Phase	Method	Verifies/Provides
SOW PDR	*Computer simulations (OpenRocket, RockSIM)*	✓ Vehicle stability ✓ Vehicle flight safety parameters ✓ Preliminary performance predictions
PDR	*Material selection*	✓ Selection of materials ✓ Estimate of structural integrity ✓ Estimate of vehicle mass
CDR	*Half-scale model*	✓ Vehicle stability/design ✓ Coefficient of drag ✓ Deployment scheme
CDR	*Material Stress Testing*	✓ Material strength and suitability
CDR	*Design Revision*	✓ All design aspects
FRR	*Static Tests*	✓ Deployment system (charges, parachutes, anchors) ✓ Vehicle robustness ✓ Vehicle stability ✓ Vehicle mass
FRR	*Full scale/full impulse flight*	✓ Vehicle stability and flight safety parameters ✓ Recovery system reliability ✓ Final performance predictions ✓ Vehicle performance ✓ Vehicle robustness ✓ Flight constraints compliance

VERIFICATION SUMMARY

Subsystem	Tests	Status
Propulsion	1. RockSIM simulations	✓
	2. Scale model flight	✓
	3. Full scale model flights	✓
Structural	1. Material selection using manufacturer's specifications	✓
	2. Static stress material testing	✓
	3. Full scale model flights	✓
Deployment Recovery	1. RockSIM simulations (to determine apogee)	✓
	2. Preliminary parachute size/descent rate calculations	✓
	3. Ejection charge calculation	✓
	4. Shockcord/parachute tensile strength static tests	✓
	5. Altimeter static tests (pressure chamber)	✓
	6. Avionics battery capacity tests	✓
	7. Anchors/tierods/links tensile strength static tests	✓
	8. Static ejection charge tests	✓
	9. Ground parachute inflation tests	✓
	10. Full scale vehicle flight data analysis	✓
Tracking	1. Ground tests	✓
	2. Battery capacity tests	✓
	3. Full scale vehicle flight tests	✓

COMPLETED

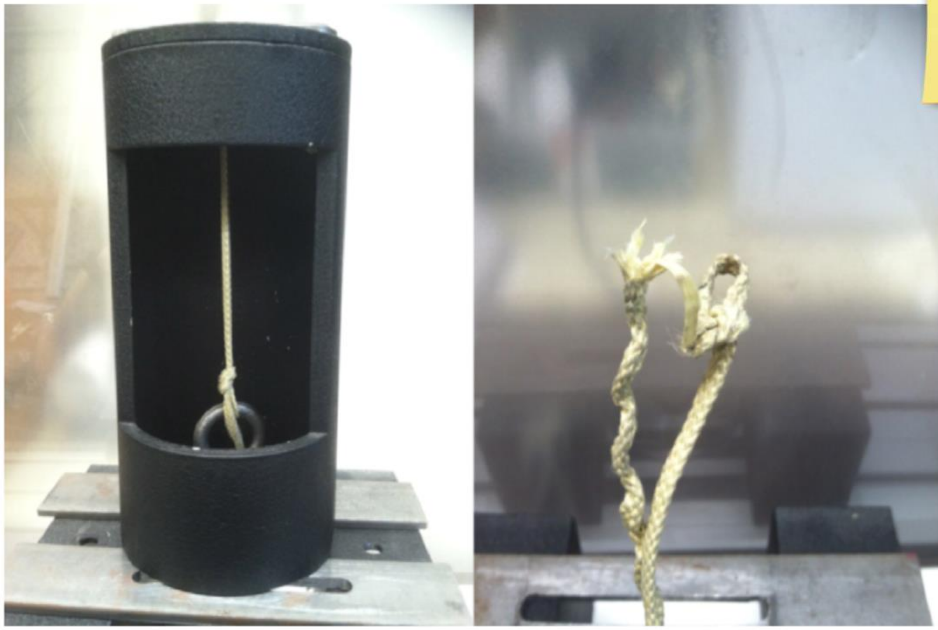
VEHICLE STRENGTH ANALYSIS

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”	540lbs
Tie-rods	8/32 stainless steel threaded rods	McMaster-Carr	93250A05	1000lbs per tie-rod, 2 tie-rods used

Calculated maximum deployment force: 236*lbs*
Weakest point of rocket: shockcord 550*lbs*

VEHICLE MATERIAL TESTING

CDR Feedback
Item #6



Deflection

fins deflection and body tubes deformation

Tensile Strength

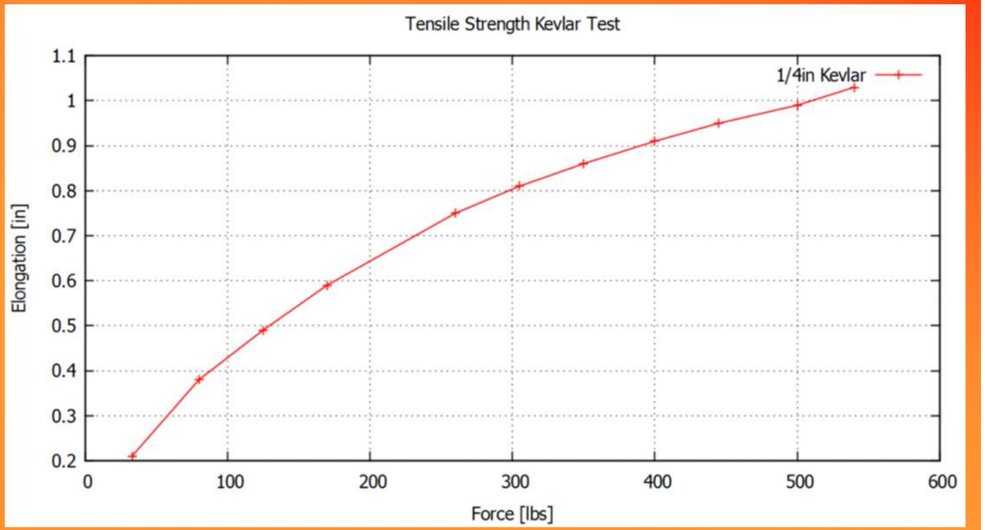
shockcords, anchors, parachutes, shroudlines, tierods, links

TENSILE STRENGTH TESTING

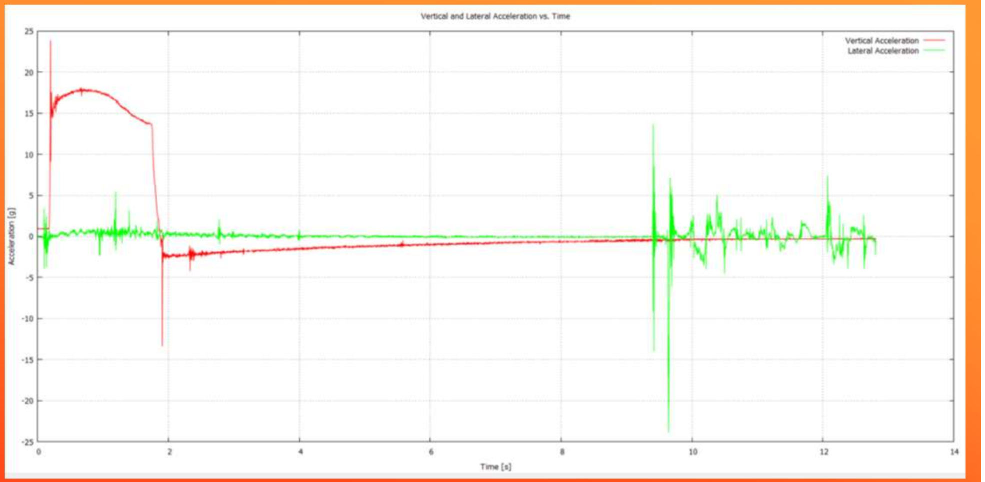
Component	Material	Strength Rating	Force tested	Result	Flight tested
Anchors	¼” stainless steel	2000lbs	1000lbs	MAX	YES
Tie-rods	#8/32 stainless steel	800lbs	1000lbs	MAX	YES
Links	QuickLink	2000lbs	1000lbs	MAX	YES
Shockcords	¼” tubular Kevlar	3600lbs	540lbs	BREAK	YES
Parachute shroudlines	Nylon	400lbs	320lbs	BREAK	YES

SHOCKCORD STRENGTH

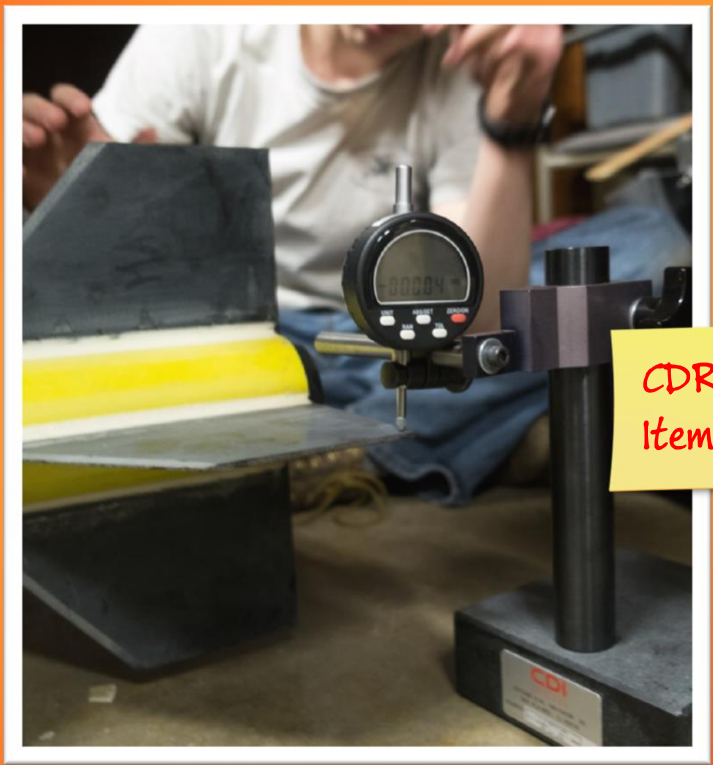
- **Sold as 3600*lbs* strength**
- **Breaks at 540*lbs***
- **Deployment forces: 236*lbs***



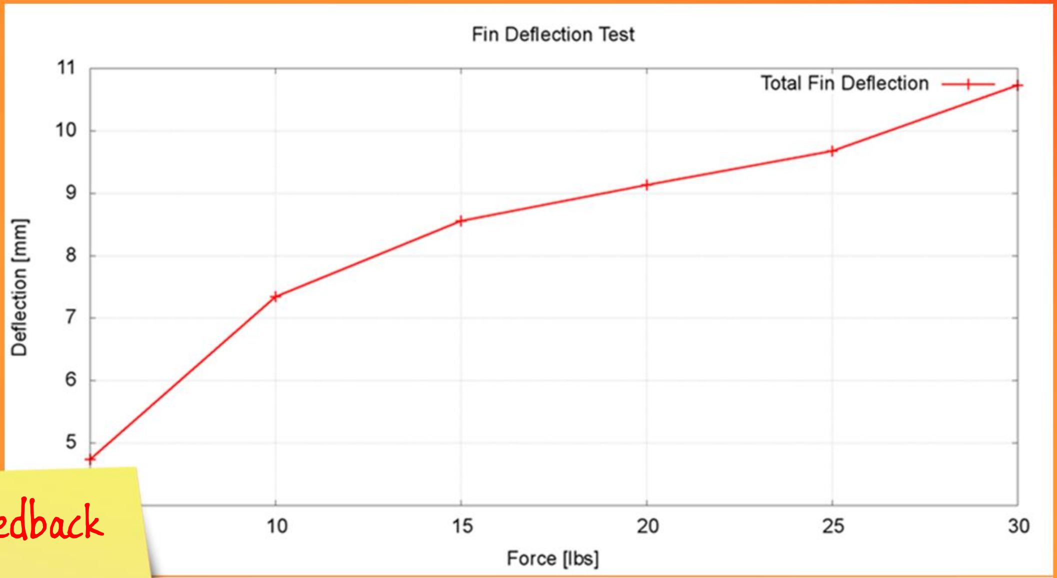
Direction	Maximum Positive		Maximum Negative	
Vertical	+24*g*	liftoff	-13*g*	burnout
Lateral	+14*g*	apogee event	-24*g*	apogee event

