

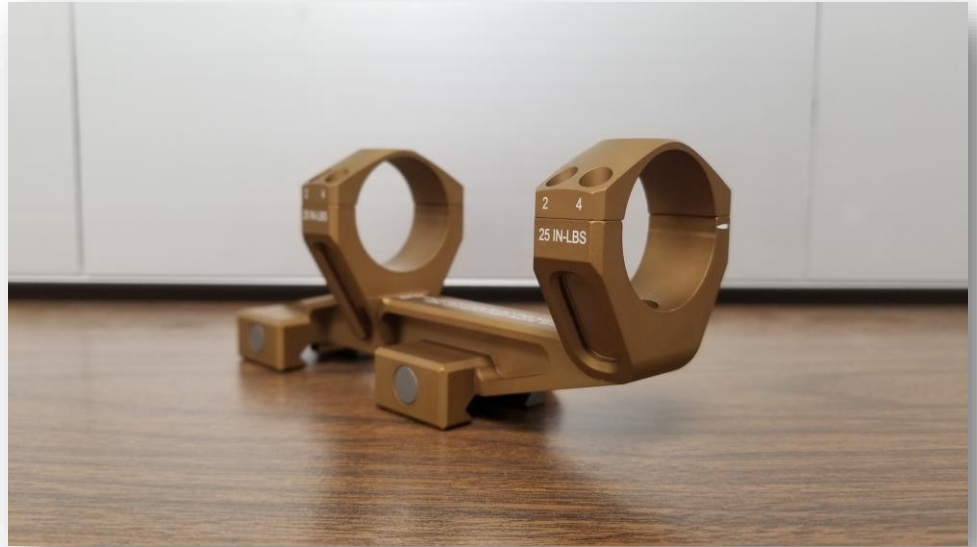
IRON SIGHT RIFLE SCOPE MOUNT OPTIMIZATION

Hector Magaña, Jacob Weber,
James Zillinger, Travis Goehring

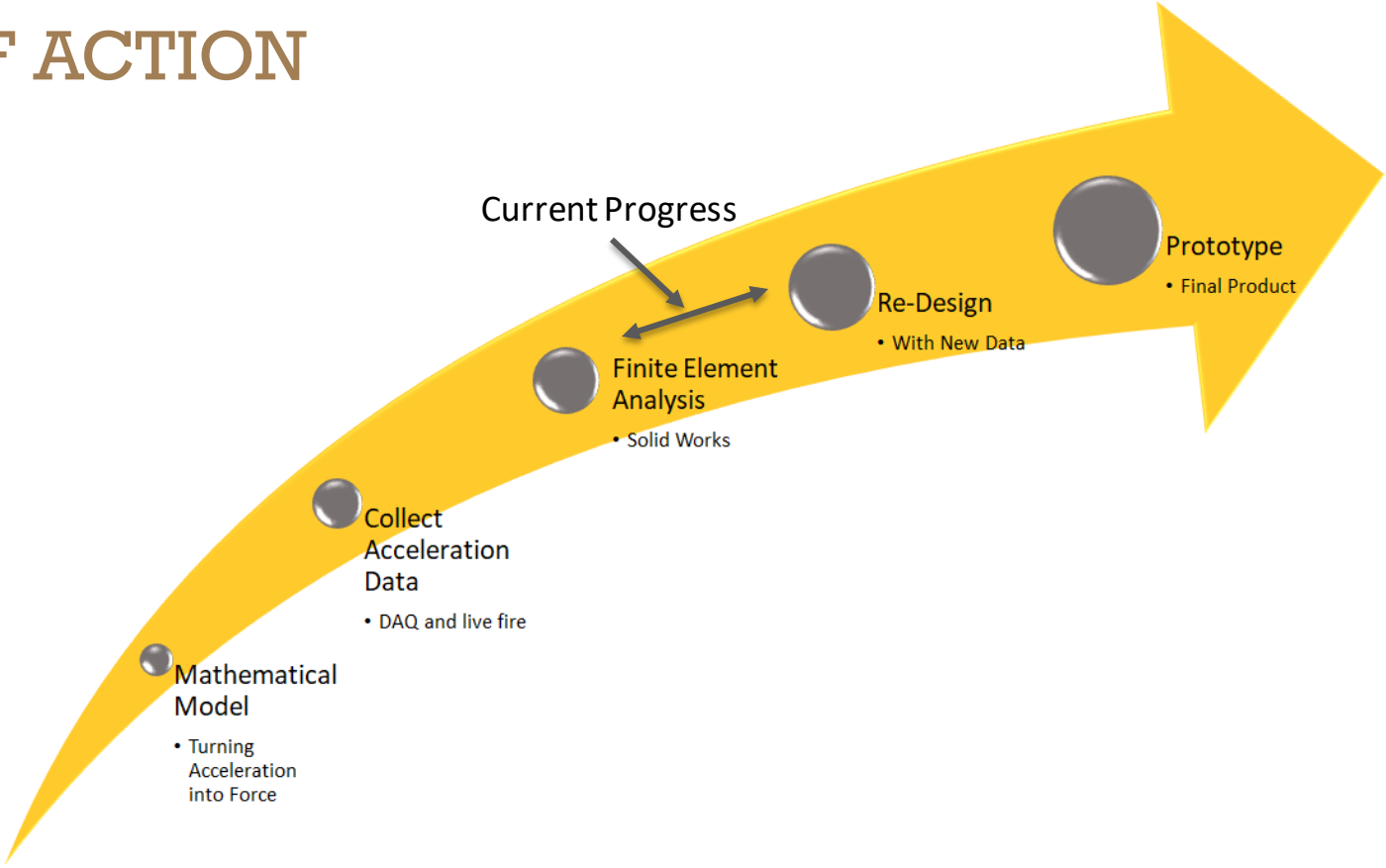


PROJECT GOALS

- Focus is on scope mount
 - Lighter
 - Less than 5.9 ounces
 - As Strong or Stronger
 - 10,000 rounds
 - Cost reduction
 - Aesthetically pleasing

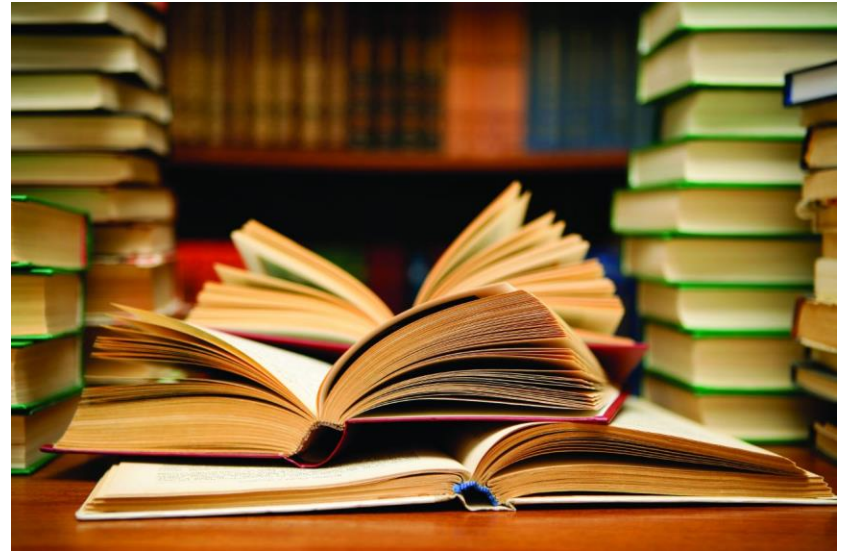


PLAN OF ACTION



PROJECT LEARNING

- Obstacles
 - Using acceleration to measure force
- Handling data
 - Logistics
- Simulations
 - Simplify, but maintain accuracy
- Contacting vendors/getting quotes
 - Phone call w/ Follow-up email



MATH MODEL AND PROOF OF CONCEPT

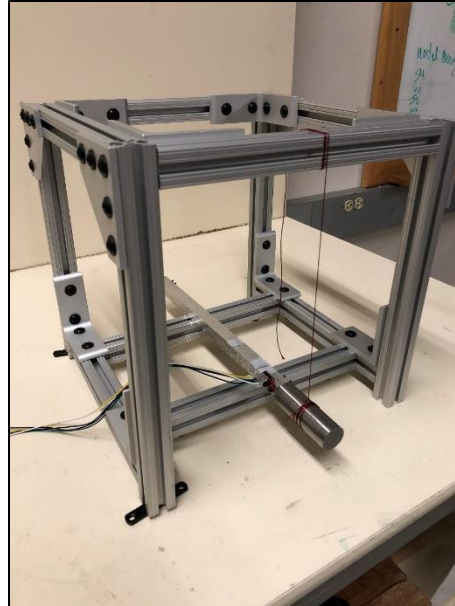
MATHMODEL

- Reduces to Newton's 2nd Law

$$Force = M * a$$

PROOF OF CONCEPT

- Gunshot modeled as an impact
- Mount assumed to be rigid
- Made to be universal



