



# Test and Evaluation of Electromagnetic Railguns

NDIA Gun & Missile Systems  
April 23-26, 2007





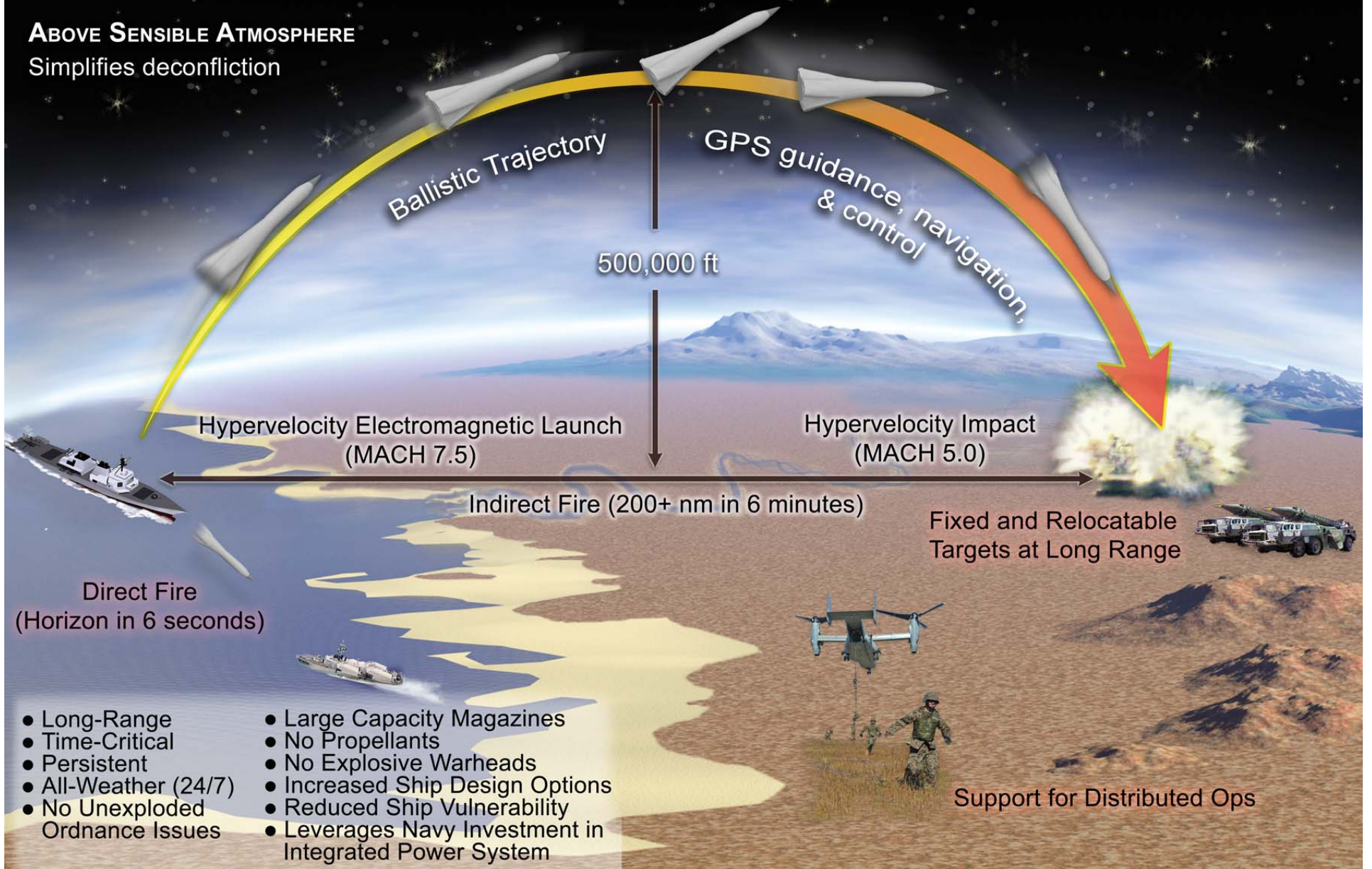
Revolutionary Research . . . Relevant Results

# NR

# EM Railgun – Game Changing



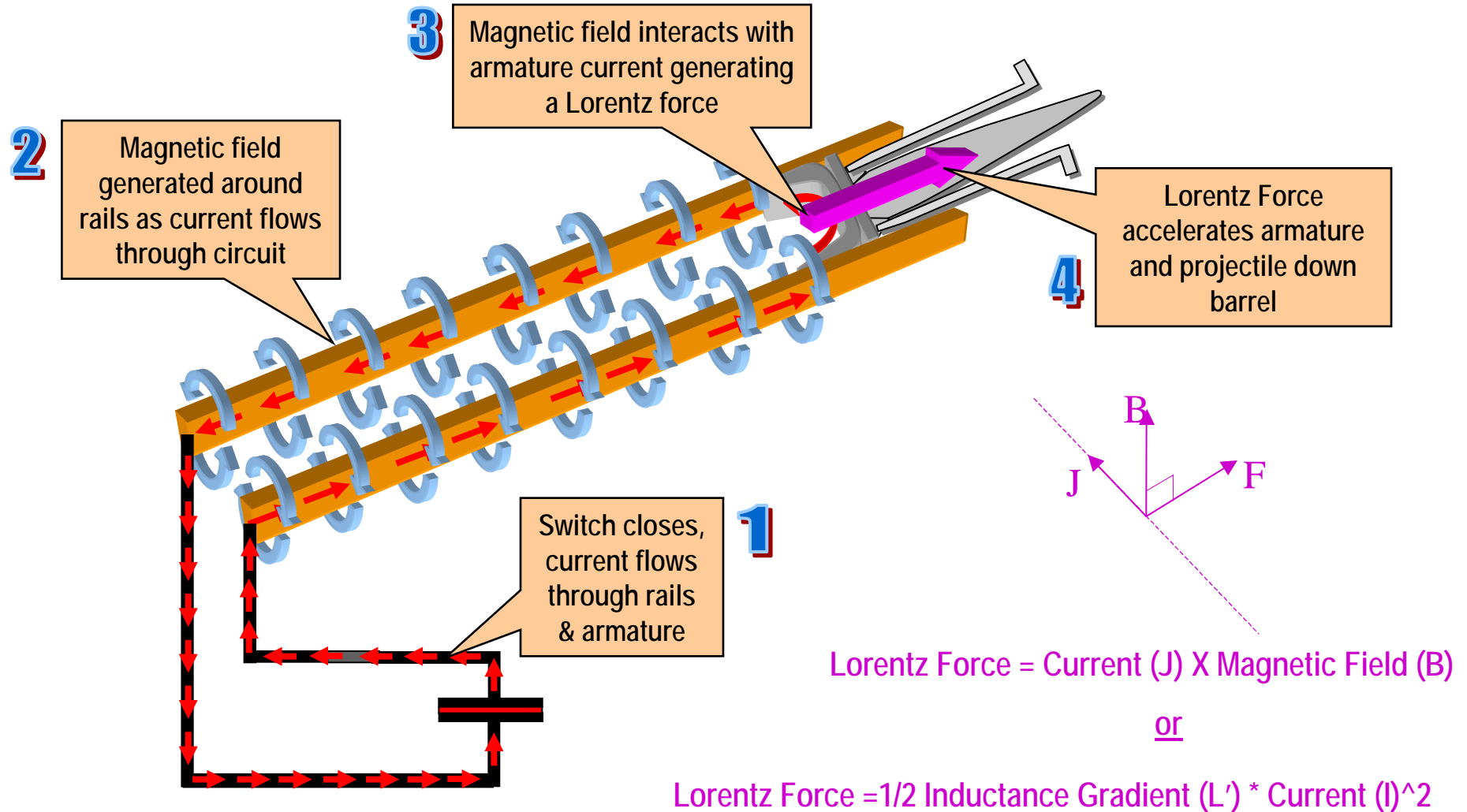
**ABOVE SENSIBLE ATMOSPHERE**  
Simplifies deconfliction



- Long-Range
- Time-Critical
- Persistent
- All-Weather (24/7)
- No Unexploded Ordnance Issues
- Large Capacity Magazines
- No Propellants
- No Explosive Warheads
- Increased Ship Design Options
- Reduced Ship Vulnerability
- Leverages Navy Investment in Integrated Power System

