

OTRA Modular Rocket (Nite-Owl)

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Project Goals

- ❖ Manufacture a modular rocket, reusable for long term testing of multiple different systems for engines, fins, recovery, etc
 - Capable of holding the Gizzard liquid engine in the future
 - Use a solid off-the-shelf motor to make a launch this year



Refined Goals

- ❖ Suitable for the 2017 LOx/Butanol engine
 - Minimum 6" diameter
- ❖ Minimal number of parts to allow more flexibility/room for individual components
 - Monocoque design
 - Purchased carbon fiber tubes
 - Fully disassemblable for full modularity
 - Maximized use of screws, minimal adhesives and epoxies
 - Combined fin and engine mount system for ease of removability
- ❖ Manufacture as many components in house as possible
 - Carbon fiber fins built for flutter resistance
 - Aluminum used for machinability and strength to weight ratio
 - Parts designed to be machinable on manual mill or lathe, or on 3 axis CNC
 - Minimal number of parts designed to require CNC

Refined Goals

- ❖ Follow design constraints of the Spaceport America Cup
 - Launch rocket to 10,000ft
 - Create active air-braking system to control rocket altitude
 - Off rail velocity of 100 ft/s
 - Motor needed a steep thrust curve
 - Stability calipers of 1.5
 - Made more difficult by the need for off rail velocity
 - Minimum 12 ft rail needed
 - Parachutes used dual deployment and swivel links



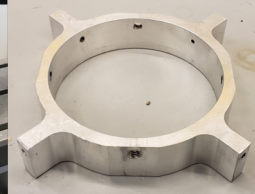
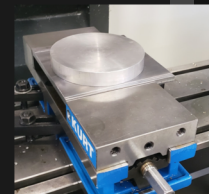
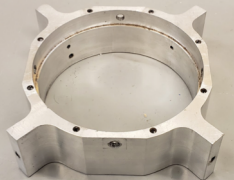
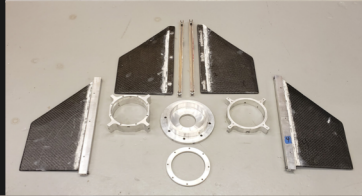
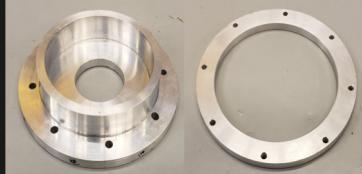
Purchased Components

- ❖ Nose Cone
 - 30" 5:1 Secant Ogive shape with metal tip, filament wound fiberglass
 - Metal tip helps to disperse estimated heating of about 86°F
- ❖ Body Tubes
 - 2x40" long, 6" inner diameter .08" thick, filament wound carbon fiber
- ❖ Fasteners
 - 5/16" shoulder fasteners for 6-32 screws
 - Prevents delamination of the carbon fiber tubes by screws
- ❖ Level 2 Motor- L805P
- ❖ Level 3 Motor Casing
 - Rocket designed for M3400
- ❖ Chutes
 - ½" Kevlar rope, 36" elliptical drouge, 120" elliptical main parachute
- ❖ Avionics Board and Ejection System
 - Pyro Co2 Ejection redundant system with Altimeter
 - Drogue Release with Secondary Altimeter



Manufactured Components

- ❖ Centering Rings/Fin Assembly
 - Designed to support 900 lb (4000 N) load and 98mm diameter Level 3 motor
 - Aluminum Centering Rings and Fin Rails
 - Done with manual mill processes
 - 1/4" and 6-32 screws allow for full disassembly
 - Upper and Lower rings
 - 3 axis CNC
 - Secured by screws into jig plate
 - Holes were drilled/tapped on mill after CNC
- ❖ Fins
 - Clipped delta shape
 - Wooden core, 3k tow, twill weave carbon fiber
 - 45° clocking on 4 layers per fin
 - Equivalent stiffness to 12k tow solid carbon fiber fin
- ❖ Additional centering rings and motor adapter
 - Fiberglass Roll Wrapped Tube and Wooden Laser Cut Centering Ring for Level 2 Motor Adapter