Momentum

$$\Delta p = m_2 v_2 - m_1 v_1$$

$$\Delta p = m(v_2 - v_1)$$

Impulse Momentum Theorem

$$F \Delta t = \Delta p$$

Newton's Second Law

$$Force = M * a$$

$v =$ velocity (from data)

$m =$ mass of scope assembly

$a =$ acceleration

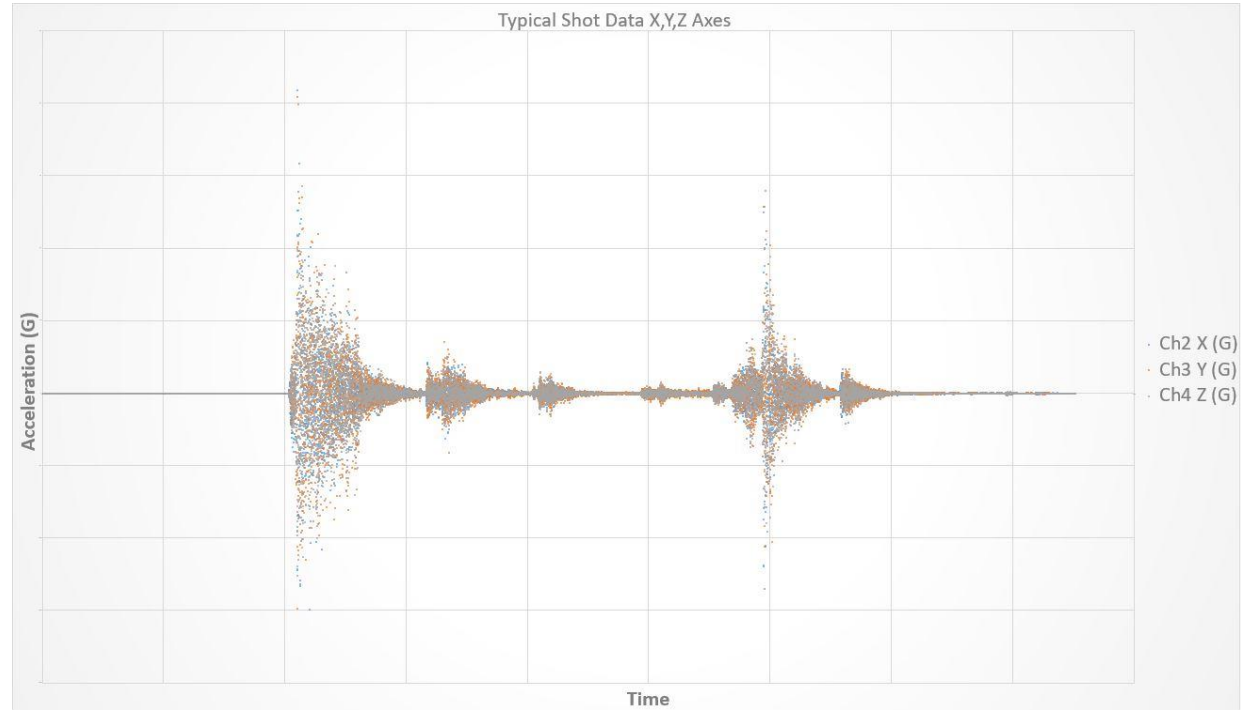
$t =$ time

$p =$ momentum



DATA ANALYSIS

- 80 live fire recordings
- Approximately 20,000-24,000 data points per record
- 1.6 - 1.92 Million points of data



DATA ANALYSIS

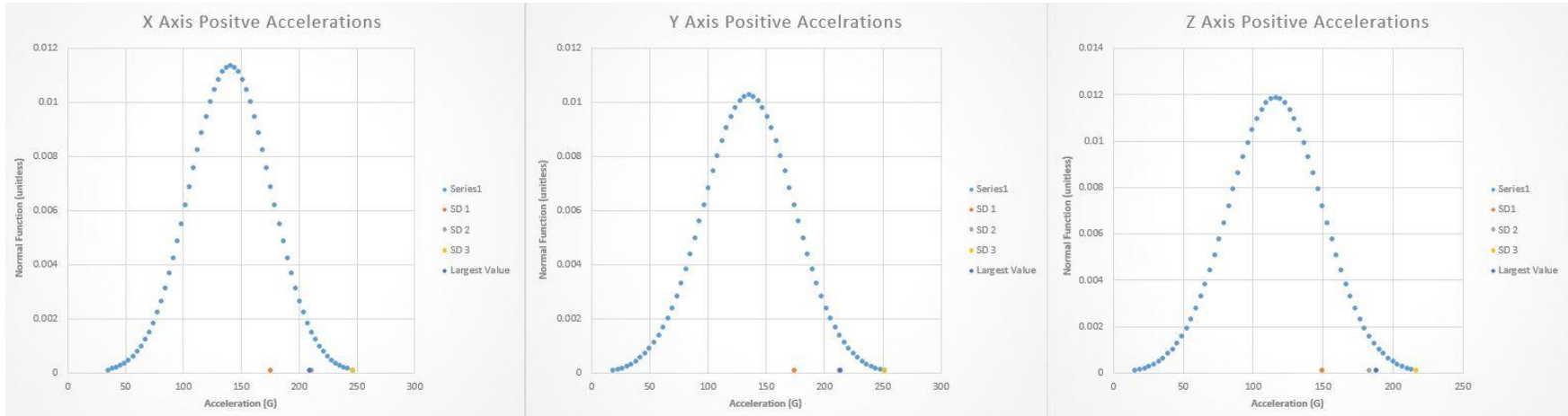
Axis Maximum and Minimum Acceleration Values Live Fire Data

Shooter Size	Shot Number	Axis Maximum and Minimum Acceleration Values Live Fire Data																							
		Front of Rail						Rear of Rail						Front Scope Position						Rear Scope Position					
		X _{max}	X _{min}	Y _{max}	Y _{min}	Z _{max}	Z _{min}	X _{max}	X _{min}	Y _{max}	Y _{min}	Z _{max}	Z _{min}	X _{max}	X _{min}	Y _{max}	Y _{min}	Z _{max}	Z _{min}	X _{max}	X _{min}	Y _{max}	Y _{min}	Z _{max}	Z _{min}
Large	1	172.3	-140.7	144.8	-112.9	123.6	-101.0	111.4	-104.1	110.1	-85.9	73.6	-62.5	194.4	-148.0	156.0	-143.7	174.4	-145.5	144.6	-136.6	150.6	-126.0	121.2	-101.6
	2	161.6	-124.5	129.3	-121.5	98.4	-87.6	110.9	-105.4	96.0	-125.5	79.2	-76.1	145.3	-138.4	142.9	-124.6	146.9	-118.1	148.4	-137.6	156.1	-126.8	123.8	-126.0
	3	131.0	-144.6	182.2	-136.8	121.4	-112.0	121.6	-89.7	111.1	-104.6	75.5	-65.6	183.6	-135.5	163.4	-124.4	168.6	-127.5	209.2	-149.2	204.9	-148.4	143.4	-125.7
	4	144.8	-137.6	100.5	-107.9	98.4	-94.2	113.3	-98.6	111.8	-105.1	129.5	-81.7	132.9	-137.9	160.6	-141.6	183.0	-124.2	144.0	-132.3	149.9	-128.4	122.9	-126.3
	5	157.5	-138.7	129.1	-109.3	83.5	-89.2	122.4	-113.4	89.1	-106.5	152.8	-76.3	155.5	-143.1	167.7	-139.2	146.2	-110.5	192.3	-153.5	190.5	-154.9	133.6	-107.1
Medium	1	132.4	-126.7	90.2	-91.8	105.8	-98.5	199.5	-144.7	122.1	-126.1	97.5	-90.3	137.5	-143.8	131.4	-132.1	130.2	-127.1	126.5	-118.4	150.7	-127.3	143.2	-113.9
	2	125.9	-83.0	73.1	-103.0	85.9	-72.4	98.6	-121.0	97.7	-108.3	87.4	-78.1	186.0	-130.5	184.6	-132.2	187.9	-119.8	127.6	-146.8	178.7	-127.6	131.7	-113.4
	3	113.6	-102.8	87.2	-105.2	67.3	-77.3	72.7	-65.2	75.5	-74.7	56.7	-71.8	164.0	-152.9	181.9	-143.7	174.9	-119.6	138.1	-141.0	152.9	-123.8	119.5	-130.4
	4	122.3	-107.3	139.8	-127.0	92.2	-85.0	85.2	-76.1	69.4	-66.2	58.2	-65.6	192.7	-133.8	139.1	-129.3	166.7	-139.2	118.6	-131.4	176.8	-152.9	100.2	-116.2
	5	111.2	-129.3	135.5	-107.9	92.2	-98.3	106.3	-111.6	104.5	-110.5	62.8	-91.7	162.6	-139.8	148.3	-127.6	136.9	-119.1	172.1	-137.4	176.9	-150.5	130.2	-135.9
Small	1	98.5	-91.4	65.6	-62.2	81.8	-59.1	60.2	-83.3	67.5	-73.8	54.8	-54.0	135.1	-133.3	151.5	-129.6	124.0	-123.9	132.0	-124.9	125.9	-114.9	140.6	-91.9
	2	88.8	-73.4	100.9	-67.5	73.9	-87.5	61.6	-91.3	60.7	-77.1	62.9	-62.9	172.4	-132.9	145.2	-139.2	150.1	-143.4	174.7	-144.6	127.2	-135.5	97.6	-93.5
	3	79.4	-86.4	76.5	-79.3	90.8	-61.1	78.8	-124.2	111.1	-102.7	81.1	-57.7	172.4	-132.9	145.2	-139.2	150.1	-143.4	175.0	-131.0	178.7	-104.4	122.4	-106.9
	4	91.7	-86.0	69.3	-67.0	60.9	-54.8	61.7	-117.7	78.4	-89.2	70.0	-55.4	205.5	-141.5	199.3	-144.0	139.4	-114.9	183.9	-150.9	164.6	-140.9	139.7	-119.7
	5	112.0	-88.3	89.1	-96.9	84.1	-65.4	128.5	-122.8	110.4	-129.3	58.3	-72.8	145.8	-150.7	207.6	-143.9	142.8	-112.2	145.6	-139.3	182.2	-141.1	123.1	-129.3
Unsupported	1	120.5	-118.2	107.1	-98.4	80.8	-70.1	142.1	-124.4	112.2	-143.2	106.6	-95.0	152.6	-143.0	213.4	-152.2	162.3	-131.7	134.5	-117.2	148.6	-133.6	139.9	-148.6
	2	128.3	-136.0	116.6	-117.7	100.0	-85.7	164.7	-125.0	130.1	-130.8	104.4	-92.1	180.9	-157.3	178.2	-155.3	154.8	-149.5	169.4	-132.3	106.7	-139.0	131.8	-123.6
	3	161.4	-117.1	96.7	-131.6	92.7	-96.6	188.6	-151.9	130.8	-130.5	146.0	-132.5	135.1	-136.1	173.0	-145.9	131.8	-111.0	150.6	-140.3	178.0	-124.6	106.4	-116.0
	4	135.6	-145.2	100.9	-89.6	106.0	-94.3	165.0	-159.6	172.1	-145.2	141.6	-116.4	173.1	-150.2	192.1	-145.8	171.1	-137.3	141.8	-122.1	138.0	-129.2	110.0	-127.0
	5	123.1	-141.1	126.7	-88.6	115.7	-105.3	188.5	-126.7	153.9	-125.0	122.0	-127.6	160.4	-146.7	189.1	-149.8	155.0	-132.4	110.0	-130.4	114.6	-126.2	113.7	-133.9



