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# Parametric Analyses Using a Computational System Model of an Electromagnetic Railgun


## NDIA Joint Armaments Conference:
## Unconventional & Emerging Armaments Session

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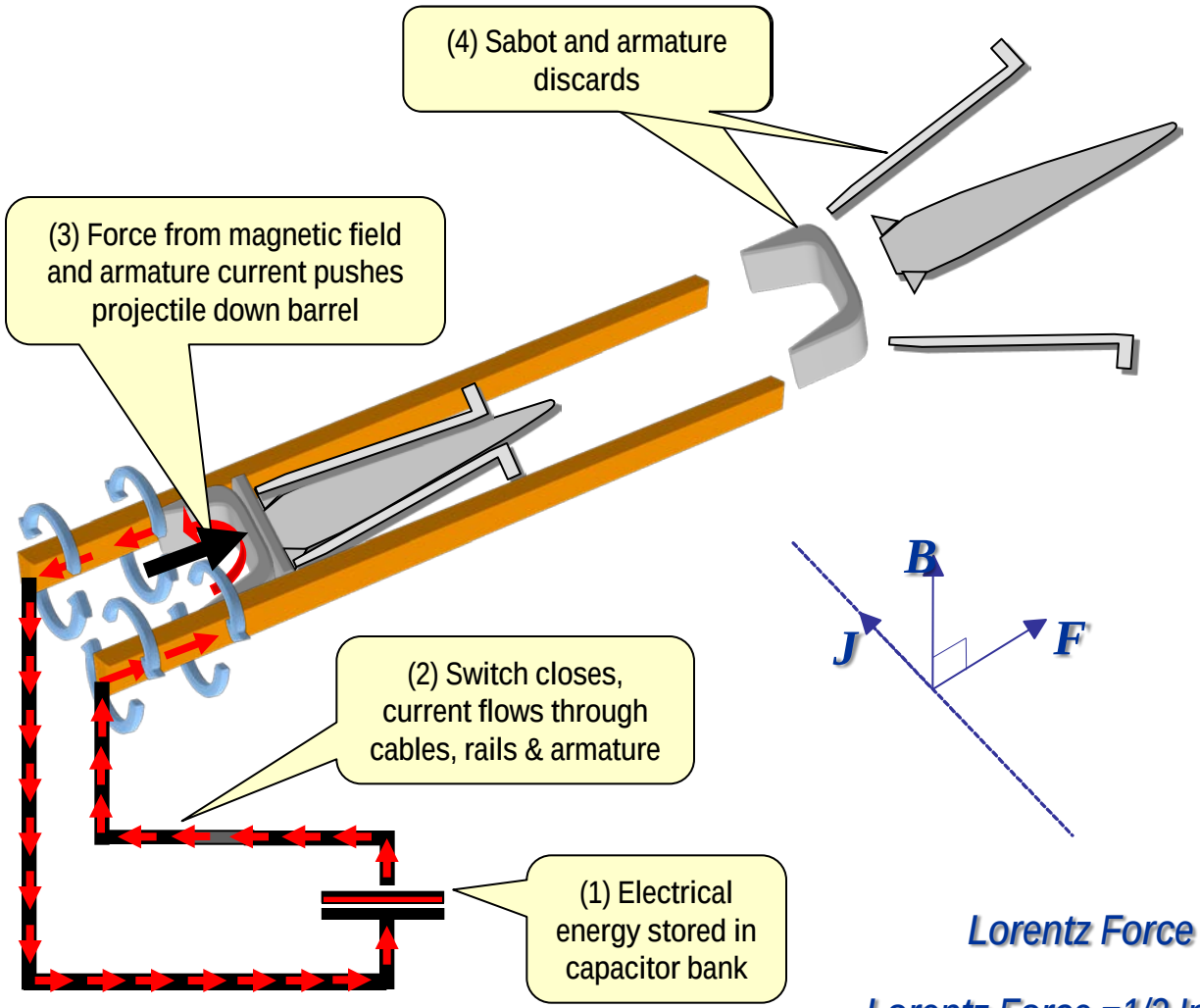
# How Railgun Works

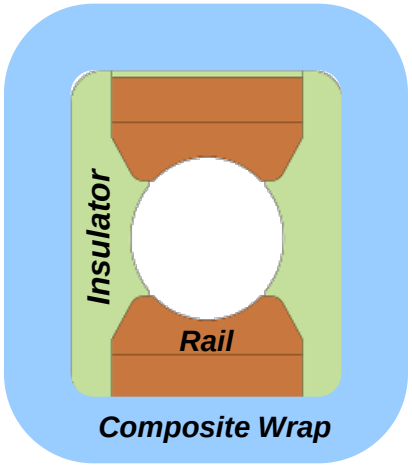
## Operating Principle







## Cross-Section




*Lorentz Force = Current (J) X Magnetic Field (B)*
*or*
*Lorentz Force =1/2 Inductance Gradient (L') * Current (I)^2*

