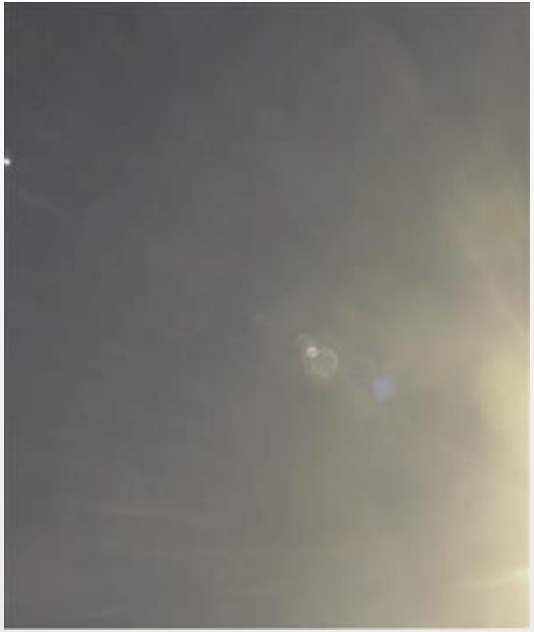
Solid Motor Casing & Design



Solid Design Team:
Tony, Jason, Andrew, Tarique, Esteban, Jack

Quick Recap

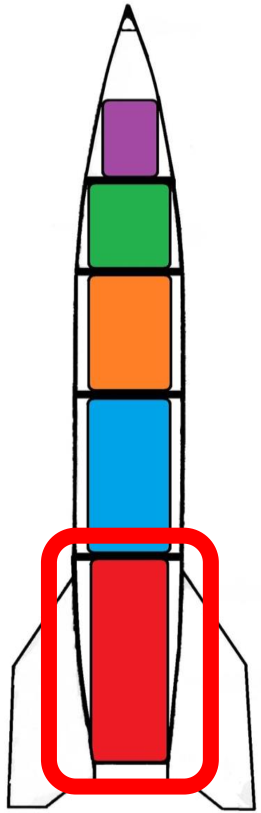
Motor and Propellant Selection

- Non-Toxic
- Non-Detonable
- HTPB/AP/AL Composite

Aerotech L2200G-P Mojave Green

Design Process

- Payload
- Drogue Chute
- Payload/Avionics
- Main Chute
- Motor and Casing



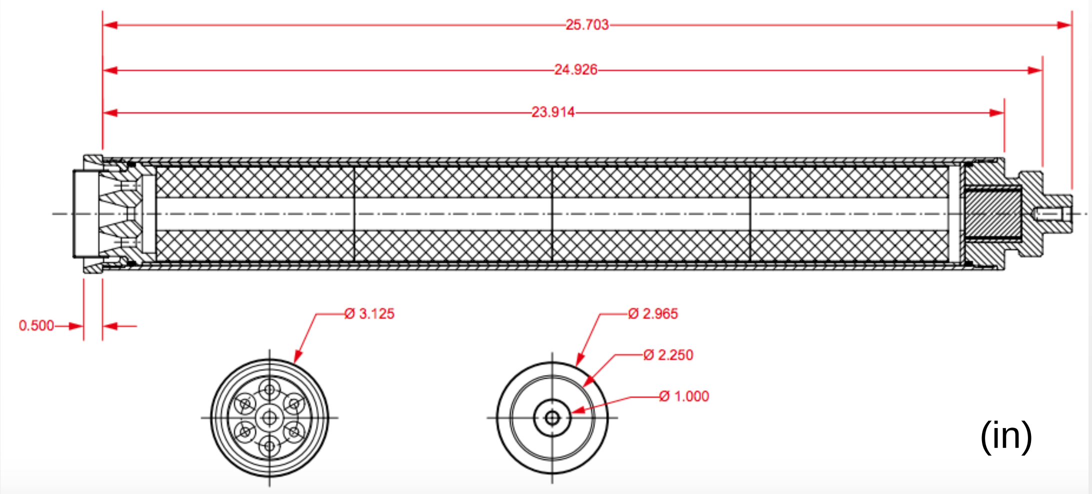
Motor Case Design Considerations

What we know:

- Peak Thrust ≈ 3100N
- Burn Duration ≈ 2.4s
- Dimensions

What we need to know:

- Chamber Pressure
- Chamber Temperature



Nozzle Design Considerations

What we know:

