Electrothermal-Chemical Gun Systems Utilizing Novel Electric Solid Propellants

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The research in this document is from the Direct Plasma Production from Electric Solid Propellant for High Velocity Launch Systems program, which is being developed by Digital Solid State Propulsion, Inc. with funding from the Defense Advanced Research Projects Agency (DARPA).

Presentation Outline

- The Goal of Extended Range
- Specialty Ammunition versus Specialty Gun System
- Leading gun contenders
- Advantages of ETC Systems-Ignition and Mid-cycle
- Where ETC Gun Systems Fit in
- Why Electric Solid Propellants for ETC systems?
- Case Study- Mark45 5”/62 MOD 4 Gun
- Current Work- 30mm testing

The Goal

- Increased stand-off distance of large ship-board cannons and artillery pieces
- Achieve similar rate of fire and similar barrel lifetime to current state of the art
- Minimize logistical burden of new system
  - Power requirements, tankage, maintenance
- Reduce hazards associated with ammunition or the gun system

Specialty Ammunition vs. Specialty Guns

- Specialty Ammunition-Extended Range Guided Munitions
  - Can utilize current gun systems and extend their range
  - Capable of precisions strike
  - Typically longer rounds and smaller warheads
  - Costs are high, >$10,000 per round
- Specialty Guns- Railgun, Light Gas Gun, ETC
  - Capable of ranges beyond guided munitions
  - Some are capable of launching conventional and guided rounds
  - Higher integration requirements, all require external infrastructure (tankage, capacitors, wiring, etc.)
  - High technological hurdles

The Leading Gun Contenders

Railgun

+ Highest Muzzle Velocity possible
+ KE kill eliminates need for explosives
- Requires advancements (longer lead time to reach maturity)
- Very high power requirements (large Pulse Forming Network, low material lifetime)

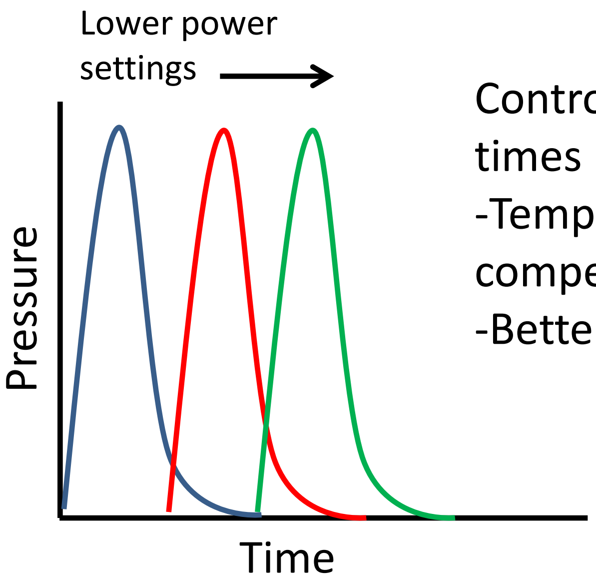
Gas-gun

+ Very High Muzzle Velocity possible
- Requires large support equipment
- Liquid propellants used
- Rate of fire improvement needed

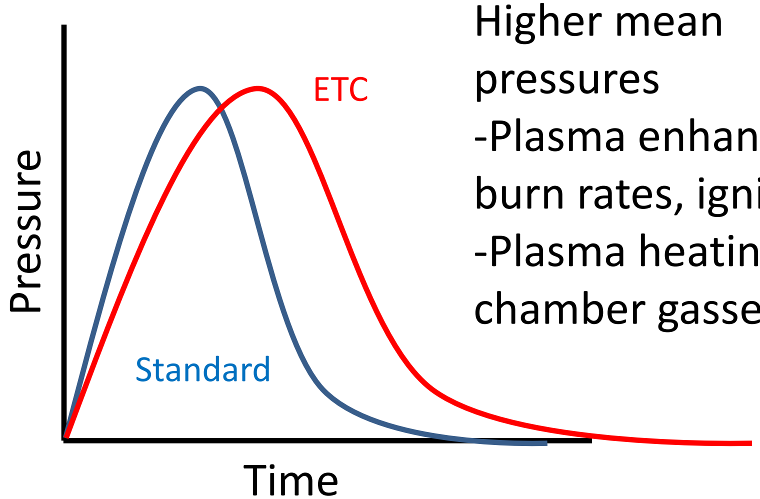
ETC-gun

+ Nearest term viable
+ Uses most of the current infrastructure
- Requires Pulse Forming Network that can be large
- Barrel wear from hot plasma is an issue
- Chemical propellants still pose potential hazards risks