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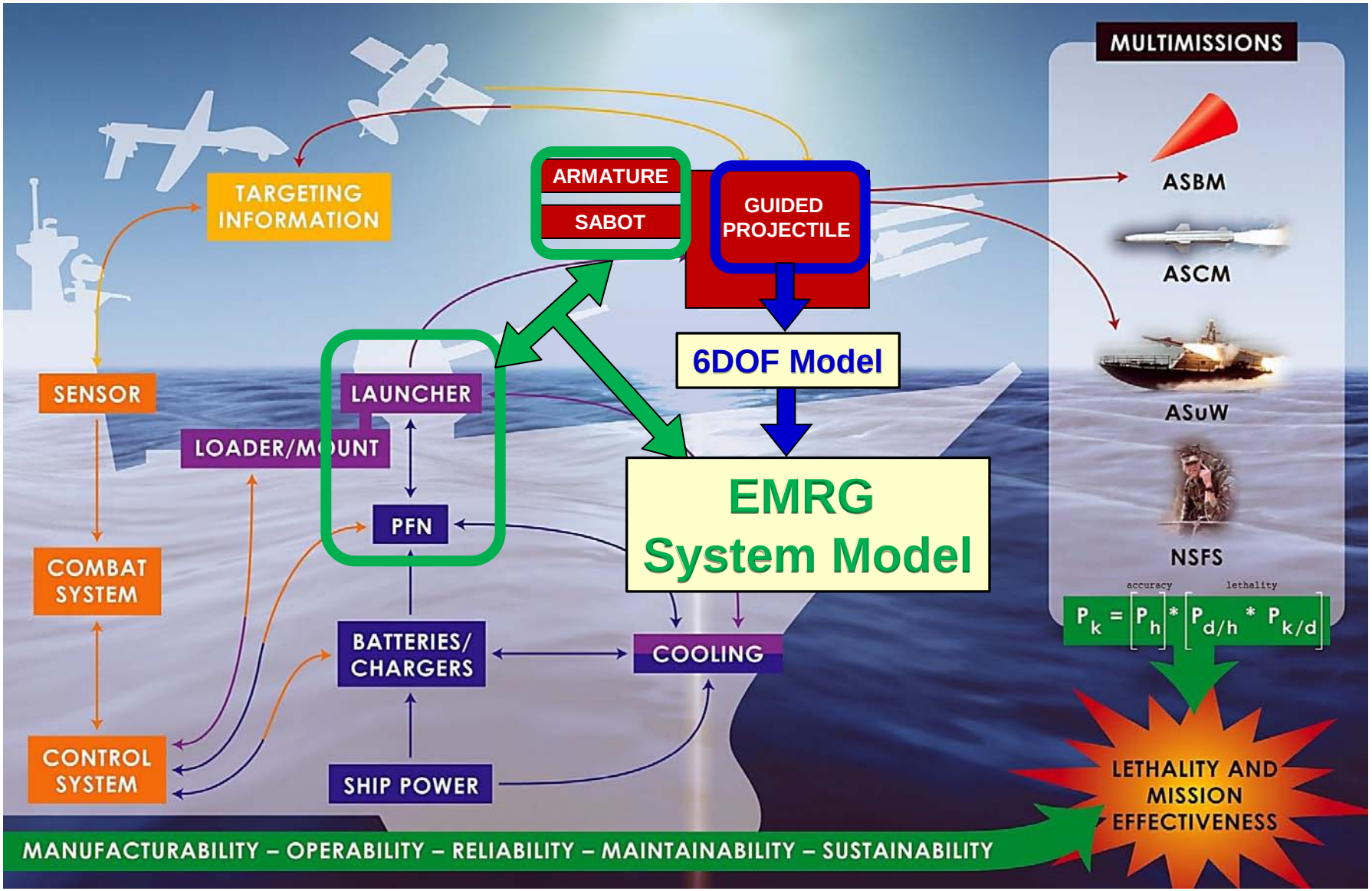
# Railgun System



# Systems Engineering Objectives

- Develop model to examine performance characteristics
  - Perform parametric trade studies
  - Understand EMRG design tradespace & parameter sensitivities
- Update tactical system parameters to form system baseline design