- Peak Thrust ≈ 3100N
- Burn Duration ≈ 2.4s
- Dimensions

What we need to know:

- Chamber Pressure
- Gas Exit Velocity
- Gas Exit Temperature

Igniter Considerations

What we know:

- Motor Overall Performance

What we need to know:

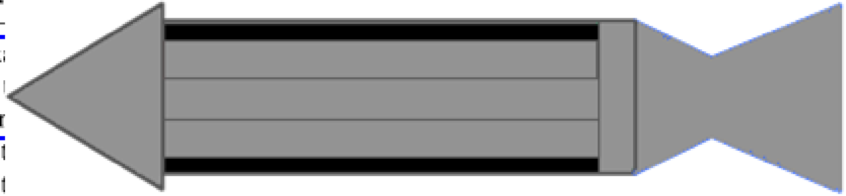
- Nothing

Solid Rocket Motor

- Case
- Solid Propellant
- Igniter
- Nozzle

Motor Case Loadings/Stresses

Origin of Load	Type of Load/Stress
Intern	
Axial	
Motor	
Thrust	
Thrust	
Aerodynamic control surfaces or wings mounted to case	Tension, compression, bending, shear, torsion
Staging	Bending, shear
Flight maneuvering	Axial, bending, shear, torsion
Vehicle mass and wind forces on launch pad	Axial, bending, shear
Dynamic loads from vehicle oscillations	Axial, bending, shear
Start pressure surge	Biaxial
Ground handling, including lifting	Tension, compression, bending, shear, torsion
Ground transport	Tension, compression, shear, vibration
Earthquakes (large motors)	Axial, bending, shear



(1)

Motor Case Materials

- Composite
  - E-glass
  - Aramid (Kevlar 49)
  - Carbon fiber
- Metal
  - Titanium alloy
  - Alloy steel
  - Aluminum alloy 2024
- Combination

Material	Tensile Strength, N/mm^2 (10^3 psi)	Modulus of Elasticity, N/mm^2 (10^6 psi)	Density, g/cm^3 (lbm/in.^{3})	Strength to Density Ratio (1000)
		Filaments		
E-glass	1930–3100 (280–450)	72,000 (10.4)	2.5 (0.090)	1040
Aramid (Kevlar 49)	3050–3760 (370–540)	124,000 (18.0)	1.44 (0.052)	2300
Carbon fiber or graphite fibers	3500–6900 (500–1000)	230,000–300,000 (33–43)	1.53–1.80 (0.055–0.065)	2800
		Binder (by itself)		
Epoxy	83 (12)	2800 (0.4)	1.19 (0.043)	70
		Filament-Reinforced Composite Material		
E Glass	1030 (150–170)	35,000 (4.6–5.0)	1.94 (0.070)	500
Kevlar 49	1310 (190)	58,000 (8.4)	1.38 (0.050)	950
Graphite IM	2300 (250–340)	102,000 (14.8)	1.55 (0.056)	1400
		Metals		
Titanium alloy	1240 (180)	110,000 (16)	4.60 (0.166)	270
Alloy steel (heat treated)	1400–2000 (200–290)	207,000 (30)	7.84 (0.289)	205
Aluminum alloy 2024 (heat treated)	455 (66)	72,000 (10.4)	2.79 (0.101)	165

(1)

Composites

Table 2.1 E357 T-6 Casted Aluminum

AMS 4288	F_{tu} (ksi)	F_{ty} (ksi)	F_{cy} (ksi)	F_{su} (ksi)	E (ksi)	ν	ρ (lb/in^3)
T=72°F	45	36	36	28	10.4E3	0.33	0.097
T=300°F							-

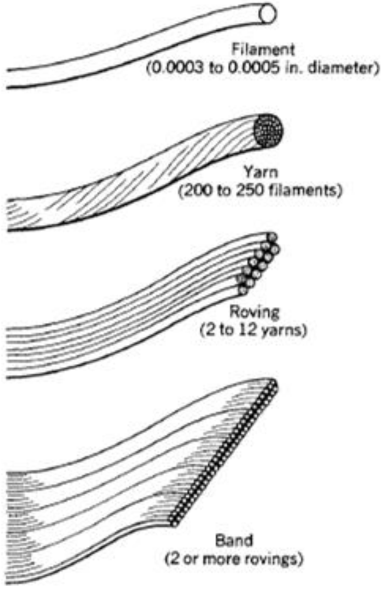
$$\begin{Bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \end{Bmatrix} = \begin{bmatrix} S_{11} & S_{12} & 0 \\ S_{21} & S_{22} & 0 \\ 0 & 0 & S_{66} \end{bmatrix} \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{Bmatrix} \tag{3}$$