DATA ANALYSIS

- Absolute maximum and minimum values
- Normal Distribution
- Largest values Typically lie in top 5% of data
- Conclusion: Using Average Value



DATA ANALYSIS

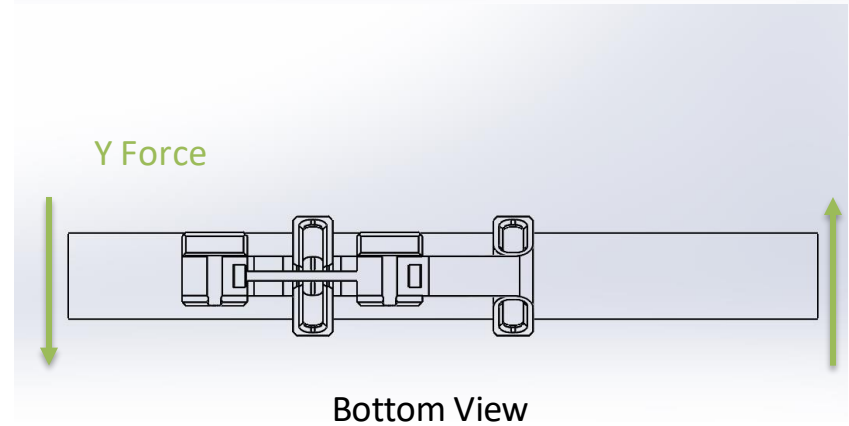
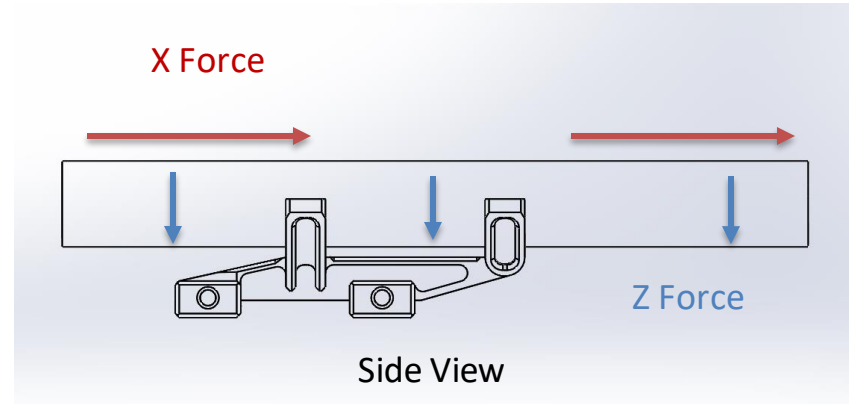
- Math model conversions
- Average data to provide lean design

Cumulative Data Analysis (lbf)						
	X_{max}	X_{min}	Y_{max}	Y_{min}	Z_{max}	Z_{min}
Average	487.190789	439.456291	468.883117	417.783333	402.434488	358.585915
Standard Deviation	121.979155	75.3265371	134.820886	82.2166605	116.485083	91.1587836
Largest value seen	726.669872	554.562524	741.300233	539.314894	652.580873	519.38998



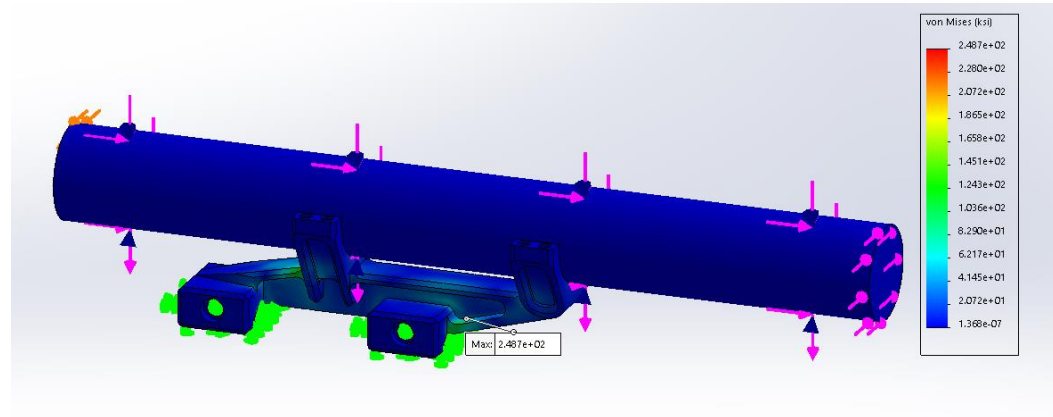
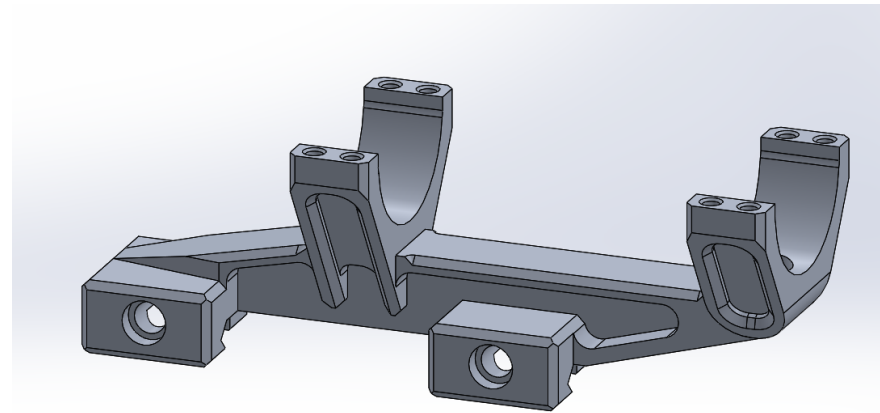
FINITE ELEMENT ANALYSIS

- Dummy Scope for rigidity
- Fixed clamping points on mount
- Apply X, Y, and Z forces to Scope
 - X Force = 1000 lbf
 - Y Force = 1000 lbf applied as a couple moment
 - Z Force = 700 lbf