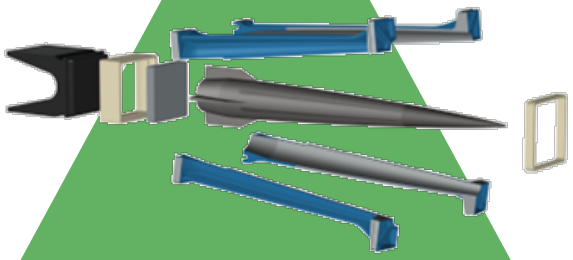
## Pulse Power

Weight
Volume
Thermal Load
Stored Energy

## Launcher

Recoil
Peak Current
Barrel Length
Muzzle Energy
Thermal Heating

## Projectile



ILP Weight
Lethal Mass
Flight Weight
Parasitic Mass
Overall Length/Diameter

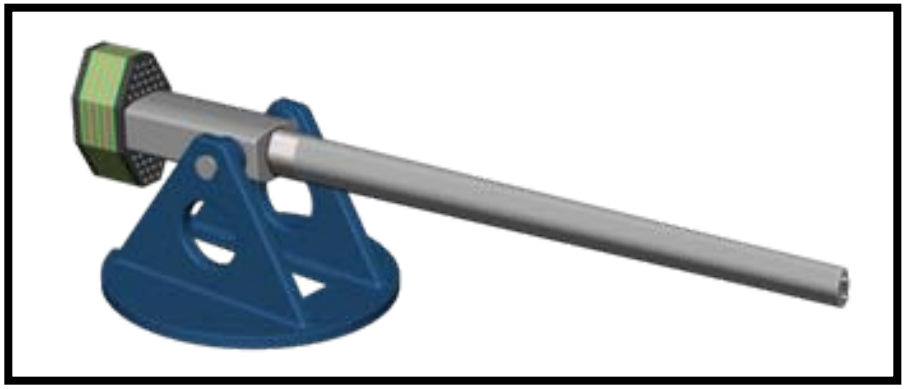
***Minimize System Risk***

# Key Parameters for Sizing a Naval EM Launcher

Pulse Forming Network Size

½ * Launch Mass * Muzzle Velocity$^2$

## Desired Muzzle Energy



## Current Profile

- Rail Separation Forces
- Transient Localized Heating

## Bore Size & Shape

Launcher Efficiency

## Barrel Length

- Max Projectile Acceleration
- Bulk Rail Heating

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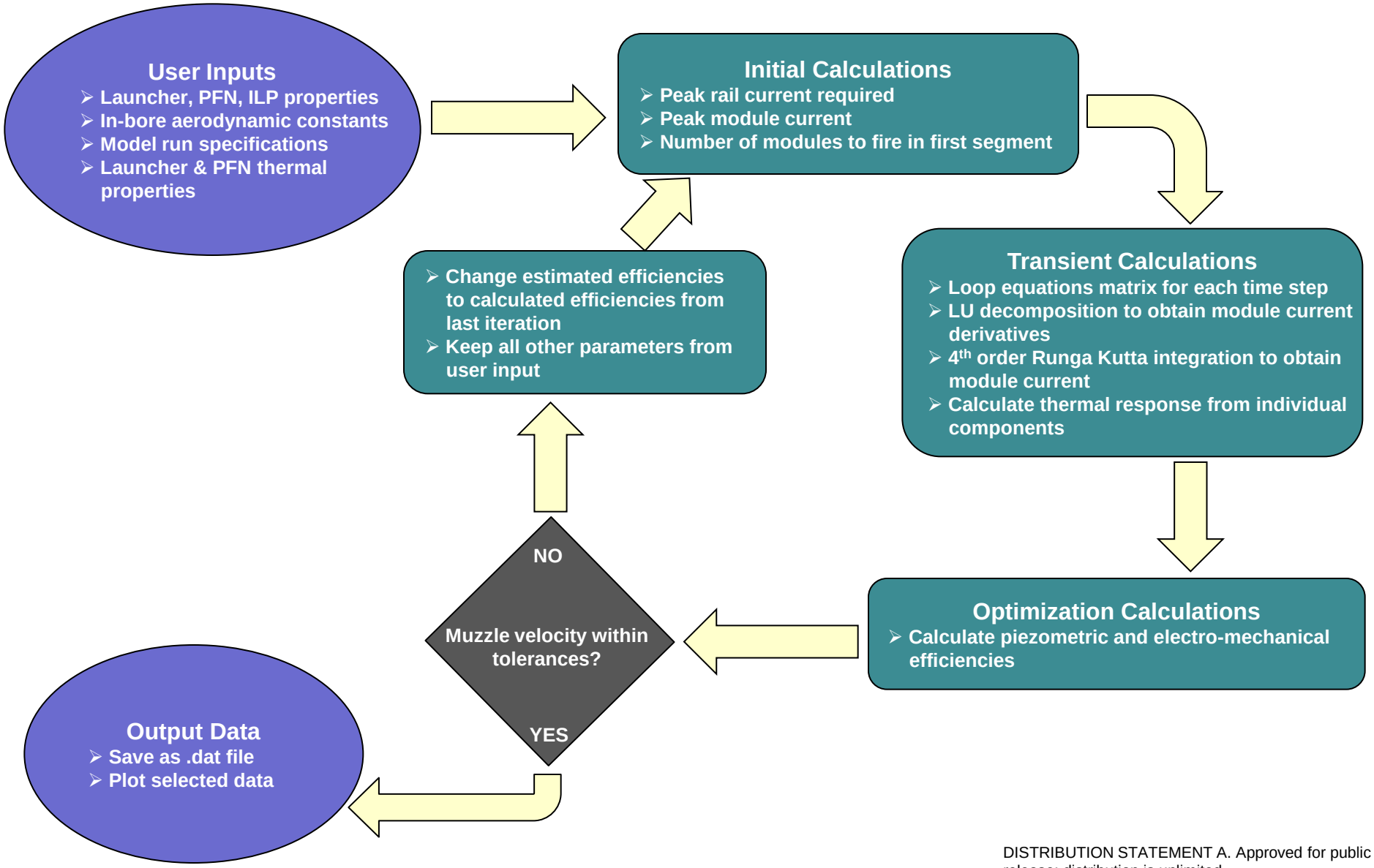
# Computational Sequence