Launch Tower

- ❖ Design goals:
 - Lock 6° from vertical
 - Deflector plate
 - 12 feet of rail for a stable launch velocity
 - Usable for a variety of rockets
 - Easy to move
- ❖ Specifications
 - Launch position height: 13ft
 - Total weight: 425 Lbs
 - Heaviest component: 195 Lbs
 - Easy to use
- ❖ Additional advantages
 - No additional hardware needed (lugs or buttons)
 - Made from common materials
 - Primarily A36 angle iron
 - Thick wall round tube



Analysis- Strengths Calculations

❖ Launch Tower

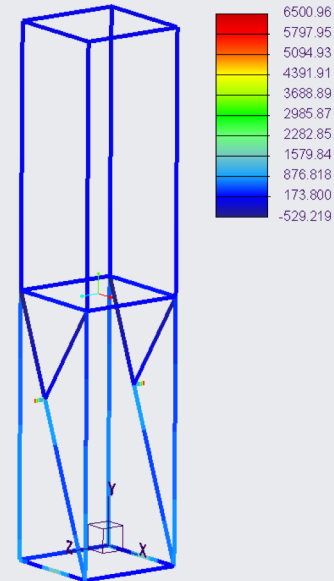
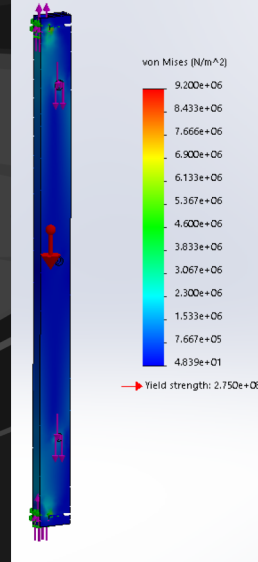
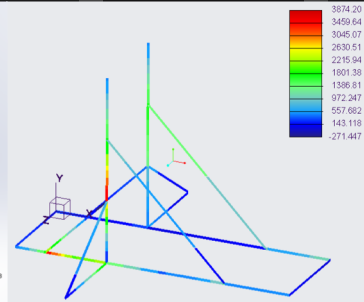
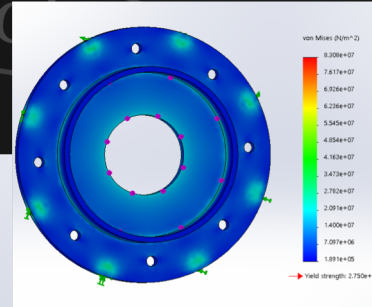
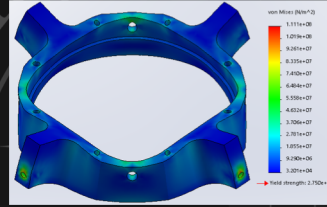
- Assuming blast plate absorbs full thrust of motor (900 lbs)
- Main tower/Base
 - Max stress of 6501/3874 Psi
 - FS = 5.5/9.3

❖ Engine Mount

- Thrust cap is the main piece taking motor thrust
 - FS 3 for 900 lb thrust and 1/4" long screws
- Fin rails receive much less force and are longer along direction of thrust
- Bottom ring takes (assumed) full thrust along a thin lip but still has acceptable FS