Table 2.2 H

								G12 (psi)	v12
room temperature	348,000	232,000	11,000	36,200	13,800	2,466,000	1,305,000	638,000	0.27
300°F	313,200	208,800	9,900	32,580	12,420				
1.5 Safety Factor	208,800	139,200	6,600	21,720	8,280				

Filament Winding

- Orientation of Filament
  - Compromise



(1)

FIGURE 14–5. Filament winding terminology (each sketch is drawn to a different scale).

Material	Tensile Strength, N/mm^2 (10^3 psi)	Modulus of Elasticity, N/mm^2 (10^6 psi)	Density, g/cm^3 ($lbm/in.^3$)	Strength to Density Ratio (1000)
		Filaments		
E-glass	1930–3100 ([illegible]–450)	72,000 (10.4)	2.5[illegible]	[illegible]040
Ara[illegible]	[illegible]60	124,000 (18.0)	[illegible]	[illegible]
Ca[illegible] graph[illegible]	[illegible]	[illegible]000	[illegible]	[illegible]
Epoxy	[illegible]	[illegible]	[illegible]19	70
E[illegible]	[illegible]	35,0[illegible] (4.6–5.0)	[illegible]	[illegible]
Kevl[illegible]	[illegible]10 (190)	58,000 (8.4)	[illegible] (0.[illegible])	[illegible]
Graphite[illegible]	2300 (250–340)	102,000 (14.8)	1.55 (0.056)	[illegible]400
		Metals		
Titanium alloy	1240 (180)	110,000 (16)	4.60 (0.166)	270
Alloy steel (heat treated)	1400–2000 (200–290)	207,000 (30)	7.84 (0.289)	205
Aluminum alloy 2024 (heat treated)	455 (66)	72,000 (10.4)	2.79 (0.101)	165

(1)

Metals

- Titanium alloy
  - Heavy
  - Good strength to weight ratio
- Alloy steel
  - Heavier
  - Strongest
- Aluminum
  - Provides good strength to weight ratio
  - Lightest

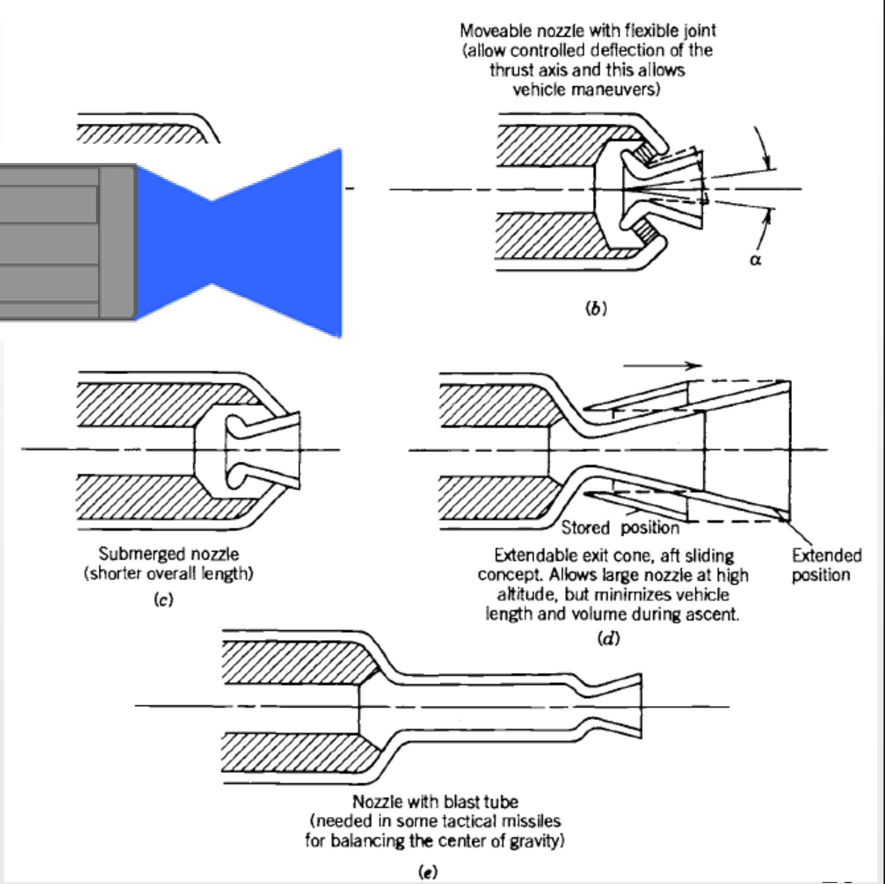
Material	Tensile Strength, N/mm^2 (10^3 psi)	Modulus of Elasticity, N/mm^2 (10^6 psi)	Density, g/cm^3 (lbm/in.^{3})	Strength to Density Ratio (1000)
Filaments				
E-glass	1930–3100 ([illegible])	72,000 (10.4)	[illegible]	[illegible]
[illegible]	[illegible]	124,000 (18.0)	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Epoxy	[illegible]	[illegible]	[illegible]	70
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	58,000 (8.4)	[illegible]	[illegible]
[illegible]	[illegible] (250–340)	102,000 (14.8)	[illegible]	[illegible]
Metals				
~~Titanium alloy~~	~~1240~~ (180)	~~110,000~~ (16)	~~4.60~~ (0.166)	~~270~~
~~Alloy steel~~ (heat treated)	~~1400–2000~~ (200–290)	~~207,000~~ (30)	~~7.84~~ (0.289)	~~205~~
Aluminum alloy 2024 (heat treated)	455 (66)	72,000 (10.4)	2.79 (0.101)	165