# Inputs

| Launcher |
| --- |
| L’ |
| R’ |
| Bore Diameter |
| Barrel Length |
| Armature resistivity (also listed under ILP) |
| Shunt resistivity |
| Cable length |
| Cable resistivity |
| Cable inductance |
| Breech resistivity |
| Breech inductance |
| Small leakage current |

| Pulse Power Supply |
| --- |
| Capacitor voltage |
| Capacitor capacitance |
| Capacitor resistivity |
| Inductor inductance |
| Inductor resistivity |
| Diode resistivity |
| Thyristor resistivity |
| Bus resistivity |
| Bus inductance |

| Integrated Launch Package |
| --- |
| Launch mass |
| Armature resistivity |

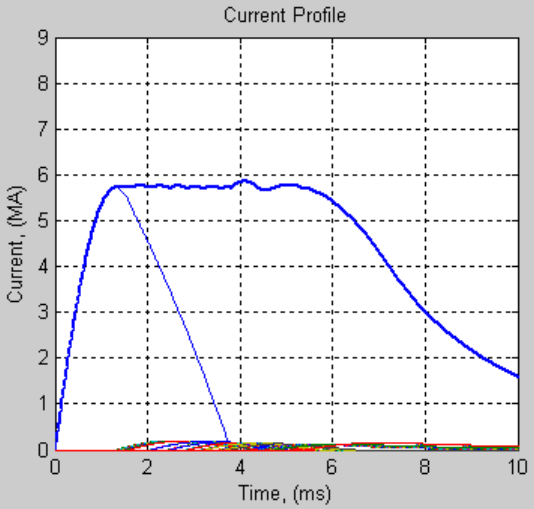
| Simulation Pulse Forming Network |
| --- |
| Total number of modules fired |
| Number of modules to fire in first group |
| Number of modules to fire in subsequent firing groups |

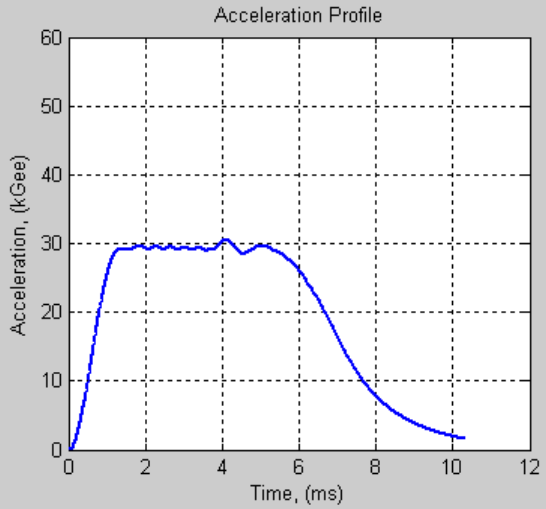
| Aerodynamic Constants |
| --- |
| Density of air |
| Cxo, drag of ILP inbore |

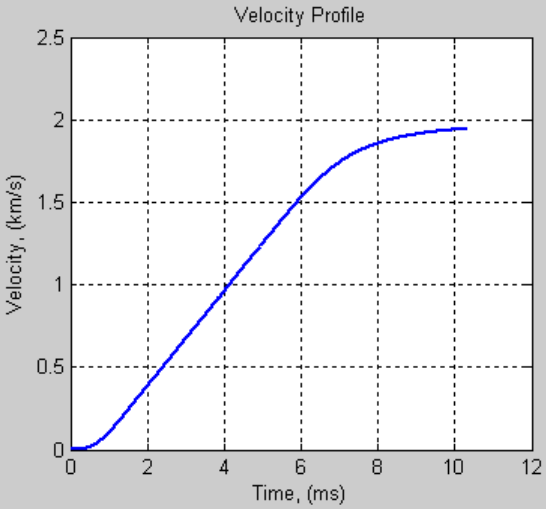
| Simulation Execution |
| --- |
| Maximum simulation time |
| Time step |

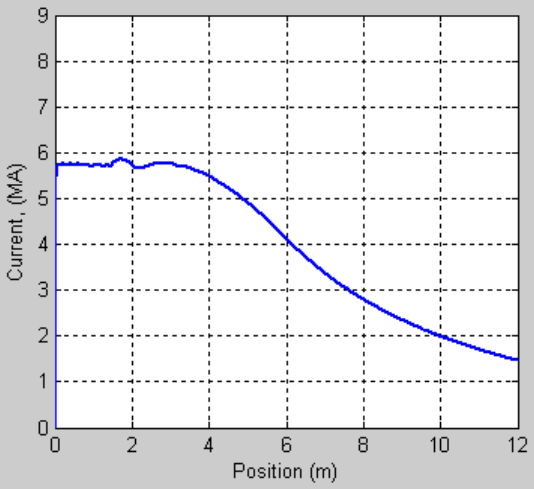
| Launcher Thermal Model |
| --- |
| Initial temperature of rails |
| Number of rail sections over length of rail |
| Effective height |
| Effective width |
| Rail permeability |
| Rail conductivity |
| Rail coefficient of thermal expansion |
| Rail density |
| Rail initial resistivity |
| Rail temperature resistivity |
| Distance between nodes normal to rail surface |