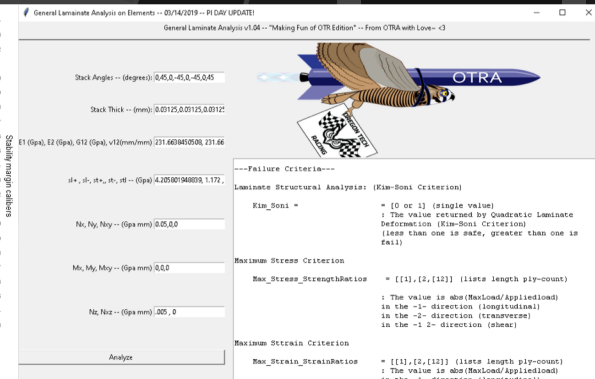
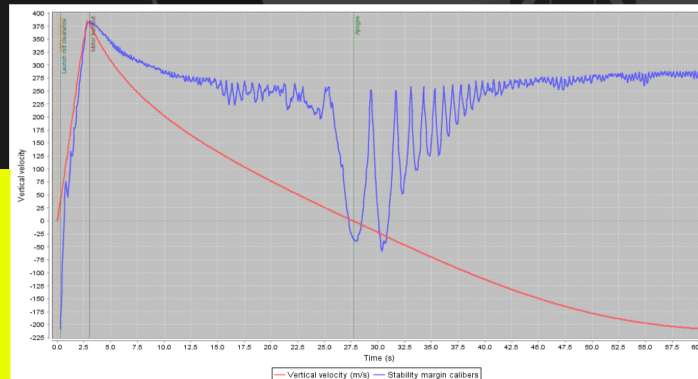
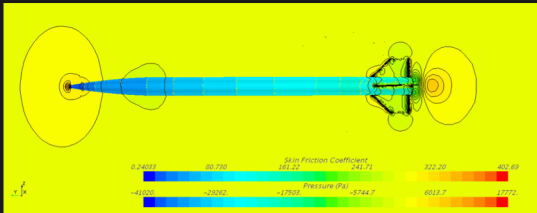
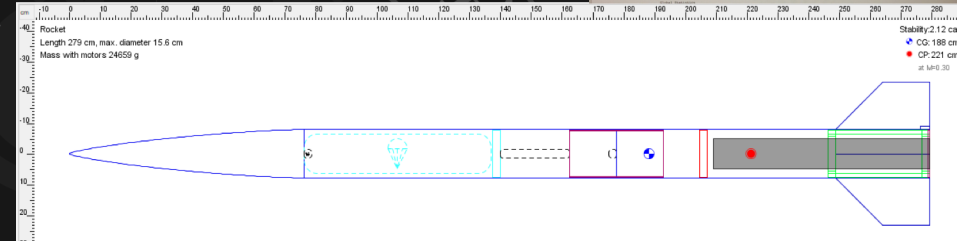
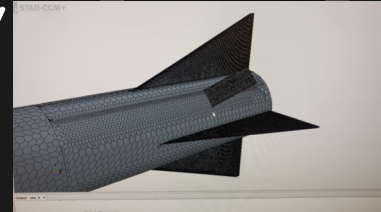
❖ Screws

- Hand calcs done to ensure 6-32 screws also take full thrust



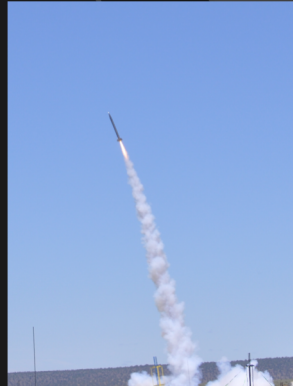
Analysis- Aerodynamics and Stability

- ❖ Weights and position of each component entered into OpenRocket
- ❖ Specific stability required off launch rail
 - Shorter rails require faster rocket
- ❖ Stability margins
 - High results in overstability
 - Low causes rocket inversion
- ❖ Fin Strength and Flutter Calculations using Classical Laminiate Theory and AeroFinSim
- ❖ CFD is hard



Testing

- ❖ Ejection Charge Testing
 - CO2 Ejection, May 25
 - System was inadequately assembled preventing a successful ejection test
- ❖ Flight tests at OROC's launches in Brothers, OR
 - First Launch Attempt, May 18
 - Ejections systems failed, before reassembly and retesting the launch was closed due to weather
 - Second Launch, June 23
 - Successful level 2 launch with a Cesaroni L805P by Chris Anderson, flew to 3438 feet



Pitfalls-Safety

- ❖ Recovery section design
 - BATF (Bureau of Alcohol, Tobacco, Firearms and explosives) explosives regulations
 - Not able to use black powder and ematch for on campus testing since they are classified as a low explosives
 - Insurance
 - Expensive to get insurance to cover the use and storage of the explosives on campus
 - Storage
 - Difficult to find a suitable location to store explosives
 - Storage Magazines are expensive and must meet class requirement
 - Causing a mechanical solution to be found