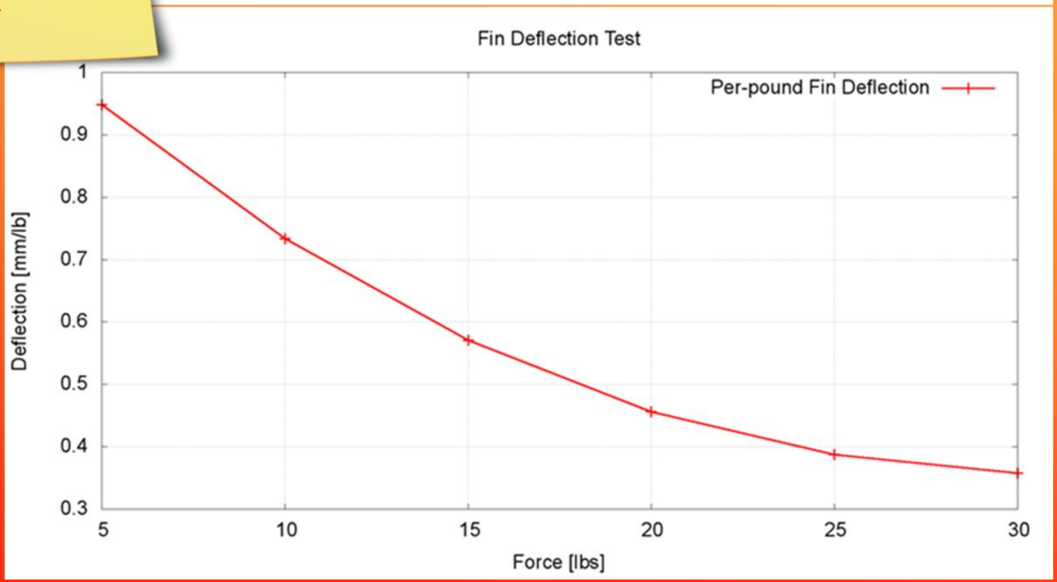


FIN DEFLECTION TESTING

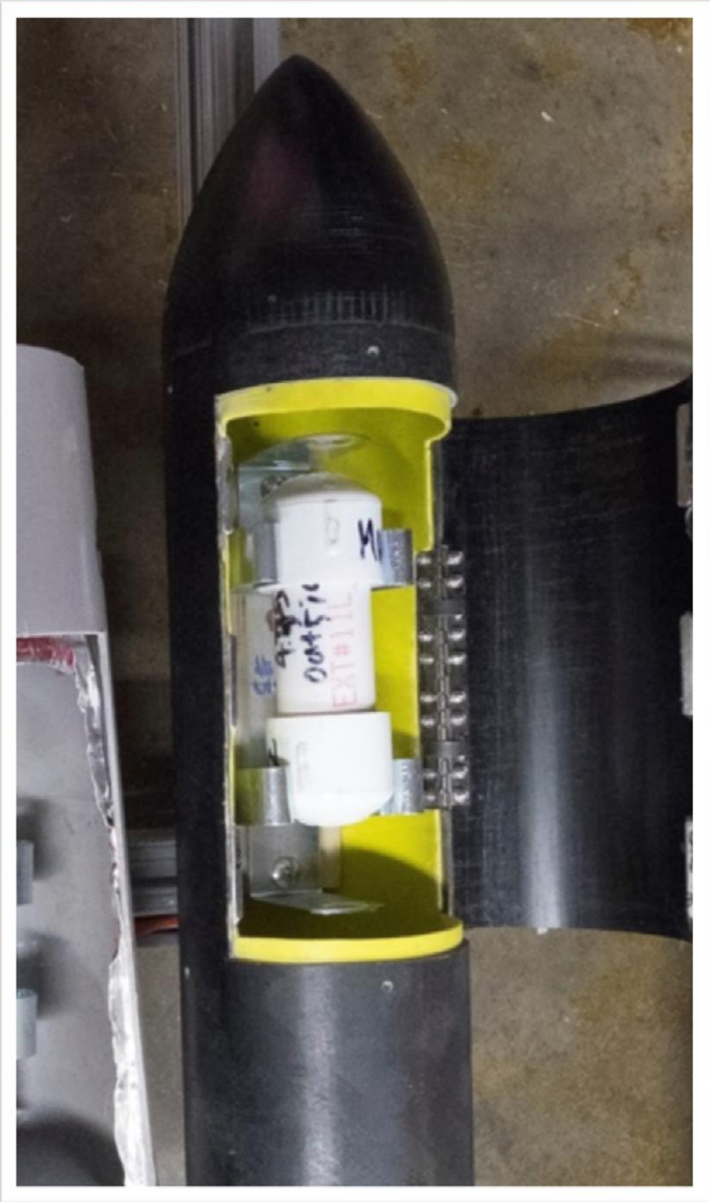


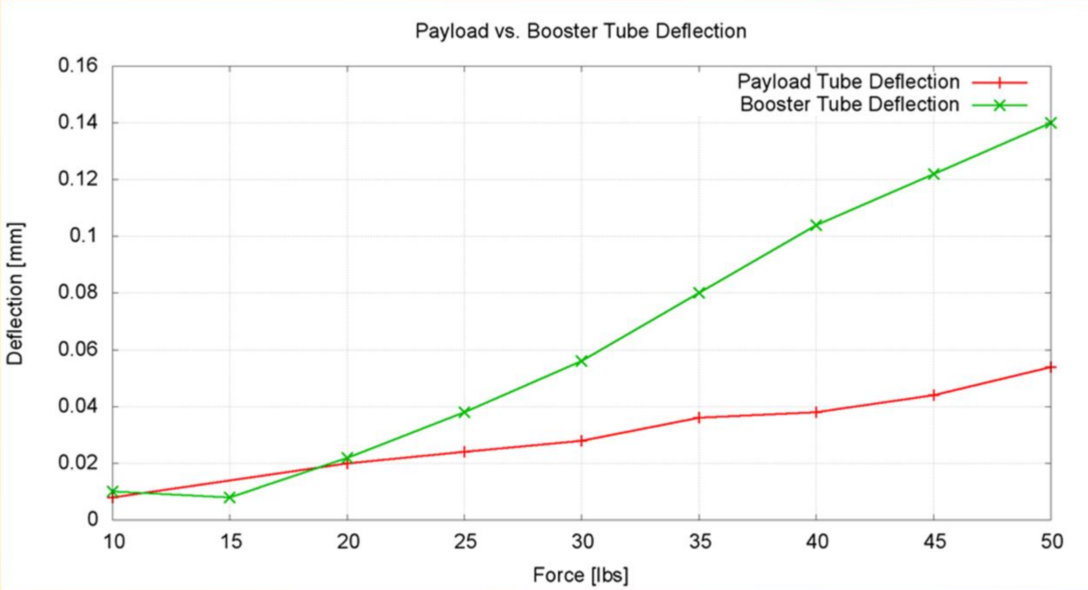
CDR Feedback
Item #4

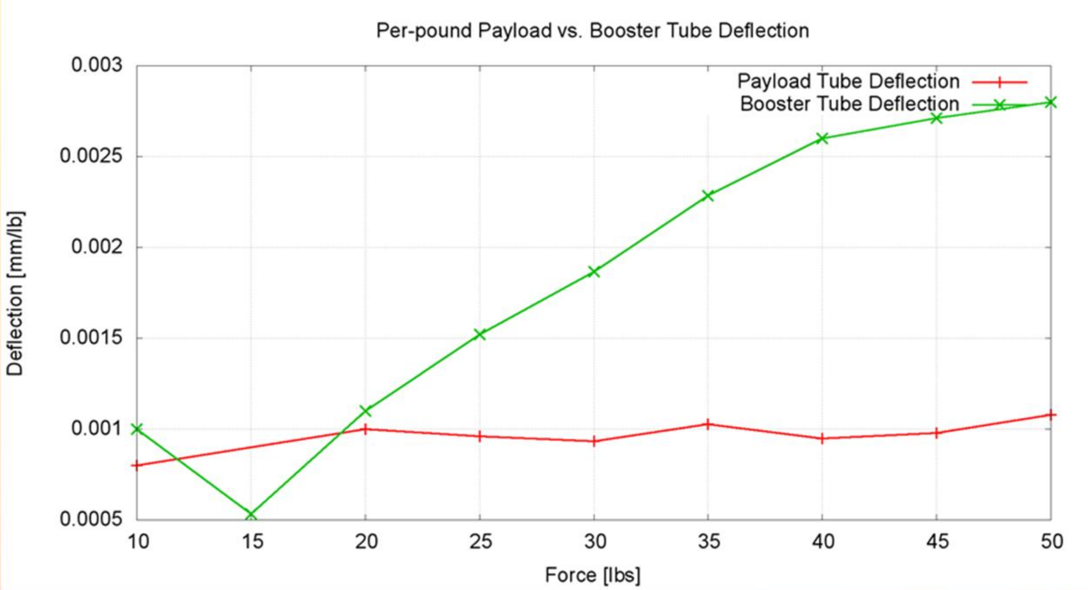




TUBE DEFLECTION TESTING







TUBE DEFLECTION TESTING

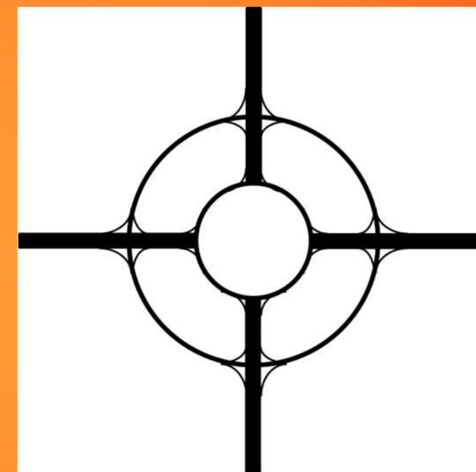
Buckling Force

$$EI = \frac{L^3}{48}\frac{F_d}{d}, F_b = \frac{\pi^2 EI}{{L_R}^2}$$

Booster Section			Payload Section		
Force *[lb]*	Deflection *[in]*	EI	Force *[lb]*	Deflection *[in]*	EI
10	0.000394	4,900,609	10	0.000315	9,143,995
20	0.000866	4,455,102	20	0.000787	7,315,196
30	0.002205	2,625,328	30	0.001102	7,837,710
40	0.004094	1,884,851	40	0.001496	7,700,206
50	0.005512	1,750,219	50	0.002126	6,773,330
$EI_{average}$		3,123,222	$EI_{average}$		7,754,087
F_b *[lbs]*		14,363	F_b *[lbs]*		22,726

CONSTRUCTION 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

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 is 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***	4.4	18.8
321	2.47	54	***CTI J449BS***	4.4	11.7

FULL SCALE VEHICLE FLIGHT TESTS

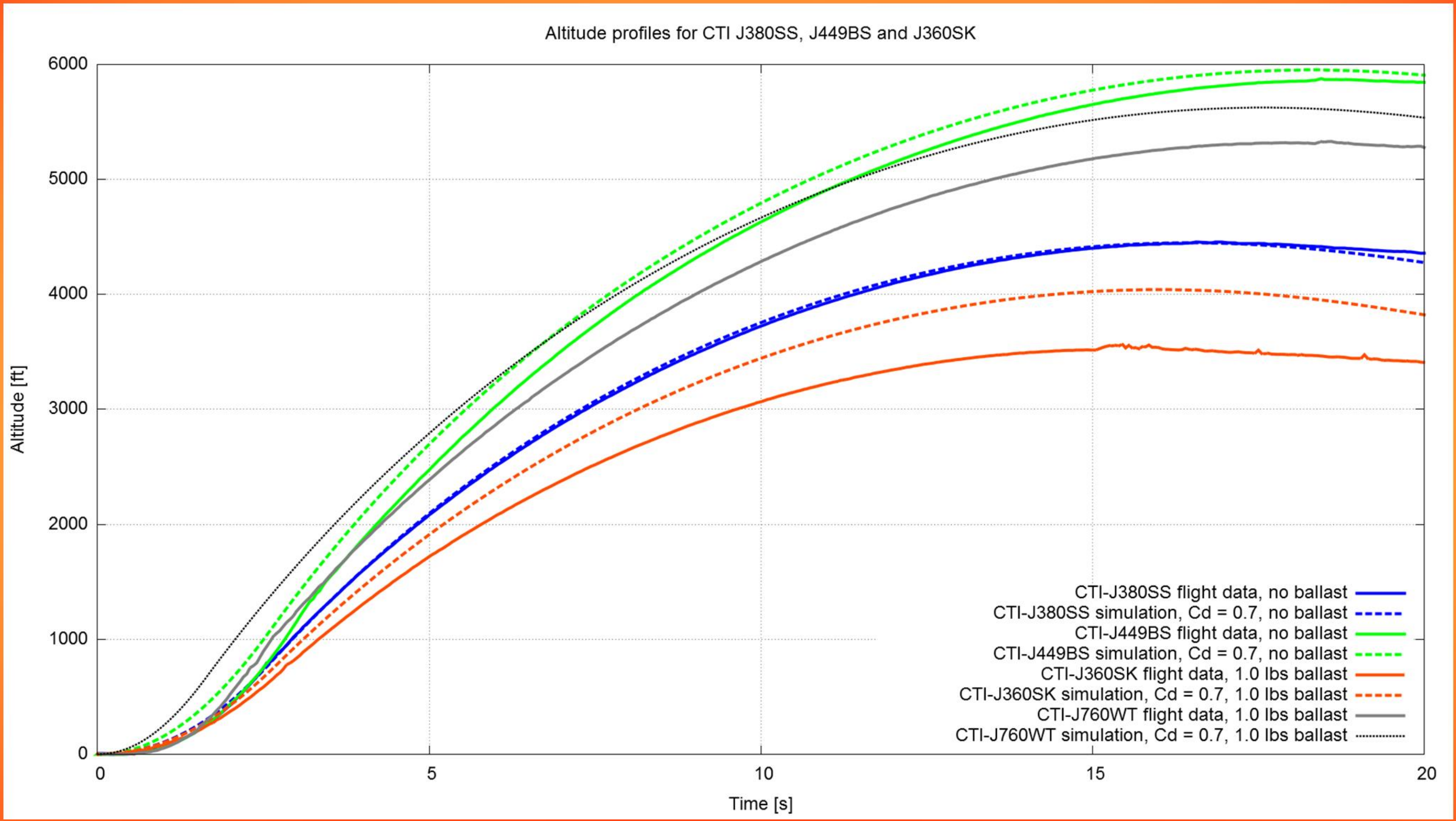
CDR Feedback Item #2

#	Motor	Wind	Ballast	Apogee	Prediction (C_d = 0.7)	Anchored C_d	Drogue Descent Rate	Main Descent Rate	E_k payload ebay booster
		[mph]	[lbs]	[ft AGL]	[ft AGL]		[ft/s]	[ft/s]	[ft.lb-f]
1	***J449BS***	10	0.00	**5867**	5951	0.719	48	19	30.3 2.5 19.9
2	***J360SK***	15	1.00	**3552**	3892	0.885	47	22	42.1 7.1 29.0
3	***J380SS***	18	0.00	**4451**	4448	0.701	49	24	47.5 8.1 23.3
4	***J760WT***	7	1.00	**5330**	5624	0.780	49	23	43.1 7.3 29.3

The verified motor choice is **CTIJ760WT**. Vehicle will fly with 1.0*lbs* (**9%** of liftoff weight) ballast

CDR Feedback Item #5

FULL SCALE VEHICLE FLIGHT TESTS



Measured flight data are compared against simulations with C_d set at 0.7

FLIGHT SAFETY PARAMETERS MATURITY OF DESIGN

Parameter	Value
Flight Stability Static Margin	**4.4** *calibers*
Thrust to Weight Ratio	**18.7**
Velocity at Launch Guide Departure (5ft launch rail)	**48.0** *mph*

MASS STATEMENT

- **Current Status**
  - Our rocket currently has a mass of 11.1*lb*, which includes a 2.37*lbs* CTI J760WT motor and 1.0*lbs* of ballast.
  - This is an actual liftoff weight of our rocket, the full scale vehicle construction has been completed.
- **Ballast Impact**
  - The rocket needs 1.0*lbs* (9% of liftoff weight) of ballast to limit flight apogee to 1*mile*.
  - 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.