Support for Distributed Ops

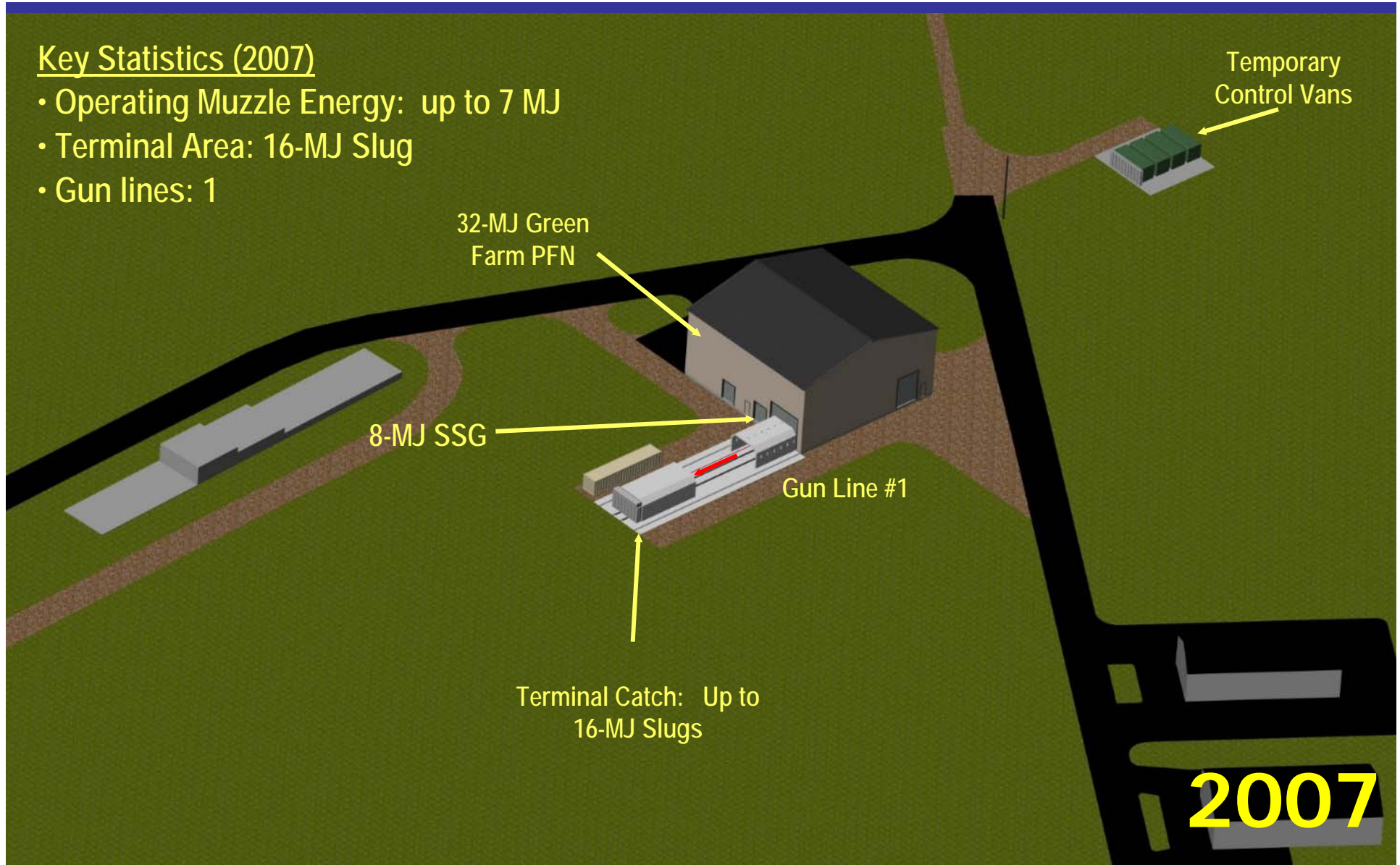
# How it Works



# Current Facility

## Key Statistics (2007)

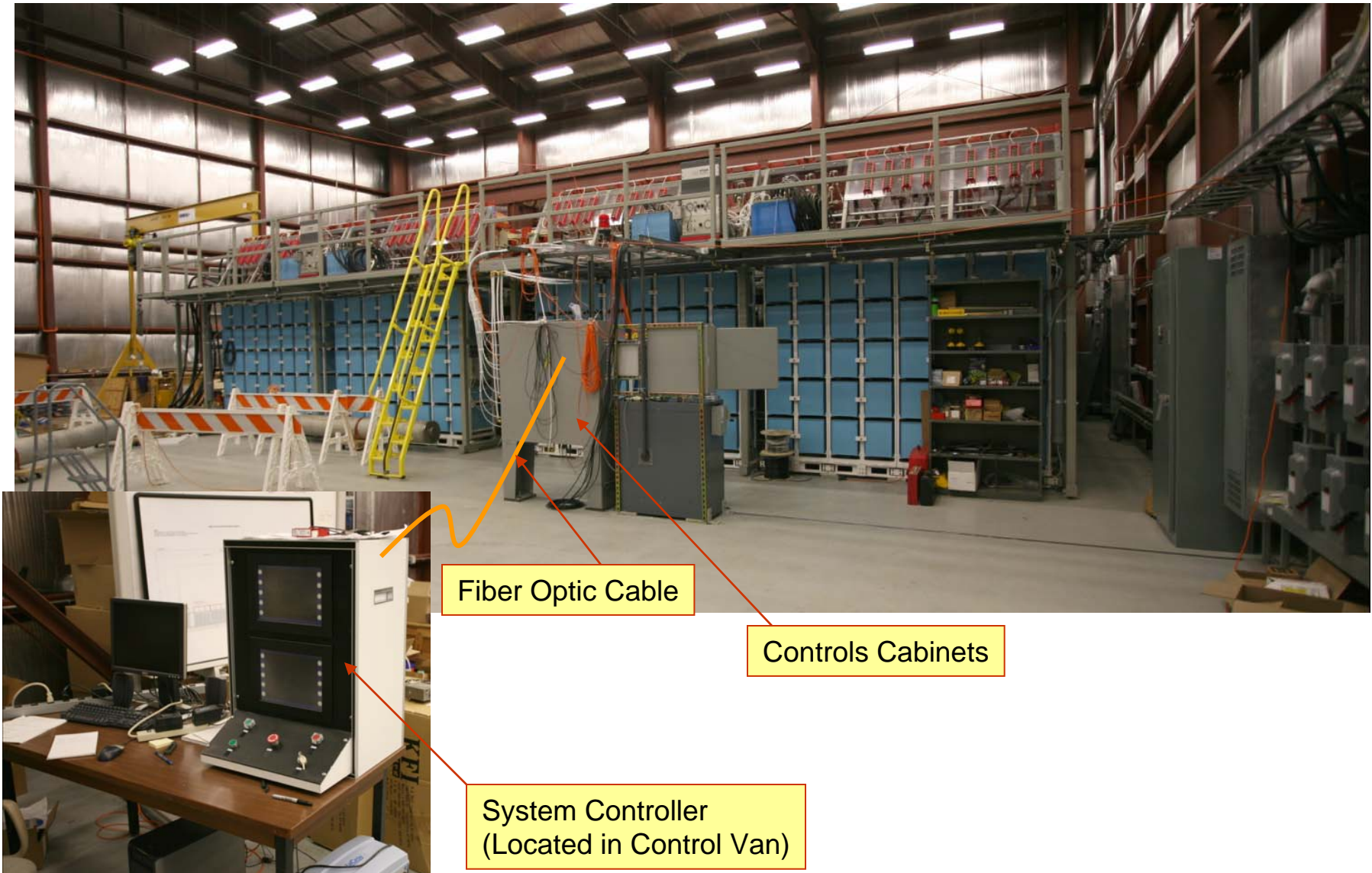
- Operating Muzzle Energy: up to 7 MJ
- Terminal Area: 16-MJ Slug
- Gun lines: 1



# Current Facility



# 32-MJ PFN





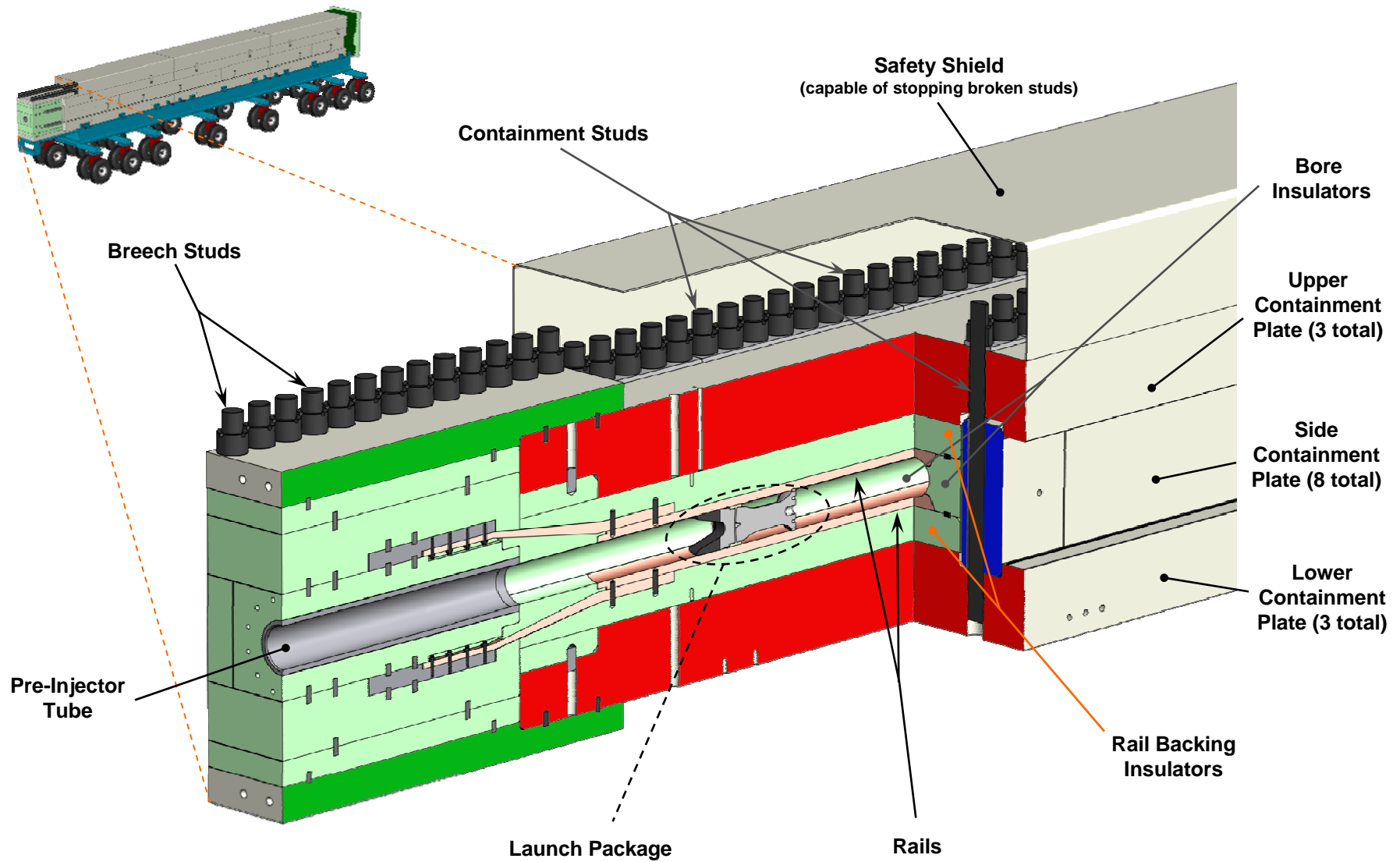
Spark Gap Switch



350-MCM  
Coaxial Cable



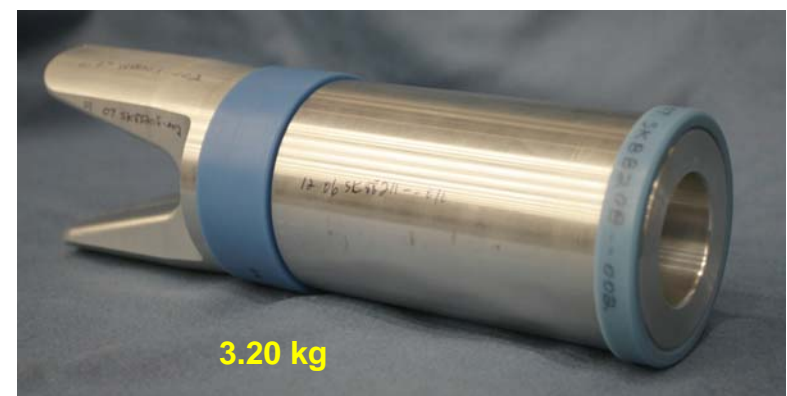
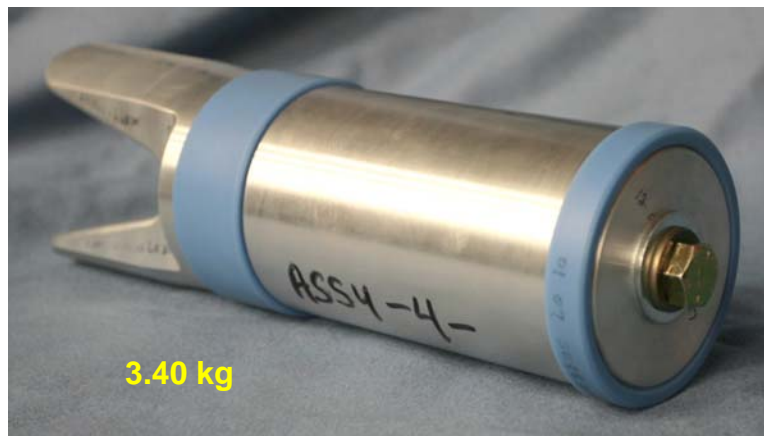
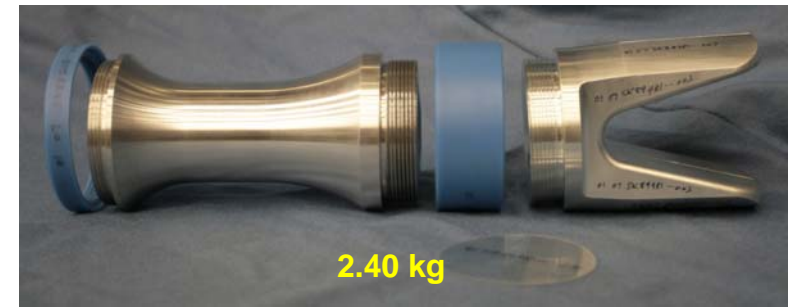
# SSG Construction