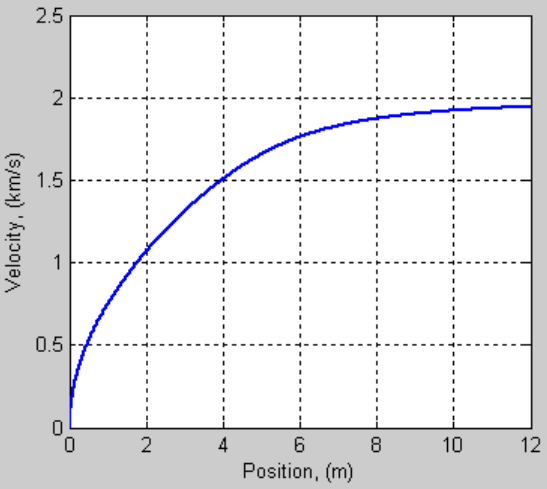
# Sample Output



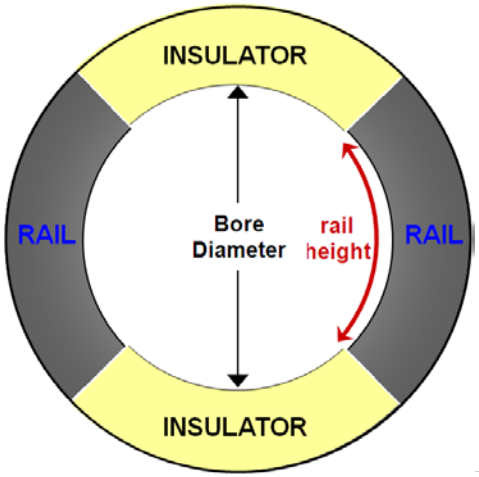



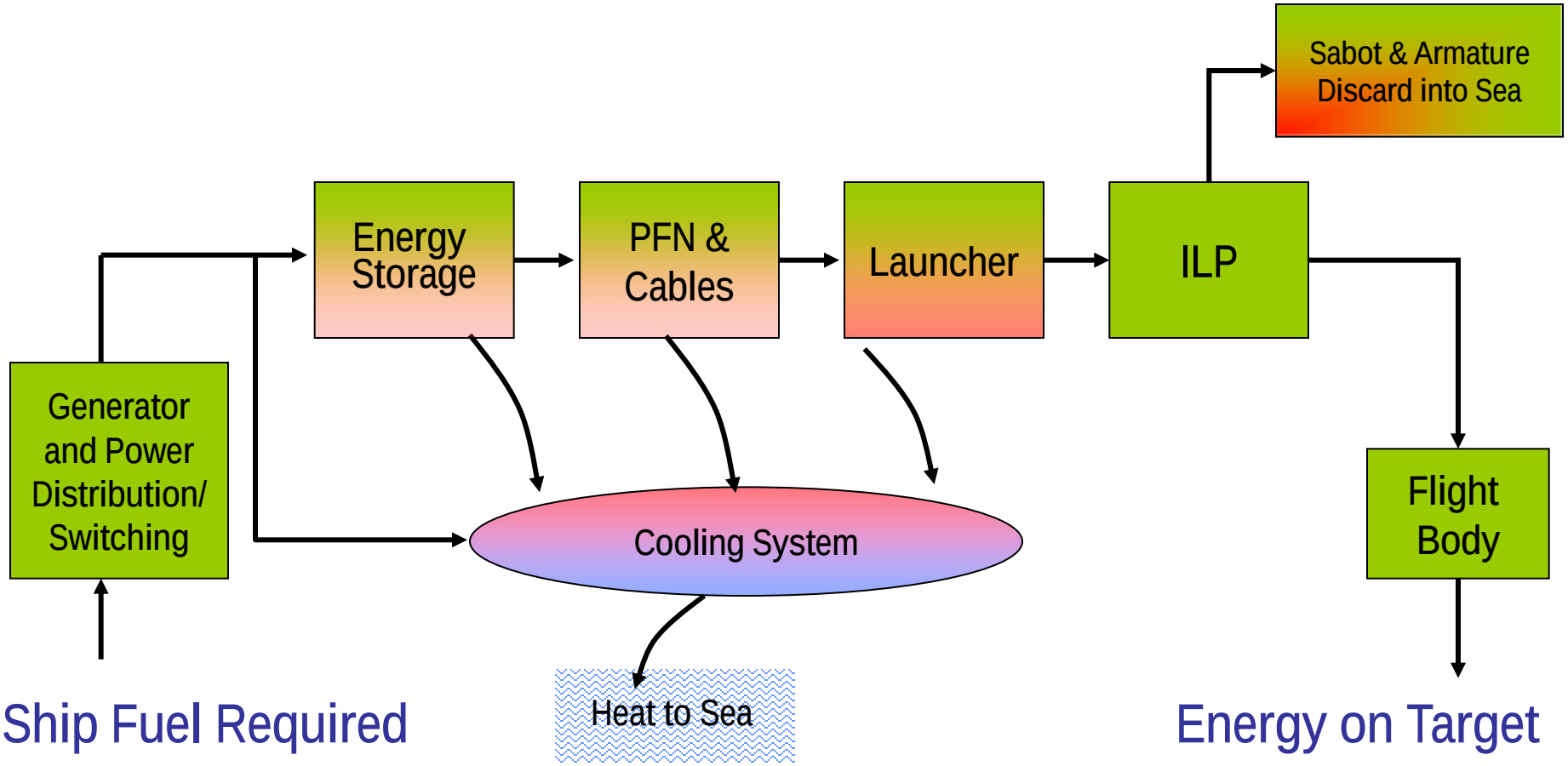




Bore diameter = 120mm