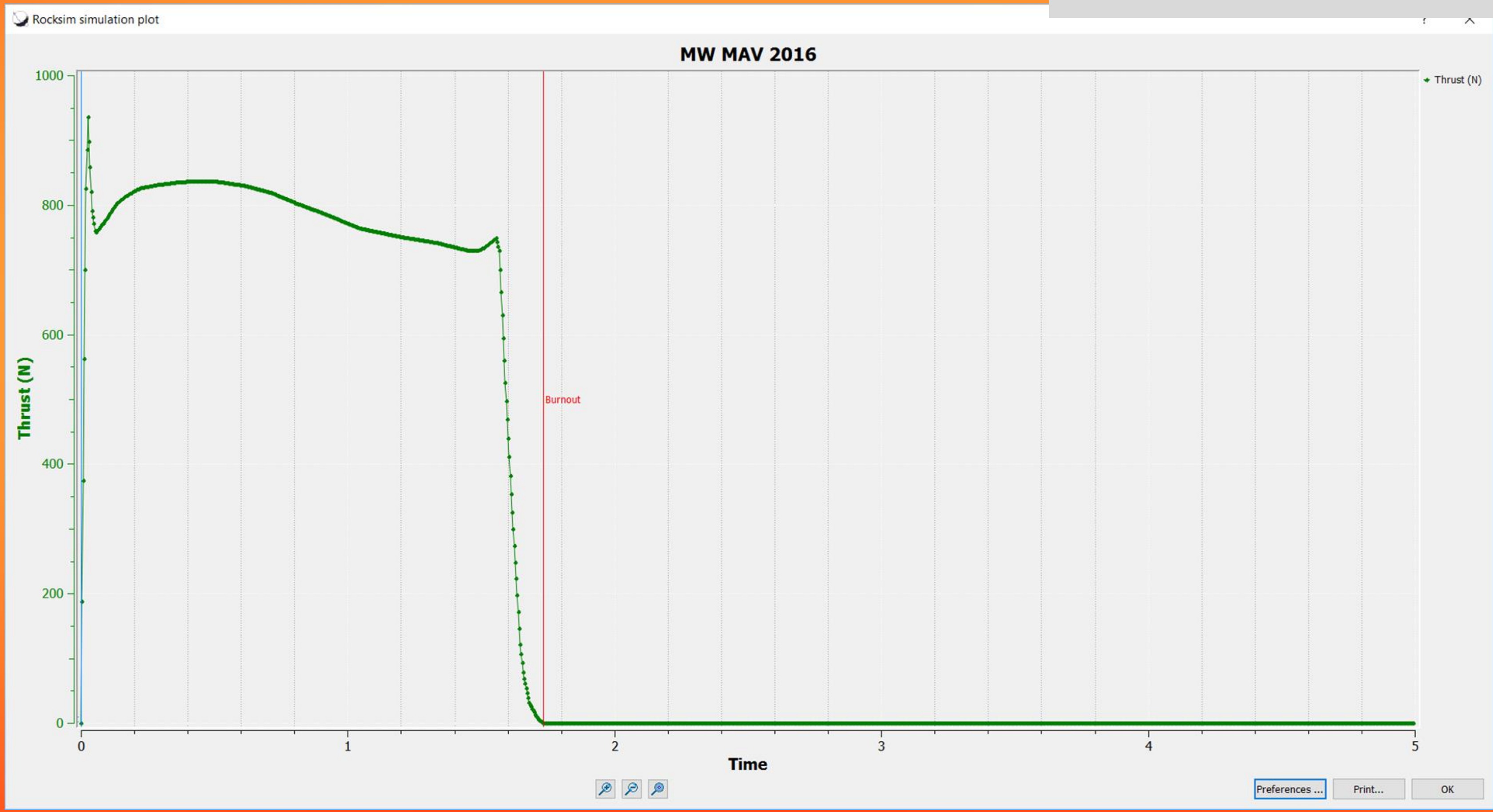
ANCHORED FLIGHT PERFORMANCE PREDICTIONS

Parameter	Value	Source / Justification
Coefficient of drag	0.780	*full scale vehicle test flight*
Liftoff weight	11.1*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: 937N
Burn Time: 1.8s

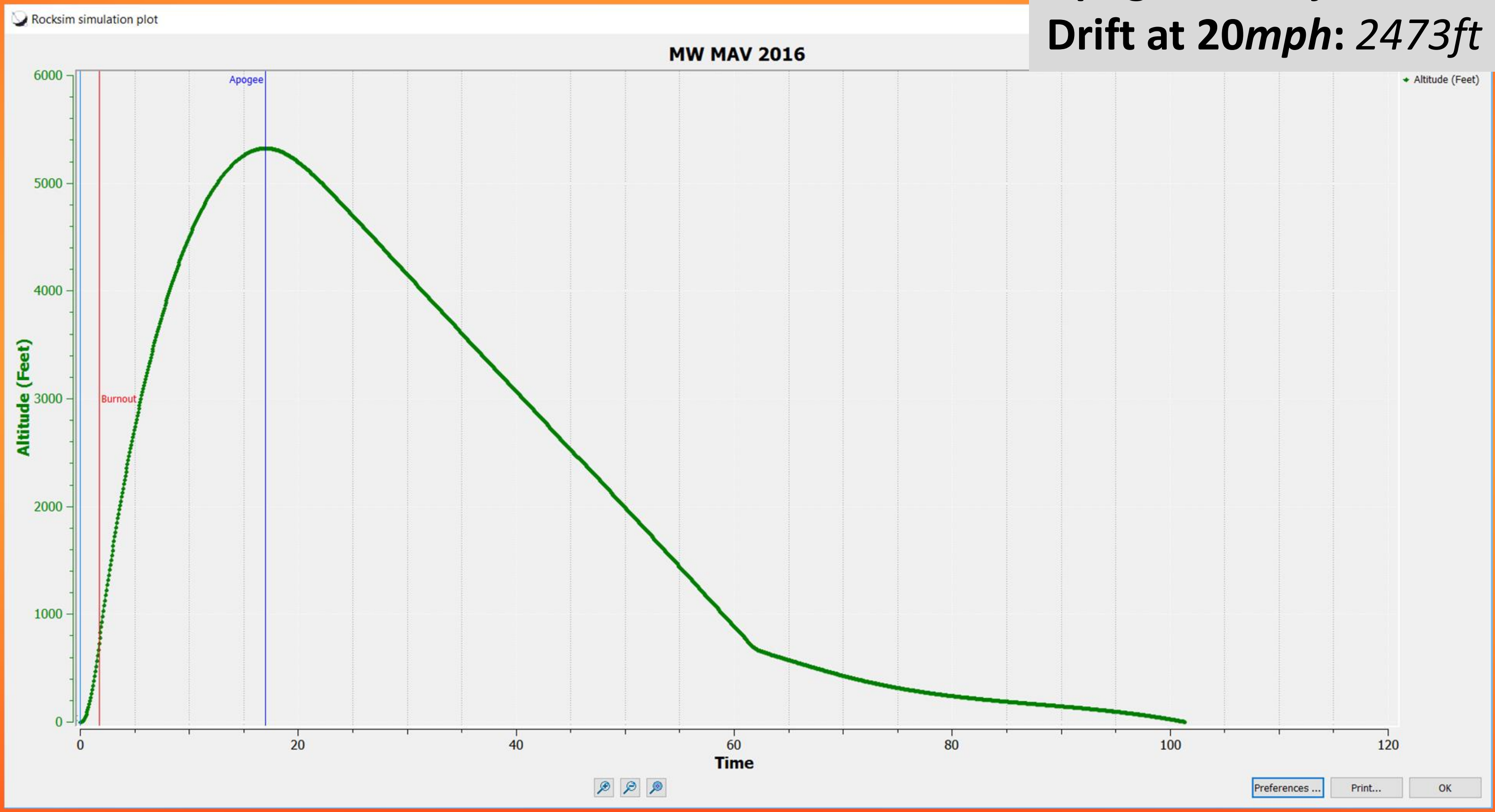
Thrust [Ns]



Time [s]

ALTITUDE PROFILE

Apogee: 5324*ft*, 17*s*
Drift at 20*mph*: *2473ft*

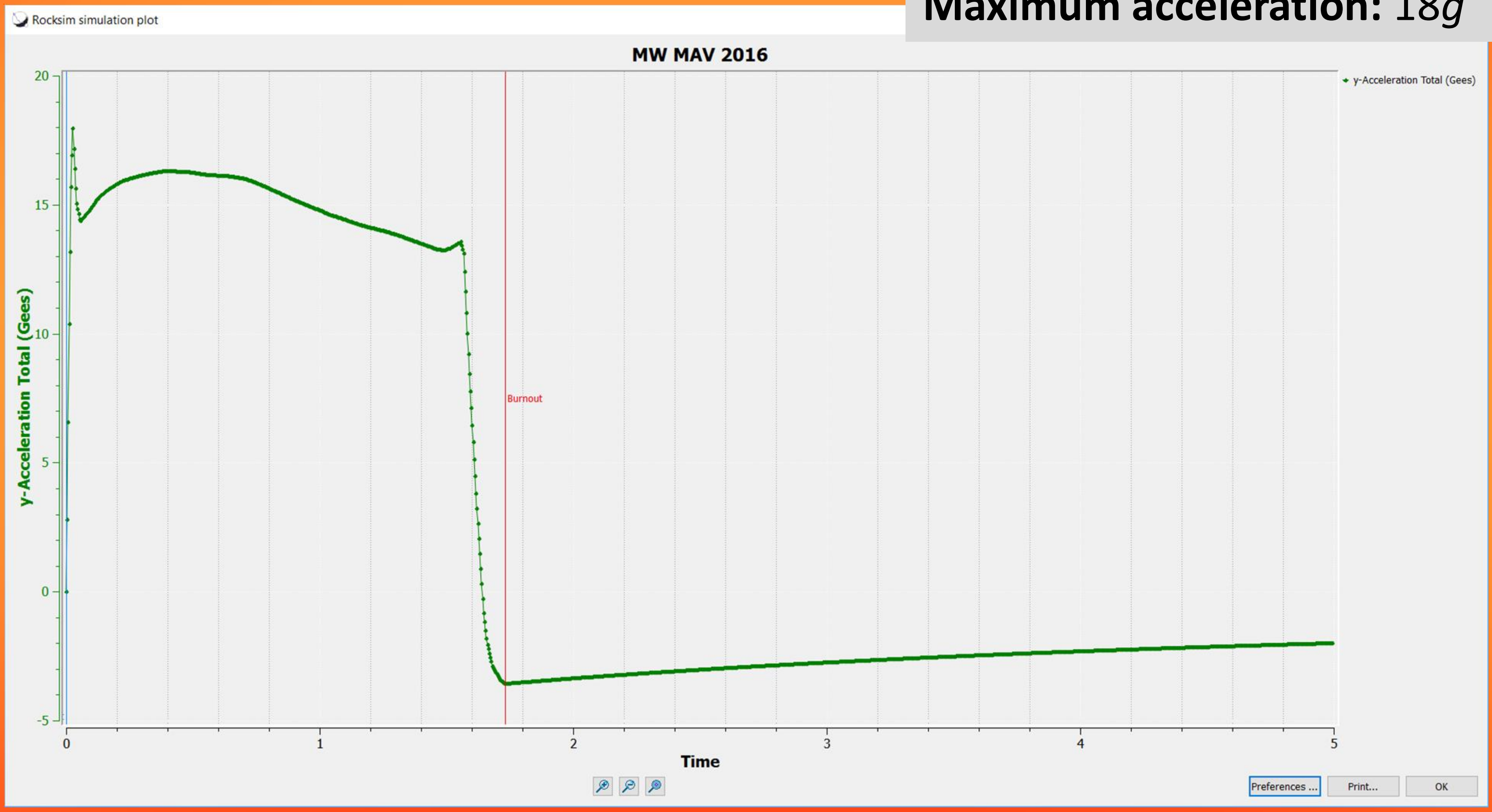


Altitude [*ft*]

Time [*s*]

ACCELERATION PROFILE

Maximum acceleration: 18g



Acceleration [g]

Time [s]

VELOCITY PROFILE

Rail exit velocity: 48*mph*
Max. velocity: 540*mph*
Mach number: 0.704
subsonic

Von Karman nosecone

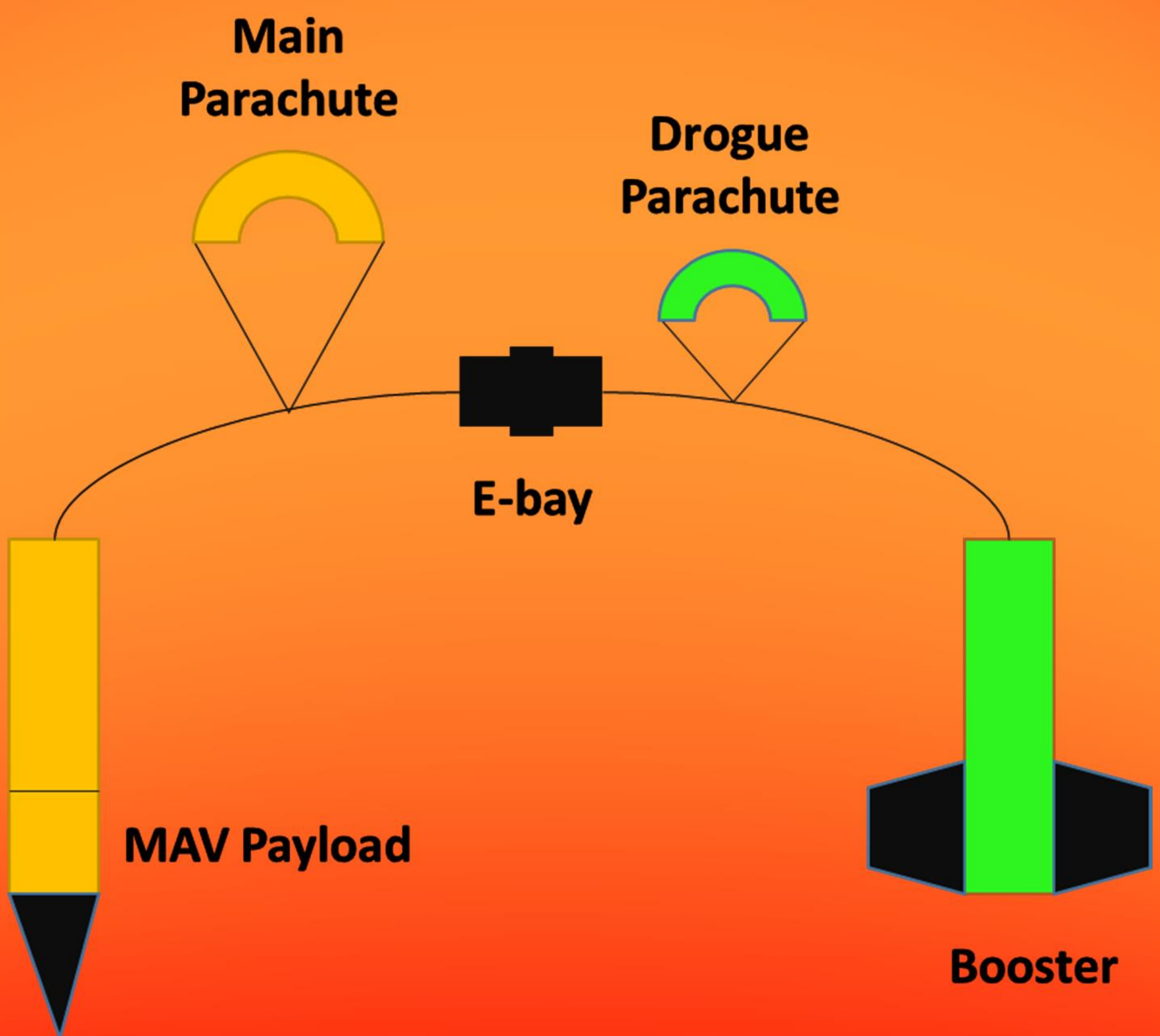
Velocity [*mph*]