# Launch Package

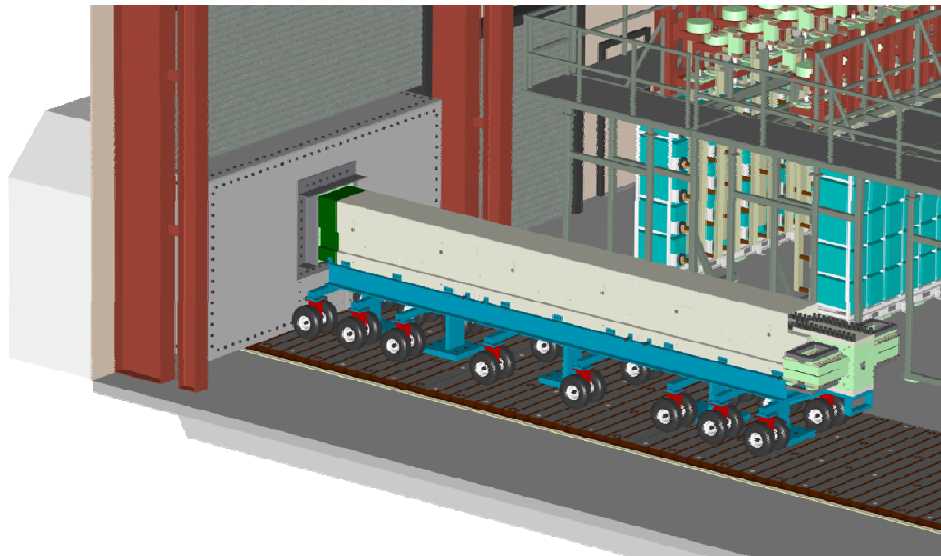
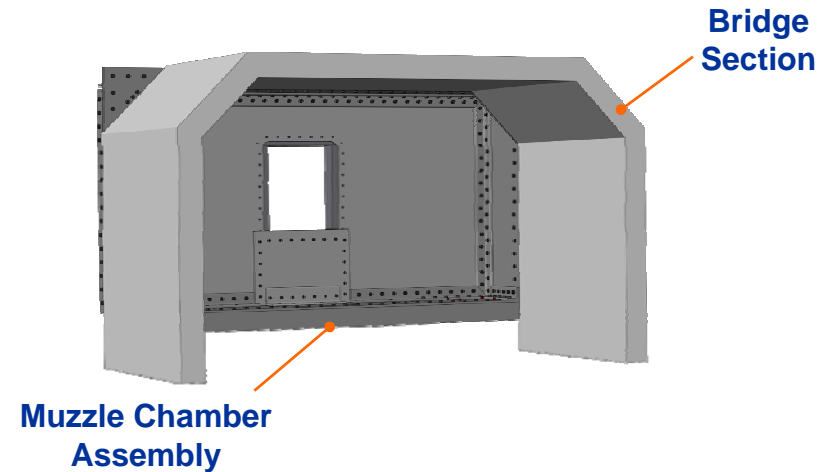
- Total Mass = 2.3-3.4 kg
- Aluminum Slug and Armature
- Nylon Bore Riders
- Design based on earlier work at Kirkcudbright and Greenfarm





## Muzzle Chamber

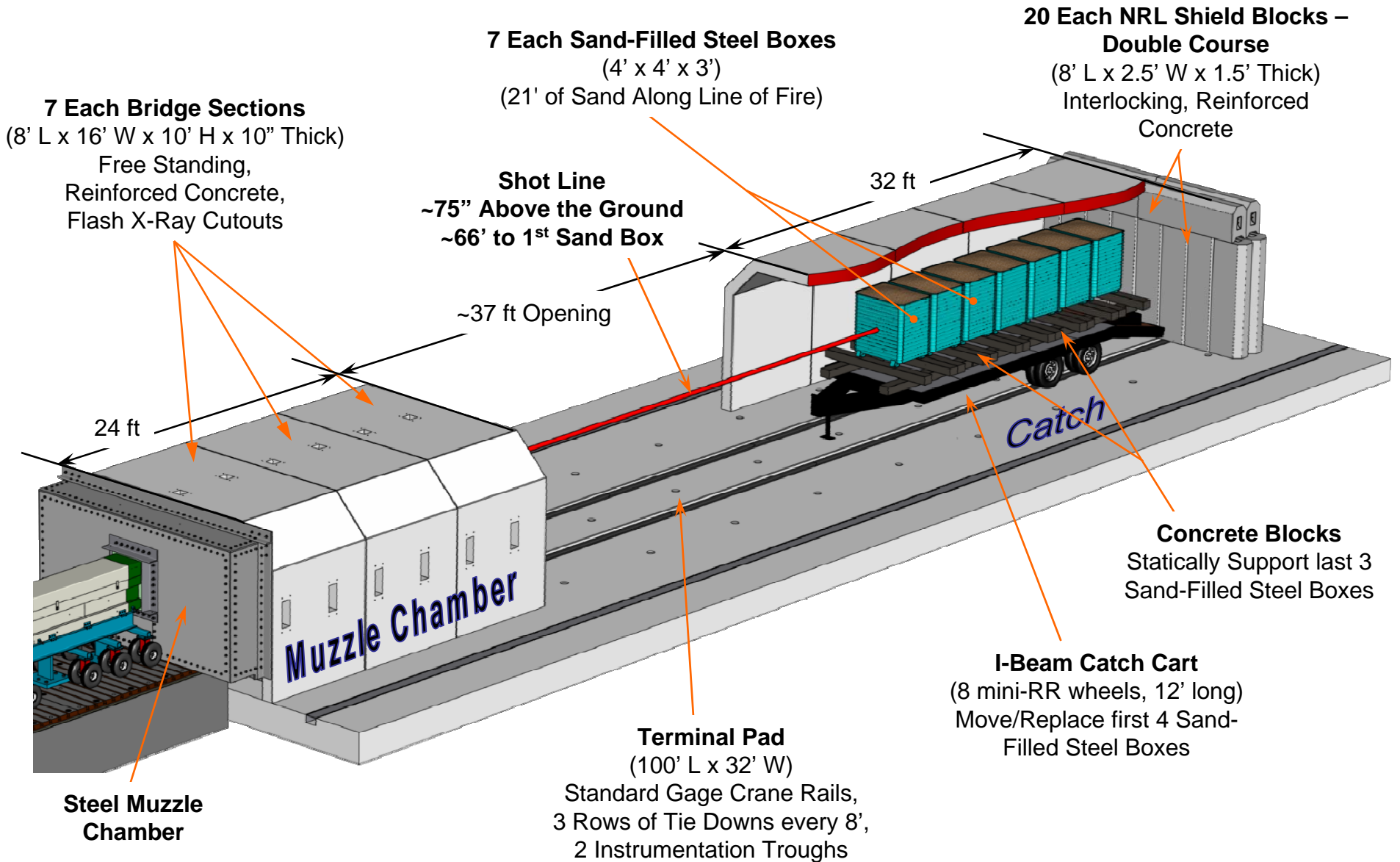
- 1" Thick A36 Steel Plate
- Bolts Directly to Gun Foundation
- Bolts Directly to Bridge Section
- Adaptable to Variety of Launchers



## Recoil Plates

- 3" Thick A36 Steel Plate
- Bolt Directly to the Gun Foundation Plates
- Bolt Directly to Underside of SSG

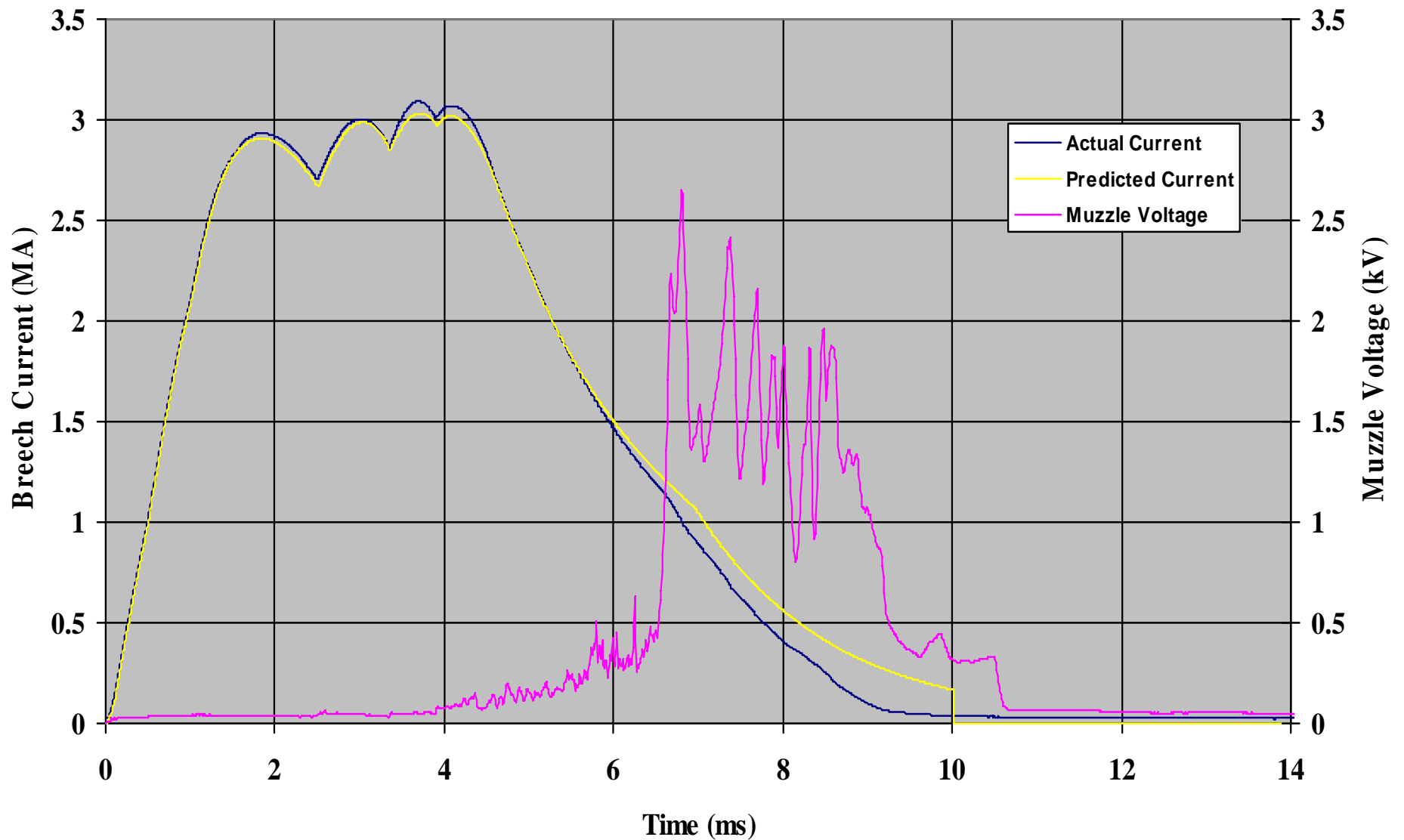
# Terminal Area Design



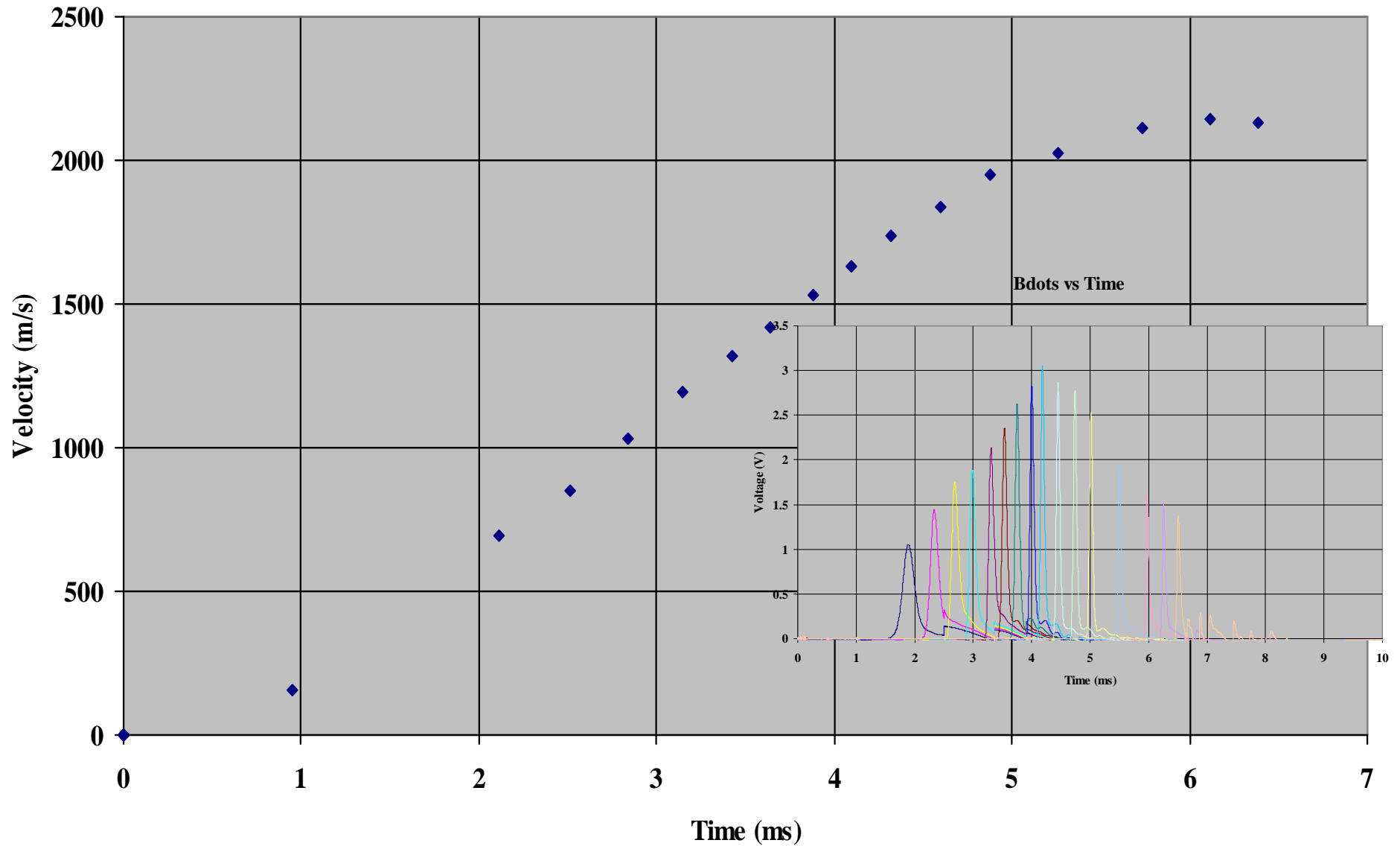
- 7 Each Sand-Filled Steel Boxes, Total of 14 On Hand
  - 4 ft x 4 ft x 3 ft
  - Wt 5740 lbs when Filled
  - 21 ft of Sand along Line of Fire
  - Open Top, Stackable, 4-Way Forklift Entry
- I-Beam Catch Cart
  - Support the First 4 Sand Boxes to Allow Quick Movement & Replacement
  - Runs on Crane Rails Using Mini-Railroad Wheels
- Concrete Blocks
  - Support the Last 3 Sand Boxes



