Exploring the Possibilities of a Naval Electromagnetic Rail Gun

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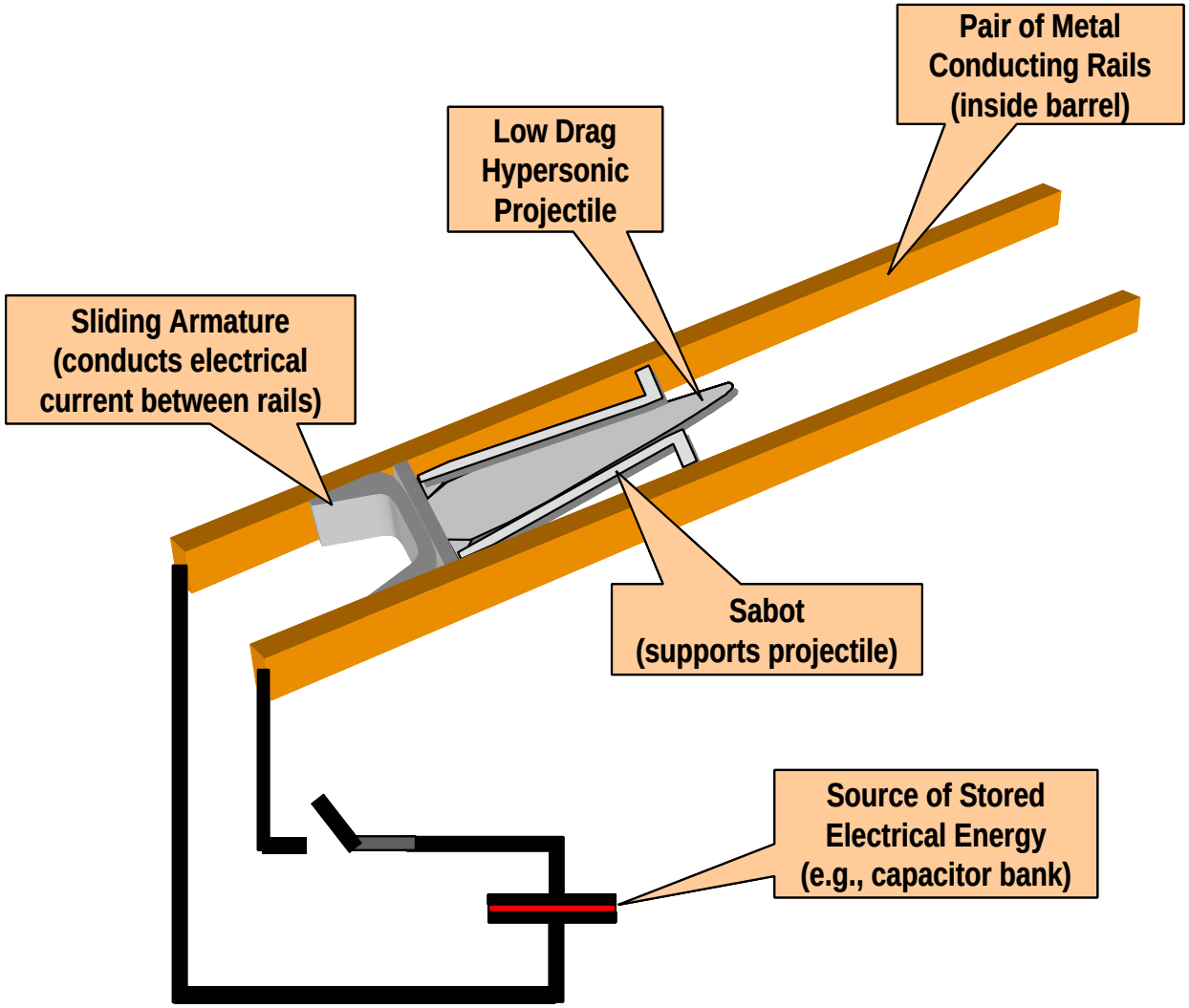
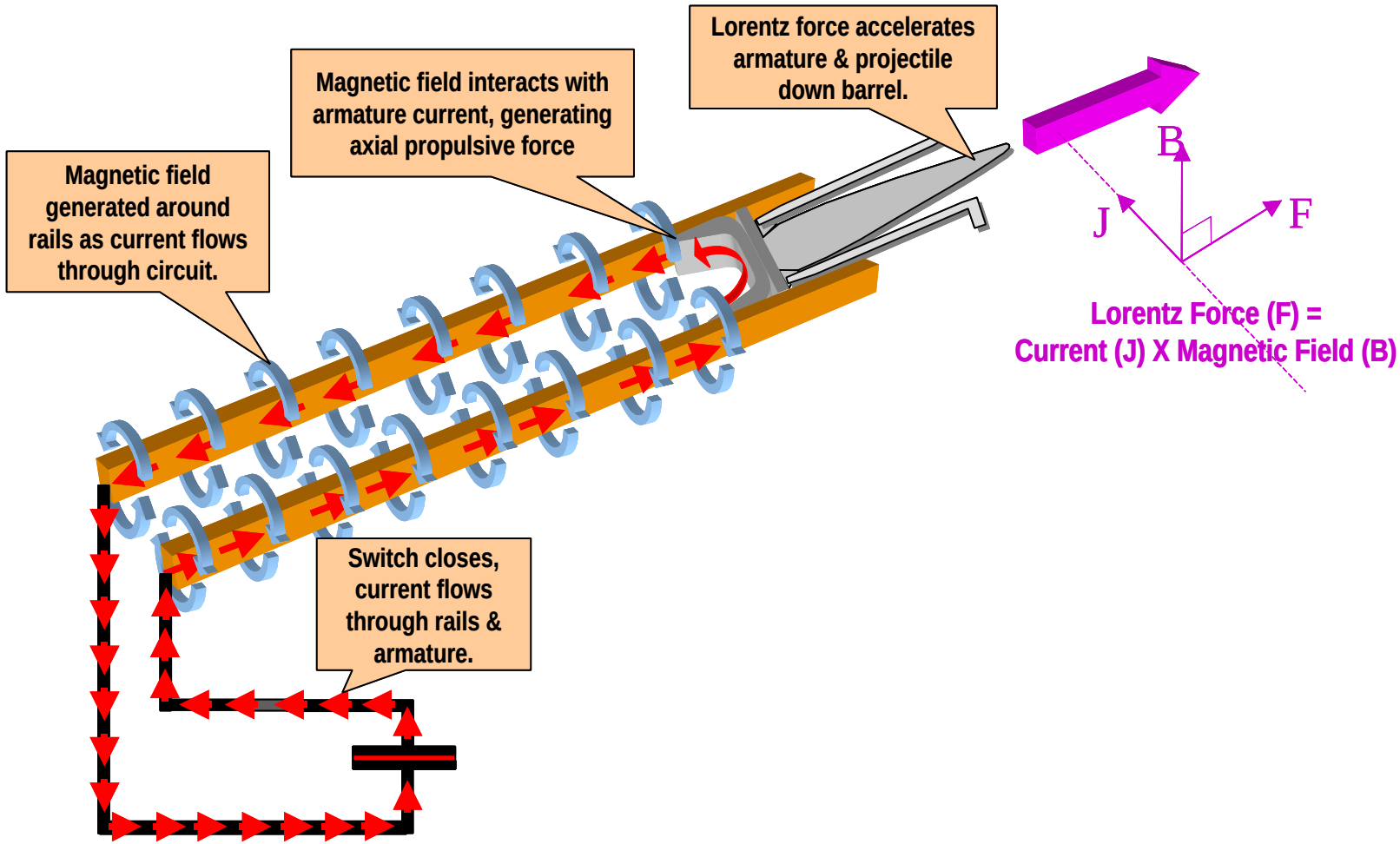
Outline