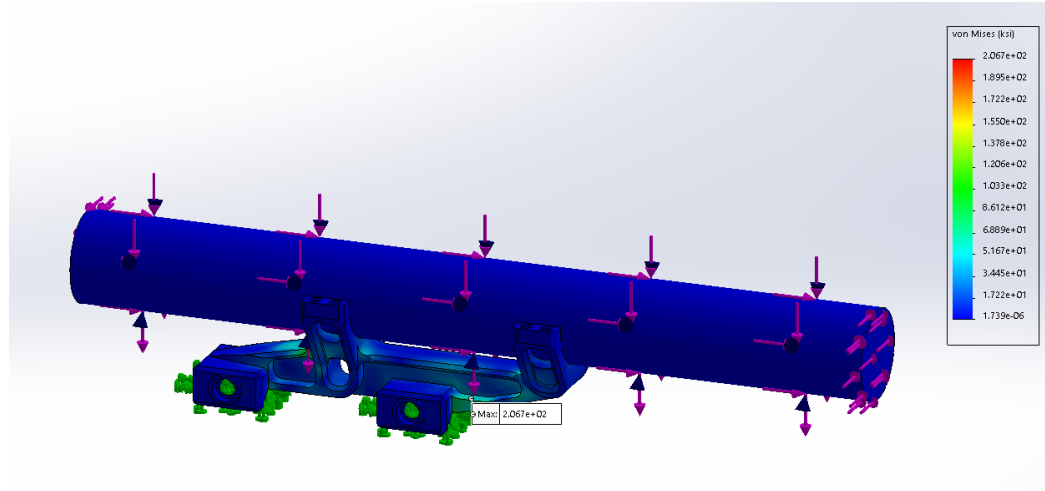
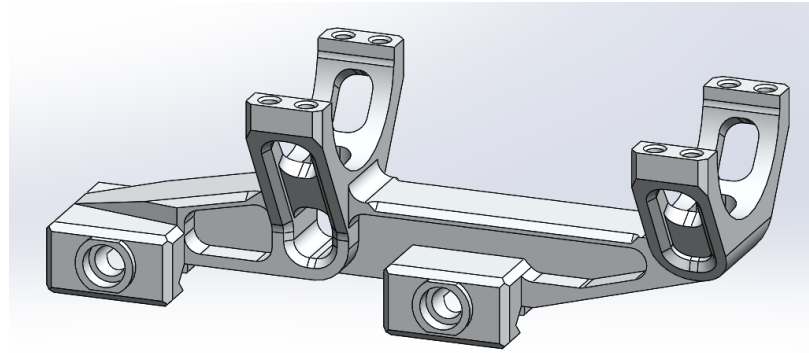
ULTRAMOUNT

- Mass: 104.6 g
- Peak Stress: 248.7 ksi

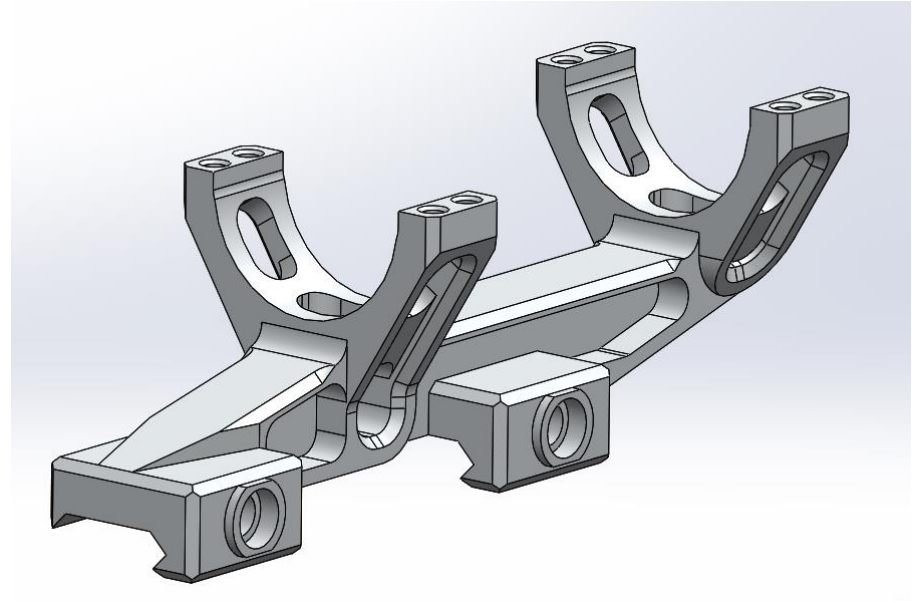
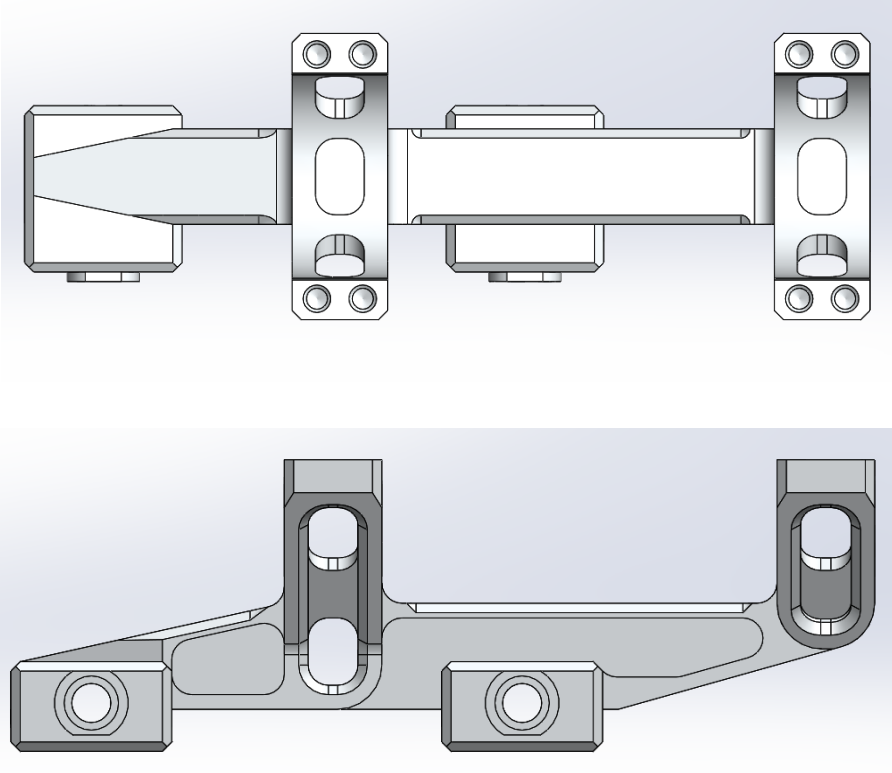


PROTOTYPE 1

- Mass: 100.1 g
 - 4% decrease
- Peak Stress: 206.7 ksi
 - 16% decrease

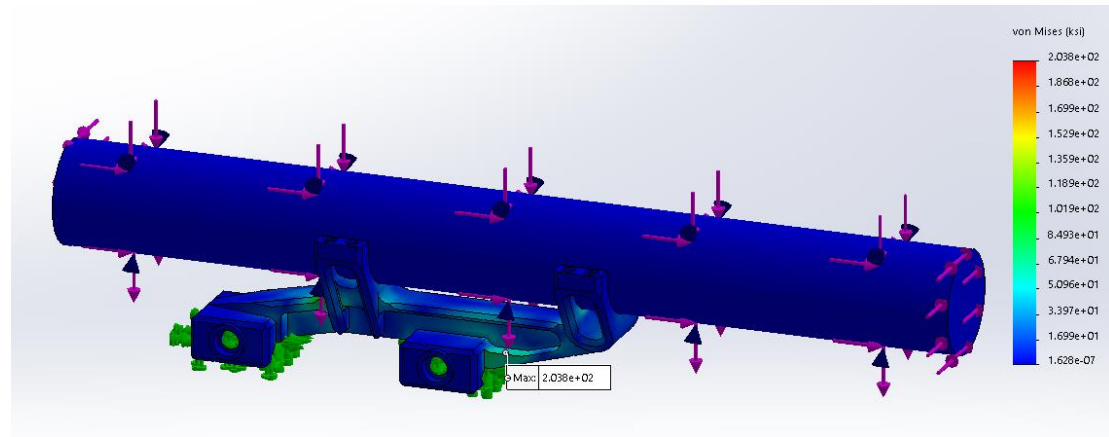
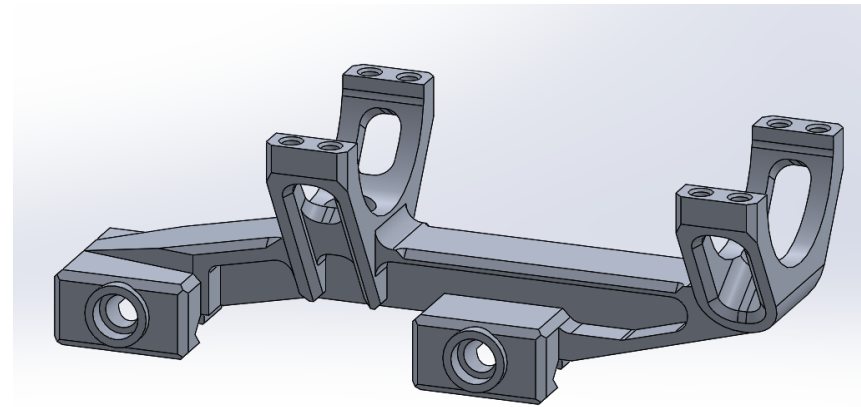