# Shot 13 Breech Current and Muzzle Voltage

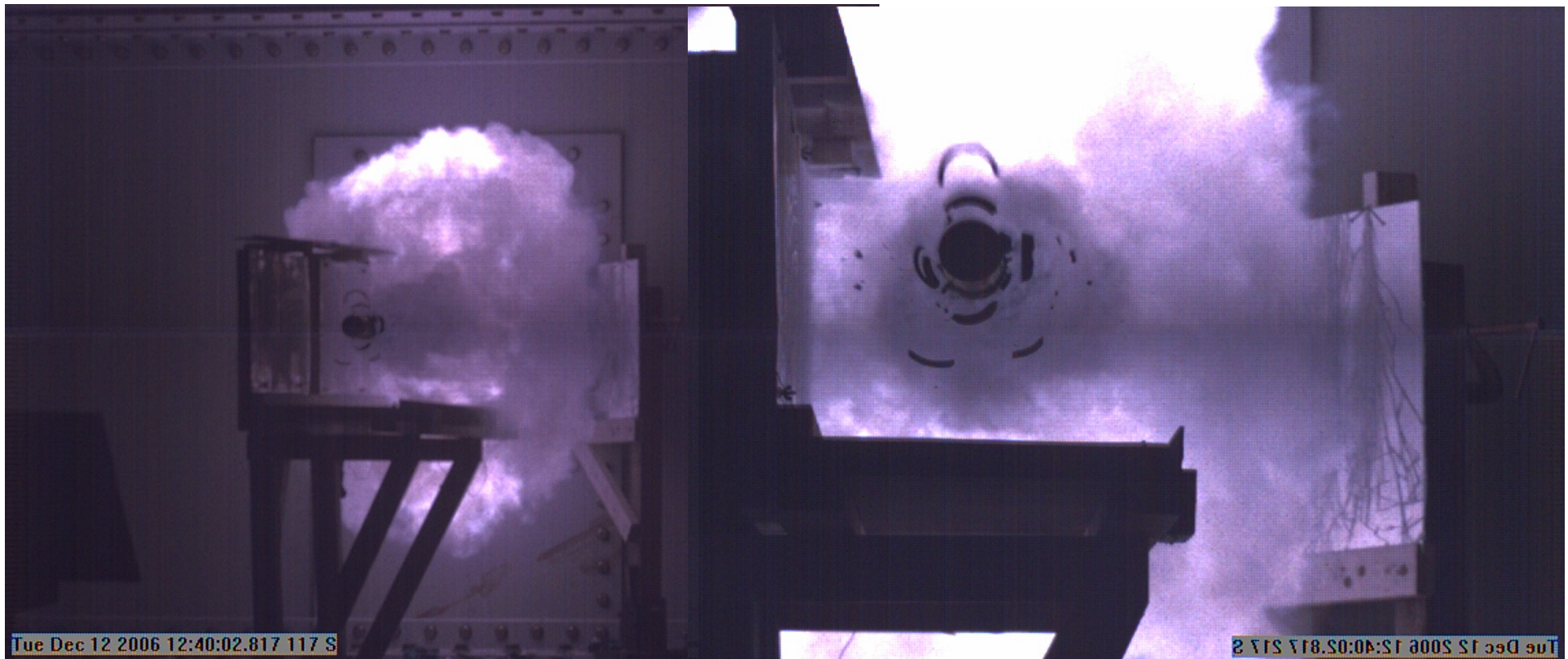


# Shot 13 Velocity



# Muzzle Launch View

- Shot 7
- Muzzle Arc is 500K Amps at 2.3 KV
- 9 PSI Overpressure at 99" from muzzle



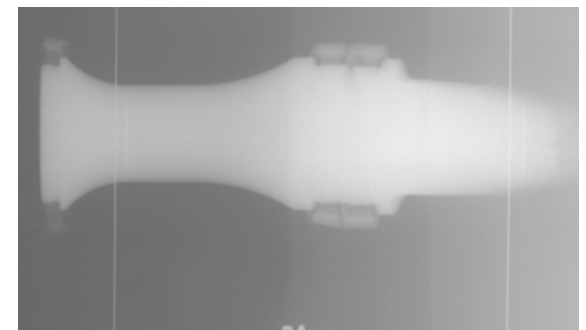
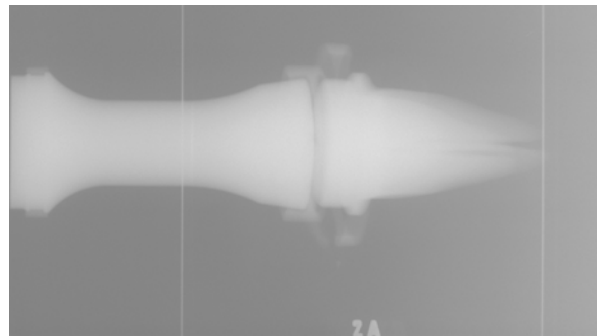
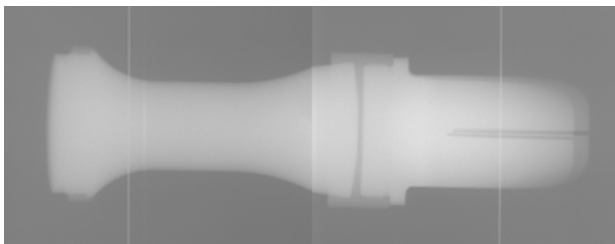
# Flash X-ray Images

**Static Xray Image**

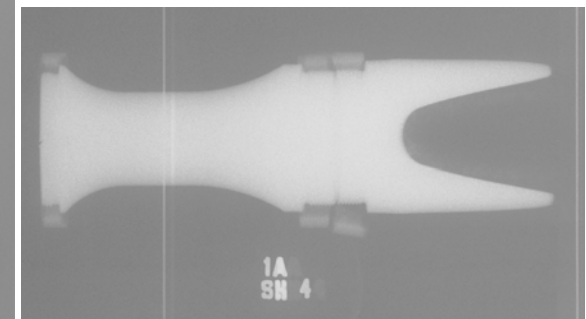
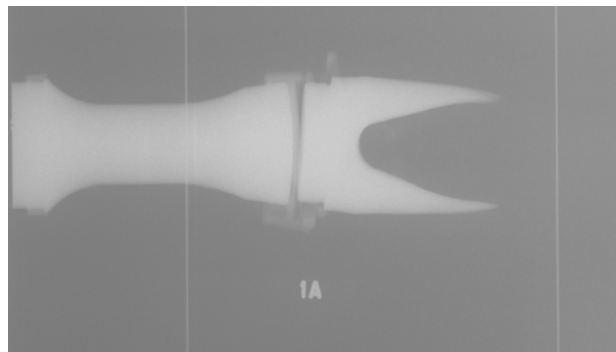
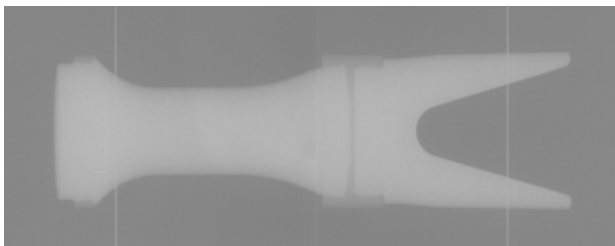
**Shot 2 Xray Image**

**Shot 4 Xray Image**

**Top View**



**Side View**



**All images are 3 feet from muzzle**



# In-Flight Images

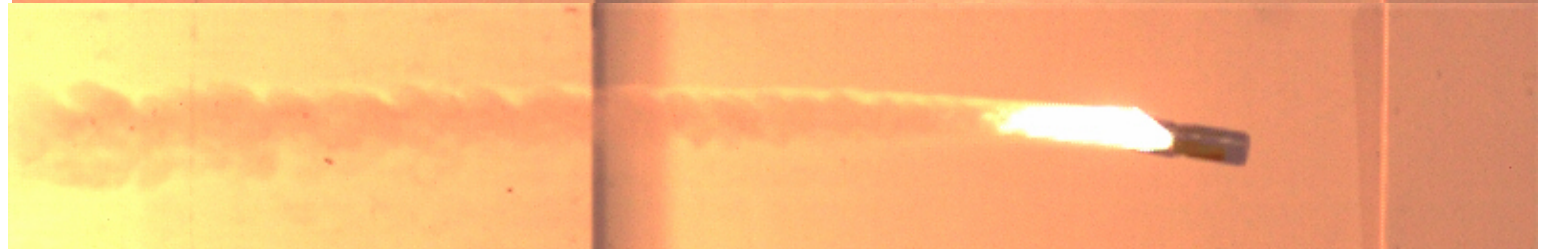
**Shot 8:**



**Shot 9:**



**Shot 10:**



**Shot 21:**

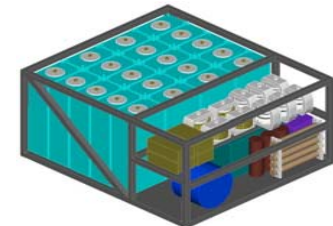
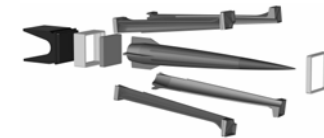