- How a Railgun Works
- Why a Naval Railgun Now?
- Parametric Model
- Parametric Studies
- Conclusions

How it Works


Pair of Metal Conducting Rails (inside barrel)
Low Drag Hypersonic Projectile
Sliding Armature (conducts electrical current between rails)
Sabot (supports projectile)
Source of Stored Electrical Energy (e.g., capacitor bank)

How it Works


Lorentz force accelerates armature & projectile down barrel.
Magnetic field interacts with armature current, generating axial propulsive force
Magnetic field generated around rails as current flows through circuit.
Switch closes, current flows through rails & armature.
B
J
F
Lorentz Force (F) =
Current (J) X Magnetic Field (B)

Why Now ?

Integrated Power System (IPS)

Guided Munitions Development

Advances in Railgun Technology

Enabling Technologies for Transformational Naval Railgun

Navy EM Workshop

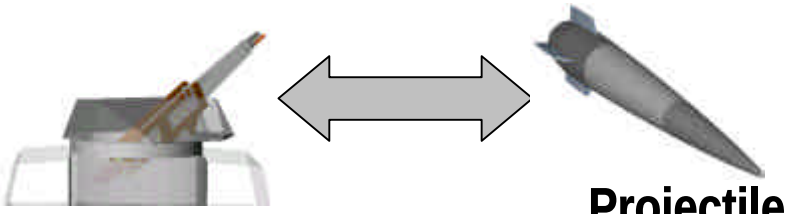
- A workshop was held in November 2001 at the Institute for Advanced Technology (IAT) to access the feasibility of a long range Naval railgun.
- Included most of the nations foremost experts in EM launch.
- Discussions were centered around a notional Navy EM Gun.
- Participants concluded that "…no current scientific or technological obstacles would preclude the development of a naval railgun."

Notional Navy EM Gun:

- Flight Mass – 15 kg
- Launch Mass – 20 kg
- Launch Velocity – 2.5 km/s
- Muzzle Energy – 63 MJ
- Breech Energy – ~150 MJ
- Barrel Length – 10 m
- Peak Accel. – 45 kg's
- Firing Rate – 6 to 12 RPM
- Peak Power – 20 to 40 MW
- Peak Current ~ 6 MA
- In-Bore Time ~ 8 – 10 msec

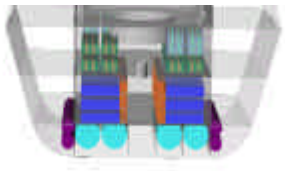
Evaluated Notional Navy EM Gun Feasibility

Why Trade Studies?



Projectile

Gun Mount



Power Supply & Magazine

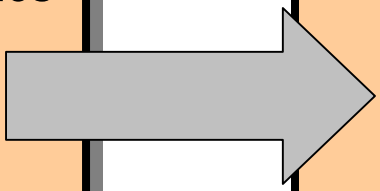
- Helps better quantify important parameters and concerns/issues from the workshop
- Understand launcher design space and relationship to/impact on projectile and PFN design space.
- Size proof of concept launcher demonstration to demonstrate feasibility of a tactical configuration.
- Track energy flow from power supply to target.

A total ship/weapon systems design approach is essential.

