Electric Missile Sizing

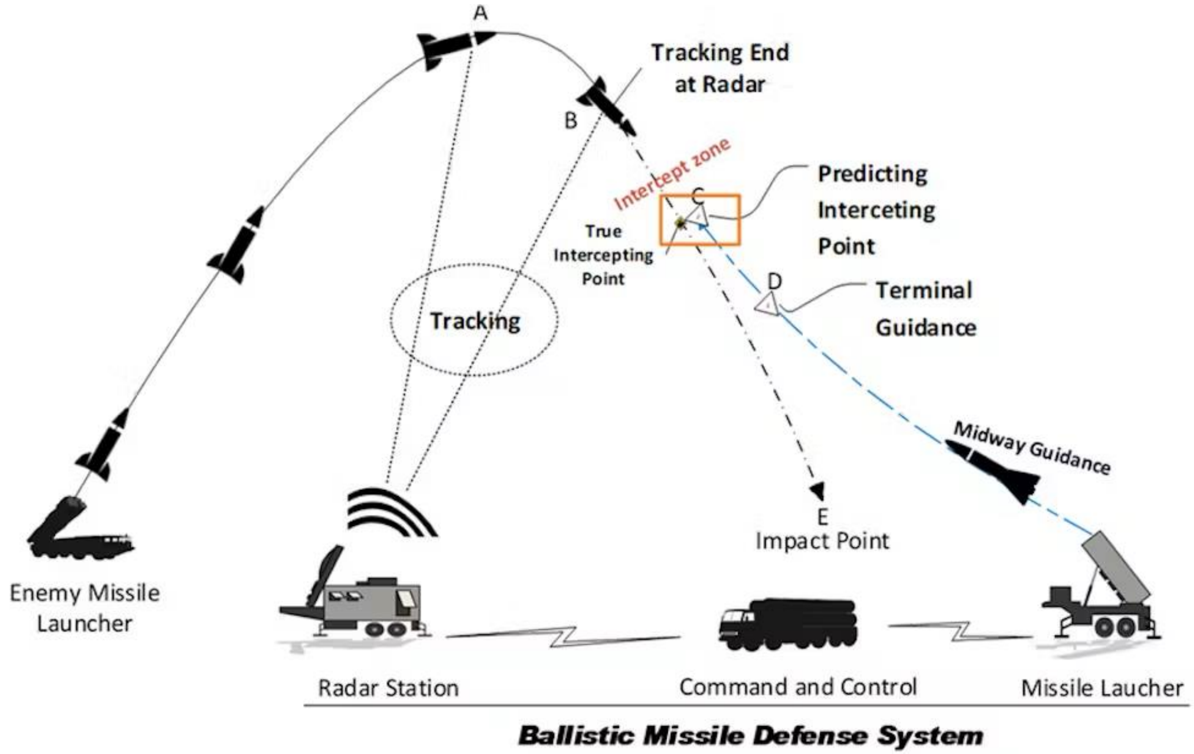
1. Reexamine the Spec:

- *Interceptor installations must provide the following capabilities for area defense from missile threats: Horizontal defense radius of 5 mi (8km)*
- *360° of azimuthal coverage*
- *Maximum engagement altitude of 30,000 ft*
- *Threats can be assumed to have the following characteristics: Ground ranges of 0.5 to 60 miles (1 to 100 km)*
- *Up to 3 g’s of non-ballistic maneuvering capability*
- *Speeds up to Mach 3*
- *Unitary missile*
- *Minimum size: 4 inches in diameter, 8 feet in length, 100 lbm mass*
- *Maximum size: 24 inches in diameter, 20 feet in length, 4000 lbm mass*