Time [*s*]

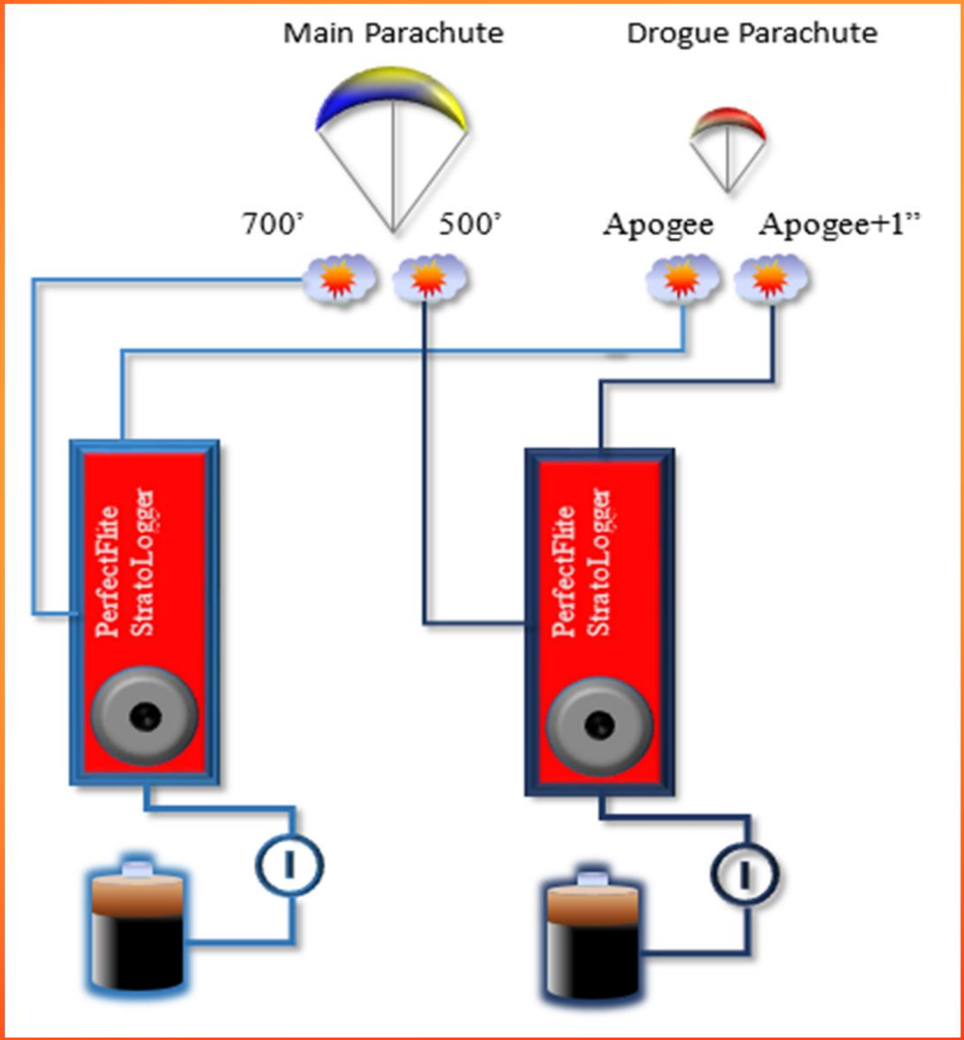
ALTITUDE VS. WIND SPEED

Wind Speed *[mph]*	Altitude *[ft]*	Change in Apogee *[%]*
0	5326	0.00
5	5356	0.56
10	5365	0.73
15	5324	-0.04
20	5316	-0.19

DEPLOYMENT SCHEME



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.

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	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).

PARACHUTE SIZE

Parachute	Diameter *[in]*	Descent Rate *[fps]*	Ejection Charge *[g]*	Deployment Altitude *[ft]*	Descent Weight *[lbs]*	Impact Energy *[ft.lb-f]*
Drogue	20	49	1.50†	5324	9.8	--
Main	40	24	1.50†	700	0.9 3.6 5.3	7.8* 23.0* 49.0*

* 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). The charges were tested with 2 nylon #2/56 shear pins per separation point.

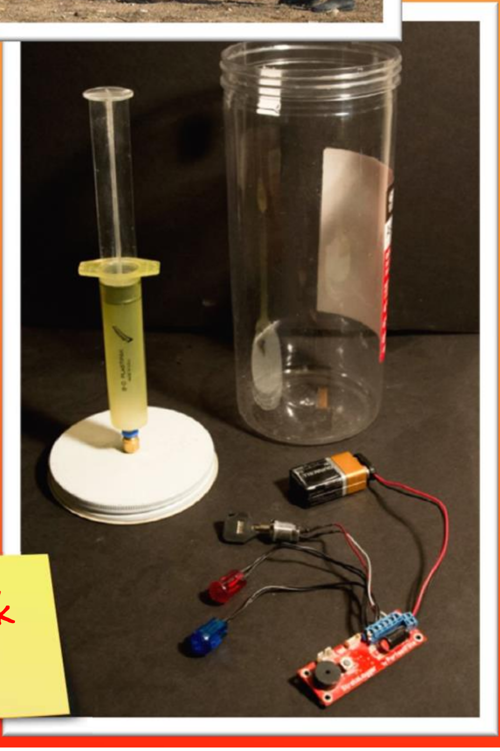
DEPLOYMENT SYSTEM STRENGTH

Component	Material	Breaking force
Shockcords	¼" tubular Kevlar	540*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	1000*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 540*lbs,* maximum expected load is 236*lbs*

DEPLOYMENT SYSTEM VERIFICATION

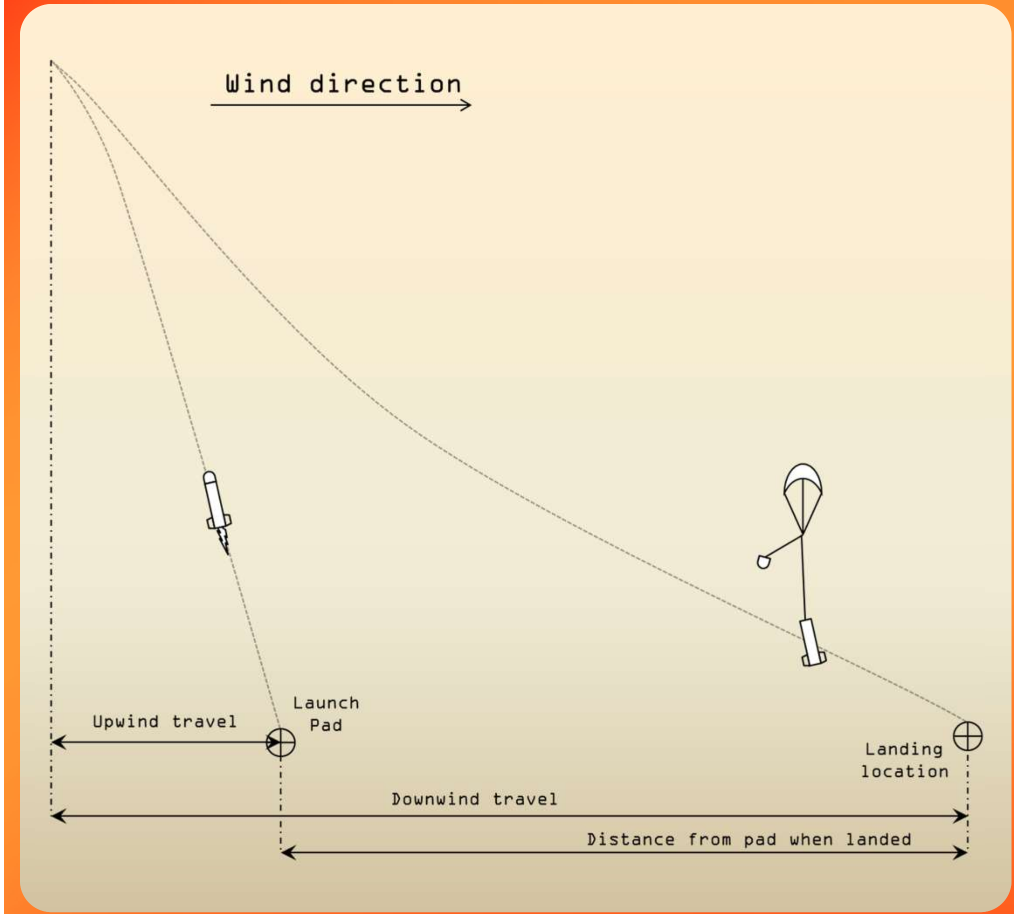
Component	Material	Strength Rating	Force tested	Result	Flight tested
Anchors	¼” stainless steel	2000lbs	1000lbs	MAX	YES
Tie-rods	#8/32 stainless steel	800lbs	1000lbs	MAX	YES
Links	QuickLink	2000lbs	1000lbs	MAX	YES
Shockcords	¼” tubular Kevlar	3600lbs	540lbs	BREAK	YES
Parachute shroudlines	Nylon	400lbs	320lbs	BREAK	YES



- ✓ Battery endurance tests (24hrs)
- ✓ Baro-chamber altimeter test
- ✓ Altimeter output current test (5A)
- ✓ Tensile tests
- ✓ Descent rate measurements (E_k)
- ✓ Parachute inflation test
- ✓ Static ejection tests

CDR Feedback Item #6

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).

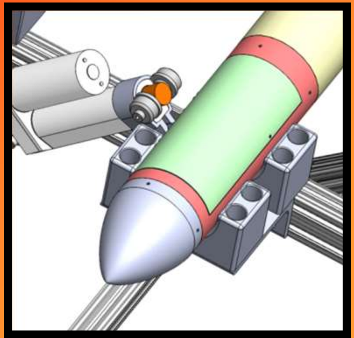
Wind speed [mph]	Upwind Travel [ft]	Downwind Travel [ft]	Distance from pad when landed [ft]	Distance from pad when landed [mile]
0	760	0	760	0.144
5	542	635	1177	0.223
10	338	1272	1610	0.305
15	136	1908	2044	0.387
20	-66	2539	2473	0.468

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.

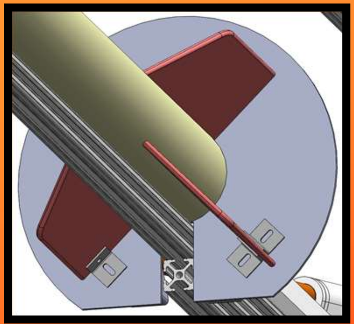
This system has been successfully tested at LDRS 33 launch during 8K+ flight.

VEHICLE TO AGSE INTERFACES

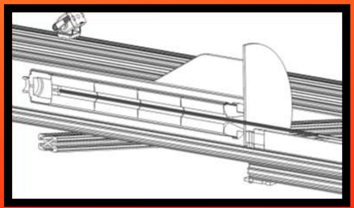


The *front cradle* is used to support the rocket during payload insertion and payload door operation.

Rail buttons guide the rocket along the launch rail.