Parametric Studies

Variables Being Explored

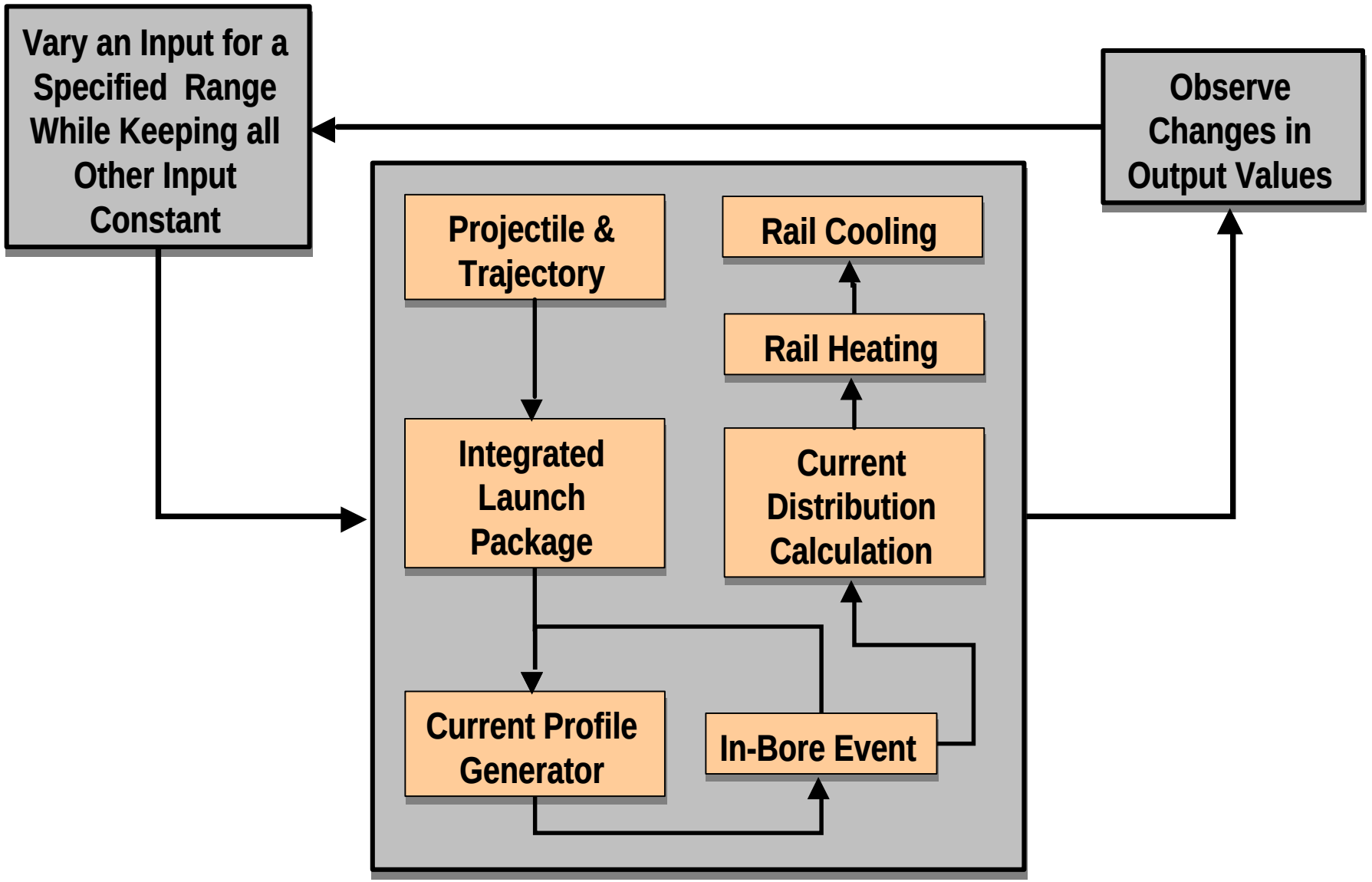
- Barrel Length
- Bore Dimensions
- Certain Projectile Characteristics
- Integrated Launch Package Characteristics
- Certain Electrical Current Characteristics
- Rail Cooling Characteristics
- Distributed Cabling



Effected Parameters

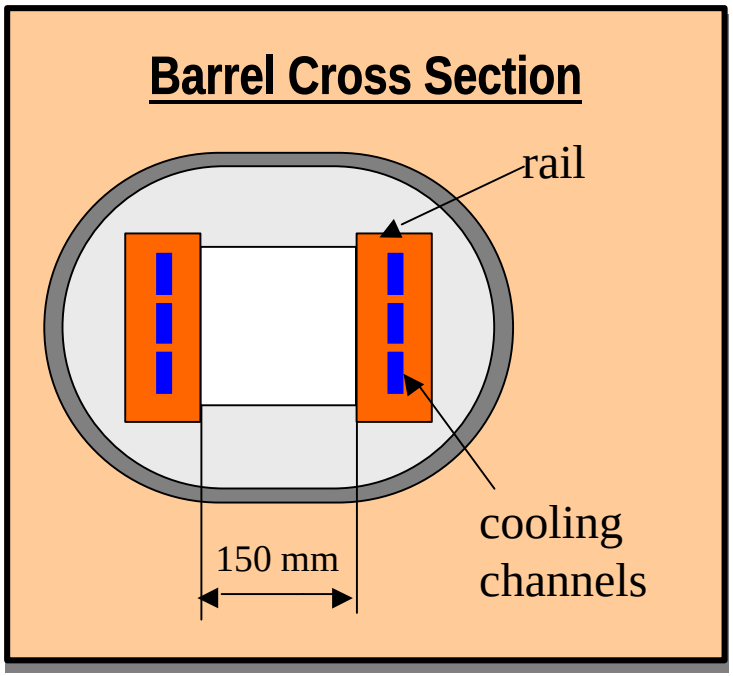
- PFN Size
- Maximum Current
- Linear Current Density
- Energy Dissipated in Rails
- Inductance Gradient
- Piezometric Efficiency
- Cooling Flow Rate
- Firing Rate
- Gun System Weight Estimates
- % Parasitic Mass
- Maximum Projectile Gee's
- Projectile Range
- Terminal Velocity