Diameter	Length											
	6"	10"	14"	18"	22"	26"	30"	34"	38"	42"	46"	50"
2"	12g	12g	12g	12g	12g	12g	12g	12g	12g	16g	16g	16g
3"	12g	12g	12g	12g	12g	12g	12g	12g	16g	16g	16g	16g
4"	12g	12g	12g	12g	12g	16g	16g	16g	25g	25g	25g	25g
5"	12g	12g	12g	12g	12g	16g	16g	25g	25g	25g	25g	25g
6"	12g	12g	12g	12g	16g	16g	25g	25g	25g	25g	38g	38g
8"	12g	12g	16g	16g	25g	25g	38g	38g	38g	38g	NR	NR
10"	12g	12g	16g	25g	25g	38g	38g	38g	NR	NR	NR	NR
12"	12g	16g	25g	25g	38g	38g	NR	NR	NR	NR	NR	NR

Pitfalls- Carbon Fiber Tubes

- ❖ Inadequate tolerancing
 - Poor machinability
- ❖ Filament winding compression
- ❖ Aluminum-carbon fiber corrosion



Interesting Findings

❖ Classification

- *Low explosives.* Explosive materials which can be caused to deflagrate when confined (for example, black powder, safety fuses, igniters, igniter cords, fuse lighters, and “display fireworks” classified as UN0333, UN0334, or UN0335 by the U.S. Department of Transportation regulations at 49 CFR 172.101, except for bulk salutes).

❖ Types of magazines

- *Type 2 magazines.* Mobile and portable indoor and outdoor magazines for the storage of high explosives, subject to the limitations prescribed by §§555.206, 555.208(b), and 555.213. Other classes of explosive materials may also be stored in type 2 magazines.

❖ Transportation

- Model rocket motors can be purchased online without special permits, and shipped via common carrier ground (USPS).

§555.219 Table of distances for storage of low explosives.

Pounds		From inhabited building distance (feet)	From public railroad and highway distance (feet)	From above ground magazine (feet)
Over	Not over			
0	1,000	75	75	50
1,000	5,000	115	115	75
5,000	10,000	150	150	100
10,000	20,000	190	190	125
20,000	30,000	215	215	145
30,000	40,000	235	235	155
40,000	50,000	250	250	165
50,000	60,000	260	260	175
60,000	70,000	270	270	185
70,000	80,000	280	280	190
80,000	90,000	295	295	195
90,000	100,000	300	300	200
100,000	200,000	375	375	250
200,000	300,000	450	450	300

Info and Questions?



Part Weights		Other Measurements		Length	
Nosecone	6.375 lbs	Cg Level 2	67.23 in	Total Length	110 in
Parachutes	1.88125 lbs	Cp Level 2	87.176 in	Nosecone Length	30 in
Parachute Shock Cord	0.6375 lbs	Stability Calipers	3.24	Body Tube Lengths (x2)	40 in
Electronics Board	1.1375 lbs	Weight with Lvl 2 Motor	33 lb	Length of Engine Section	28.675 in
Parachute Bulkhead	0.975 lbs	Expected Max Velocity Lvl 2	Mach .5	Engine-Recovery Clearance	17.485 in
Top Body Tube	3.6 lbs	Expected Max Acceleration Lvl 2	262 ft/s^2	Parachute Packing Length	23.1875 in
Bottom Body Tube	3.43125 lbs	Expected Apogee Lvl 2	4394 ft	Length of Level 2 Engine	25.515 in
Coupler	1.19375 lbs	Cg Level 3	75.898 in	Length of Level 3 Engine	27.64 in
Engine Bulkhead	2.02 lbs	Cp Level 3	87.176 in		
Fins + Fin Rails	2.9 lbs	Stability Calipers Lvl 3	1.83		
Middle Centering Ring	0.454 lbs	Weight with Lvl 3 Motor and Payload	56.4 lb		
Bottom Ring and Retainer	0.686 lbs	Expected Max Velocity Lvl 3	Mach 1.15		
Lvl 2 Motor Adapter Tube	1.2125 lbs	Expected Max Acceleration Lvl 3	504 ft/s^2		
Weight without motors or payload	26.50375 lbs	Expected Apogee Lvl 3	13771 ft		