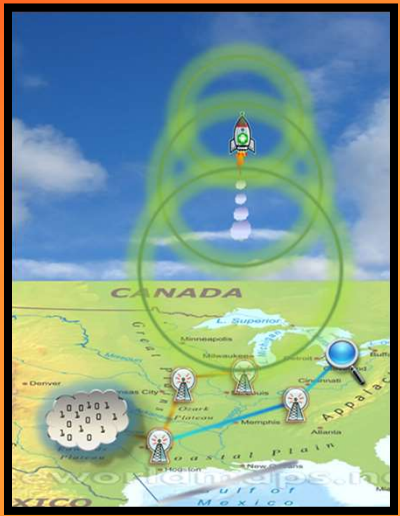


The *aft stabilization* system is used to prevent rocket from rolling off the rail during payload insertion and rail erection

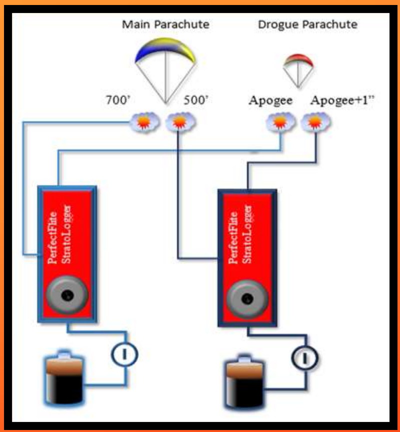


Igniter insertion system inserts an igniter into motor bore

OTHER INTERFACES



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



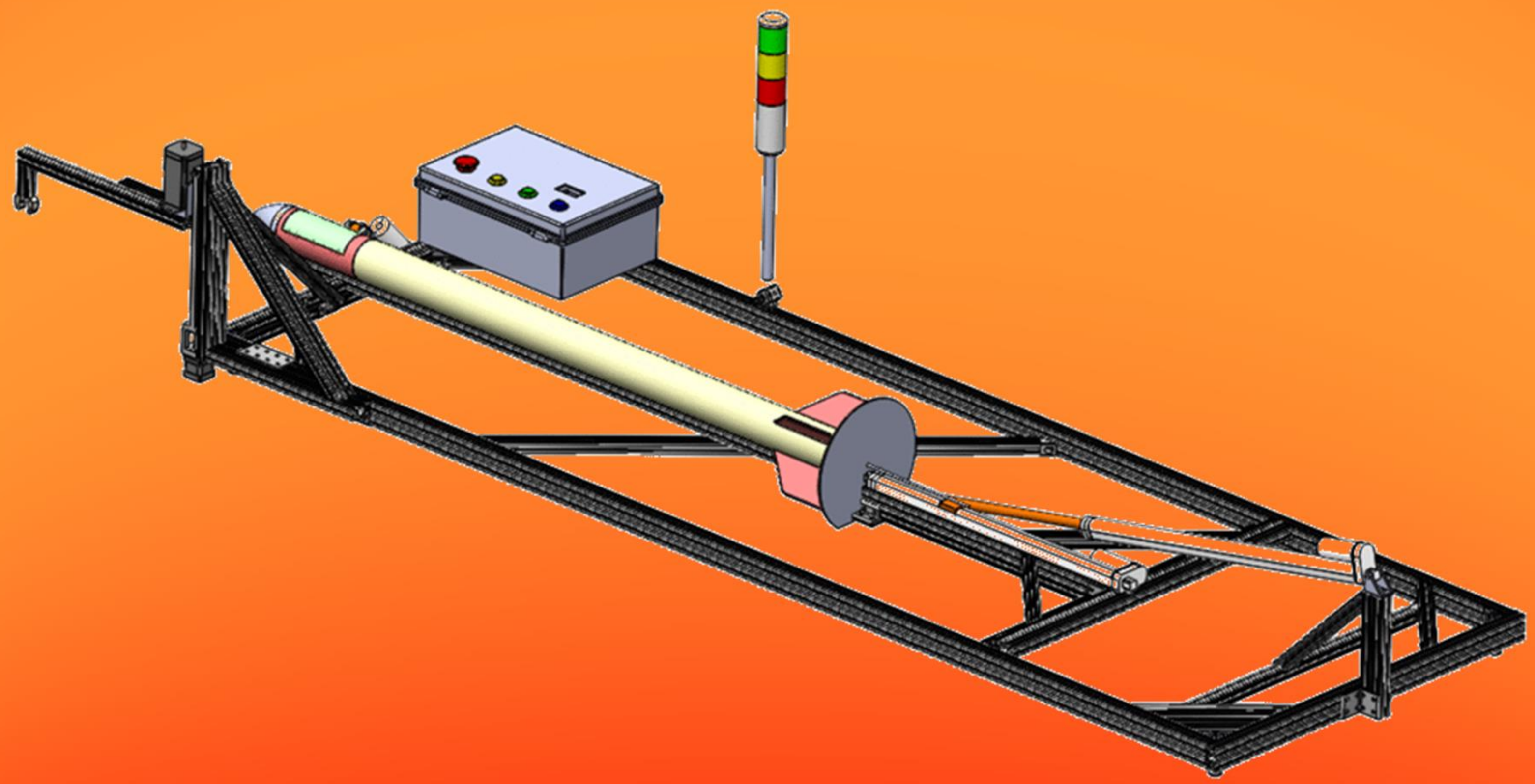
***Internal interface*: deployment electronics and ejection charges**

SAFETY

- Safety Officer Duties
- Vehicle and AGSE Checklists
- Team Safety Briefings
- Failure Mode Effect Analysis
- Personal Hazards (RAC and PPE use)
- Environmental Concerns
- MSDS Data (collection, access, maintenance)

	MISHAP SEVERITY CATEGORY			
MISHAP PROBABILITY	1 CATASTROPHIC	2 CRITICAL	3 MARGINAL	4 NEGLIGIBLE
A FREQUENT	HIGH RISK	HIGH RISK	SERIOUS RISK	MEDIUM RISK
B PROBABLE	HIGH RISK	HIGH RISK	SERIOUS RISK	MEDIUM RISK
C OCCASIONAL	HIGH RISK	SERIOUS RISK	MEDIUM RISK	LOW RISK
D REMOTE	SERIOUS RISK	MEDIUM RISK	MEDIUM RISK	LOW RISK
E IMPROBABLE	MEDIUM RISK	MEDIUM RISK	MEDIUM RISK	LOW RISK

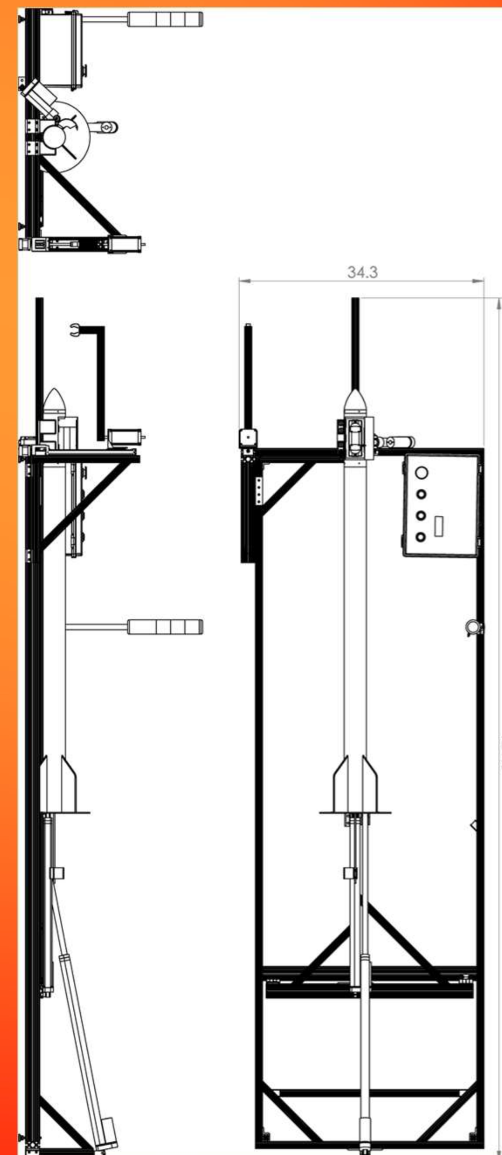
PART II: AGSE



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

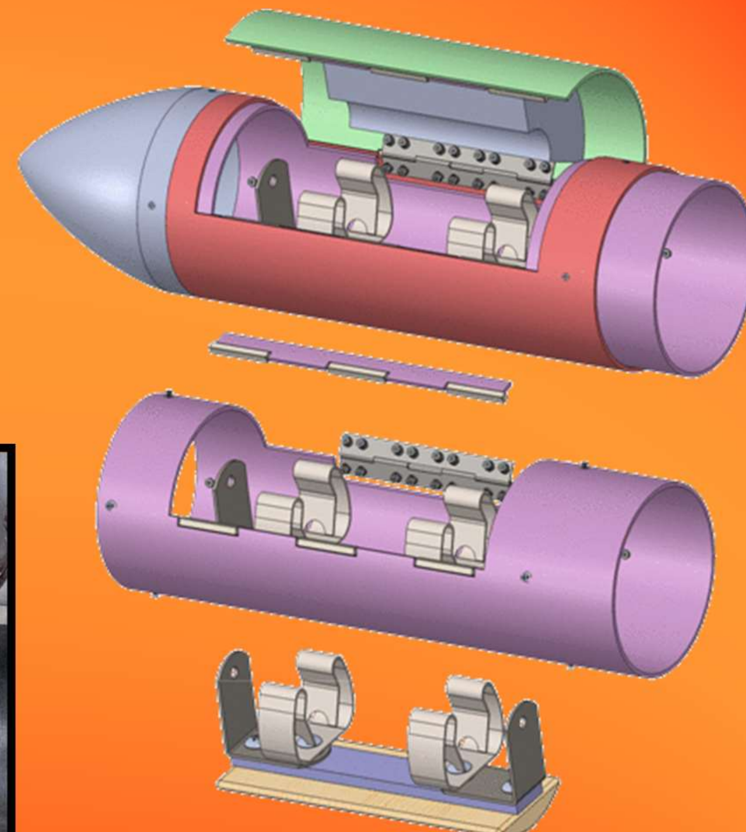
AGSE SUPERSTRUCTURE



- 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.

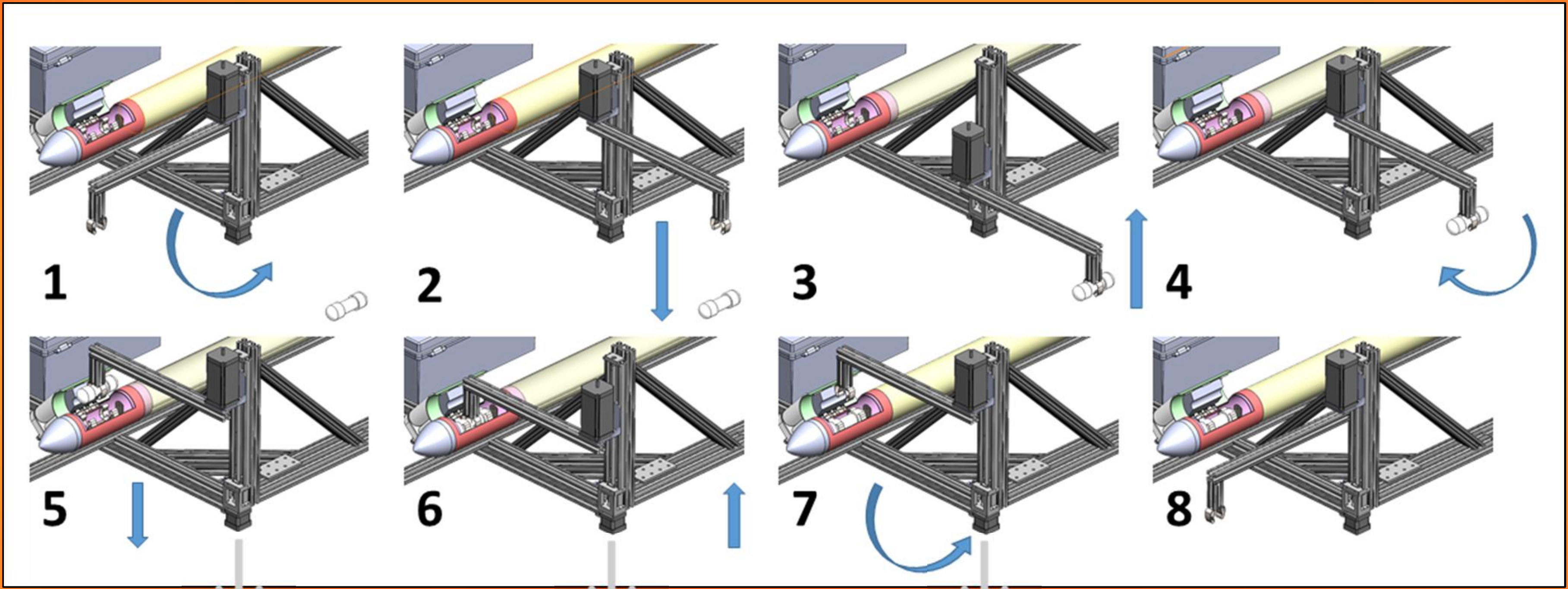


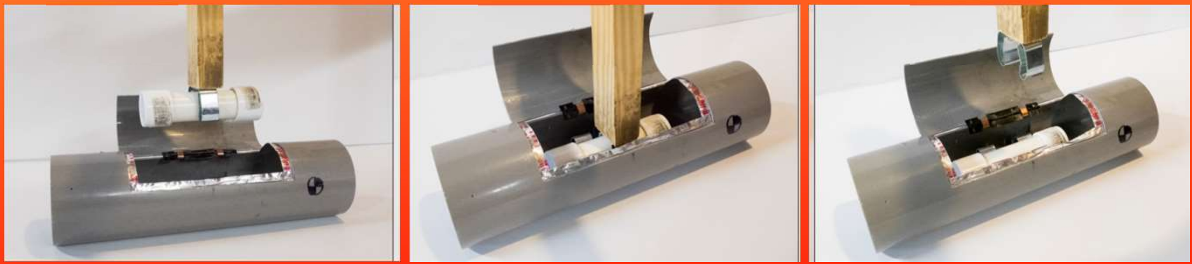
Coupler reinforces payload compartment to compensate for weakened structure.

PAYLOAD RETRIEVAL AND INSERTION

Payload placement guide (laser mark)

1-8 RETRIEVAL AND INSERTION SEQUENCE

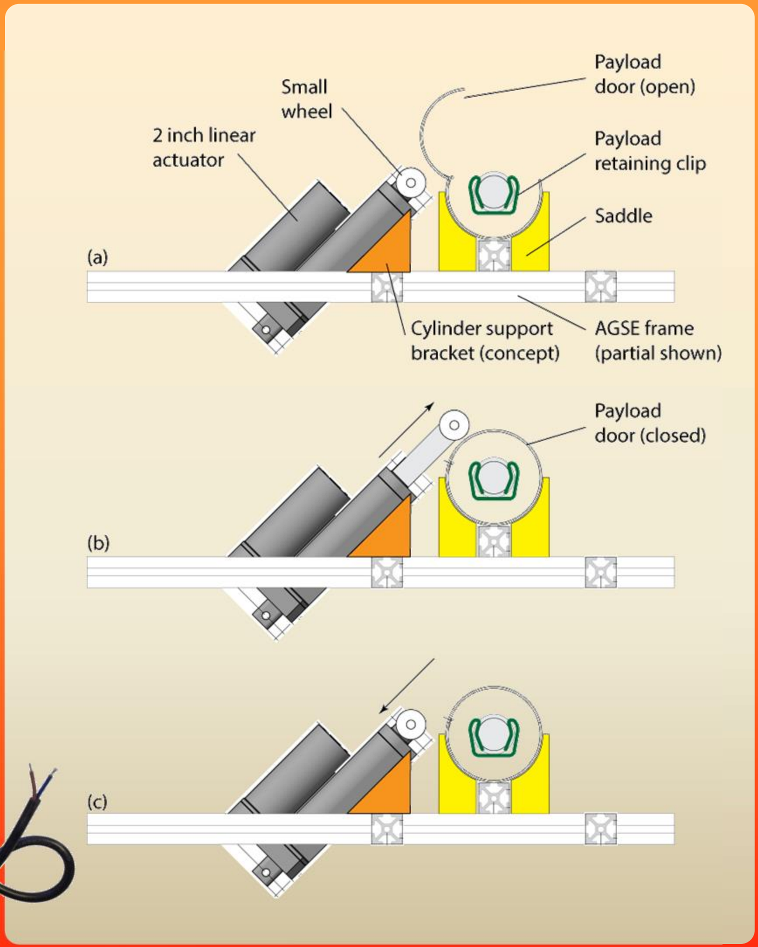




Pretotype demonstration of payload insertion and retention utilizing 2:1 grip:retain force ratio

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.