Model Methodologies
Model Components



Launcher Trades Baseline

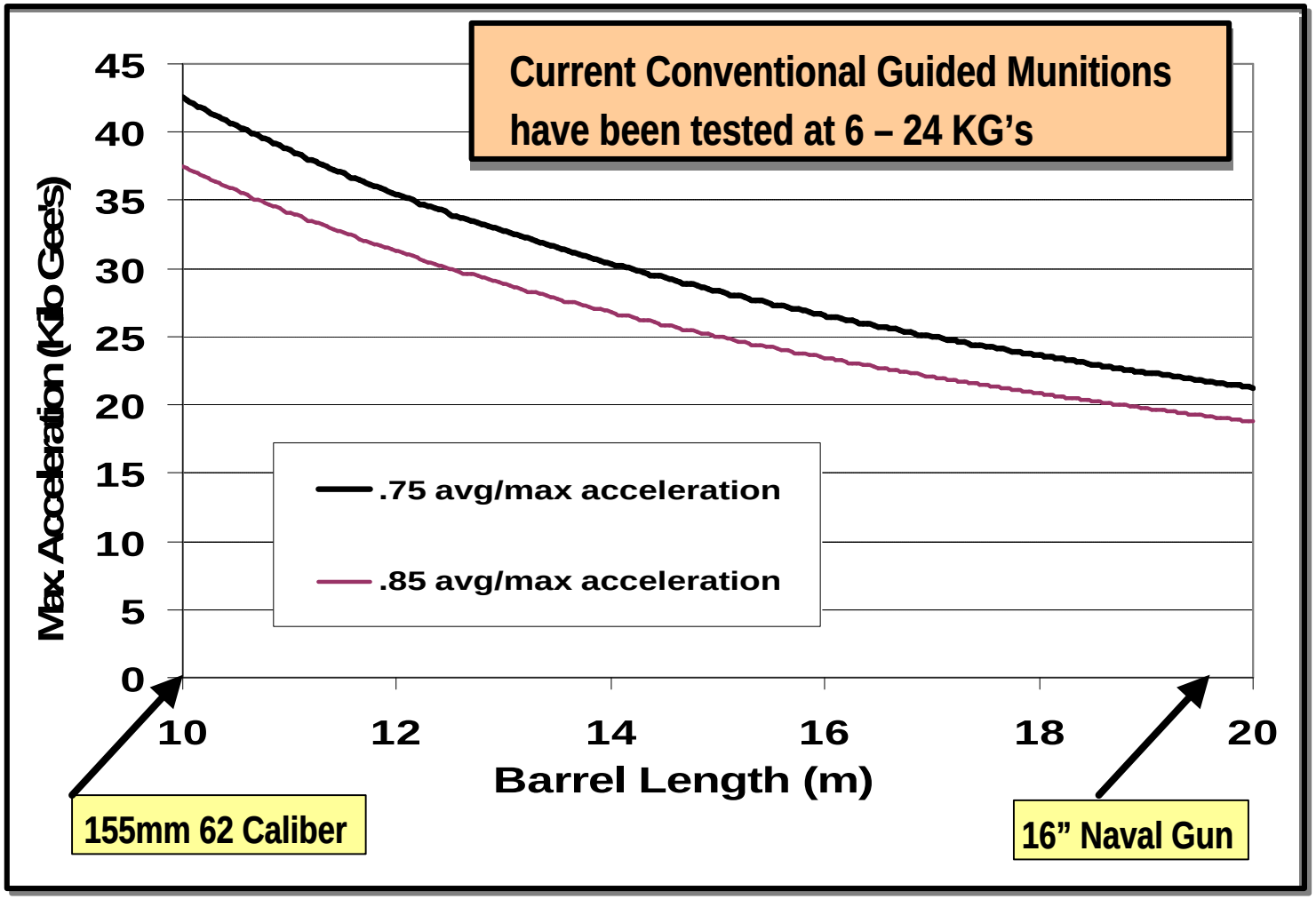
- **Barrel Configuration**
  - 10 m barrel
  - Cabled at Breech
  - Train and Elevate
  - Simple Cooling Channels
- **Bore**
  - 150mm x 150mm *
  - 100 mm rail thickness *
- **Electrical Current Profile**
  - 6.5 MA/msec linear rise rate *
  - 0 slope linear secondary rate *
  - 2 MA/msec linear decay rate *
  - 40% max current a muzzle exit *
- **Projectile**
  - 20 Kg Launch Mass
  - 2.5 Km/sec
  - Base Push
  - "Barrage Like"



Barrel trade initial inputs based on Center for Naval Analysis' notional gun which was evaluated at the Navy Electro-Magnetic Launch Workshop (7-9 November 2001, Austin Texas

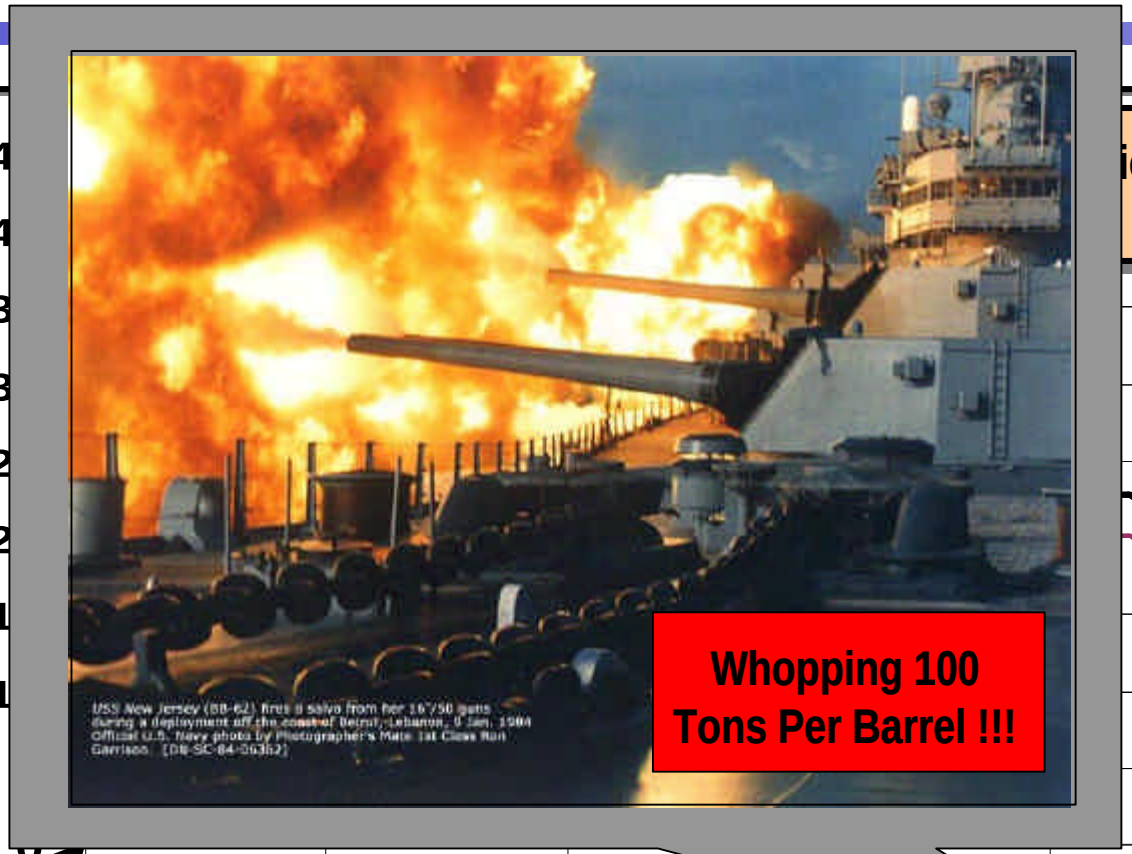
★Implied Characteristics from Notional Baseline