Tue Jan 30 2007 16:00:09.355 793

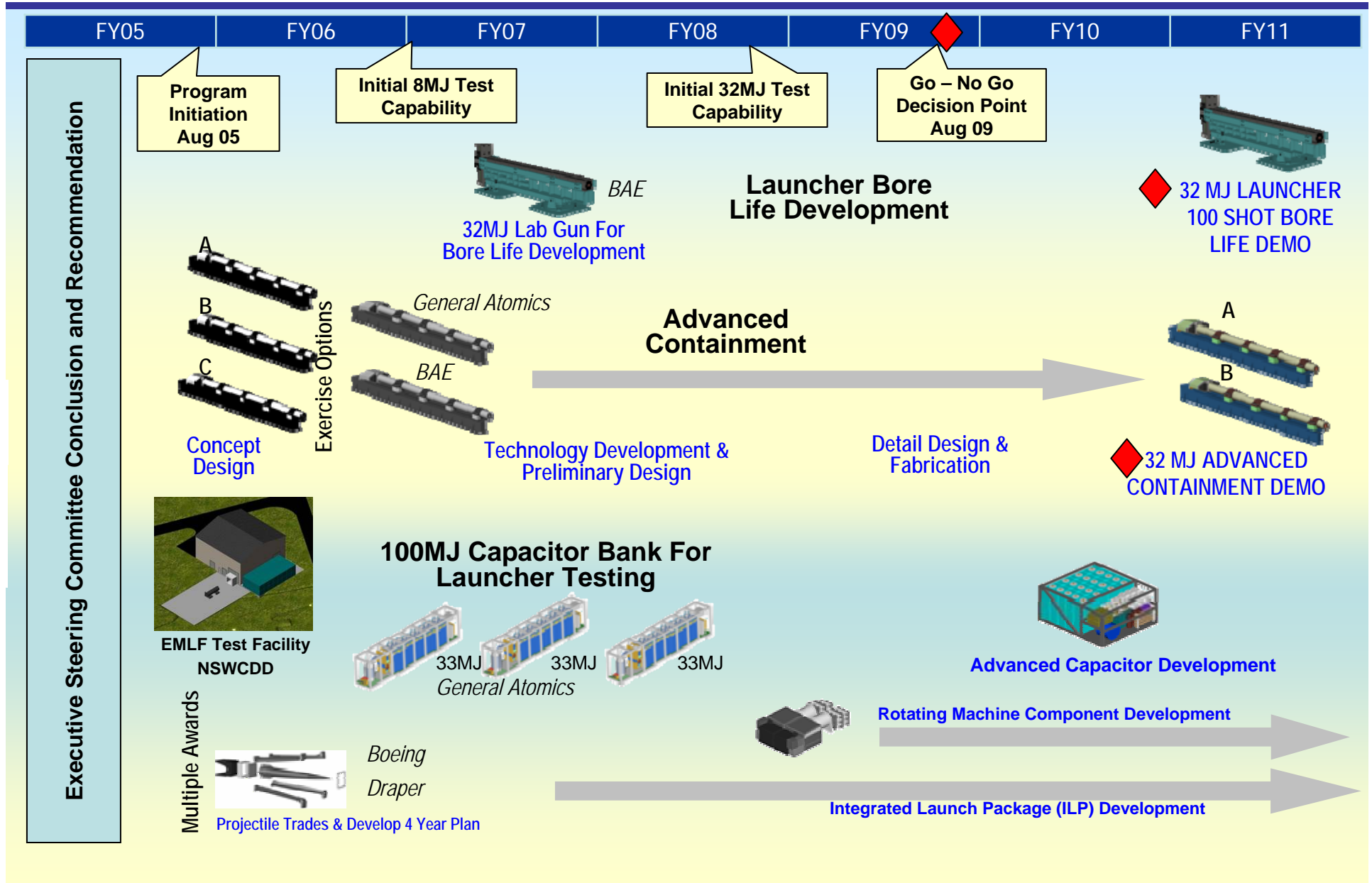
# Target Impact



- Launcher
  - Multi-shot barrel life
  - Barrel construction to contain rail repulsive forces
  - Scaling from 8MJ (state of the art) to 32MJ → 64MJ Muzzle Energy
  - Thermal management techniques
- Projectile
  - Gun launch survivability (45 kGee acceleration, Electromagnetic Interference Potential)
  - Hypersonic guided flight for accuracy
  - Lethality mechanics
- Pulsed Power System
  - Energy Density
  - Rep rate operation & thermal management
  - Switching
  - Torque management and multi-machine synchronization (rotating machine)



# ONR INP Phase I Program



# Milcon Addition

## Key Statistics (2009)

- Muzzle Operating Energy: 32 MJ
- Terminal Area: 64-MJ Projectile
- Gun lines: 2

P306 FY09 MILCON (\$9.9 M)

Protected Control Room

100+ MJ Pulsed Power System

Gun Line #2

Gun Line #1

Ballistic Tunnel

Terminal Catch: Up to 16-MJ Slugs

Terminal Area:  
64-MJ Projectiles

2009

# Test Results

## [Video of Test Results](#)

# Electromagnetic Launch Facility



TEST SHOT #1  
2 October 2006





Tue Dec 12 2006 12:40:02.815 617 S

# Electromagnetic Launch Facility Ribbon Cutting

16 Jan 2007





# Railgun Contact Information



## ONR

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## NSWC

### Mr. Charles Garnett (Program Manager)

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540.653.3186

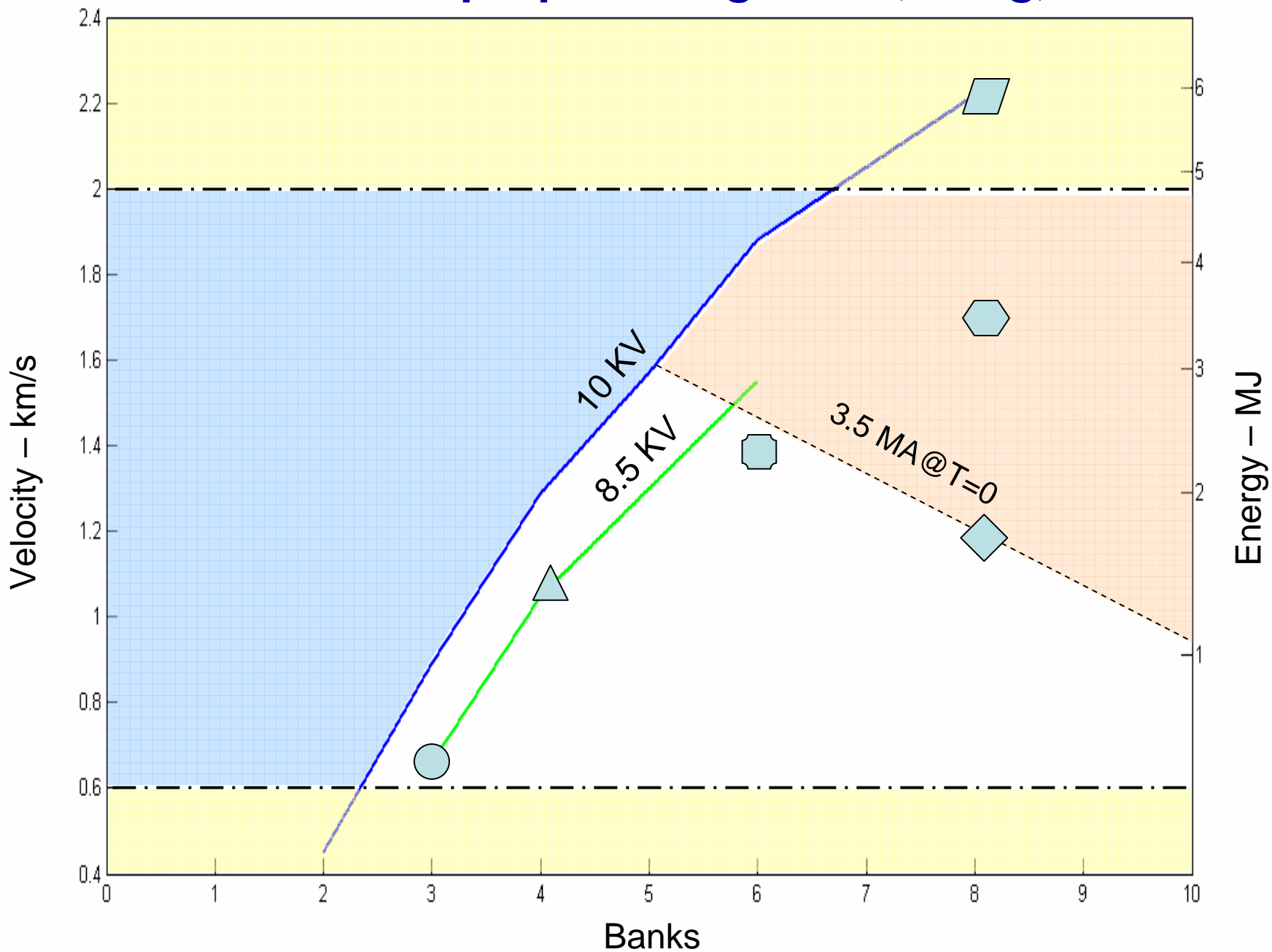
### Mr. Tom Boucher, P.E. (EMLF Test Director)

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Dahlgren VA 22448-5116  
540.653.6273

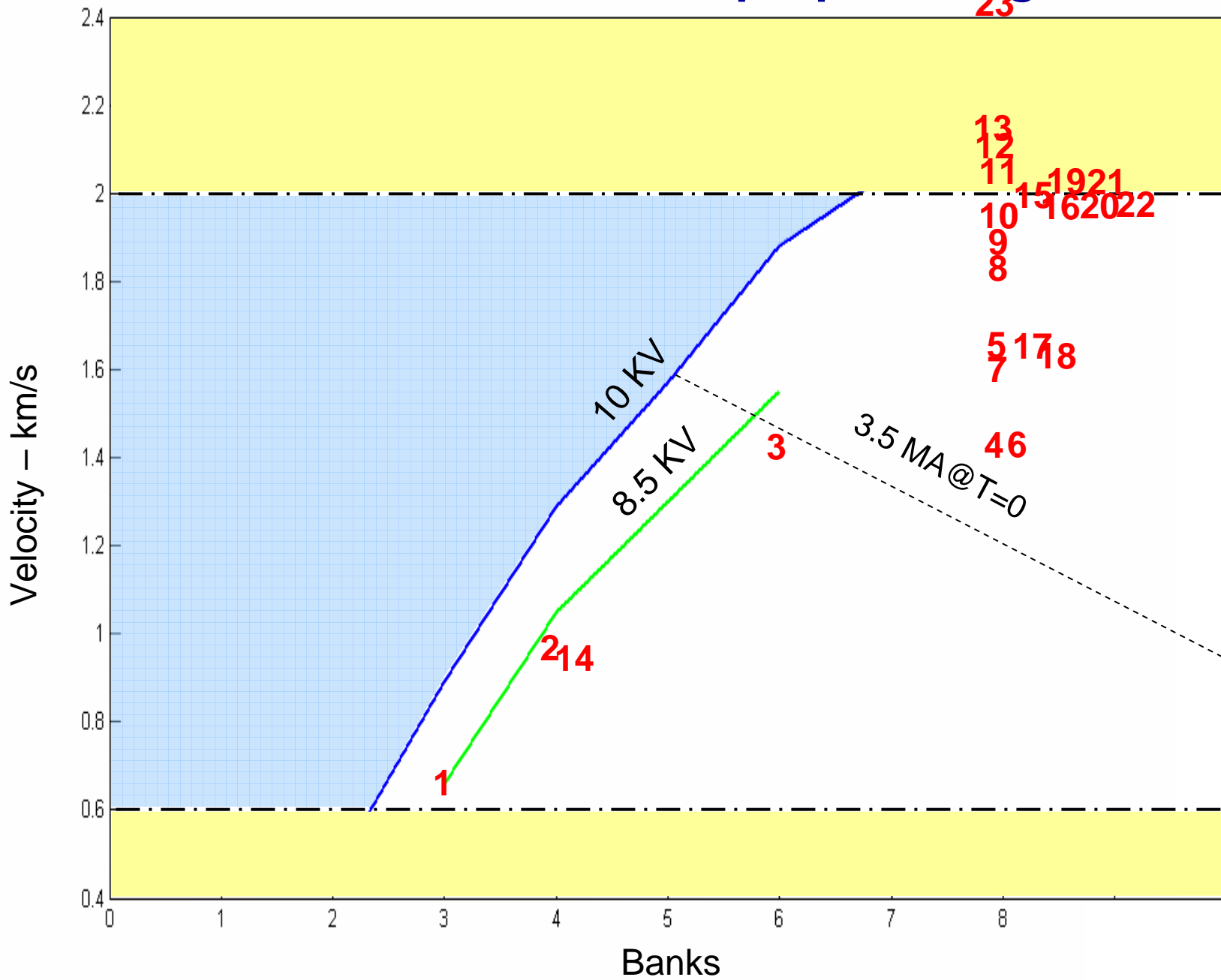


# Back-up

# Power Ramp Up Testing Plan (2.4kg)



# Actual Power Ramp Up Testing



# Test Results

Shot	Mass (KG)	Charge Voltage (KV)	Peak Current (MA)	Muzzle Velocity (m/s)	Muzzle Energy (MJ)	Efficiency (%)
1	2.4	8.2	1.7	837	0.841	12.6
2	2.41	8.18	1.8	1117	1.5	16.9
3	2.416	7.85	2.35	1560	2.94	24.5
4	2.456	6.25	2.79	1540	2.91	28.3
5	2.456	6.85	2.83	1760	3.8	30.7
6	3.29	6.9	3	1500	3.7	29.4
7	3.29	7.68	3.13	1680	4.64	29.8
8	3.288	8.3	3.09	1850	5.63	30.9
9	3.29	8.6	3.1	1920	6.06	30.9
10	3.29	8.9	3.09	1990	6.51	31
11	3.288	9.2	3.1	2070	7.04	31.4
12	3.346	9.68	3.13	2117	7.5	30.2
13	3.2	9.65	3.09	2146	7.38	29.8