Advantages of ETC-Ignition effects



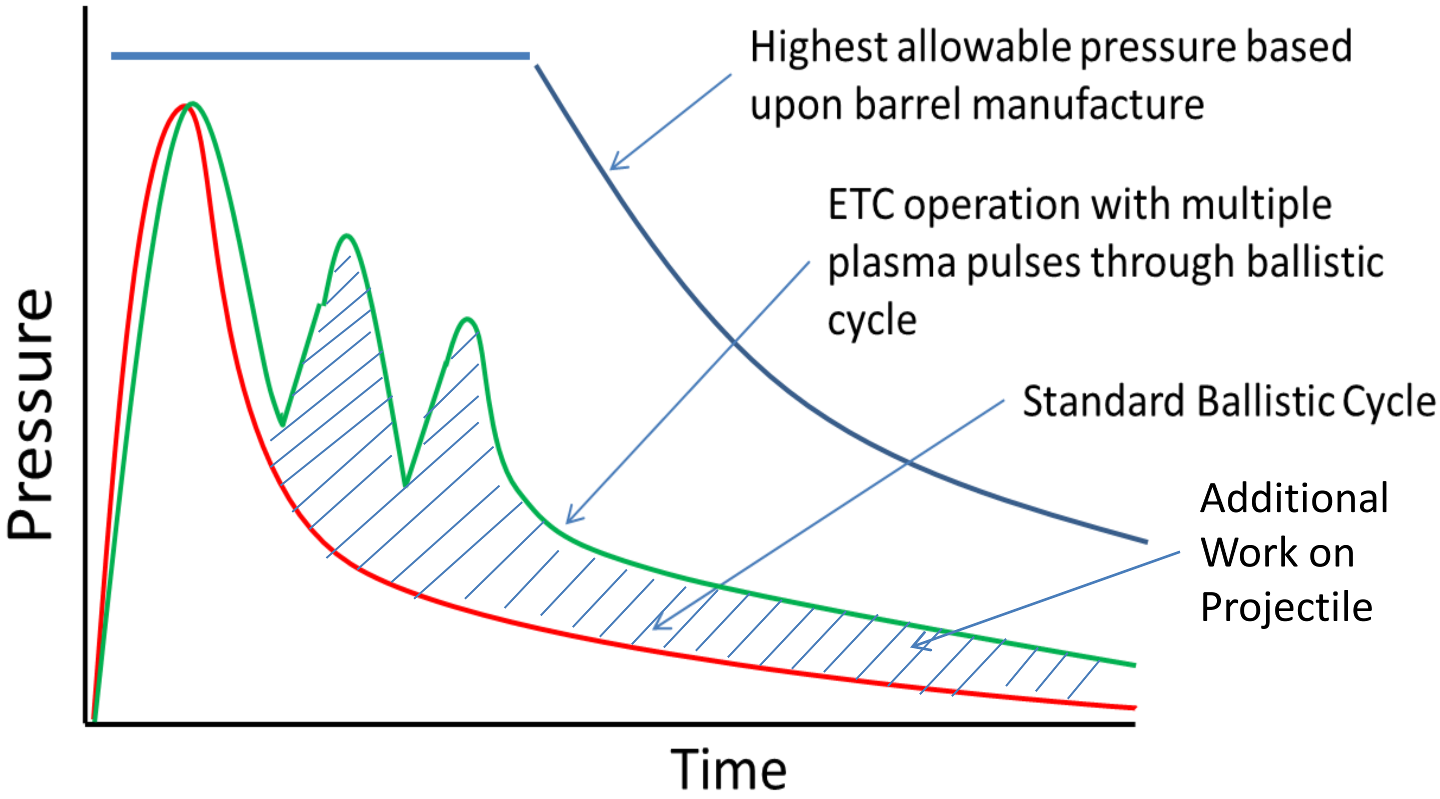
Controlling ignition times by power input
-Temperature compensation
-Better ignitions