Barrel Length vs. Max G's



The Longer the Barrel – The Lower the Projectile Gee's

Barrel Length vs. Max G's



Max Acceleration (Kilo Gee's)

4
4
3
3
2
2
1
1

10 12 14 16 18 20

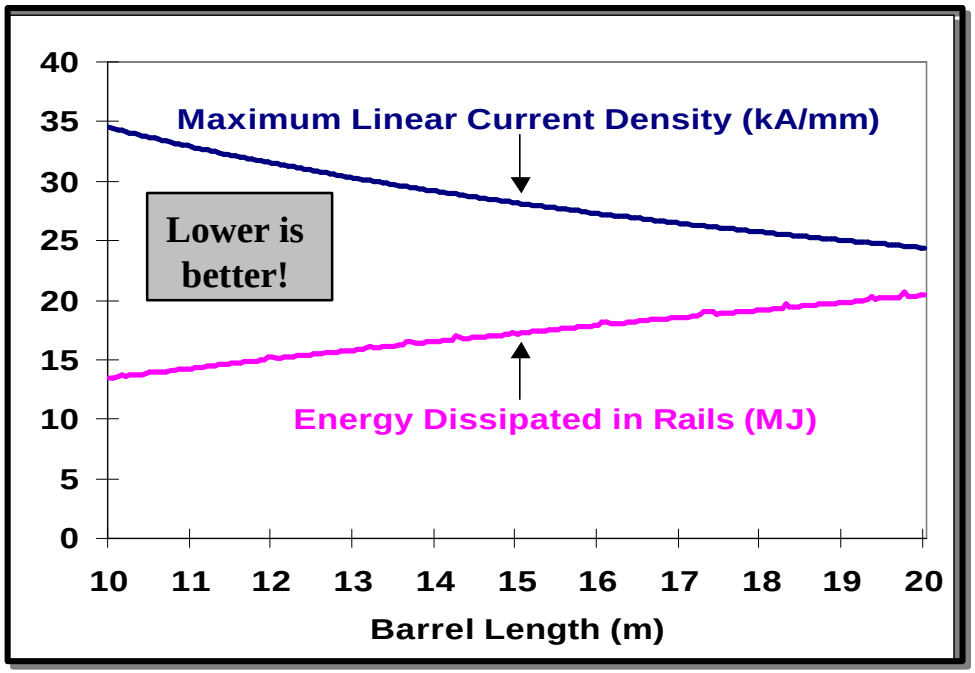
Barrel Length (m)

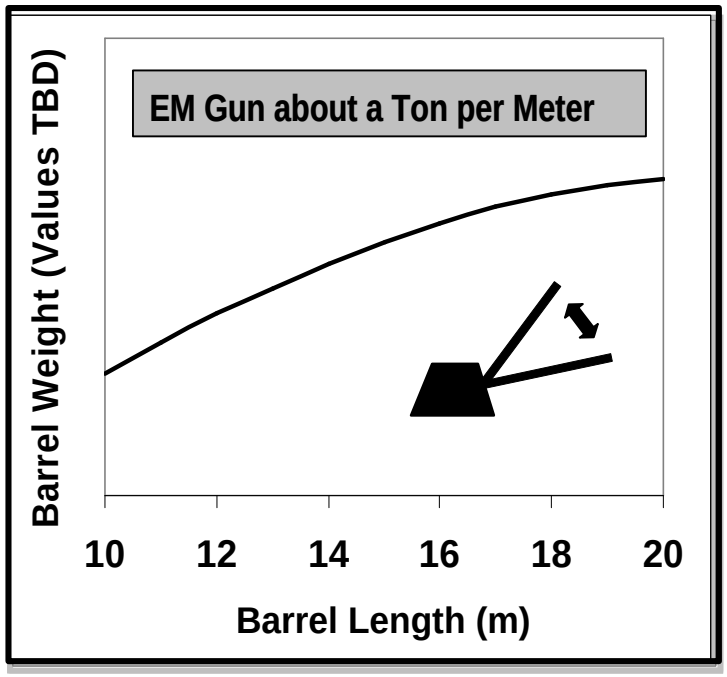
155mm 62 Caliber

16" Naval Gun

20 meter, 100 ton barrels have been done before!