# Test Results (continued)

Shot	Mass (KG)	Charge Voltage (KV)	Peak Current (MA)	Muzzle Velocity (m/s)	Muzzle Energy (MJ)	Efficiency (%)
14	2.46	8.2	1.87	1106	1.5	16.9
15	2.31	8.01	2.46	2005	4.65	27.4
16	2.89	8.89	2.75	2059	6.13	29.3
17	3.29	7.8	3.18	1722	4.87	30.3
18	3.29	7.8	3.18	1717	4.85	30.1
19	3.402	9.69	2.99	2053	7.17	28.9
20	2.892	8.9	2.75	2025	5.93	28.3
21	2.888	8.9	2.75	2019	5.88	28.1
22	2.89	8.9	2.73	2012	5.85	27.9
23	2.454	9.49	3.08	2519	7.79	32.7



## Original Launch Package



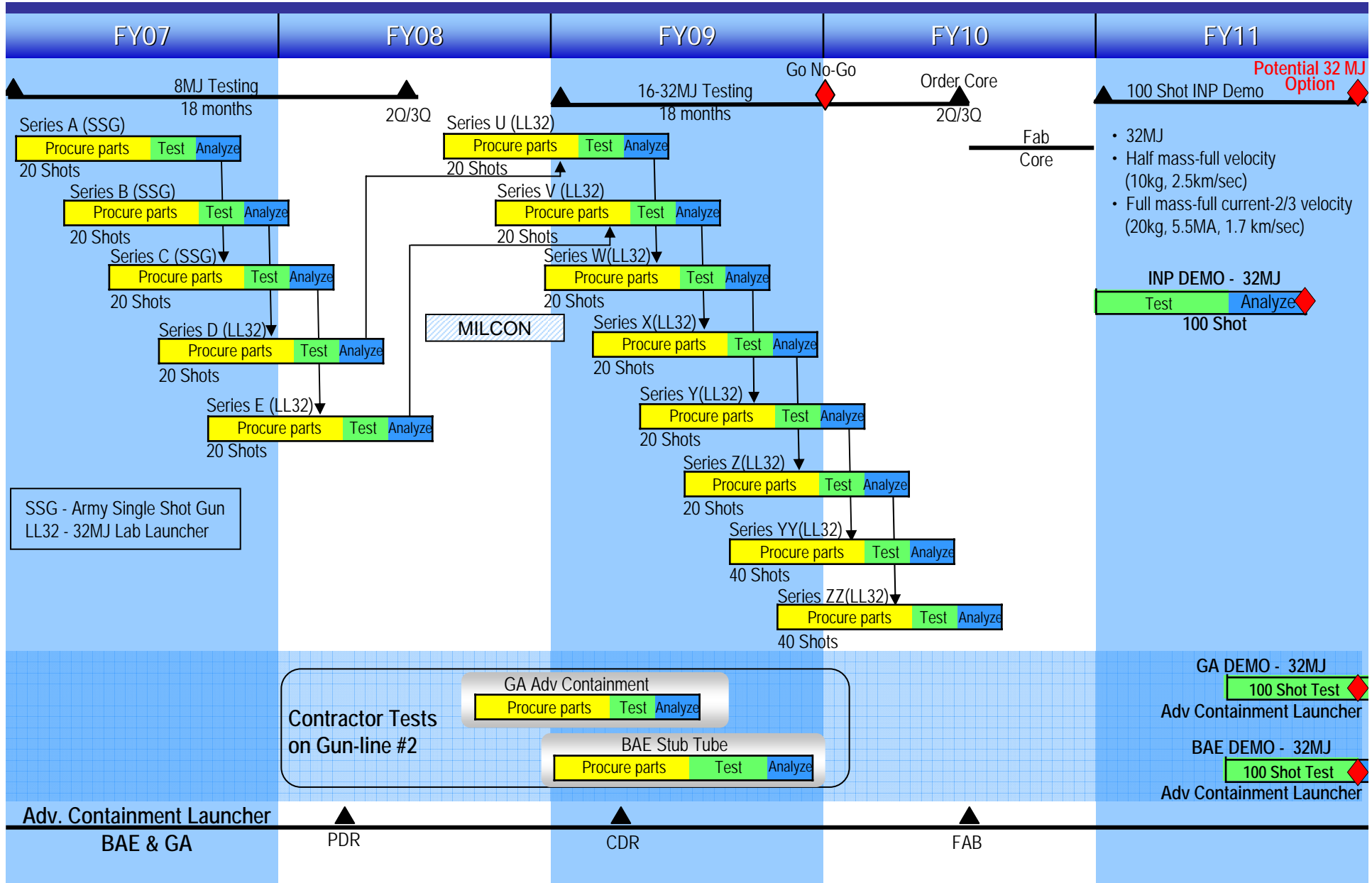
## Recovered from Shot 1



## Recovered from Shot 2



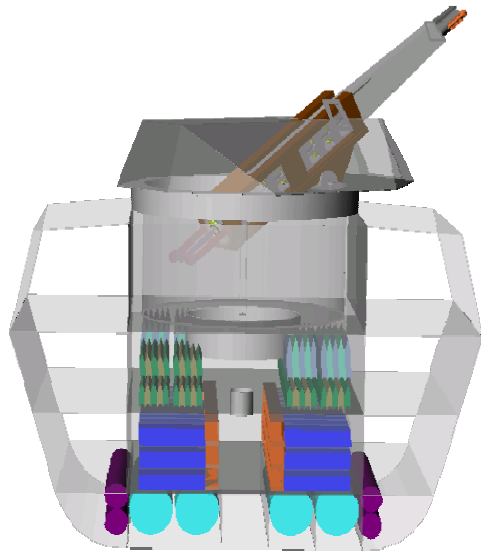
# Bore Life EMLF Testing Concept





Revolutionary Research . . . Relevant Results

# NR Navy Electromagnetic Railgun



## Why is it important?

- Volume & Precision Fires
- Time Critical Strike
- All weather availability
- Variety of payload packages
- Scalable effects
- Deep Magazines
- Non explosive round/No gun propellant
  - Greatly simplified logistics
  - No IM (Insensitive Munitions) Issues
- Missile ranges at bullet prices

## What is it?

- Gun fired with electricity rather than gunpowder
- Revolutionary 250 mile range in 6 minutes
- Mach 7 launch / Mach 5 hit
- Highly accurate, lethal GPS guided projectile
- Minimum collateral damage

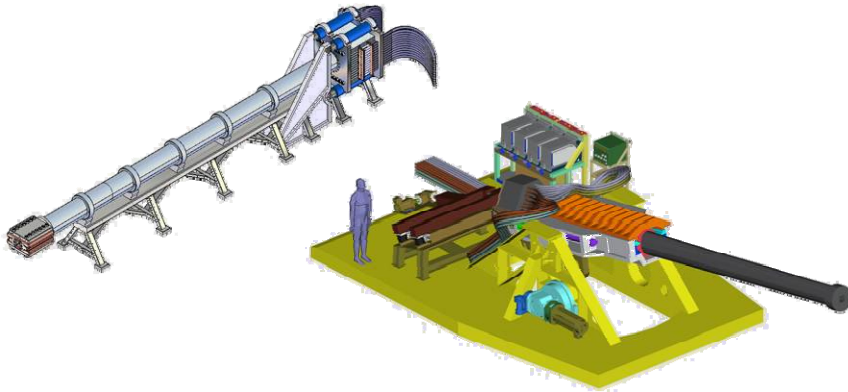
## Who needs it?

- Marines and Army troops on ground
- Special forces clandestine ops
- GWOT
- Suppress air defenses

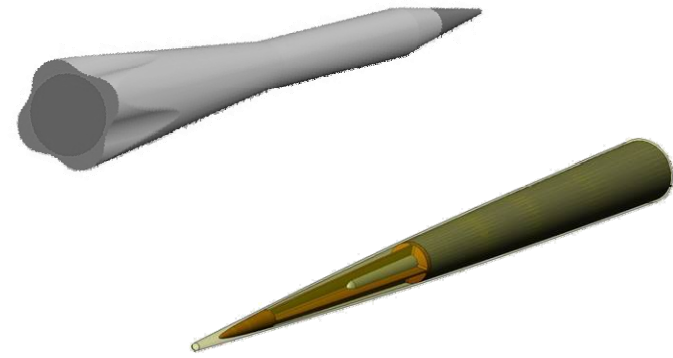
## When?