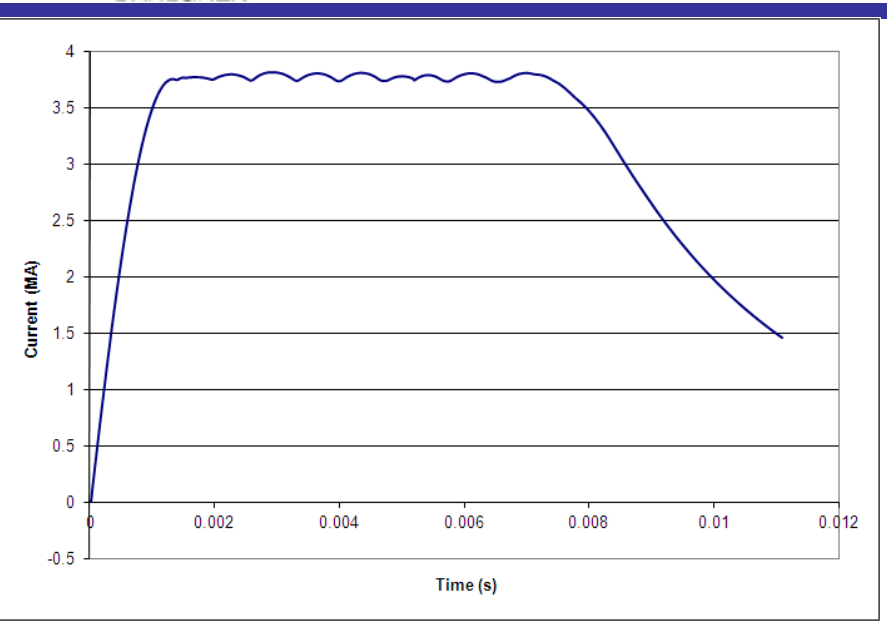


# Energy Flow & System Design

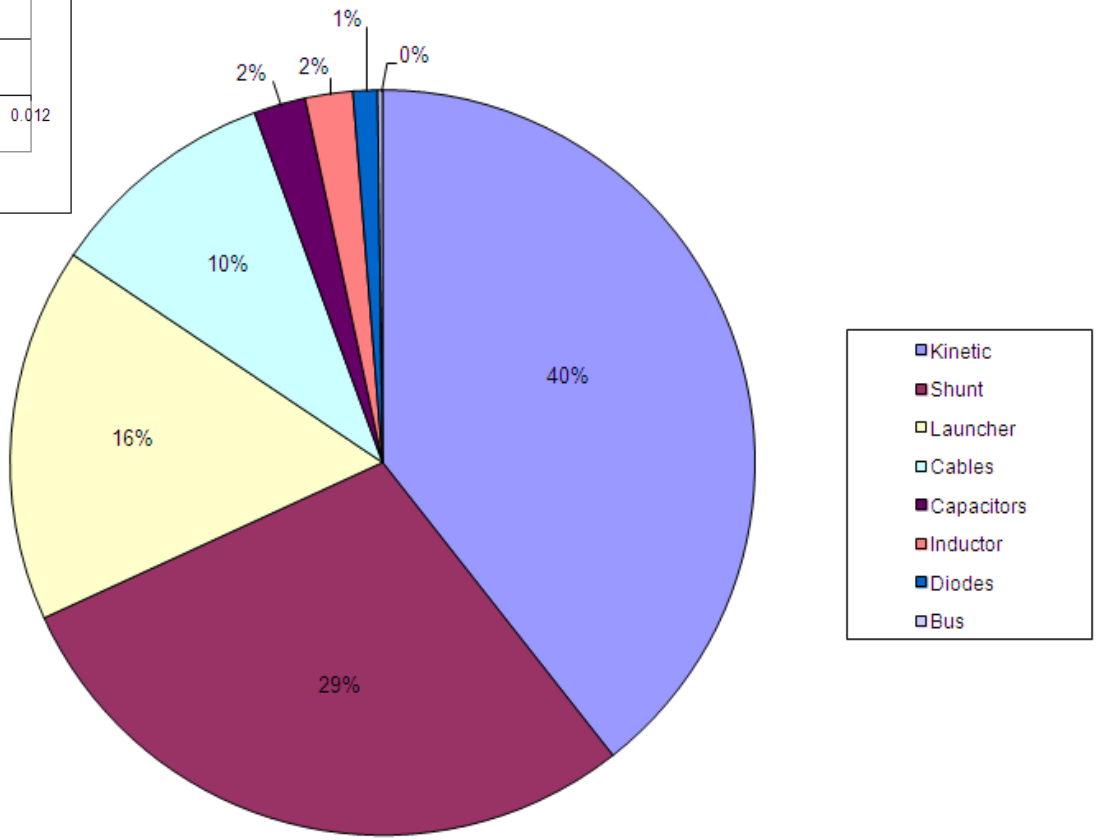



**Gun Operation Requires a Weapon/Ship Systems