Other Barrel Length Effects

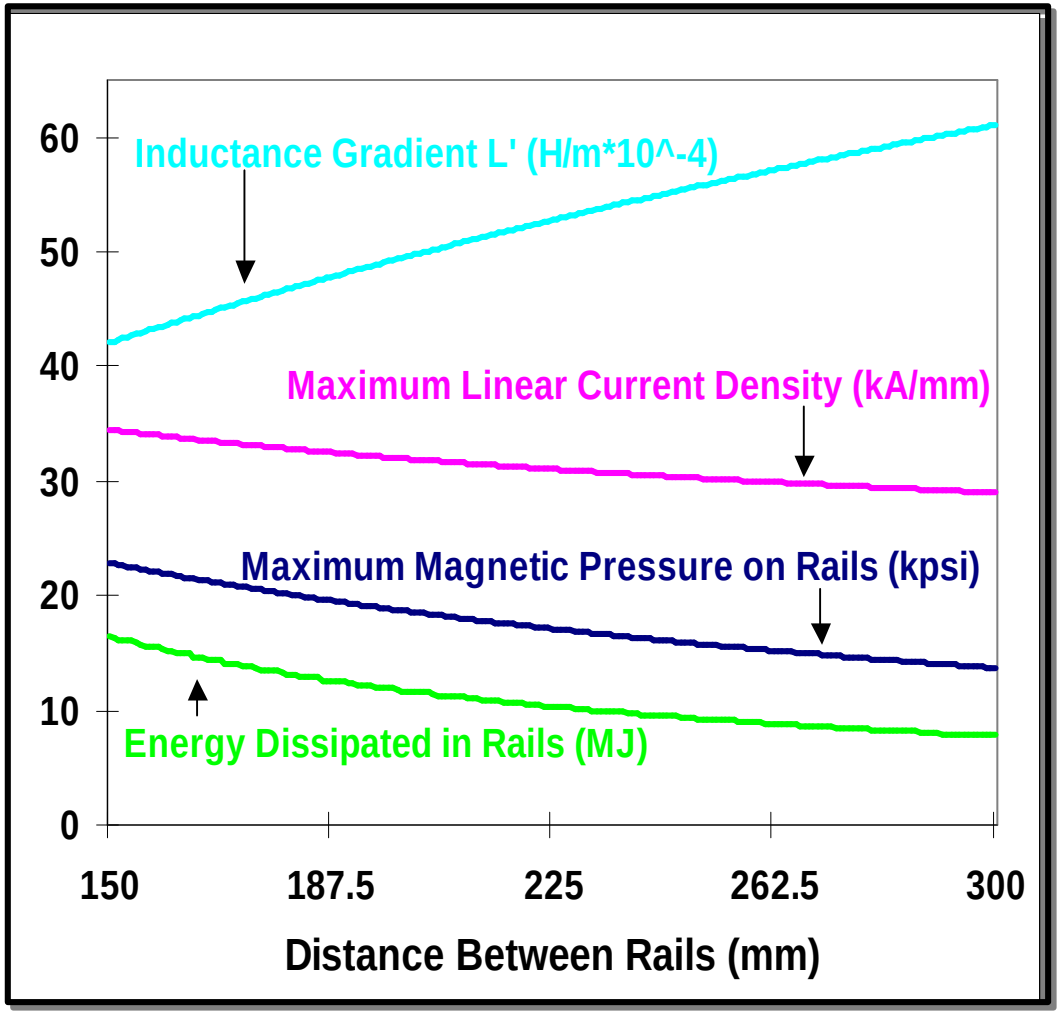




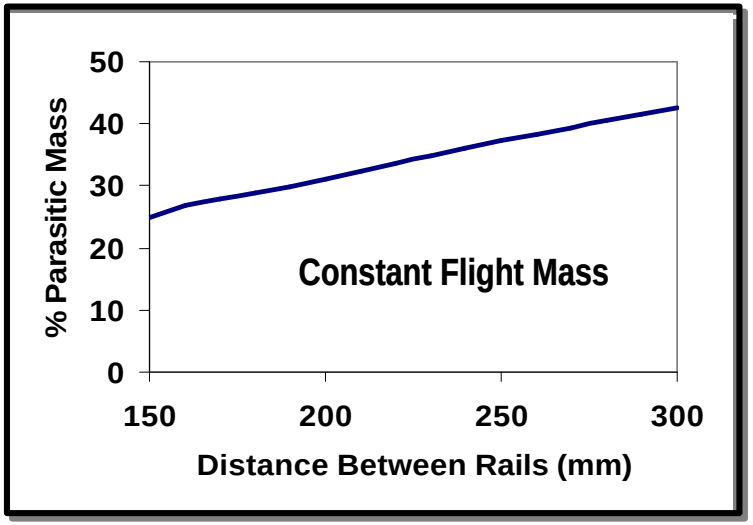
- Amount and location of energy dissipated in the rails dictates cooling system size and achievable firing rate.
- Too high of linear current density can cause excessive transient local heating/melting in rails and armature.
- Increased barrel length affects gun train and elevation power requirements.