PROTOTYPE 1

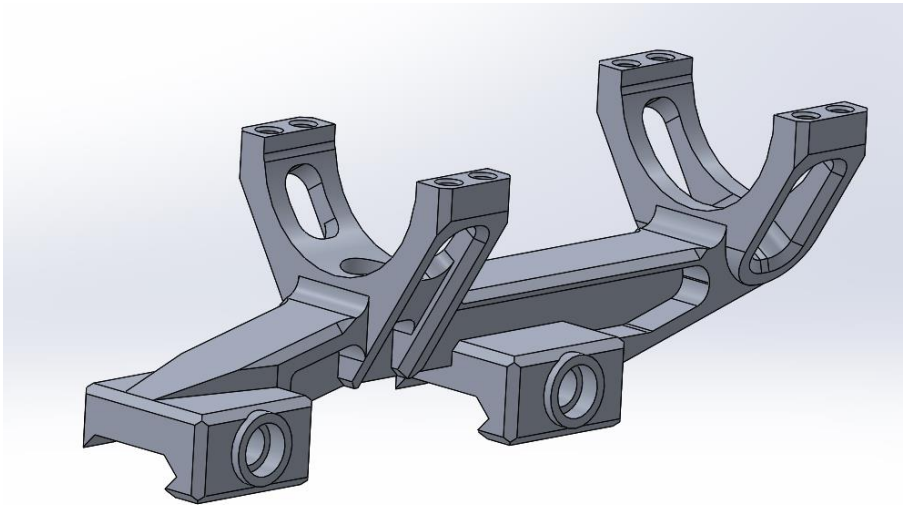
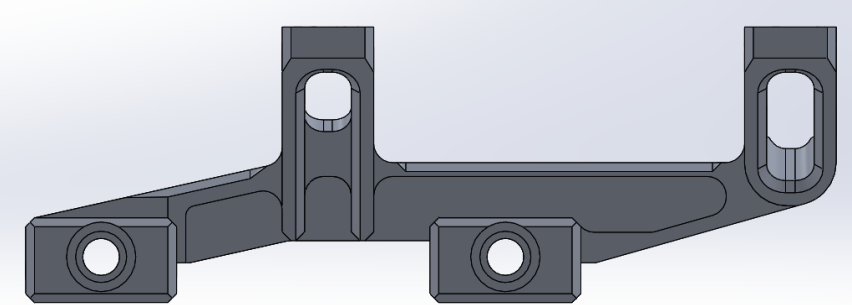
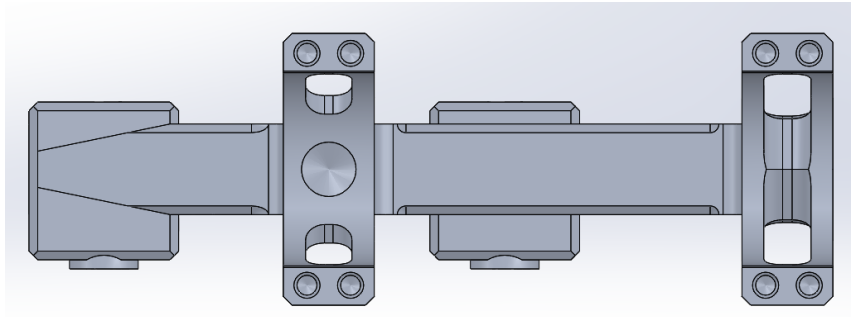


PROTOTYPE 2

- Mass: 94.8 g
 - 9% decrease
- Peak Stress: 206.7 ksi
 - 18% decrease

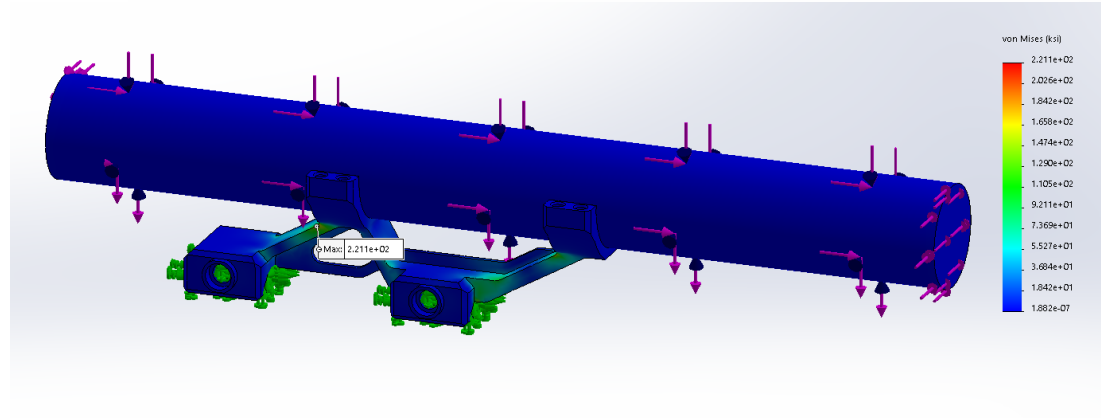
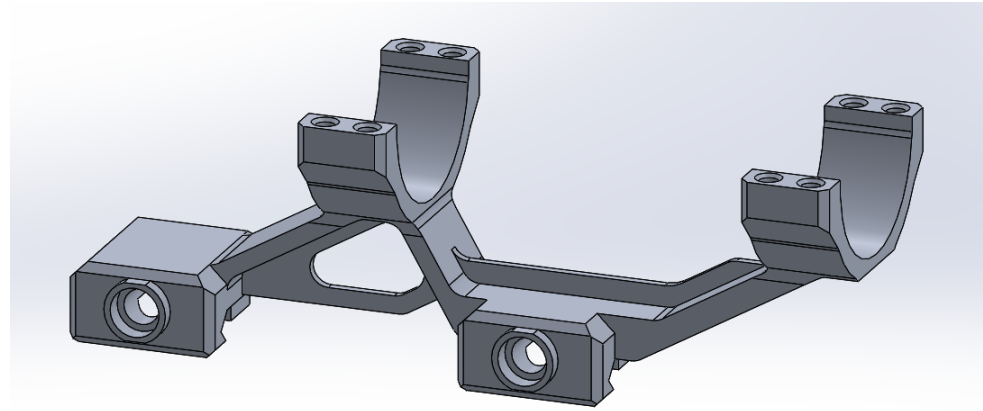


PROTOTYPE 2

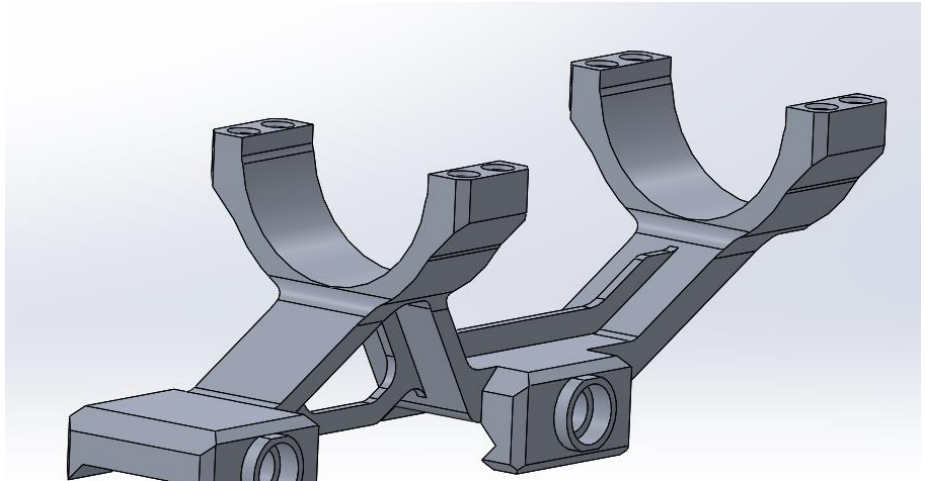
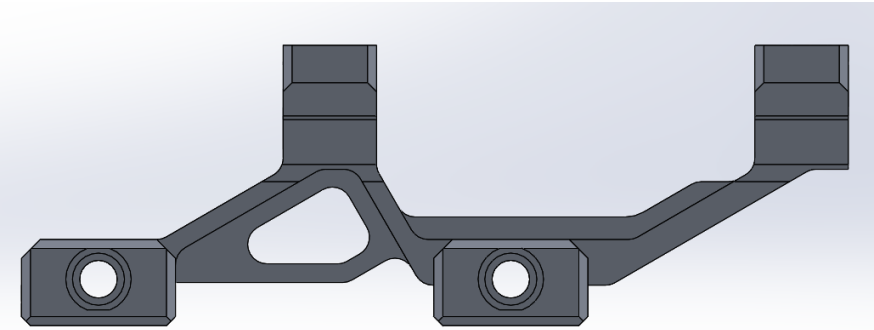
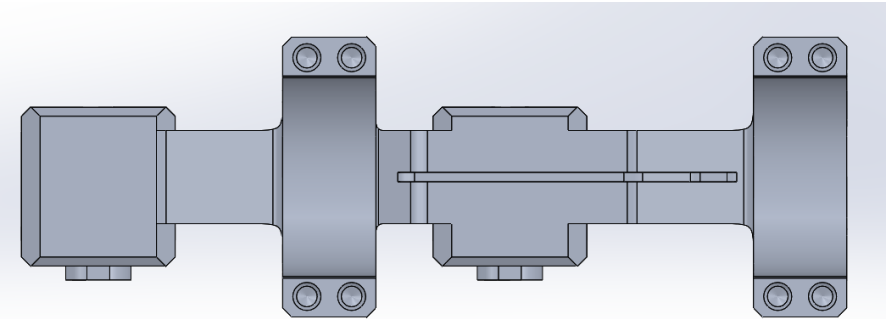