Electric Missile Sizing

2. Estimate time to Intercept Incoming Missile at 5mi/30,000ft (8km/9.1k)

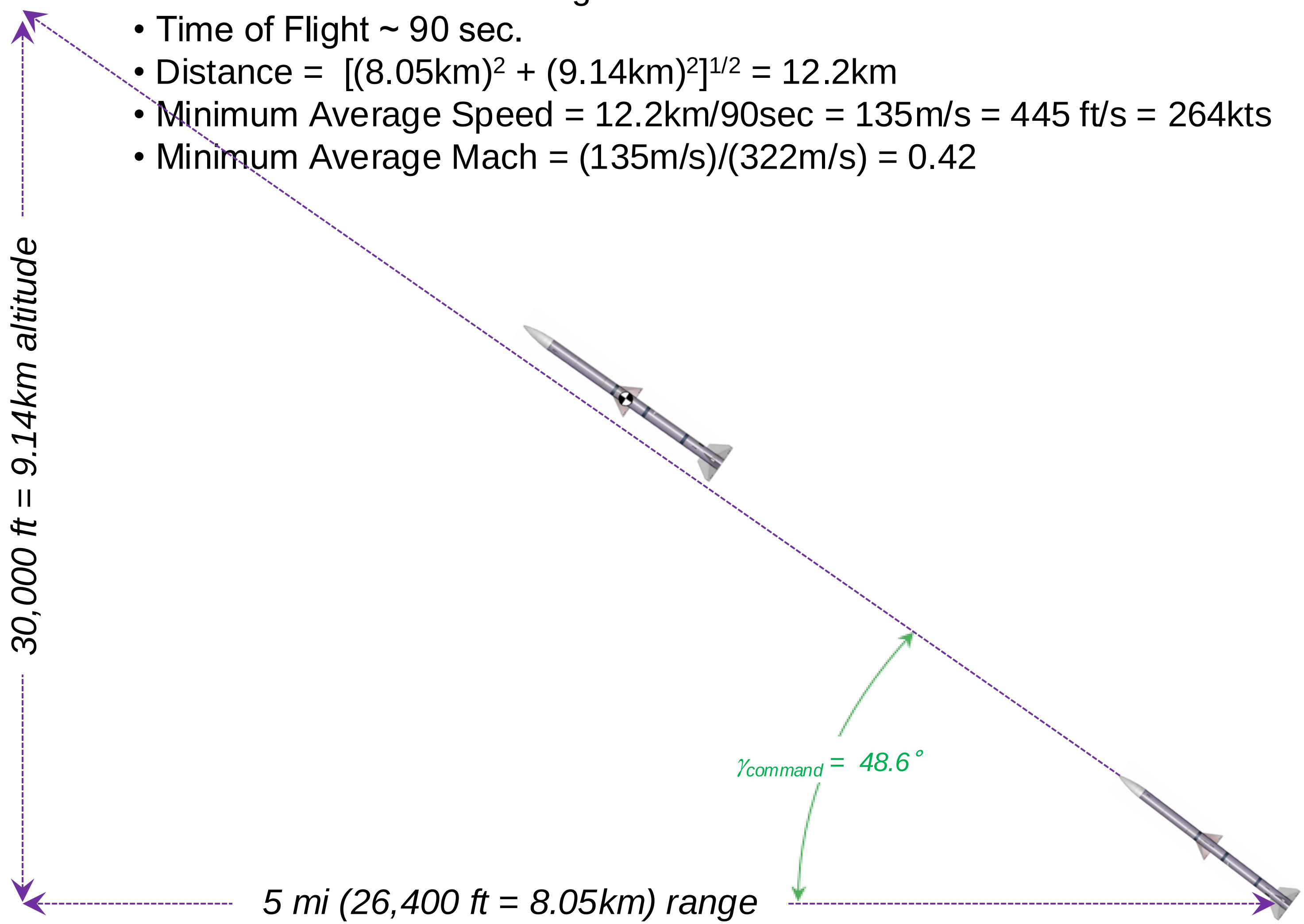
- Generally only large missiles approach targets from altitudes like this
- This implies a long range shot (from spec: 60mi/96km)
- First detection generally occurs within 5 sec. of shot ~ 3.1mi (5.1km) from launcher
- Critical time comes from high speed missiles
- Conservative assumption= Mach 3 (3x995 ft/s = 2985 ft/s = 910 m/s)
- Range to intercept point: $R_{intercept}$ ~ 60mi – 5mi – 3mi = 52 mi = 83.7km
- Time to intercept = $t_{intercept}$ ~ 83.7km/910m/s = 92 sec.



Electric Missile Sizing

3. Estimate minimum speed of interceptor

- By former estimate tintercept ~ 92sec
- Consider ~ 2 sec for arming
- Time of Flight ~ 90 sec.
- Distance = $[(8.05km)^2 + (9.14km)^2]^{1/2}$ = 12.2km
- Minimum Average Speed = 12.2km/90sec = 135m/s = 445 ft/s = 264kts
- Minimum Average Mach = (135m/s)/(322m/s) = 0.42