Higher mean pressures
-Plasma enhanced burn rates, ignitions
-Plasma heating of chamber gasses

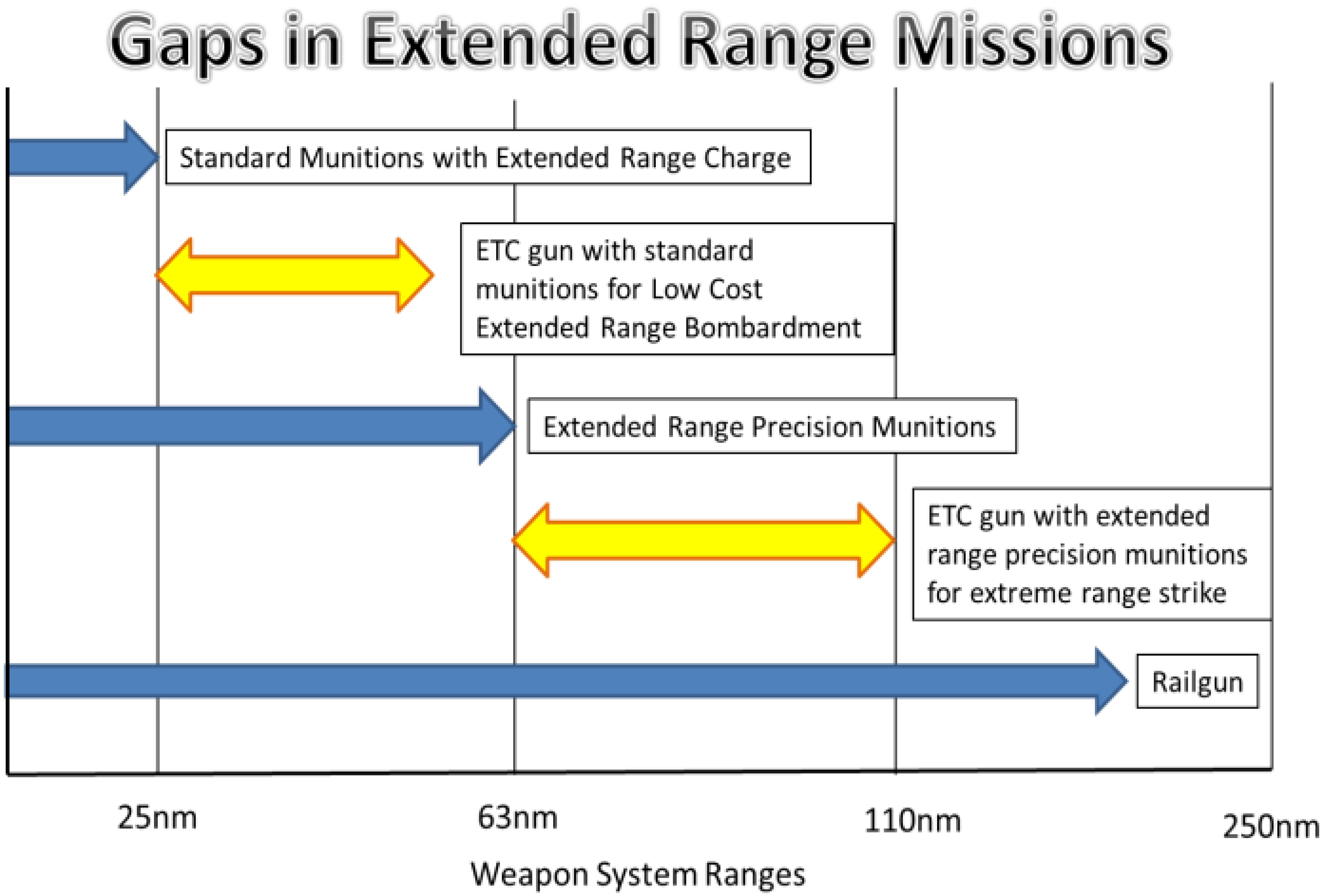
- External energy input into system (exceeds chemical energy limit)
- Potentially higher level of control
- Uses solid propellant main charge reducing amount of energy input required.
- Can fire standard rounds or specialty munitions