- Feasibility Demo 2011
- System Demo 2015
- IOC 2020-2025

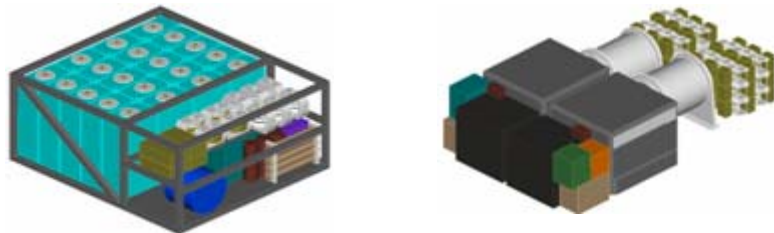
## Launcher



## Projectile

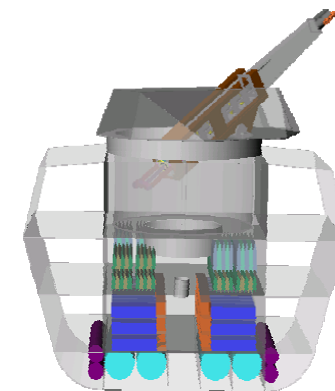


## Pulse Forming Network (PFN)



Capacitors or Rotating Machines

## Ship Integration



# Key Parameters for Sizing a Naval EM Launcher

{ Pulse Forming Network Size }

$$\frac{1}{2} * \text{Launch Mass} * \text{Muzzle Velocity}^2$$

Desired Muzzle Energy

Current Profile

- Rail Separation Forces
- Transient Localized Heating



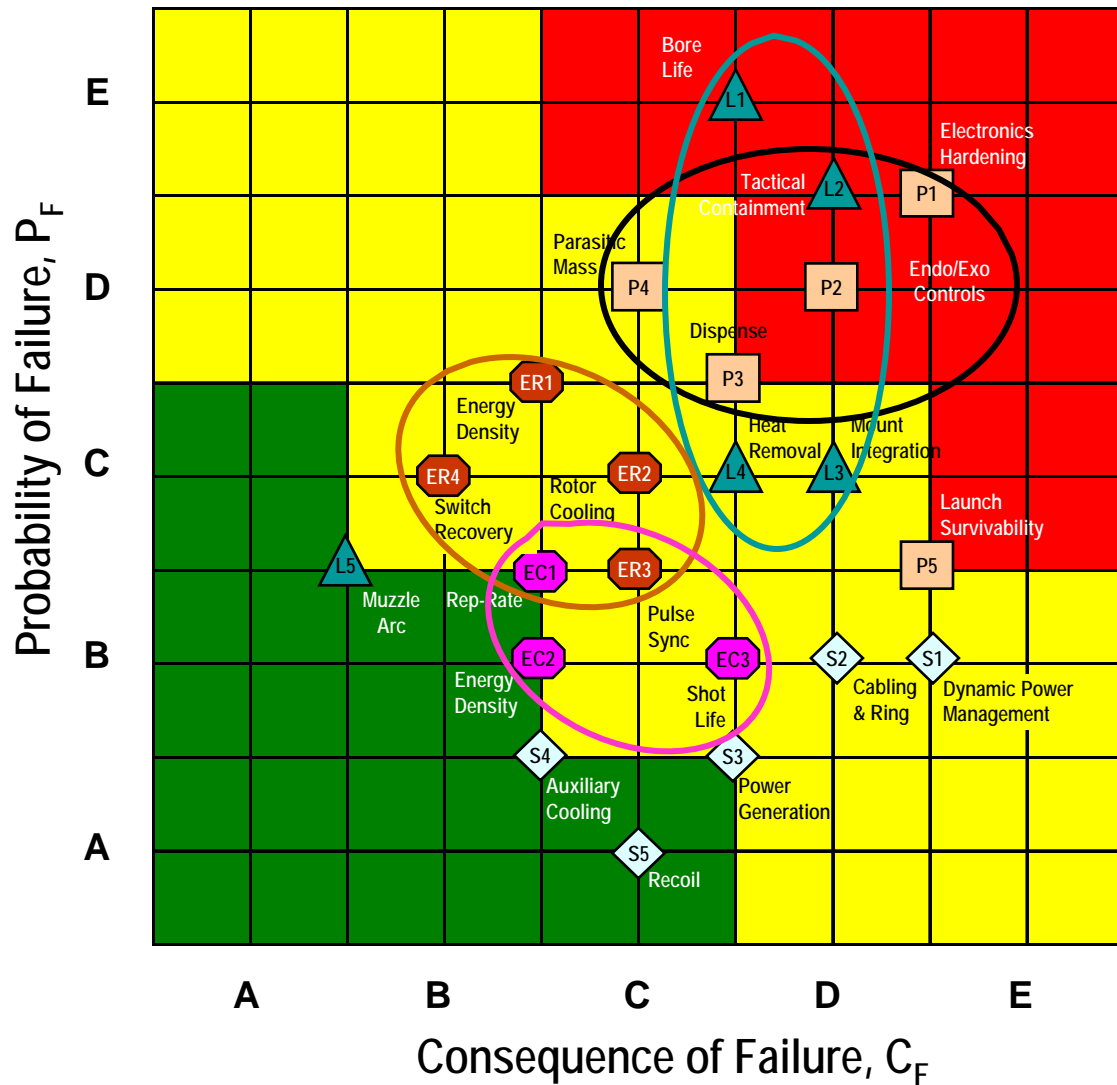
Barrel Length

- Max Projectile Acceleration
- Bulk Rail Heating

Bore Size & Shape

- { Launcher Efficiency }

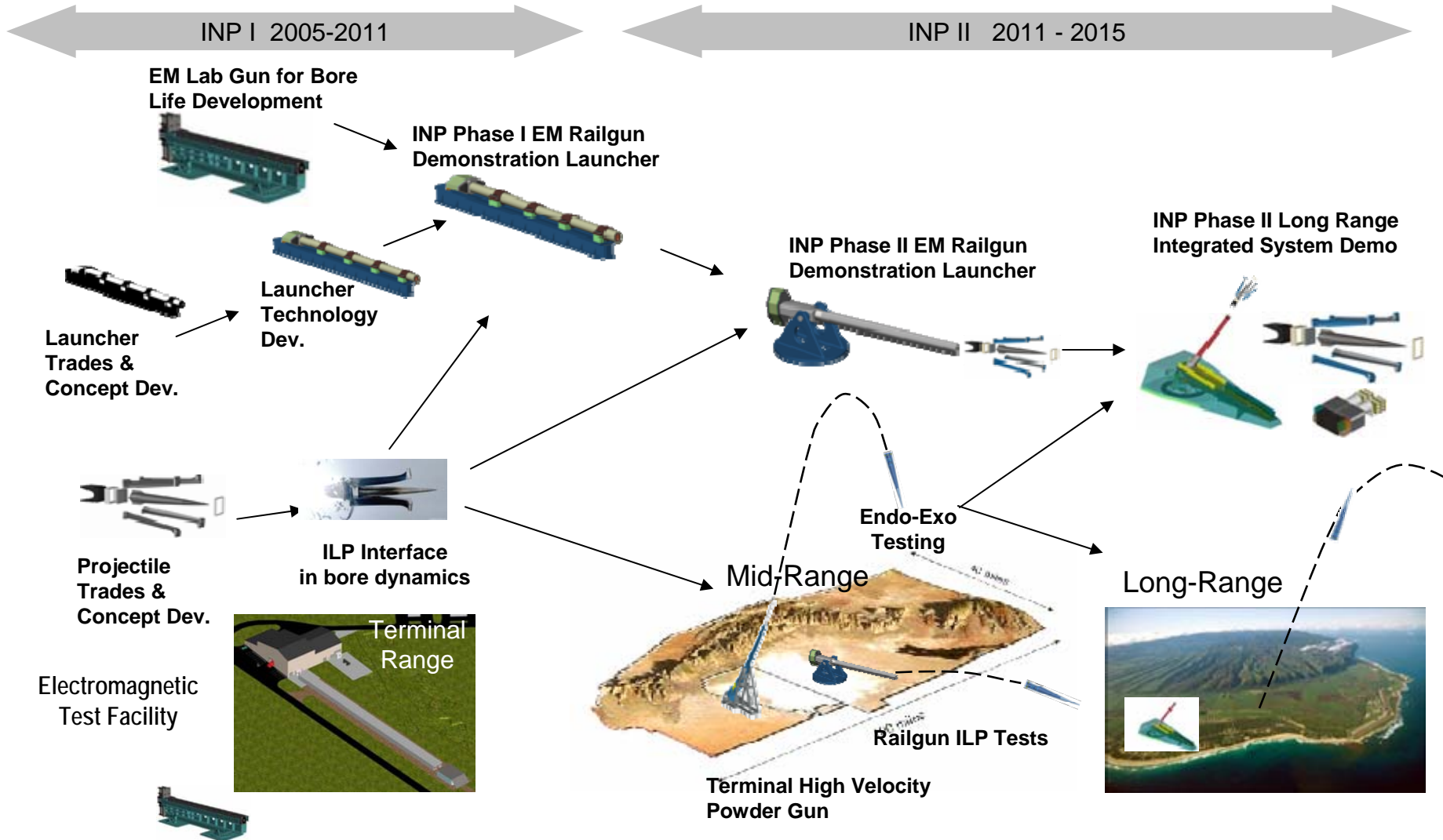
# Risk Matrix Summary



## Risk Ranking & Key Impacts

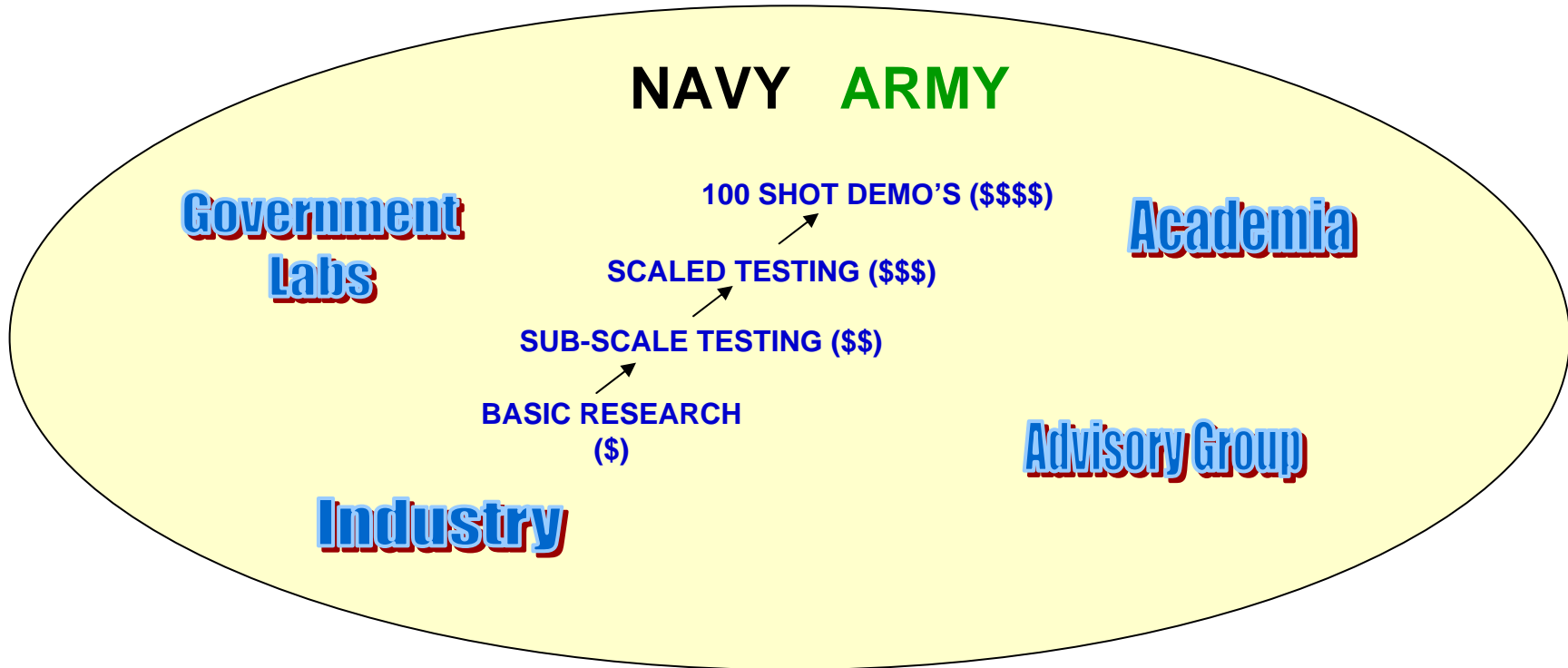
	Launcher	} Failure Impacts Capability
	Projectile	
	Rotating Machine PPS	} Failure Impacts Volume, Weight & Cost
	Capacitor PPS	
	Ship Integration	

- Traceability to 64MJ, 6-10 round / min indirect fire weapon system
- Bore Life
  - 32 Mega-Joule (Muzzle Energy) EM Lab Launcher
  - 10kg launch package; full muzzle velocity of 2.5km/sec
  - 20kg launch package with full current of ~5.5MA
  - Demonstrate more than 100 shot bore life
- Containment
  - 32 Mega-Joule Advanced Containment Launcher
  - 10kg launch package; full muzzle velocity of 2.5km/sec
  - 20kg launch package with full current of ~5.5MA
  - 1000+ round predicted containment structural barrel life
  - Design for thermal management at a rate of 6 round / min
  - Design launcher for minimal round dispersion
  - Transportable on pallets and/or in sea containers,
  - Consider marine environment