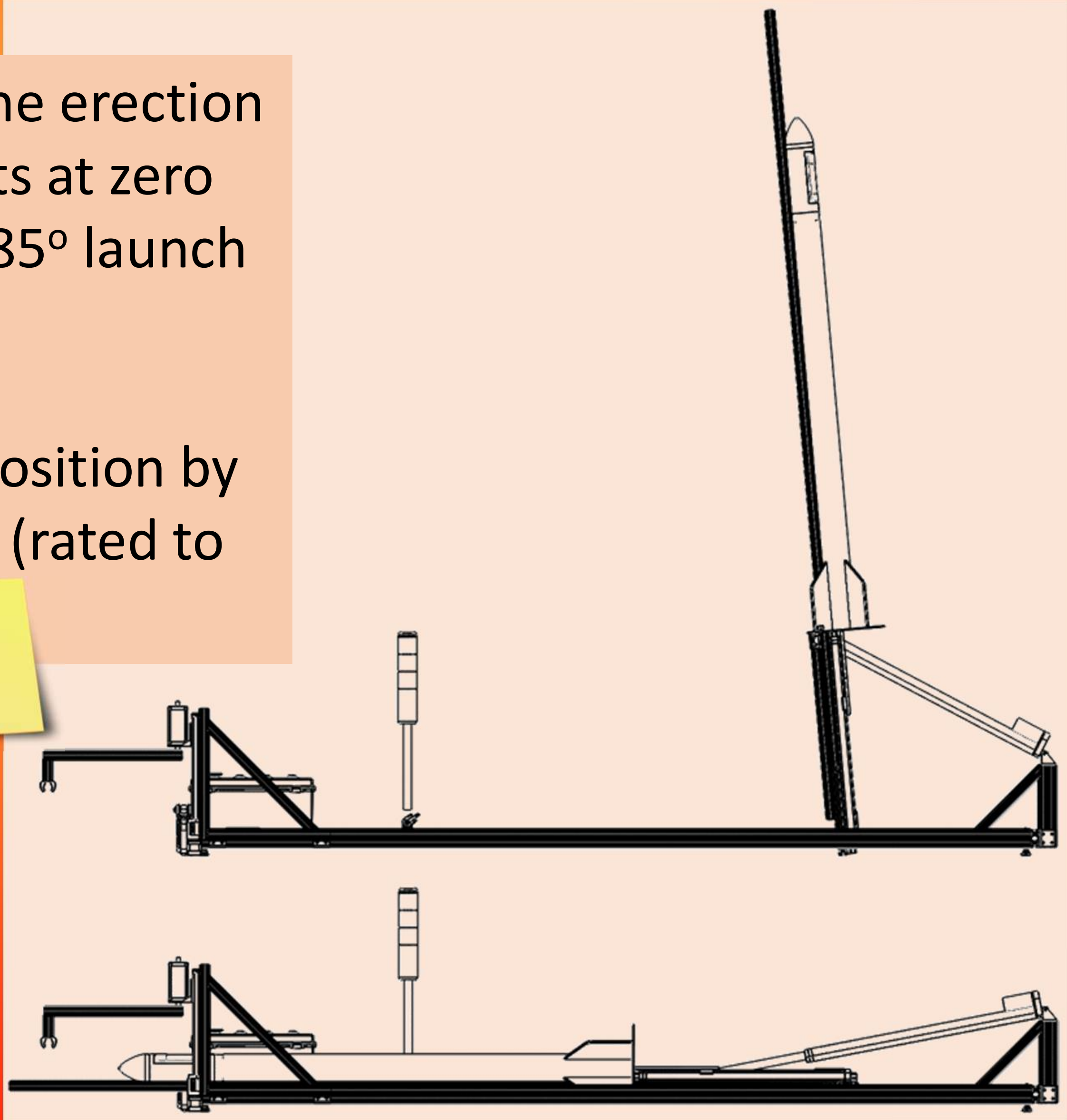


THE ERECTION SYSTEM

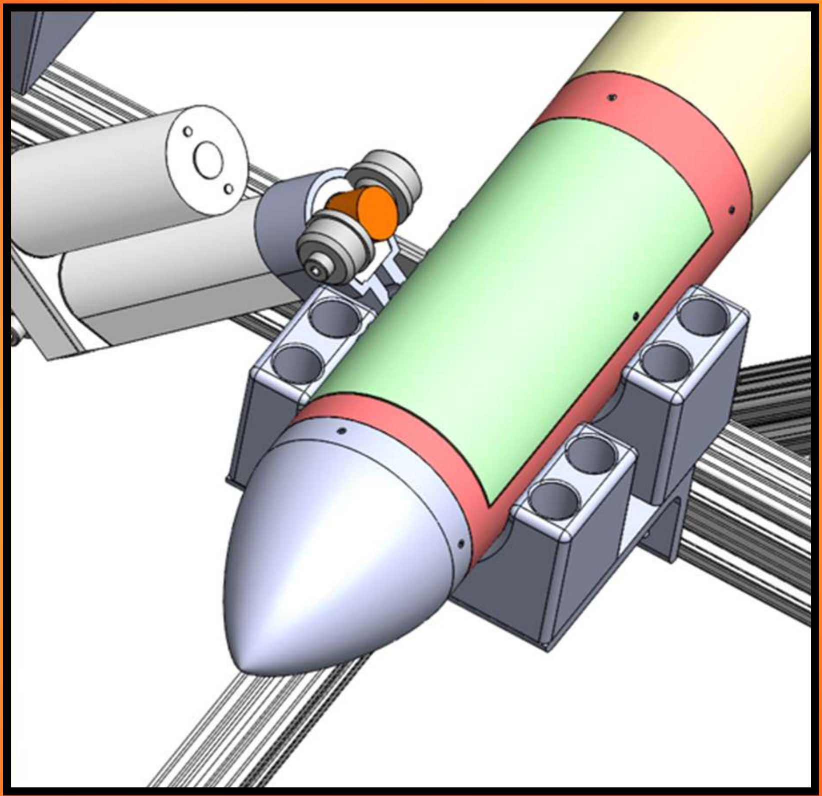
Linear actuator is used for the erection system. Linear actuator starts at zero angle and pulls the rail to a 85º launch position.

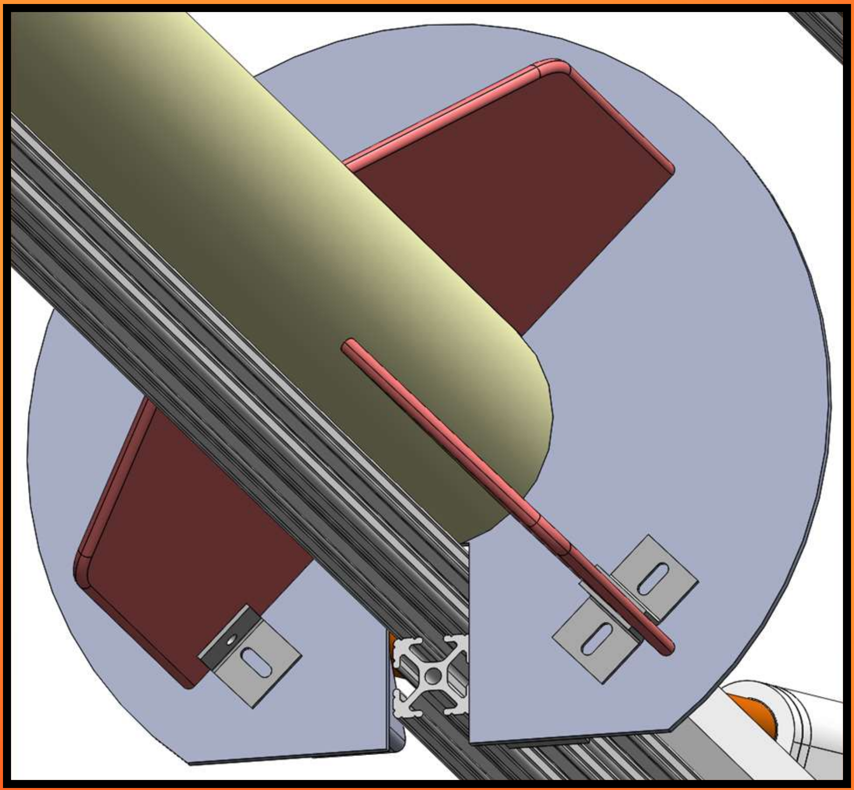
The rail is locked in launch position by resistance of linear actuator (rated to 400*lbs*).

CDR Feedback Item #7



ROCKET STABILIZATION



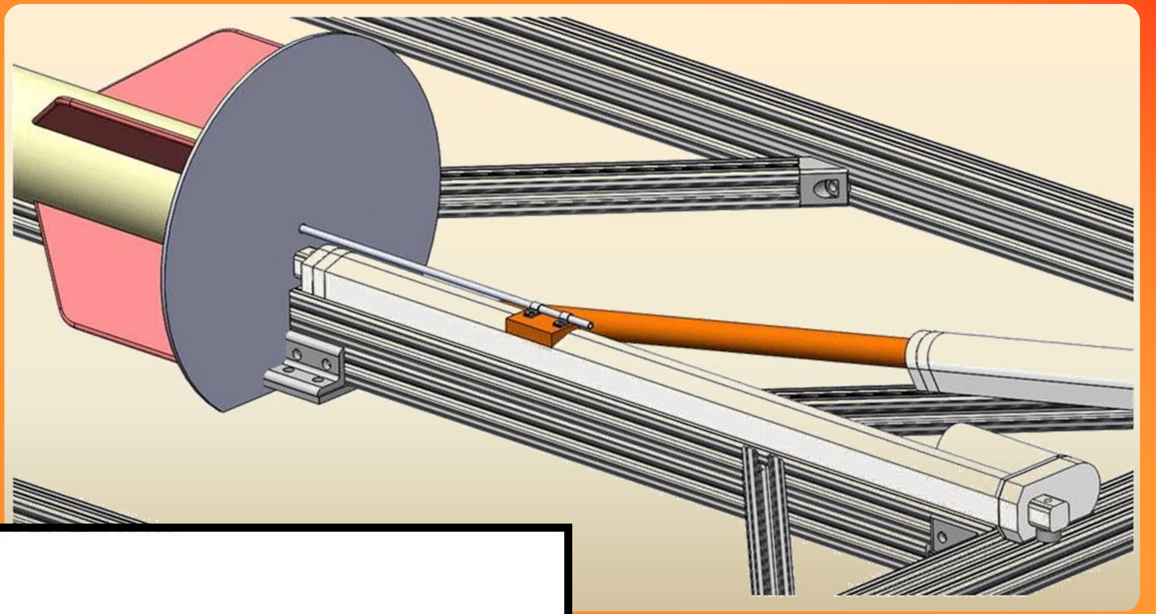


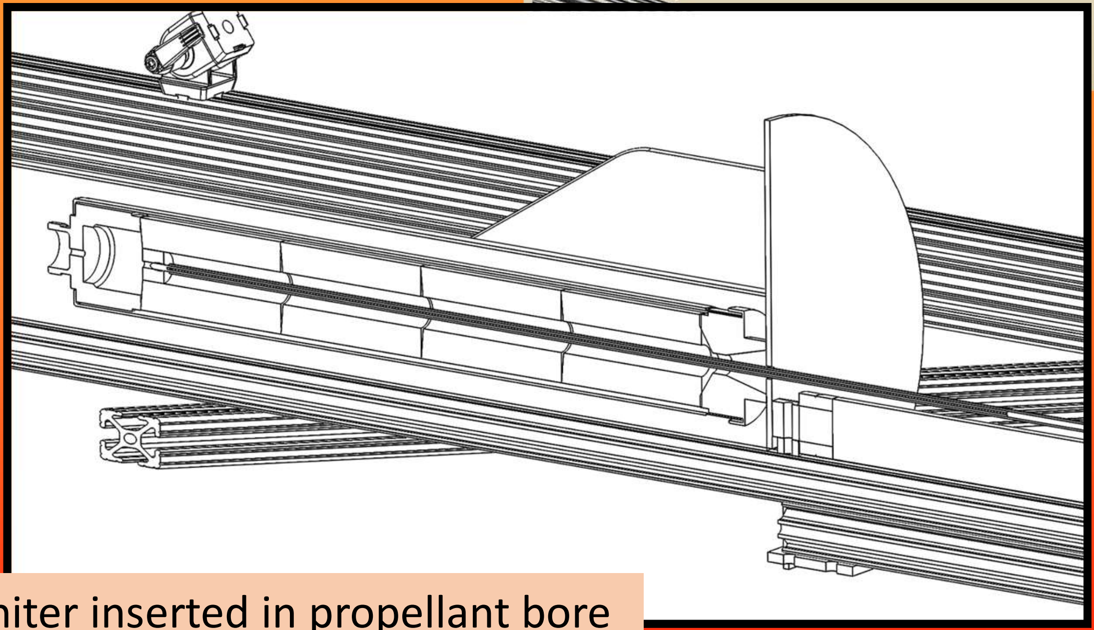
The front cradle is used to support the rocket during payload insertion and payload door operation.

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.