Longer Barrel Reduces Localized Heating But Raises Total Rail Heating

Bore Dimensions

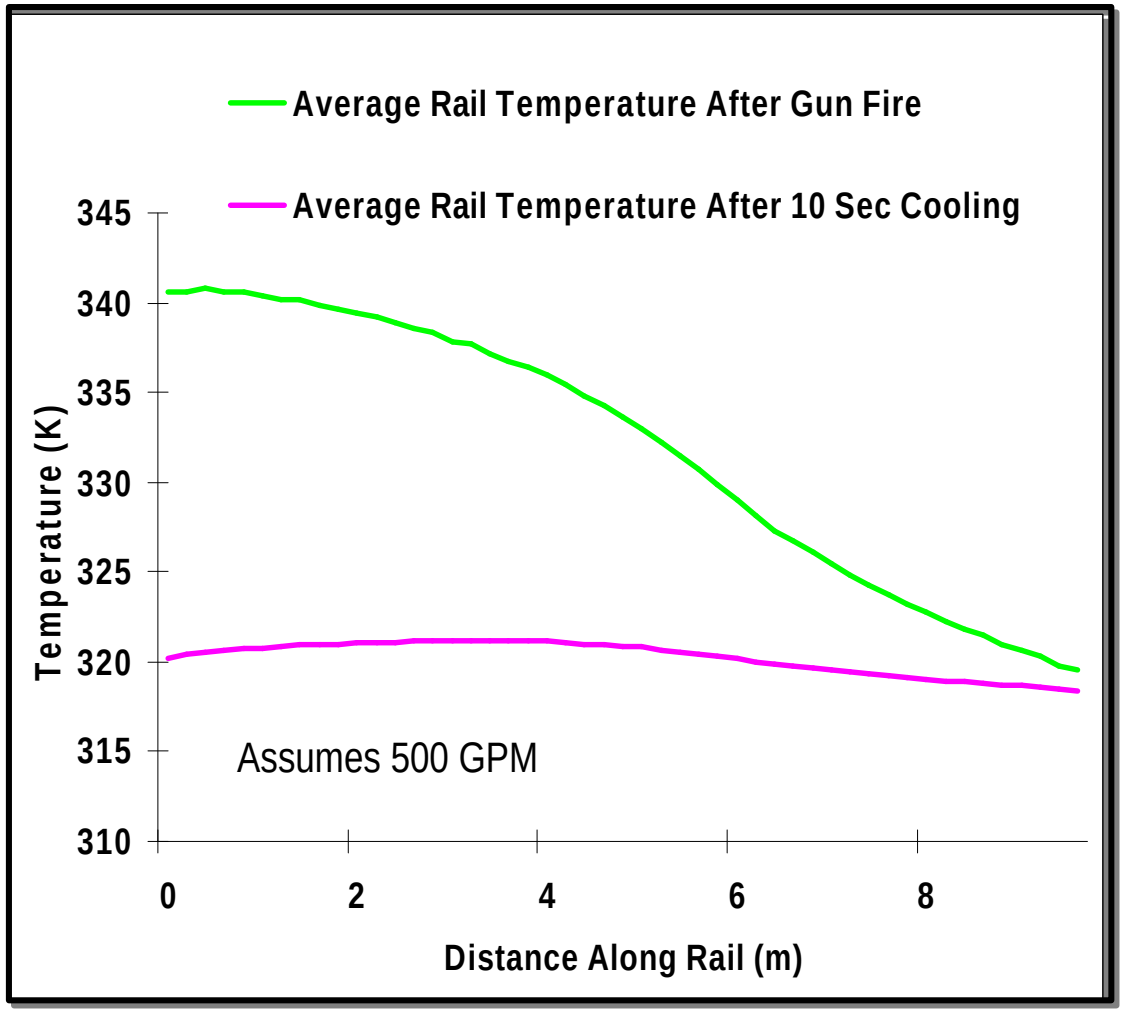


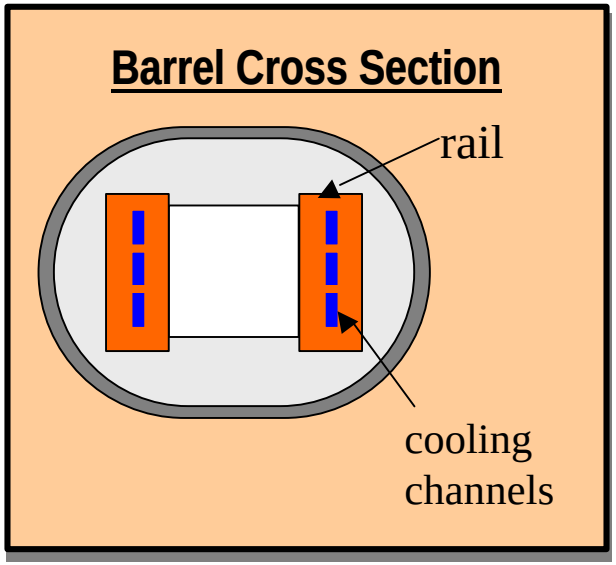
- As bore sizes increase, linear current density, rail heating, and bore pressure decreases due to an increase in the linear inductance gradient (less resistance to current flow, greater current efficiency).
- Benefits must be weighed against increases in parasitic mass.