Approach**

# Sample Output: Heat Generation

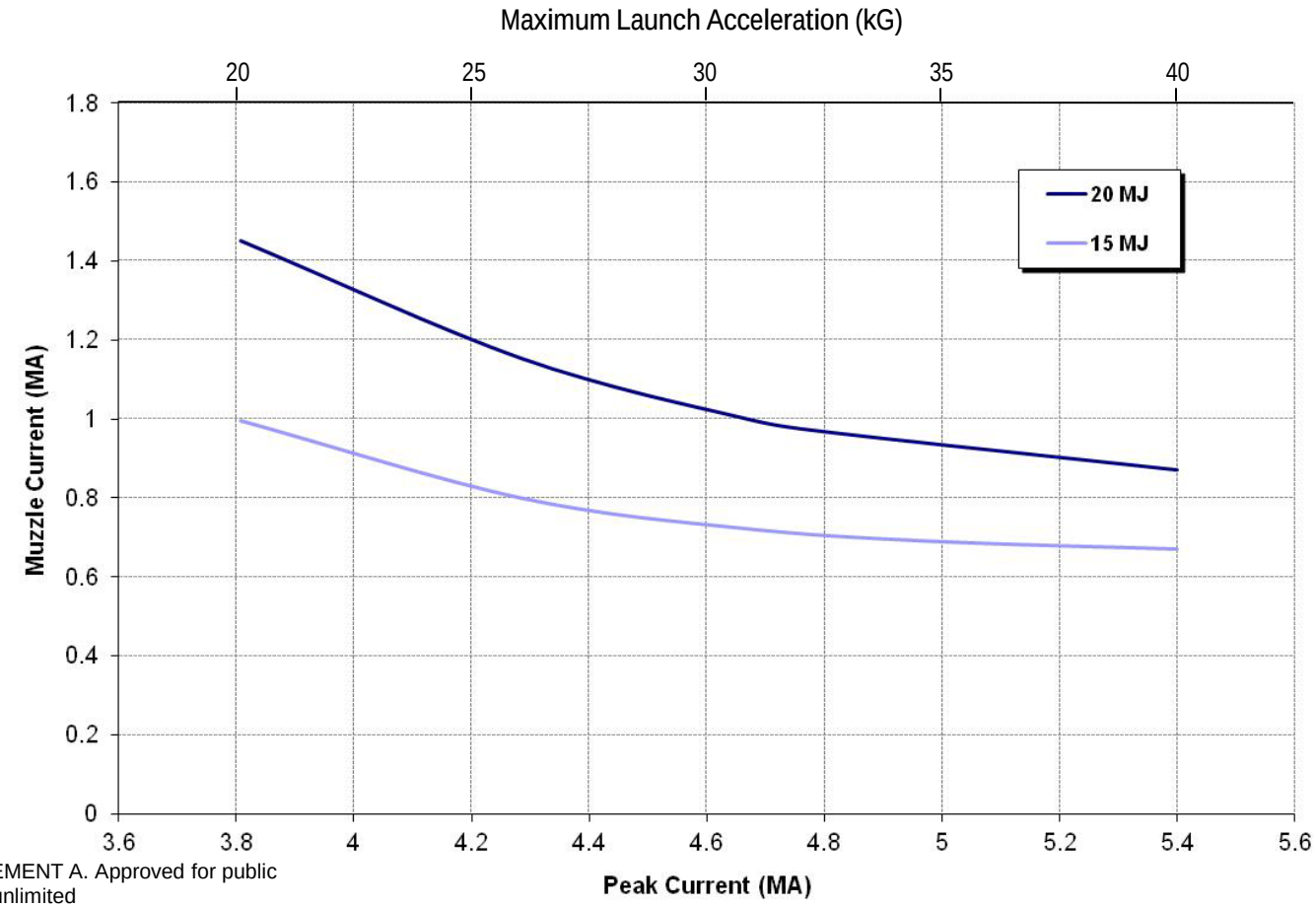



- Track heat deposited in each component per shot
  - Use data for cooling design