PROTOTYPE 3

- Mass: 73.9 g
 - 29% decrease
- Peak Stress: 221.1 ksi
 - 11% decrease



PROTOTYPE 3



MATERIAL SELECTION

Overview

- Al-7068, Mg-AZ61A, Al-2024 were selected for prototype materials in November via material indexing
- Finding, quoting, and ordering alloys
 - Round: 3" diam./ 7" length
 - Square: 3"x3"/ 7" length
 - Quotes for both unit (2-3 pcs.) and bulk (4000+)
- In-depth corrosion analysis of Mg, w/ hard coating feasibility study



MATERIAL SELECTION

Material Acquisition

- Quotations/ Purchases

- Al-7068

- Unit: \$19.77/lb

- Bulk: N/A

- Al-2024

- Unit: \$15.35-\$23.16/lb

- Bulk: N/A

- Mg-AZ61A

- Unit: \$4.06-\$42.89/lb

- Bulk: \$11.562/lb

- Significant price gap from US vs. China

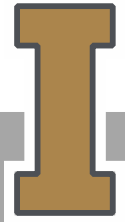
- Projected antidumping duties as well

*shipping and handling costs factored into cost

- Bulk hard coating: \$500/batch order



ALCOBRA



MATERIAL SELECTION

Coating Investigation

- Paint/Thin Film Coating
 - Investigated: Doesn't meet abrasion resistance requirements
- MIL-A-8625, Type III Hard Coating
 - Al-7068
 - Should hard coat like 7075, no problem, according to experts
 - Al-2024
 - High Cu content in alloy; causes non-uniform coating and damage to the product (i.e. burning)
 - Hard coat would be possible after a selective etch of the surface
 - Mg-AZ61A
 - Very susceptible to corrosion before anodization occurs
 - Several hard coat steel methods are available, with open patents available for reference in effectiveness.

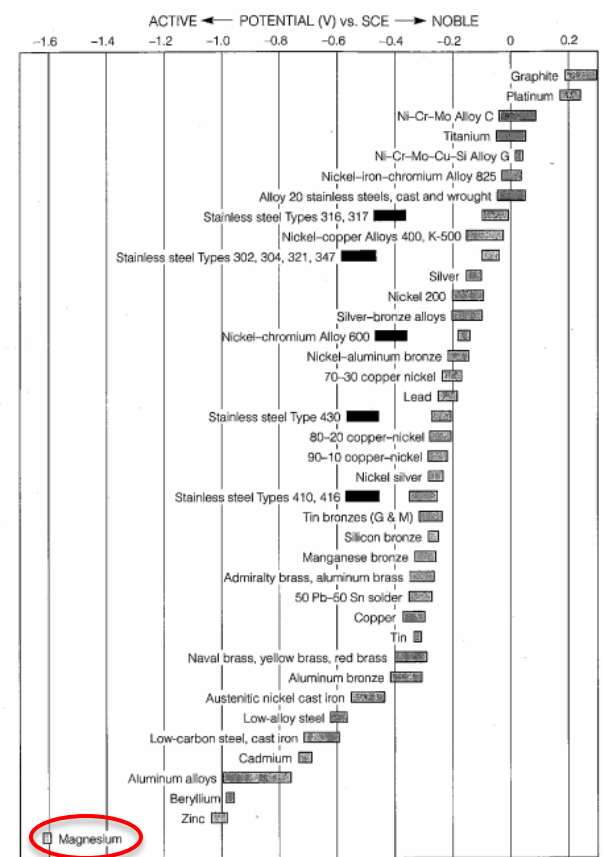


FIGURE 6.1 Galvanic Series for seawater. Dark boxes indicate active behavior for active-passive alloys. (From H. P. Hack, *Metals Handbook, Vol. 13, Corrosion, 9th ed.*, ASM, Metals Park, OH, p. 234, 1987. Reprinted by permission, ASM International.)

MATERIAL SELECTION

$$\text{Corrosion Rate} \left(\frac{\text{mm}}{\text{year}} \right) = 3.27 * i_{\text{corr}} * \frac{EW}{\rho}$$

- i_{corr} = corrosion current $\left(\frac{\mu\text{A}}{\text{cm}^2} \right)$
- EW = Equivalent weight
- ρ = material density $\left(\frac{\text{g}}{\text{cm}^3} \right)$

Magnesium Corrosion Literature Review

- Galvanic Corrosion minimal
- Unprotected Mg will rapidly oxidize and degrade (1)
- ASTM B117 salt fog test of hard coated Mg
 - Achieved “10” rating after 700 hours
 - Several open sources for hard coating Mg could be achieved in lab setting.

Maximum Corrosion rate (mm/year) of treated and untreated alloys in salt spray tests

	Al-7075	Mg-AZ61A
Base Metal	0.08587 (3)	17.96 (1)
Hard Coated	0.015 (4)	0.022 (2)

(1) Dhanapal et al., “Experimental Investigation of the Corrosion Behavior of Friction Stir Welded AZ61A Magnesium Alloy Welds under Salt Spray Corrosion Test and Galvanic Corrosion Test Using Response Surface Methodology.”

(2) Sreekanth, Rameshbabu, and Venkateswarlu, “Effect of Various Additives on Morphology and Corrosion Behavior of Ceramic Coatings Developed on AZ31 Magnesium Alloy by Plasma Electrolytic Oxidation.”

(3) Al-Moubaraki and Al-Rushud, “The Red Sea as a Corrosive Environment.”

(4) P. B et al., “Effect of Anodization on the Corrosion Behavior of Aluminium Alloy in HCl Acid and NaOH.”



MATERIAL SELECTION

Conclusions

1. Al-7068: Plan to use for prototypes
2. Mg-AZ61A: Has potential, needs OK from sponsor. Ready for purchase
3. Al-2024: Would add additional coating steps, may increase overhead. Ready for purchase
4. Magnesium prices appear to be much lower internationally
5. Hard coating preparation of Magnesium is feasible and proven effective.
 1. Sealed or unsealed hard coat?



PROJECT SCHEDULE

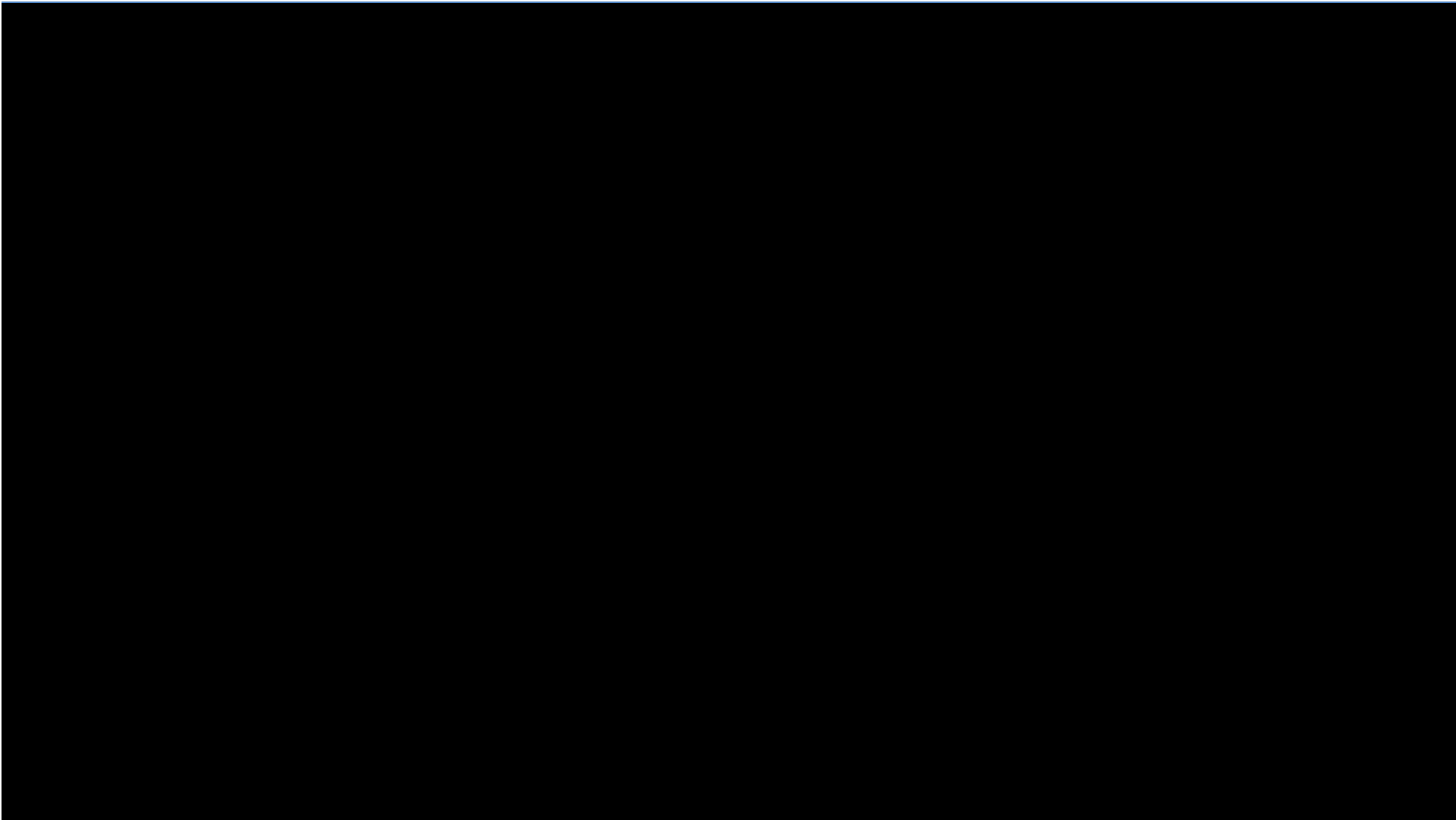
Task	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Math Model	█	█	█					
Collect Data				█				
Analyze Data					█			
Engineer Prototype					█	█	█	
Build Prototype						█	█	█