(1)

Nozzles

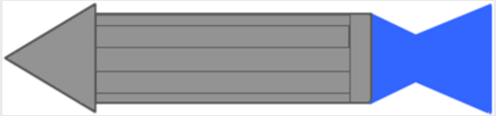
There are five

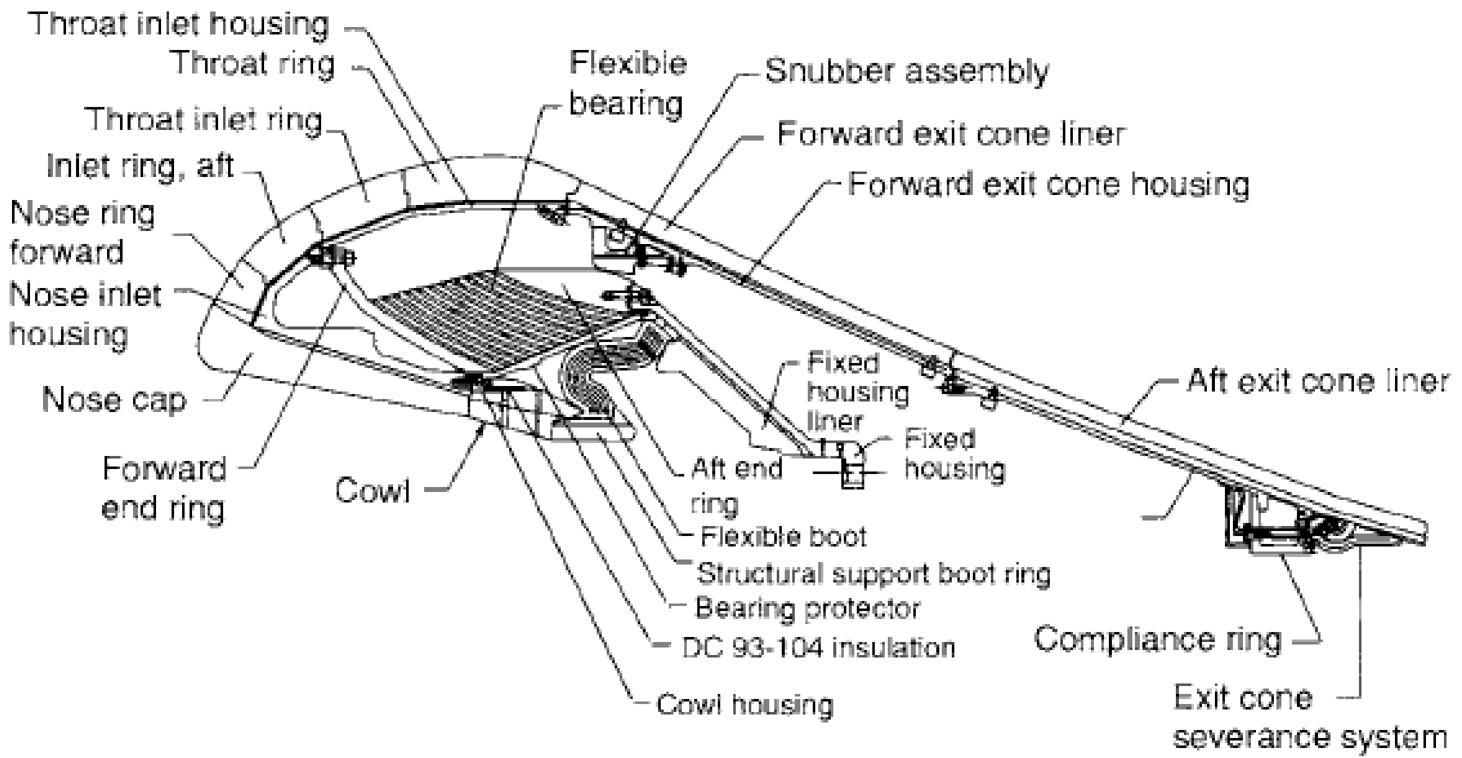
- Fixed (a)
- Movable (b)
- Submerged (c)
- Extendible (d)
- Blast-Tube-Mounted (e)