Larger Bore Improves Electrical Current Efficiency But Adds Parasitic Mass

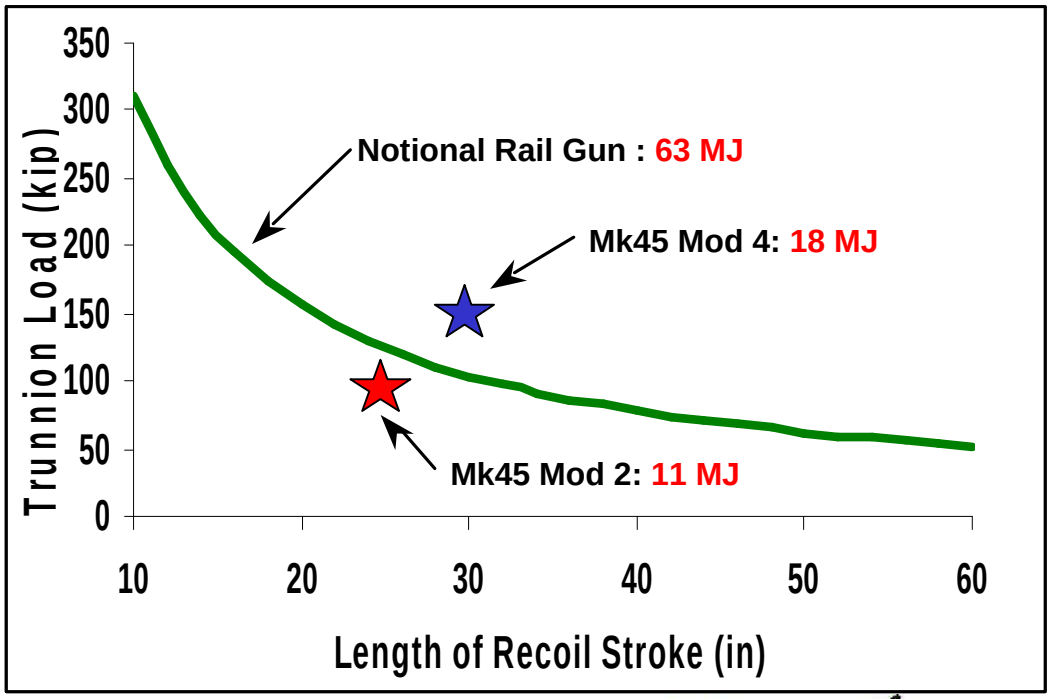
Rail Heating & Cooling

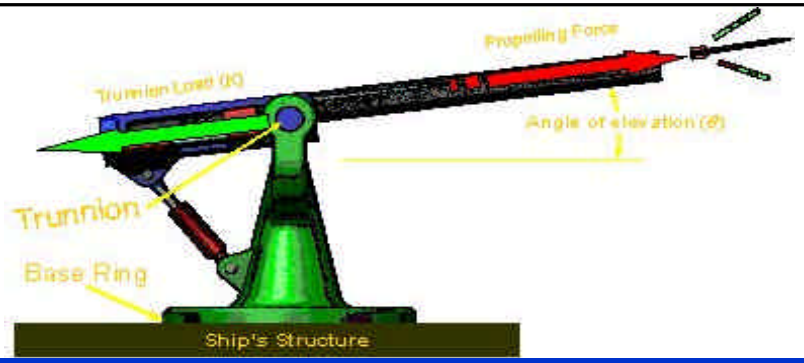




Cooling Rails Appears Manageable

Recoil and Ammo Loading

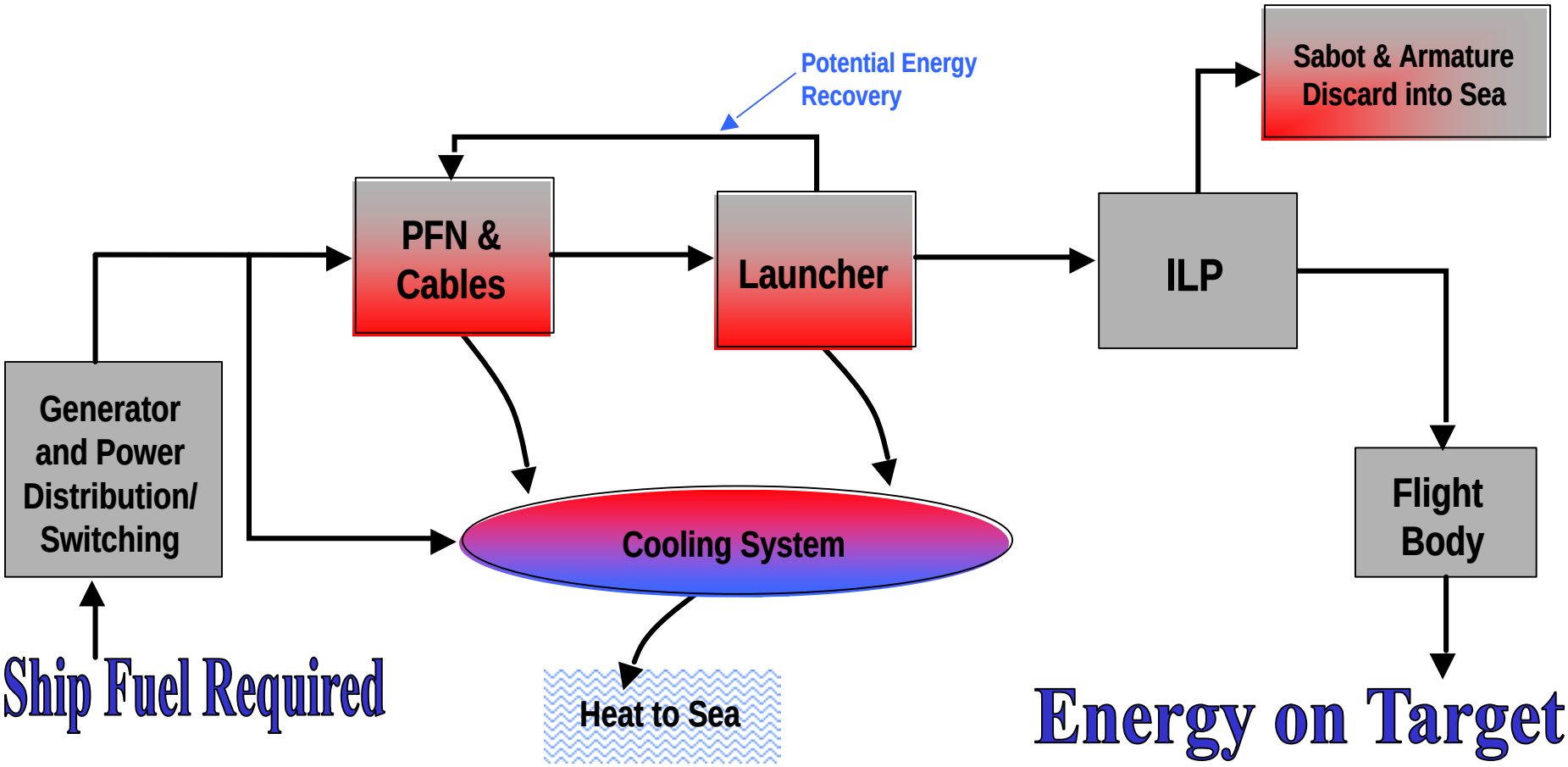




- Recoil is less on an EM gun due to the absence of an accelerated propellant gas.
- Recoil loads are likely to also be less due to a relatively higher recoiling mass depending on the final barrel length and required cooling.
- Alternative ammo loading configurations may need to be explored.

Recoil Loads Should Be Less Than the 5" 62 Conventional Gun

System Energy Flow



Gun Operation Requires a Weapon/Ship Systems Approach

Conclusions

- An electric ship, guided munitions & advances in railgun technology enable the development of a transformational naval railgun.
- A naval railgun parametric model has been developed & exercised.
- Conceptual design space has been established & naval railgun appears feasible.
- Parametric model to be continuously improved as the total system concept is being developed and as higher fidelity is required.
- Navy is pursuing a Proof of Concept Demonstration.