# Bore Life Consortium

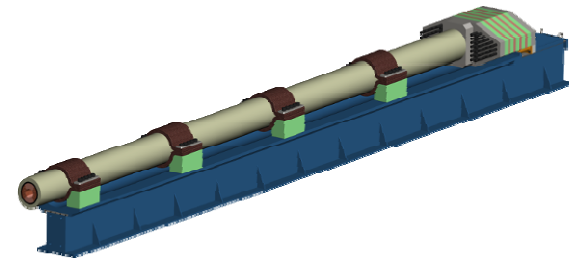
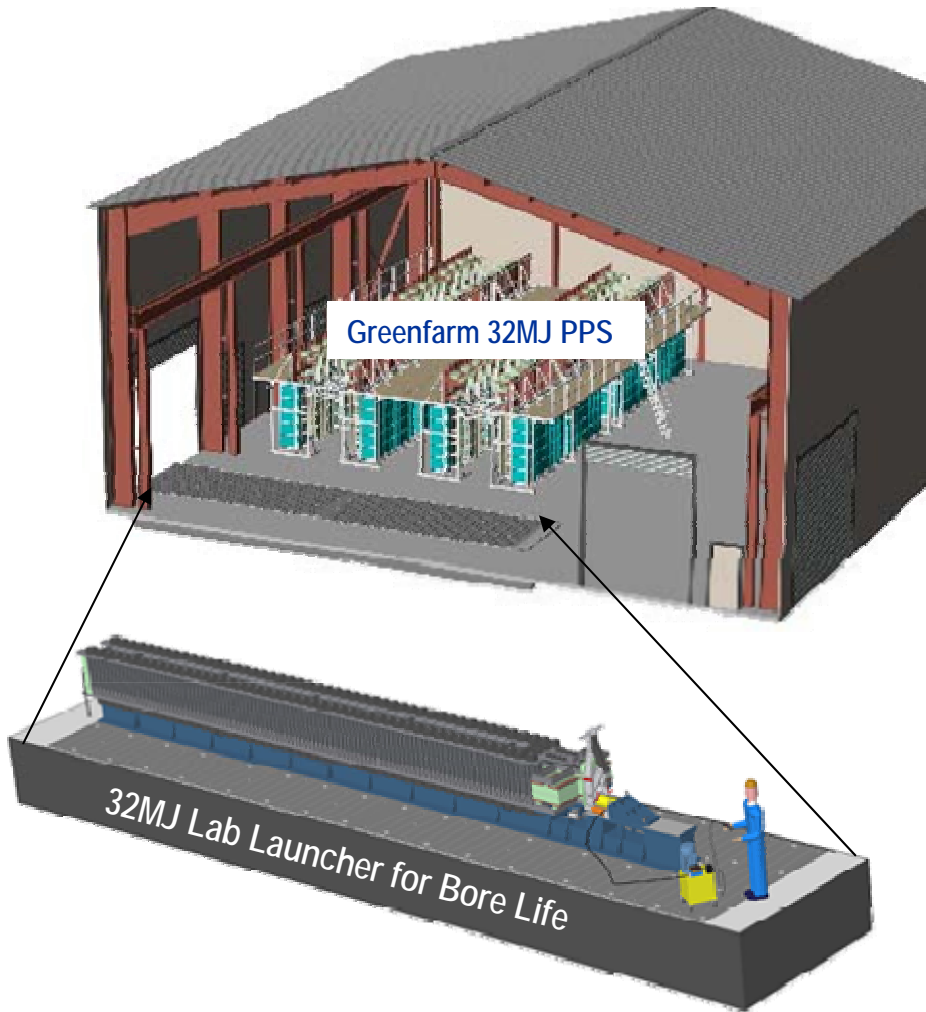


- Spans Basic Research to Full-Scale Demo's
- Parallel development paths via multiple research sites
- Avoids Duplication
- Efficient use of test resources
- Supports both Navy and Army EM Efforts
- Government purpose data rights to permit competition during the acquisition phase.

*Coordinated Development!*

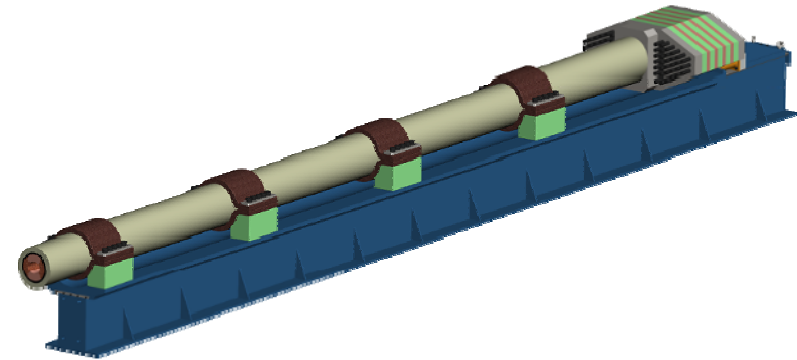
## Lab Launcher - EMTF

## Advanced Containment Launcher



Phase	Phase of Project	Period
Basic	Conceptual Design Trade Studies	7 mos.
Army Add	Trade Studies for Army Application	3 mos.
Option I	Technology Development and Preliminary Design	30 mos.
Option II	Detailed Design, Fabrication and Demonstration	29 mos.

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## General Atomics Team

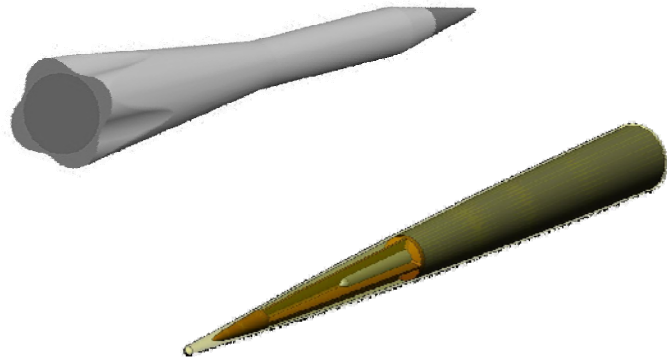


## Northrop Grumman Team



## BAE Team





## Description of Effort

- Develop long range projectile concept
  - Lethal
  - Consistent with Navy CONOPS
  - Compatible with any EML gun development
- Identify critical development
  - GN&C
  - Aerobody (drag and thermal protection)
  - launched survivability
- Produce a development plan

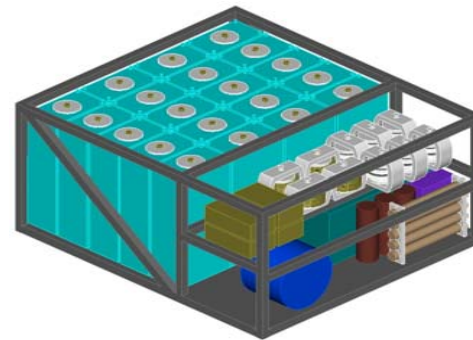
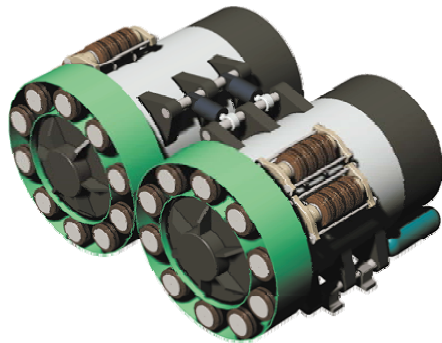
## The Boeing AASP Team



## Draper Team

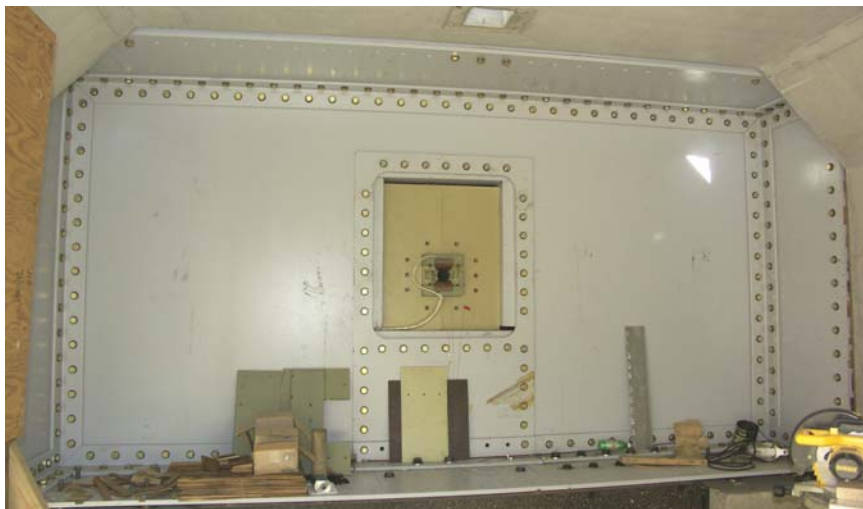
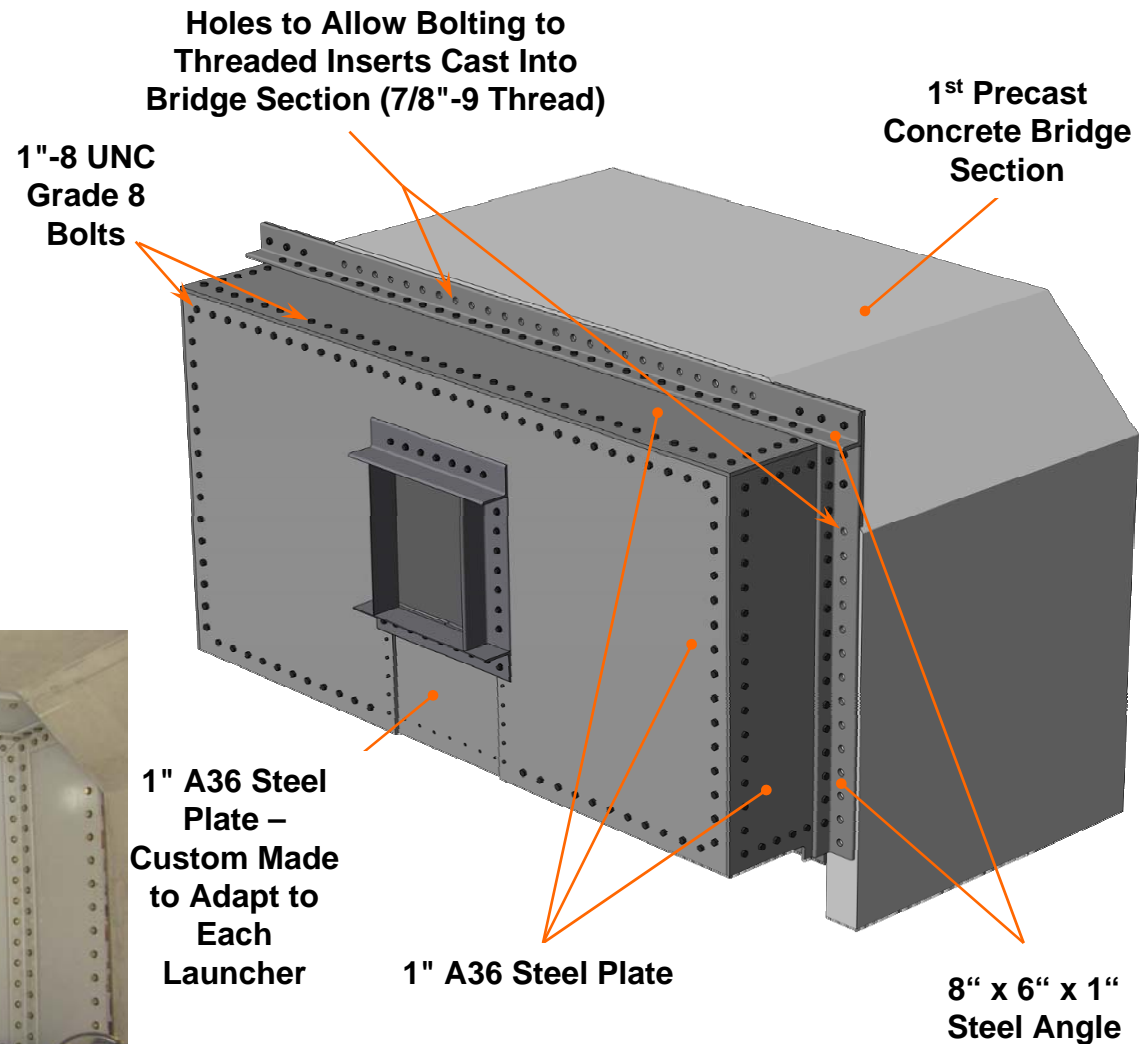


- Rotating Machine
  - Watch Army Effort (Demo in FY08)
  - Navy Specific Critical Component Development
- Advanced Capacitor
  - Increased Energy Density
  - Thermal Management for Multi Shot Operation



# Steel Muzzle Chamber Component

- Steel Muzzle Chamber
  - Mates to both SSG & Lab Launcher
  - Bolts to 1<sup>st</sup> Concrete Bridge Section
- Collar Plates Seal Gaps between Launcher & Chamber



# Vans on Van Pad