Nozzles: Design and Construction

- Ablatively Cooled
- Steel or aluminum Shells
- Composite ablative liners

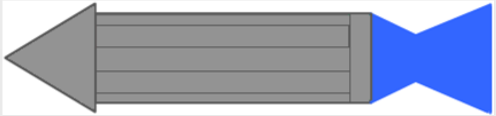



Throat inlet housing
Throat ring
Throat inlet ring
Inlet ring, aft
Nose ring forward
Nose inlet housing
Nose cap
Forward end ring
Cowl
Flexible bearing
Snubber assembly
Forward exit cone liner
Forward exit cone housing
Fixed housing liner
Fixed housing
Aft end ring
Flexible boot
Structural support boot ring
Bearing protector
DC 93-104 insulation
Cowl housing
Aft exit cone liner
Compliance ring
Exit cone severance system

Nozzle Design Decision

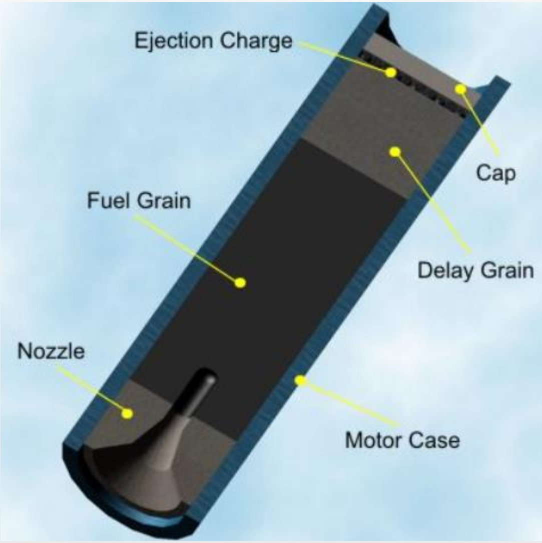
WE’RE NOT BUILDING ONE!!

Why?!?



Nozzle Selection

- Aerotech L2200G-P Mojave Green and RMS 75/5120 kit comes with a nozzle



Solid Rocket Motor Expert

Robert Watson

Robert at BuyRocketMotors.com
817-494-3834

rwatson@buyrocketmotors.com
www.BuyRocketMotors.com

Igniters

Pyrogens
Pyrotechnic

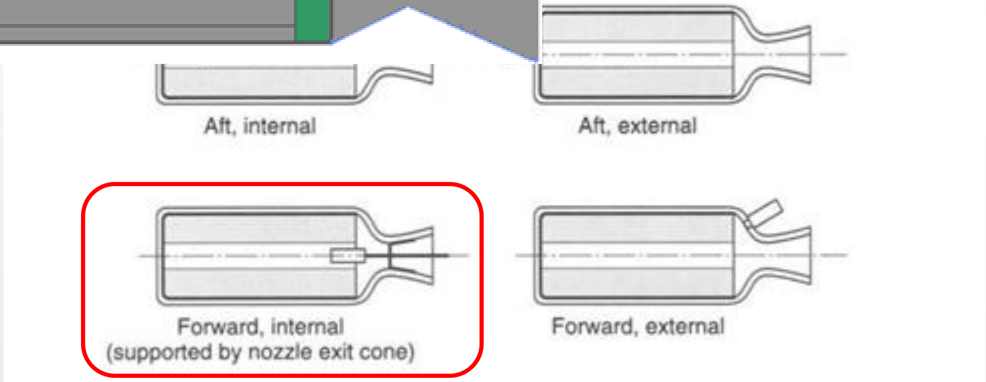
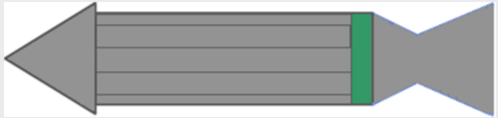