Electric Missile Sizing

4. Proverse Design Interceptor at 300kts, Get Starting Point Design:

- Given that V_{min} = 264kts, consider 300kts as a buffer
- Consider for first design, using Valkyrie Configuration
- From FIM-92 Stinger data, min. Warhead mass = 3kg = 6.6lb
- From Nathan & Joe's Valkyrie, $WF_{warhead}$ ~ 12.5%
- Initial guess of W_{to} = 6.6lb/0.125 = 52.8lb
- Weight ratio = 52.8lb/.4631lb = 114
- Linear scale factor = $114^{1/3}$ = 4.6
- Initial fuselage dia = 33mm * 4.6 = 151mm = 6"
- Initial fuselage length = 25cm x 4.6 = 115cm = 45.3"
- Initial wing area, S = $9in^2$ x (4.6^2) = $190in^2$ = 1230 cm^2

Mission Midpoint Analysis:

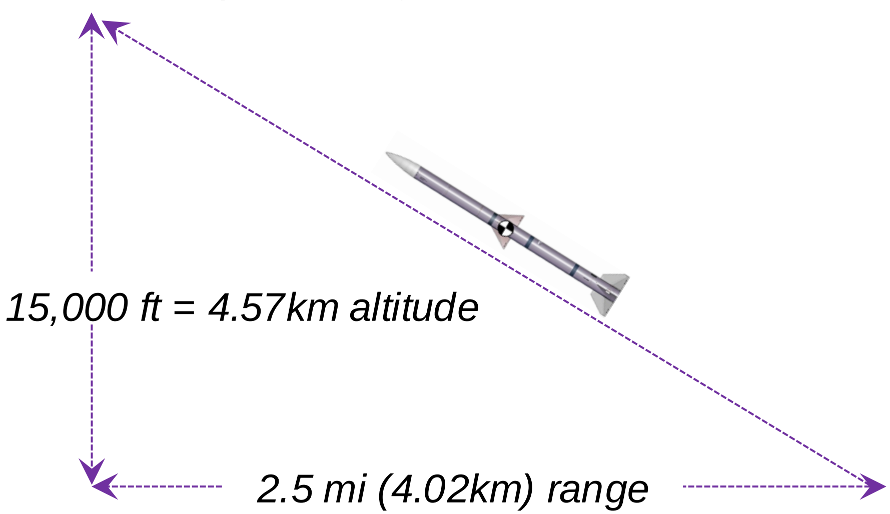


Table 14.1.1 Component Weights and Locations

Component	Weight (lbf)	F.S. (ft)	B.L. (ft)	W.L. (ft)
Fuselage & Frame	0.0585	0.4593	0.0000	0.0446
Wing	0.0166	0.4003	0.0000	0.0000
V-Tail	0.0128	0.5971	0.0000	0.0732
Battery 1	0.0358	0.2543	0.0000	0.0446
Battery 2	0.0358	0.3101	0.0000	0.0446
Battery 3	0.0362	0.3658	0.0000	0.0446
Battery 4	0.0421	0.4216	0.0000	0.0446
Battery 5	0.0421	0.4774	0.0000	0.0446
Shell	0.0579	0.5217	0.0000	0.0446
Barrel	0.0165	0.5775	0.0000	0.0446
Motor	0.0377	0.1312	0.0000	0.0446
Propeller	0.0077	0.0082	0.0000	0.0446
Electronics	0.0633	0.3937	0.0000	0.0446
Total:	**0.4631**	**0.3513**	**0.0000**	**0.0403**

Electric Missile Sizing

5. Analyze Design to 30,000 ft, Execute Mid-Point Analysis:

- At 15,000 ft, density, σ = 0.6292, r = .0015sl/ft^3 = .77 kg/m^3
- Solve for lift coefficient:

$$C_L = \frac{2W}{\rho V^2 S} = \frac{2(52lb)}{(0.0015lbf - s2/ft4)(506ft/s)^2 1.32ft^2} = 0.205$$

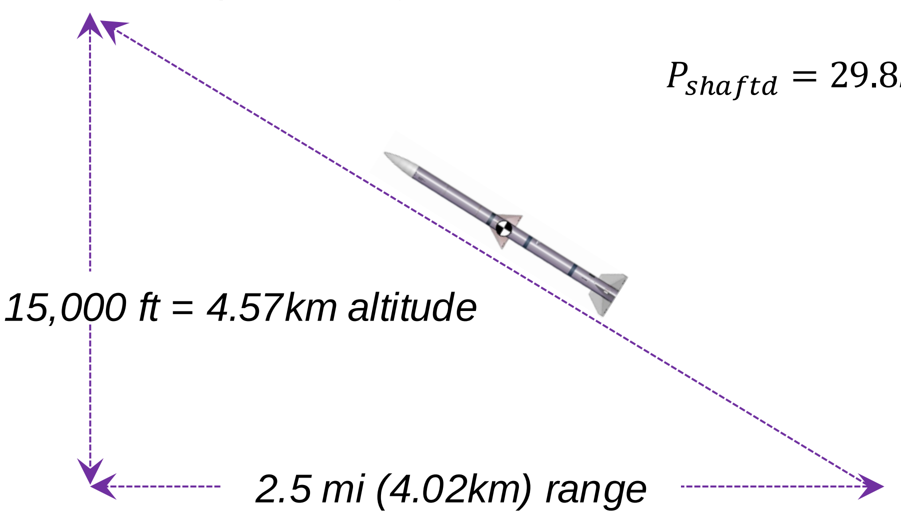
- From Nathan & Joe's Valkyrie: C_D=0.0126+0.0663$C_L{}^2$=0.0154
- L/D = CL/CD = .205/.0154 = 13.3