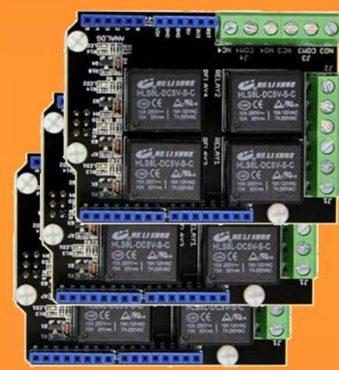




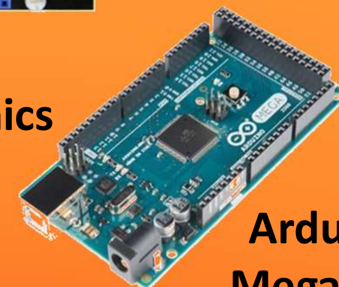
Igniter inserted in propellant bore

CONTROL DRIVER

Information display



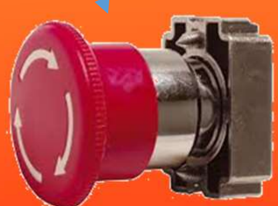
Driver electronics



Arduino Mega2560

Stack lights (information)

Control panel

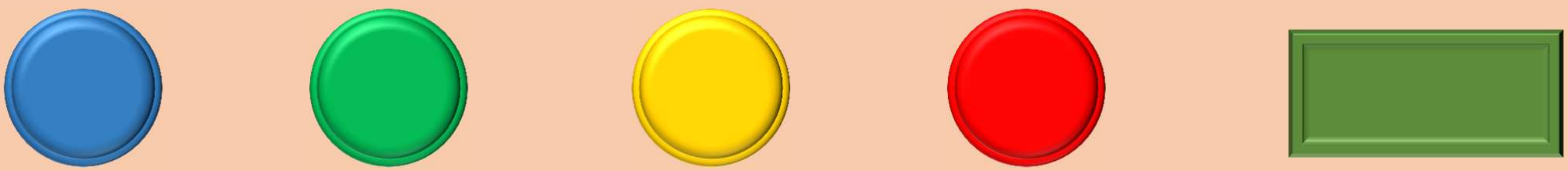


E-stop button

Power source (battery)

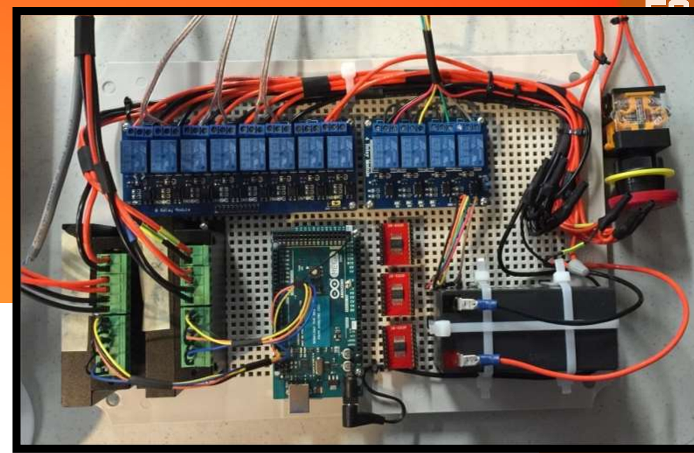
There will be LED display designed to communicate the conditions and progress of the AGSE

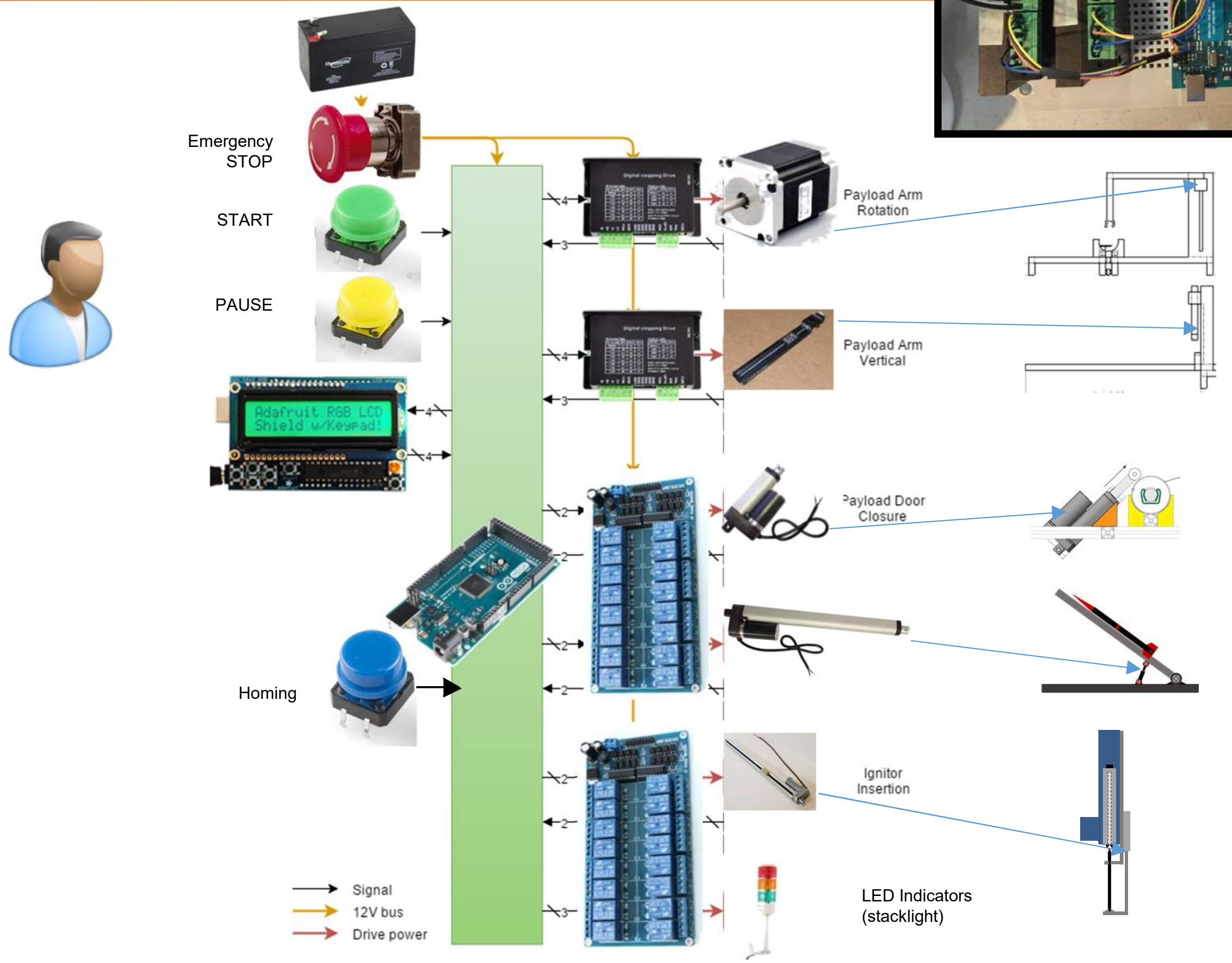
CONTROL PANEL



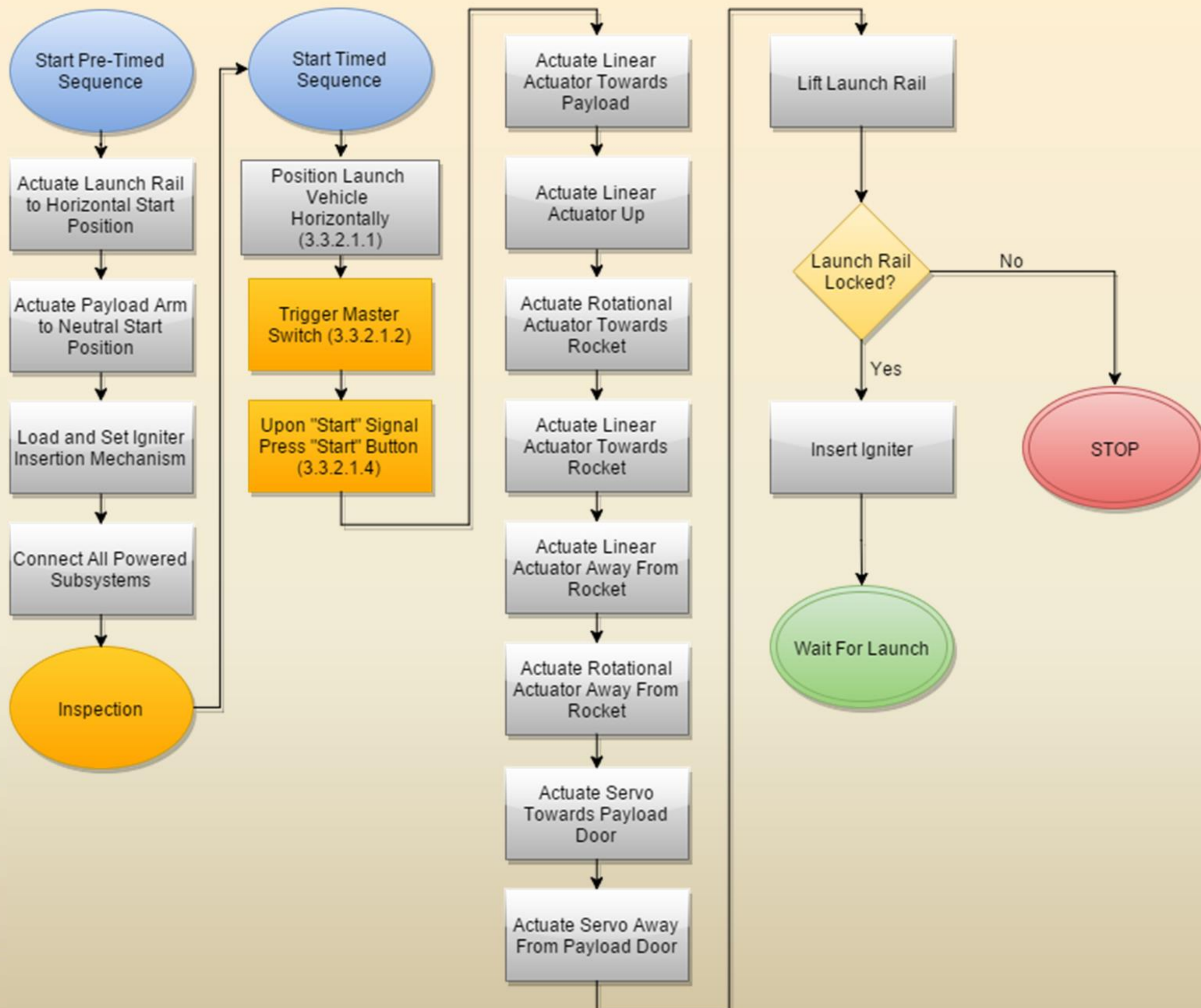
Returns AGSE to HOME position	STARTs/resumes autonomous operation of AGSE	PAUSEs autonomous operation of AGSE	Physically disconnects power (emergency STOP)	Information display

AGSE BLOCK DIAGRAM





PROCESS FLOW



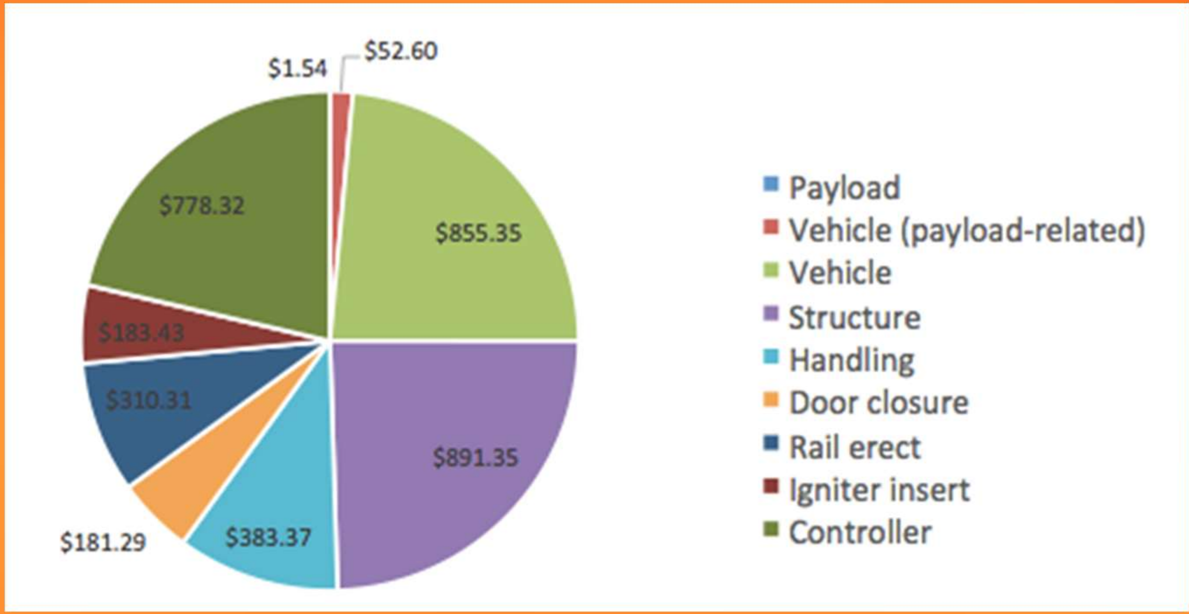
TIME TO COMPLETE SEQUENCE

Action	Duration [sec]	Running Time [min:sec]
Move to "Home" Position	38	0:38
Payload Capture	37	1:15
Payload Dropoff	81	2:36
Clear SCARA Arm	35	3:11
Close Payload Door	14	3:25
Erect Rocket	47	4:12
Ignitor Insert	21	4:33
TOTAL	273	4:33

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	Sparkfun	
Controller	Battery, 12 Pb-acid/gel	Tenergy or similar	e.g., TB12120
Controller	Indicator tower	uxcell/Amazon	12V tricolor

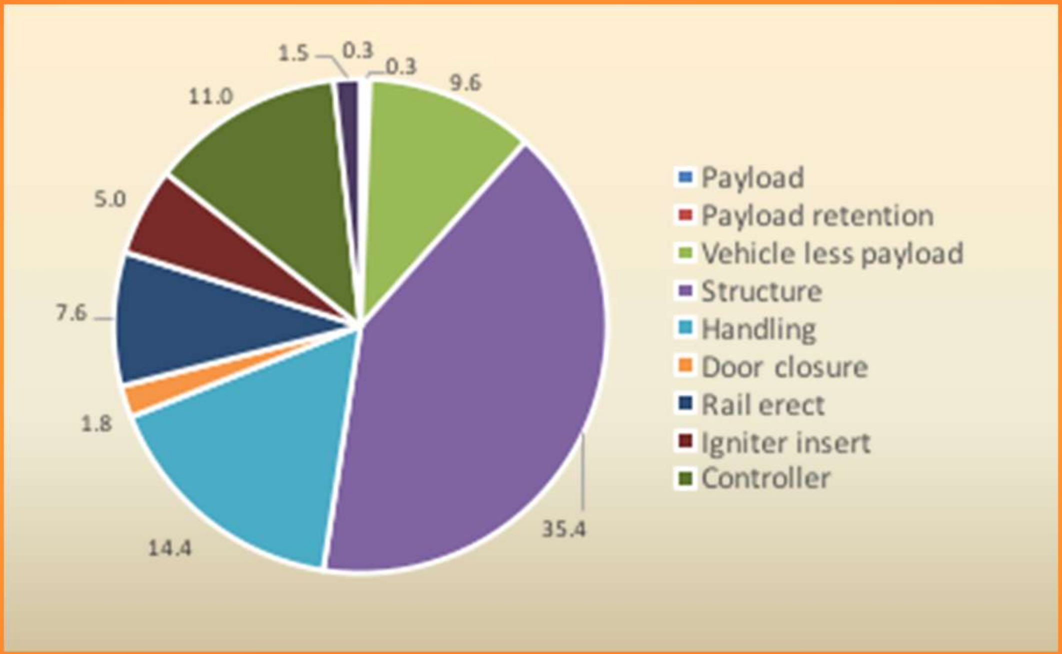
BUDGET



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.