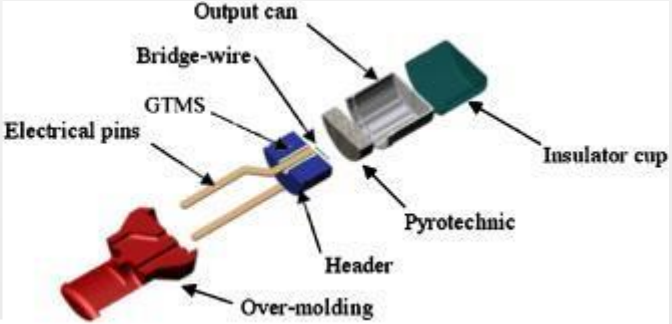
FIGURE 14–13. Simple diagrams of mounting options for igniters. Grain configurations are not shown.



Igniters

Most frequent is Electroexplosive device (Pyrotechnic)

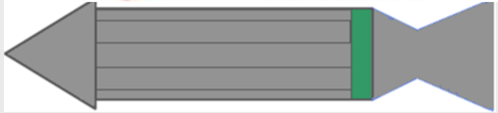
- Bridgewire



3.0.1 Design Requirements

The igniter design shall be based on the following priority of requirements:

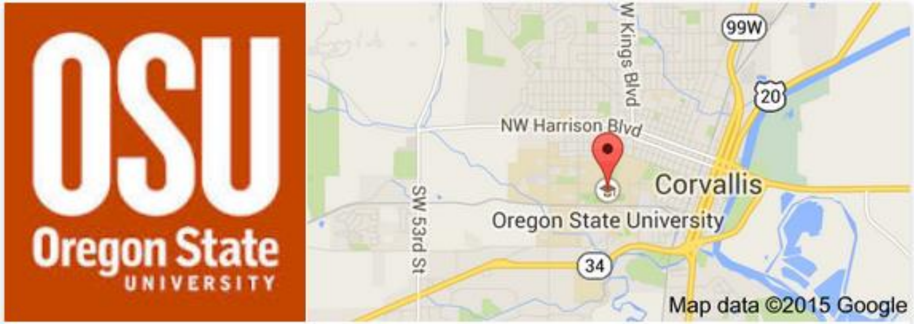
(1) *Specified Performance*
(2) *Specified Reliability*
(3) *Lowest Possible Cost*



NASA- *Solid Rocket Motor Igniters* March 1971 pg. 45
http://electronicpackaging.asmedigitalcollection.asme.org/article.aspx?articleid=1408779

http://electronicpackaging.asmedigitalcollection.asme.org/article.aspx?article id=1408779

Field Trip?



Oregon State University

University in Corvallis, Oregon

Directions | Write a review

Oregon State University is a coeducational, public research university in Corvallis, Oregon, United States. The university offers more than 200 undergraduate, graduate, and doctoral degree programs and has the largest total enrollment in Oregon. Wikipedia

Summary

- Motor Case: 2024 Aluminum Alloy
  - Lightweight
  - Capable of enduring thermal and pressure loads
  - Machined or Off-The-Shelf (TBD)
- Nozzle: Built into Motor
  - Saves time and money
  - Redundant to build additional nozzle
- Igniter: Bridgewire explosive
  - Reliable
  - Good “performance”
  - Cheap

Whats Next?

- Propellant Combustion
  - Burn rate
  - Flame Pattern
  - Ignition Characteristics
- Propellant Stability
  - Acoustic Resonance
  - Ignition Wire Configurations
  - Internal Gas Flow Cavity Considerations

References

(1) *Rocket Propulsion Elements, 8th Edition*. Sutton, George P. and Biblarz, Oscar.
(2) *Solid Rocket Motor Igniters.* NASA
(3) Cowles, Devon K. "Design of a Rocket Motor Casing." Diss. Rensselaer Polytechnic Institute, 2012. Print.

Questions?