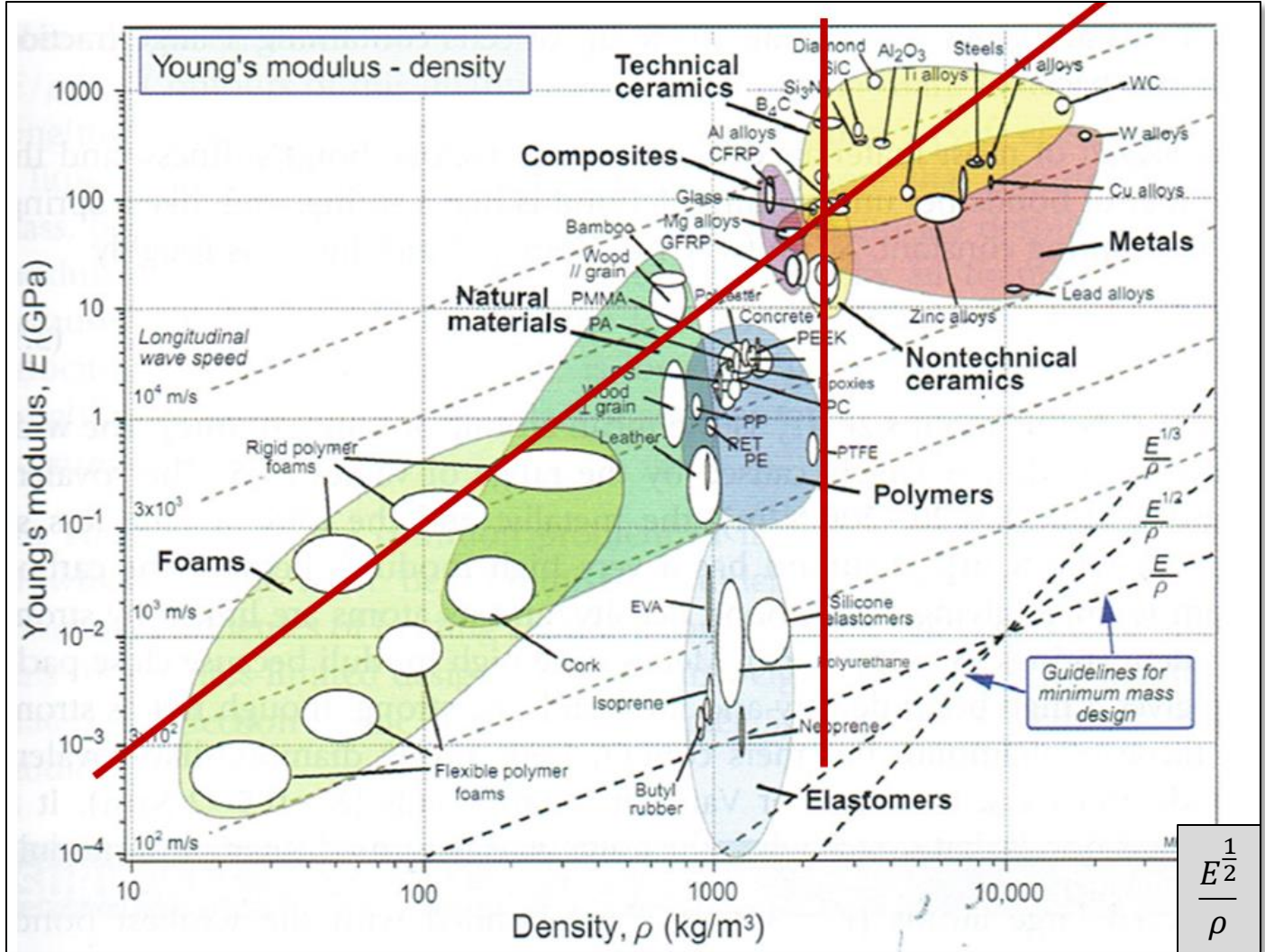


CONCLUSION

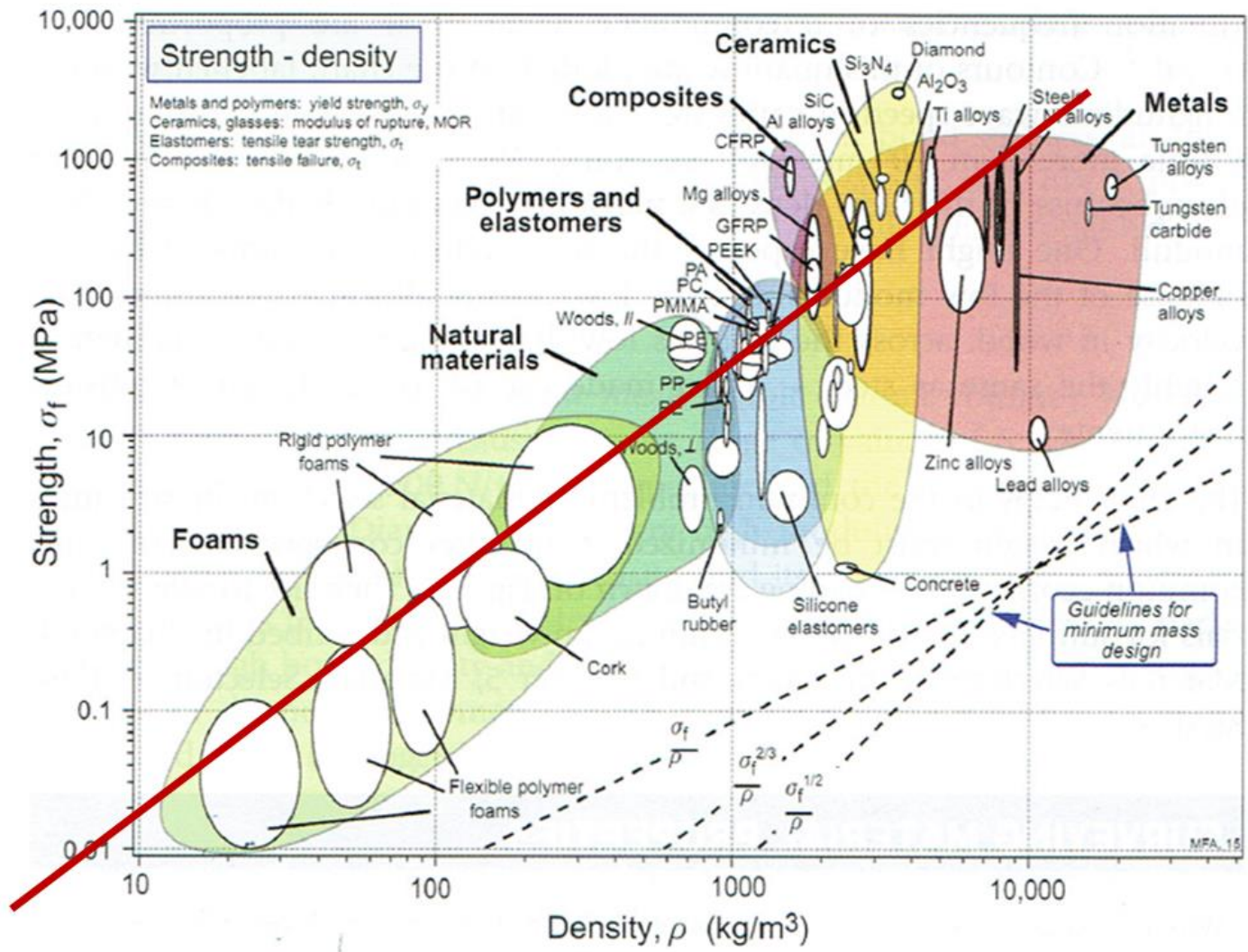
- Math Model
- Data Collection
- FEA Analysis
- Re-Design
- Prototype