Advanced ETC- Controlled Plasma Injections



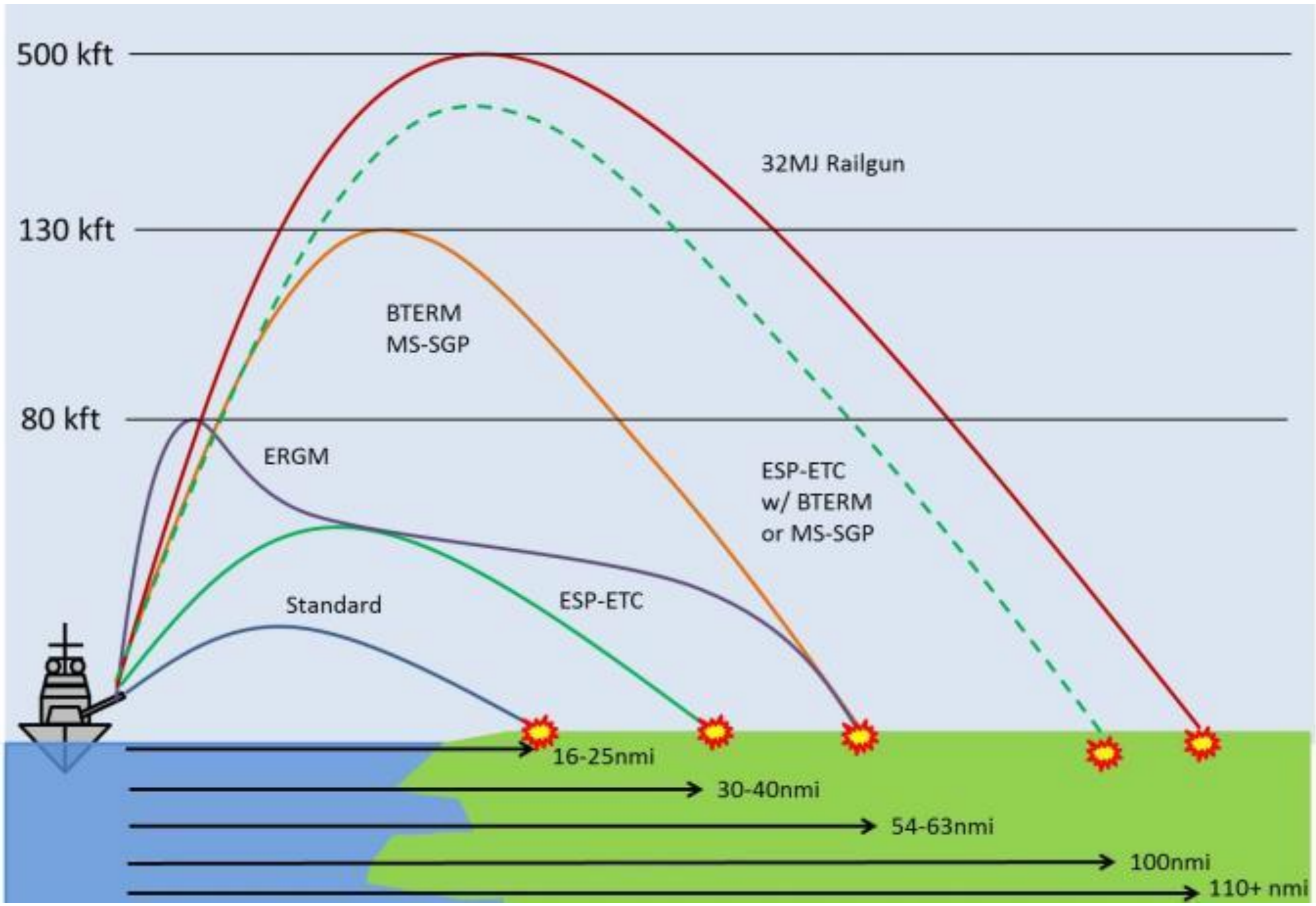
- Plasma injections mid ballistic cycle increase chamber pressure
- Higher overall pressure does more work on the projectile producing higher muzzle velocities

Where ETC Guns Fit In



- Low-cost fire missions for Mid-Extended Range
- High Energy Launcher for Extended Range Guided Munitions