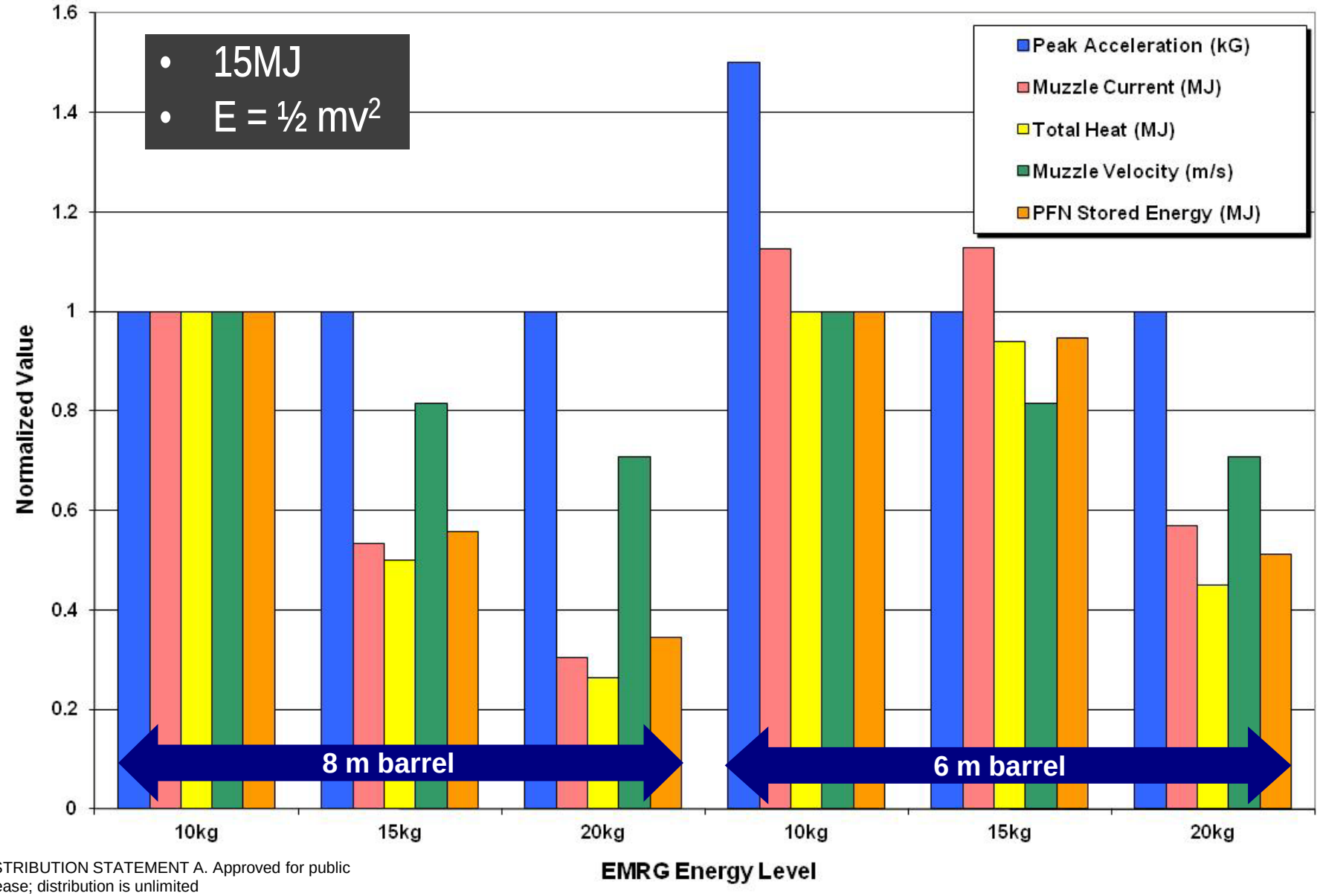


# Parametric Study:
## Muzzle Current vs. Peak Acceleration & Peak Current

- Examine tradespace for peak & muzzle current and maximum launch accelerations
  - Sample case: 10m barrel, 120mm round bore
- Understand muzzle blast effects
  - Unlike conventional guns, consider muzzle exit current blast / arc
  - Impact to ship and/or laboratory environment; effect on nearby equipment and personnel



# Sample Multi-Parameter Study: Vary Point Designs



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# Summary

- Working model to examine performance characteristics
  - Easily plot in-bore characteristics
- Model can perform a variety of parametric studies
  - Track heat generation in system and/or individual components
  - Understand implications of single parameters on total system performance
  - Communicate system-level EMRG design tradespace
- Use studies to determine point design
  - Compare multiple point designs

*In-House System Model for Quick Turn-around Studies*

# Contact Information


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