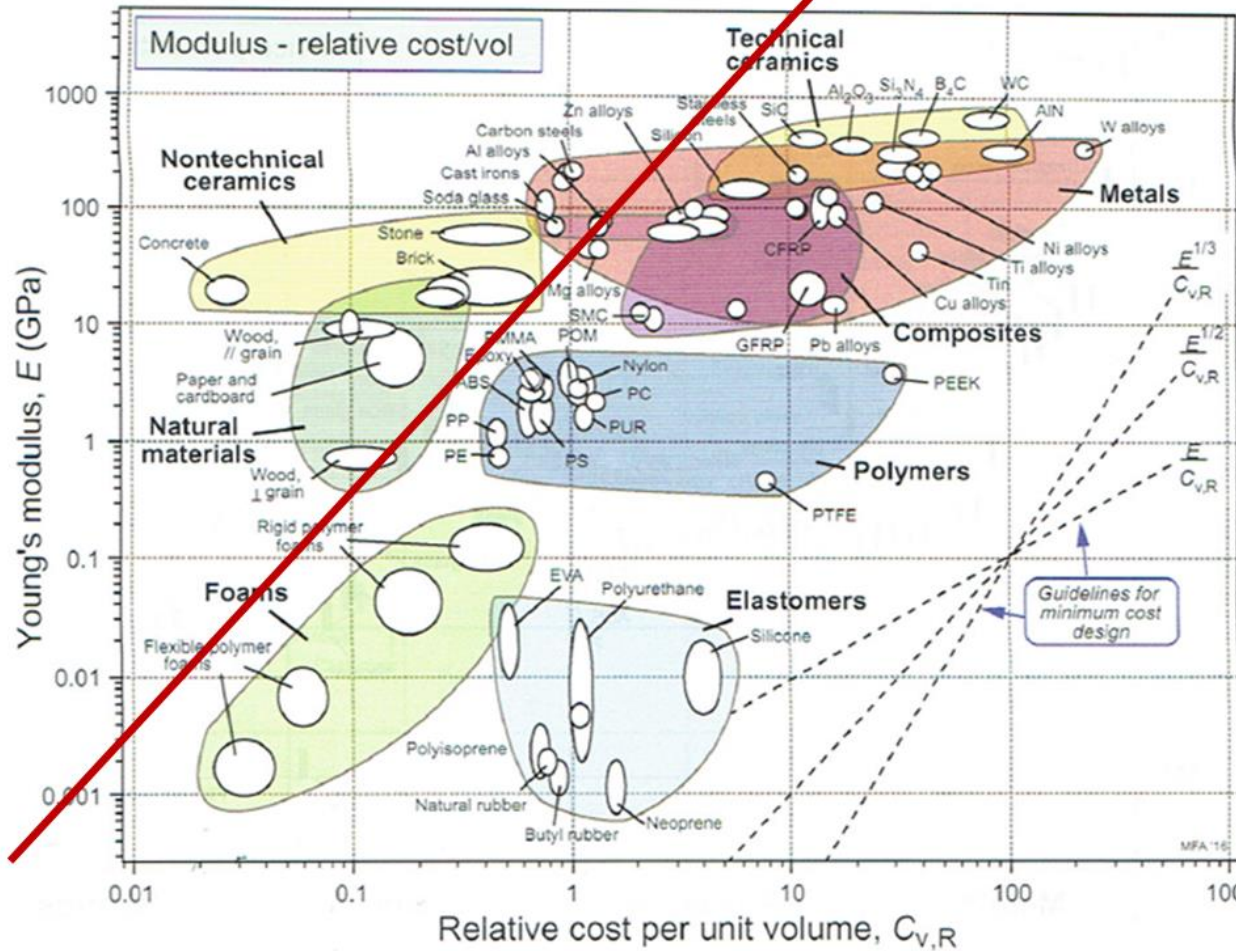




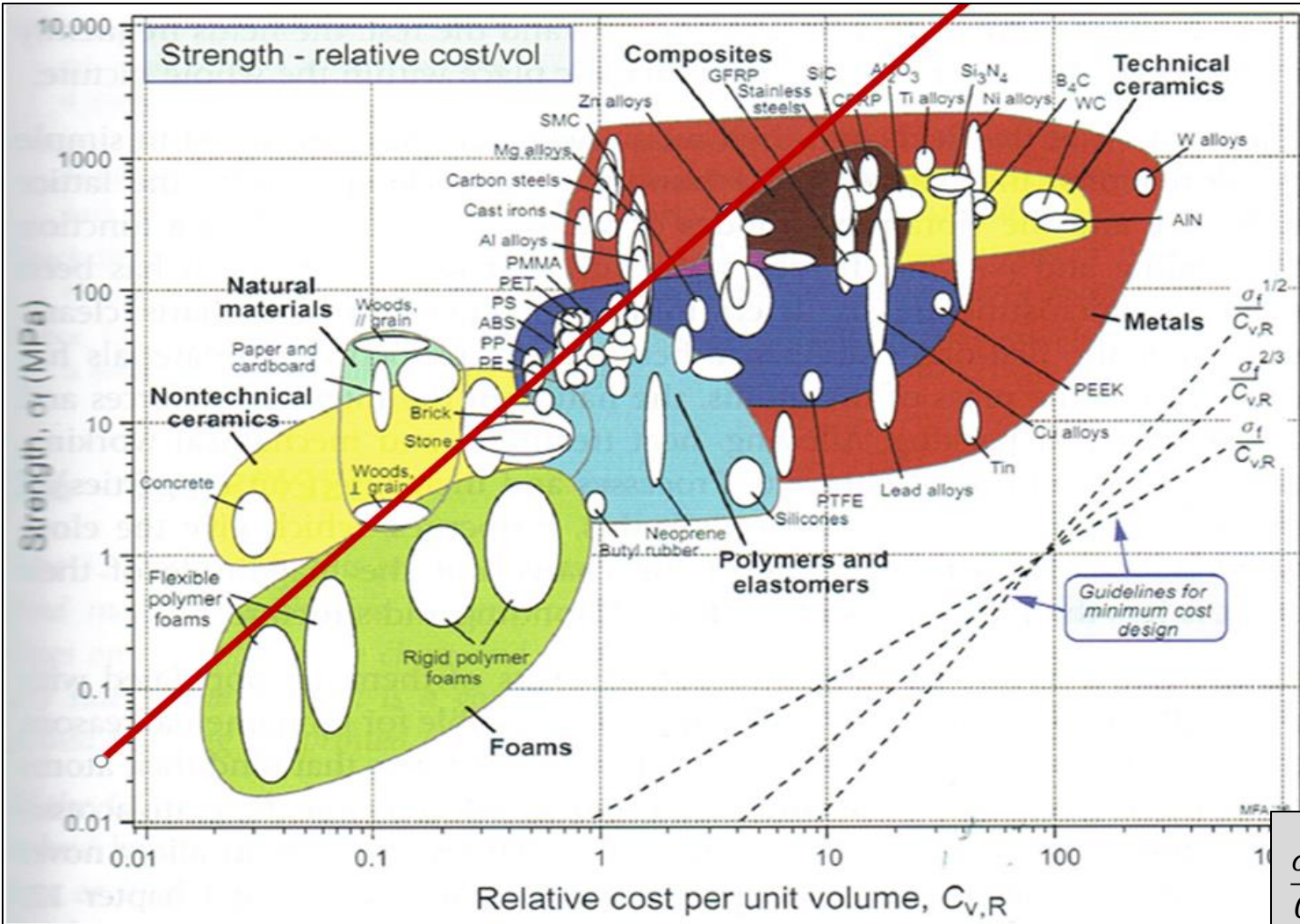
$$\frac{1}{\rho} \frac{E^2}{\rho}$$



$$\frac{\sigma_f^{2/3}}{\rho}$$



$$\frac{E^{1/2}}{C_v}$$



$$\frac{\sigma_f^{2/3}}{C_v}$$

SANITY CHECK

Large Rifle Weight = 10.7 lbm

Largest Acceleration Observed = 213 G's

Acceleration (ft/s²) = G's * Gravity

Force = Mass * Acceleration

Force/Area = Stress



213 G's * 32.2 ft/s² = 6858.6 ft/s²

Force = 10.7 lbm * 6858.6 ft/s²

Force = (73387 lbm-ft/s²) / (32.2 lbm ft / lbf s²)

Force = 2279.1 lbf

2279.1 lbf / 8 in² = 284.88 psi

Yield strength of bone = Approximately 16 ksi



Reference:

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1888202/>