$$P_{aerorq'd} = TV + W * ROC = \frac{WV}{L/_D} + WV\frac{\Delta h}{\cdot dtot} = \frac{52.8lb * \frac{506ft}{s}}{13.3} + 52.8lbf506ft/s\frac{30,000ft}{40,000ft}$$

$$P_{aerorq'd} = 2010\ ft - \frac{lbf}{s} + 20000ft - \frac{lbf}{s} = 40\ hp * \frac{745.7W}{hp} = 29.8kW$$

Mission Midpoint Analysis:

$$P_{shaftd} = 29.8kW/\eta_p = \frac{29.8kW}{.91} = 33kW$$

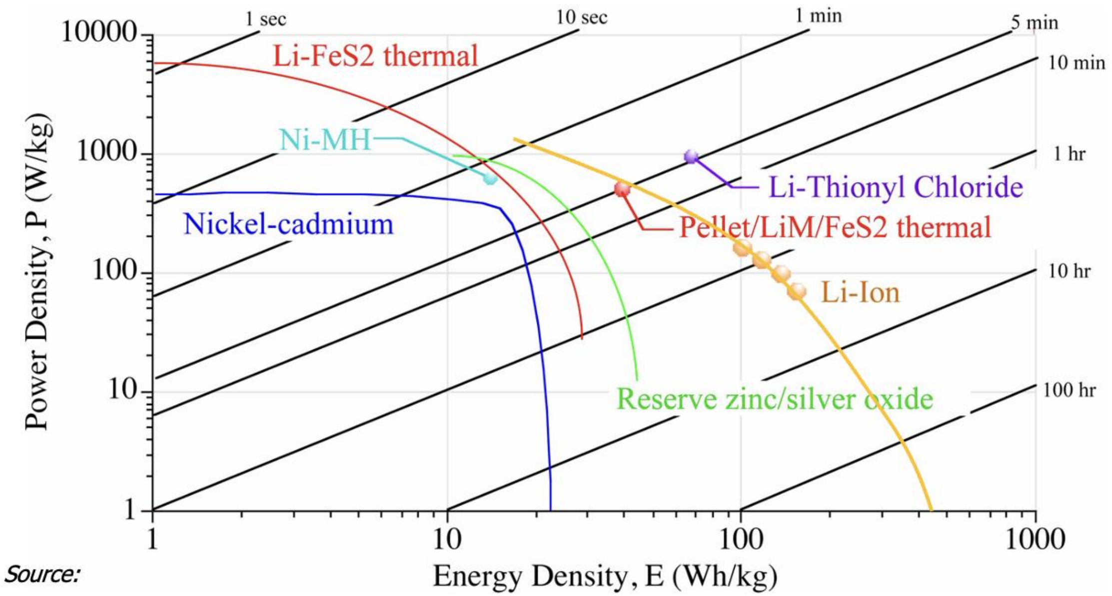


Electric Missile Sizing

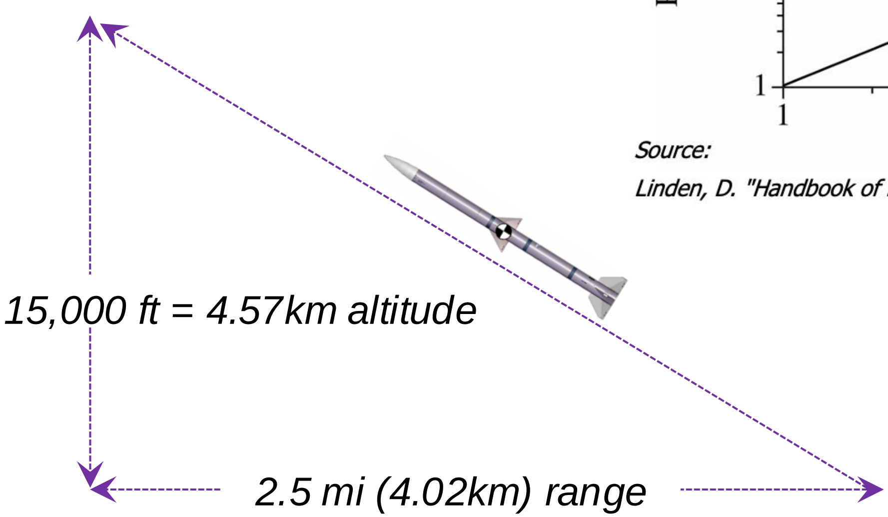
6. Analyze Design to 30,000 ft, Execute Mid-Point Analysis:

From Linden, get power and energy specific densities ~ 1200 W/kg

Get battery size: 33kW/1200 W/kg = 27.5kg



Source:
Linden, D. "Handbook of Batteries" McGraw-Hill & Lutronix Corp.



Electric Missile Sizing

7. Resize Aircraft if Trouble Found:

With 27.5kg (61lb) battery, the aircraft burns too much power.
Try reducing climb speed:

@ 264kts the power is cut substantially:

Not accounting for increase in L/D:

P_{new} = 33kW*(264/300)^3

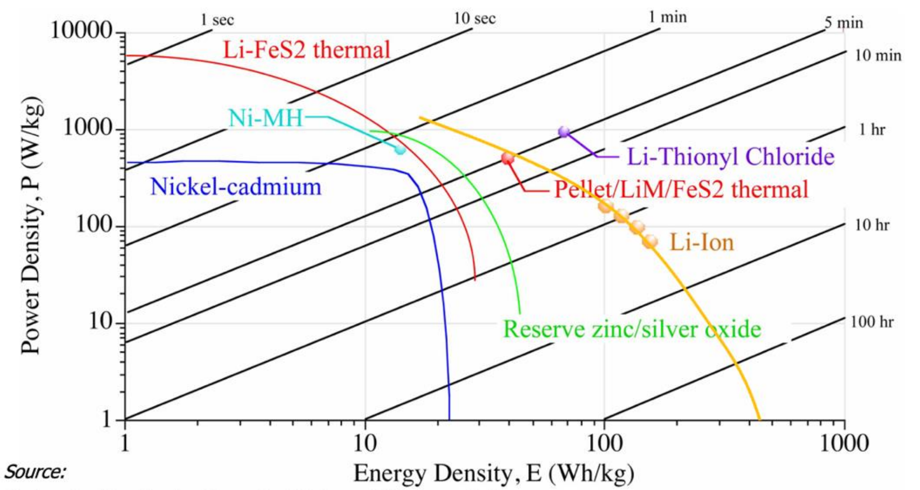
P_{new} = 22.5kW

$M_{battnew}$ = 22.5kW/1200W/kg

$M_{battnew}$ = 18.8kg = 41.4lbm

It's still high, so halve the warhead & try again

Don't forget to include increase in L/D from lower speeds



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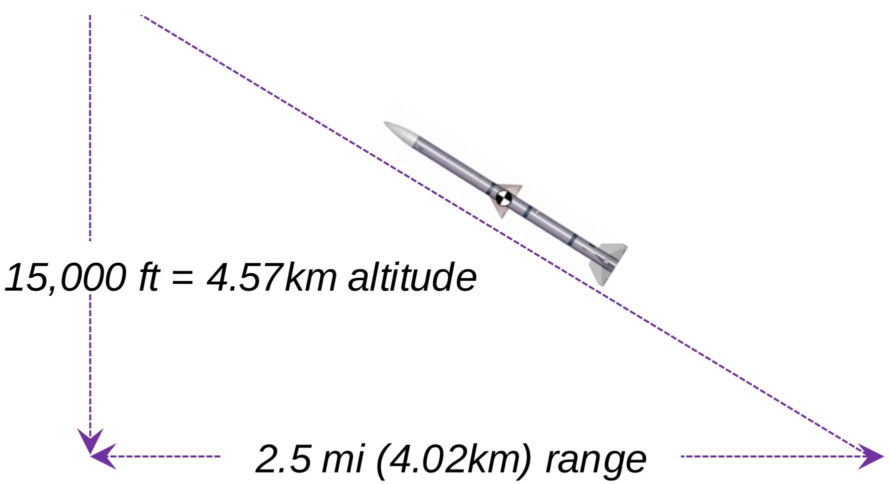

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