AGSE MASS STATEMENT



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	

AGSE VERIFICATION OUTLINE

CDR Feedback
Item #6

#	Step	Goals	Milestone	Status
1	*Concept design*	• Preliminary structure/launcher design • Preliminary payload manipulation & insertion approach • Preliminary control system approach • Preliminary power source and architecture • Preliminary vehicle payload retainment approach • Preliminary weight and budget estimate	SOW	✓
2	*Solid Modeling and Development*	• Use SolidWorks® software to develop full AGSE assembly • Determine required dimensions for each component • De-conflict ranges of motion for robotic subsystems	PDR/CDR	✓
3	*Hardware Familiarization*	• Assemble critical subsystems in isolation • Gain proficiency with hardware assembly techniques • Verify motor functionality and suitability	PDR/CDR	✓
4	*Assembled Hardware Test*	• Assemble full AGSE • Manually actuate robotic components through required MAV procedures • Perform live launches from AGSE	CDR	✓
5	*Firmware Verification - Component*	• Verify correct firmware function prior to use with robotic subsystems • Check stepper motor controller using oscilloscope trace • Check linear actuator controller with multimeter • Check microswitches, control inputs, and general functionality with serial print commands	FRR	✓
6	*Hardware/Firmware Integration - Component*	• Test subsystems individually • Verify correct microswitch function for all motors • Verify correct travel distances and speeds for stepper motors • Ensure functionality of stack lights and LCD • Test payload placement procedure	FRR	✓
7	*Full System Verification*	• Perform fully autonomous MAV Challenge routine • Pause and resume during every phase of autonomous motion	FRR	✓

AGSE SUBSYSTEMS VERIFICATION

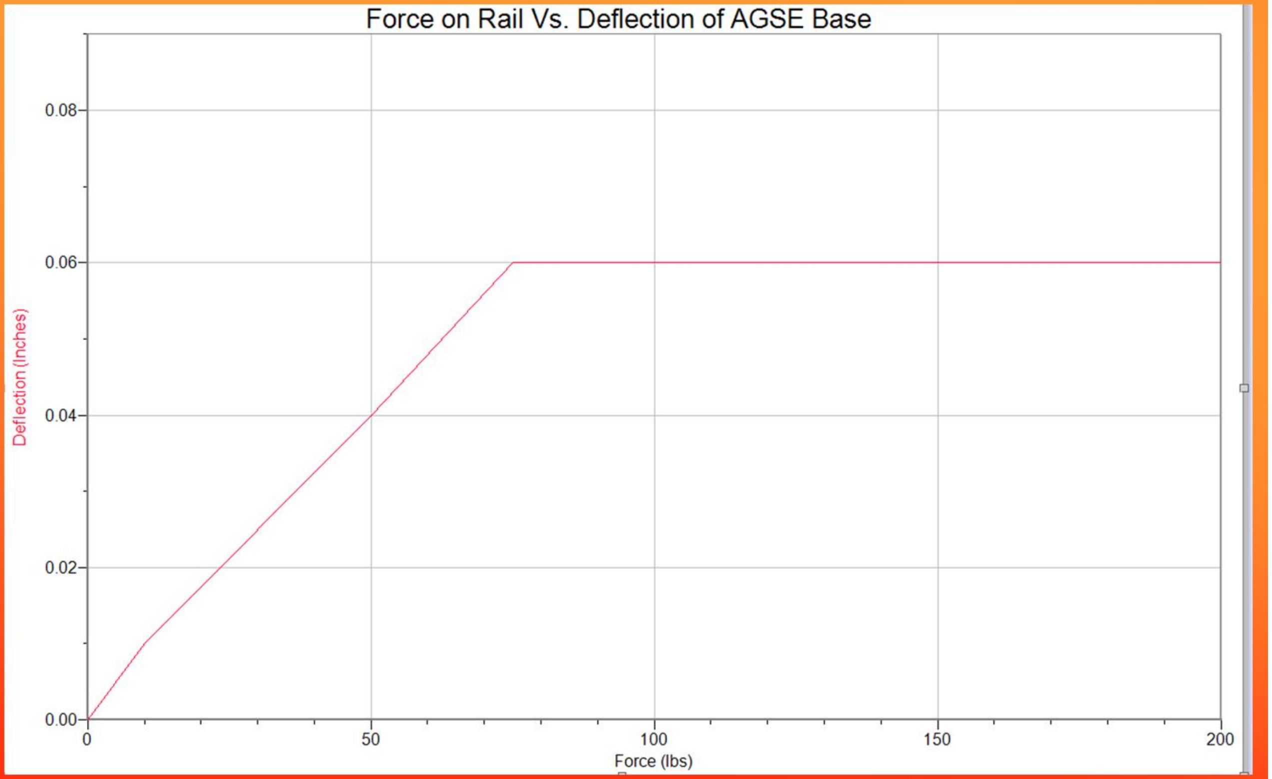
Subsystem	Tests	Status
AGSE Structure	1. General rigidity and stiffness verification 2. Launch rail testing; vehicle and wind loading 3. Wind stability load testing 4. Full scale launches and environmental testing 5. Weight assessment	✓ ✓ ✓ ✓ ✓
SCARA Arm	1. Load testing 2. Motion accuracy tests 3. Microswitch functionality tests 4. Full payload pickup procedure	✓ ✓ ✓ ✓ ✓
Linear Motors	1. Range of motion tests 2. Microswitch functionality 3. Igniter insertion	✓ ✓ ✓
Outputs: Stacklight/LCD	1. Light operation tests 2. LCD operation tests	✓ ✓
Power/control	1. Pause/interrupt testing 2. Procedure length/timing	✓ ✓

COMPLETED

AGSE BASE DEFLECTION

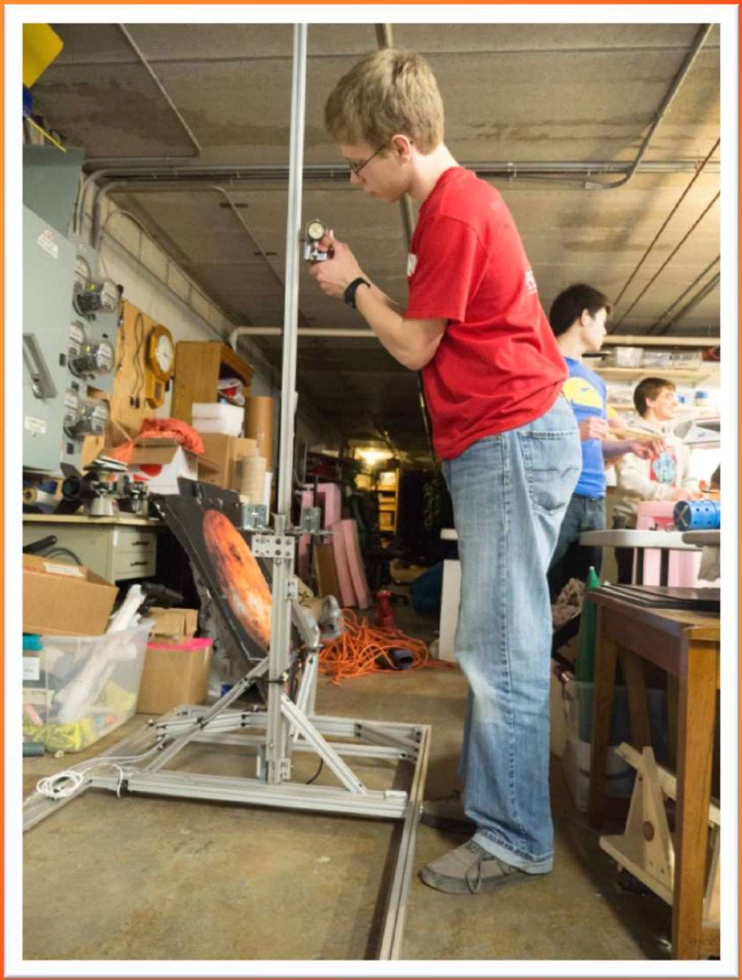
Top load: 10*lbs*

Bottom load: 200*lbs*



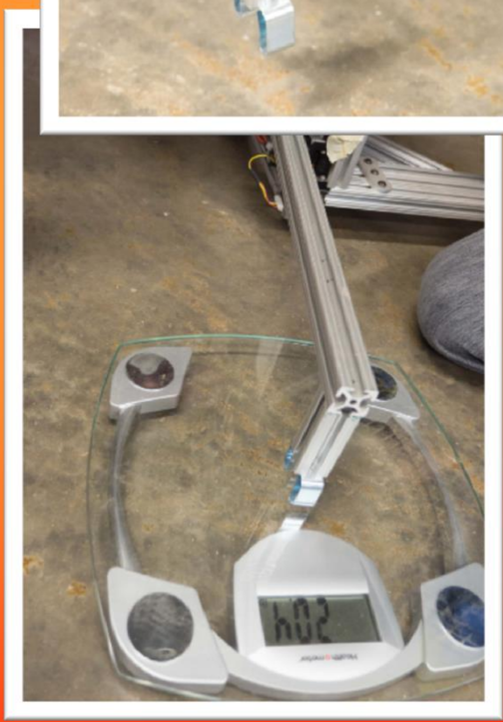
AGSE LOAD TESTS

Rail Load test (20*lbs)*



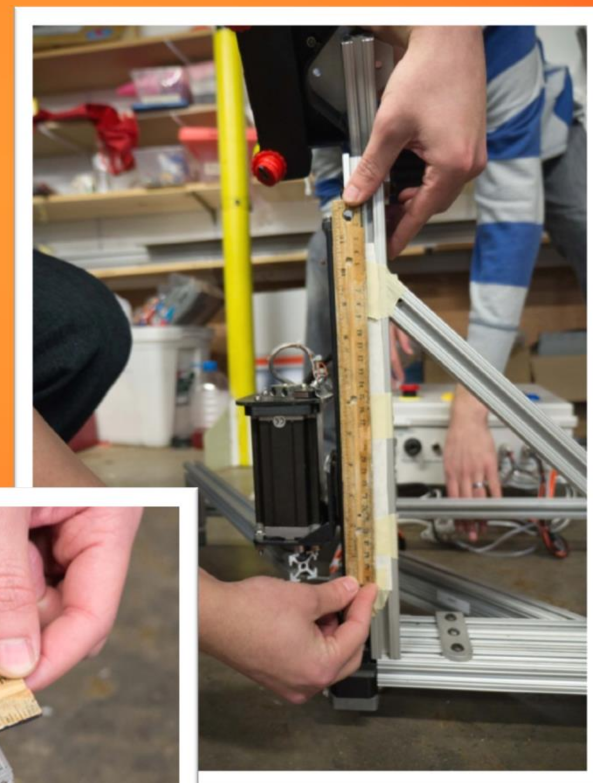
Wind Stability Test (20*lbs* side force)

SCARA ARM TESTS



Load Tests

Motion Accuracy Tests



PAYLOAD COMPARTMENT FLIGHT STRESS TEST

The payload compartment ability to remain closed and retain the payload during flight and landing has now been tested during four different test flights using motors of different thrust (CTI J449BS, CTI J360SK, CTI J380SS and CTI J760WT).

AGSE LAUNCH TESTS

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

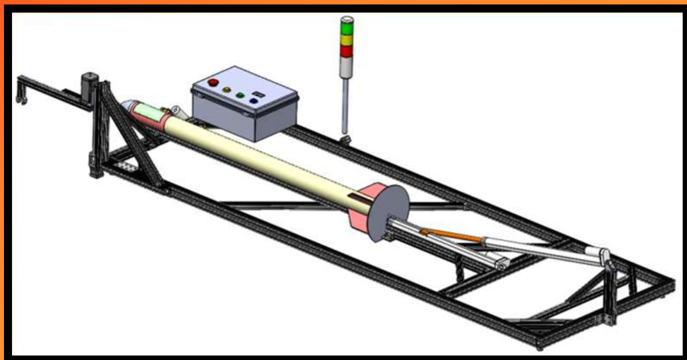
ADVANCED: H-class fiberglass/Blue Tube rockets, 1500g, to further test the blast deflector and to uncover possible stability problems

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 FUNCTIONALITY TEST

AGSE Demonstration video: https://youtu.be/DaTEIZG-wGI

AGSE STATUS



AGSE STATUS

Superstructure: completed.

Movements: all linear actuators and stepper motors were tested and are suitable for the tasks assigned to them. AGSE automated sequence can be executed as required by contest rules.

End switches: microswitches for detection of movement completion were tested and integrated with the superstructure. The firmware handles all events from microswitches.

Firmware: code has been developed for each AGSE movement, integrated with the rest of the system, unit tested and tested.

Controller: the controller is now fully functional.

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

AGSE Verification: Completed.


QUESTIONS?