Where ETC Guns Fit In

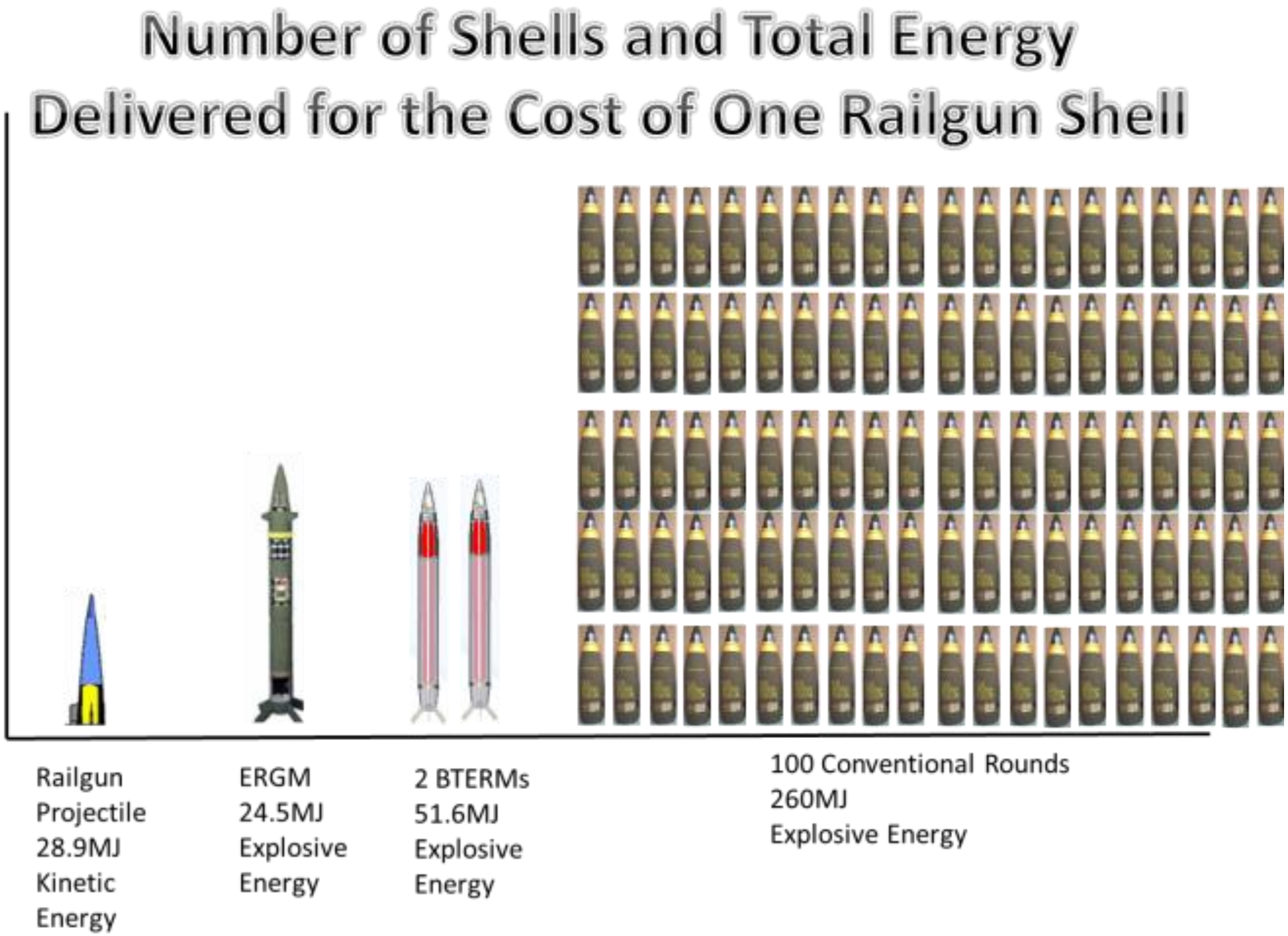


ETC guns are augmented launchers

Longer range on conventional rounds

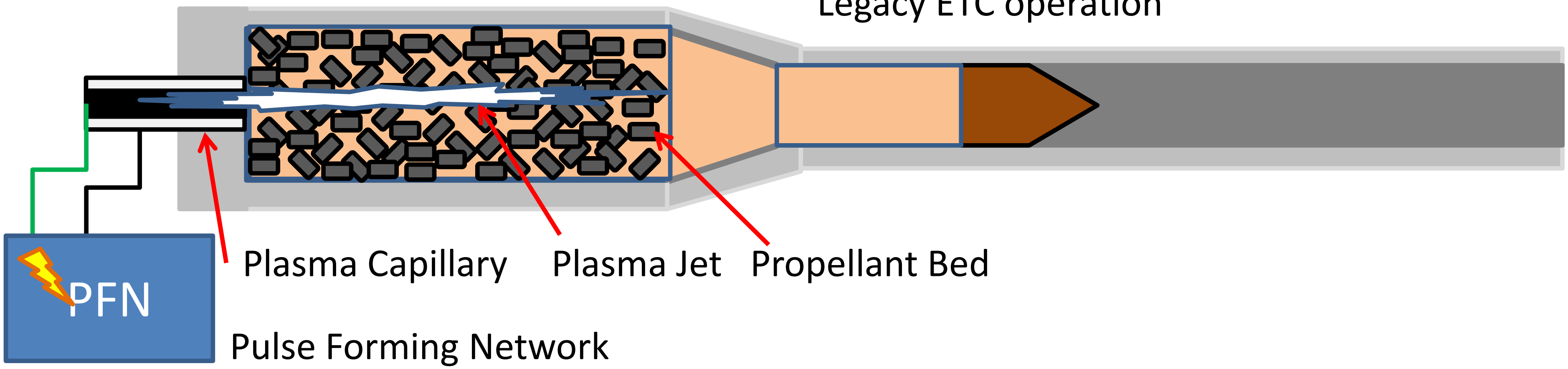
Extra boost for extended range munitions

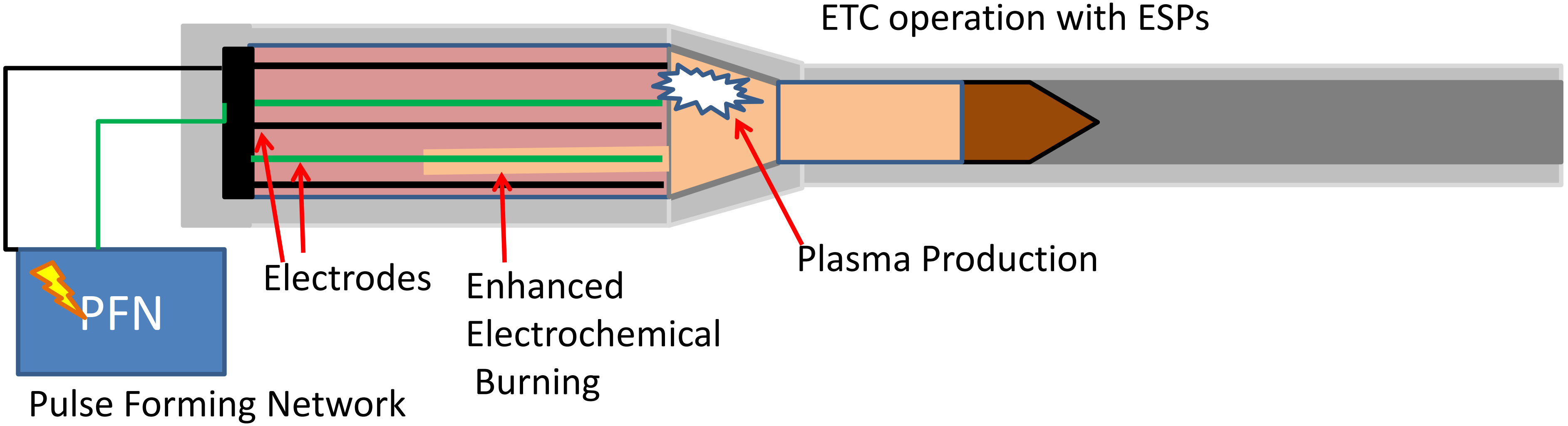
Advantage of Extending Range of Conventional Rounds



- Not all shots beyond 25nm require guided munitions
- Great cost can be saved by using standard rounds launched further

ETC Gun Operation- Legacy versus ESP





Why Electric Smart Propellants (ESPs)

Insensitive Munition (IM) Properties

Does not self sustain at ambient temperature (baseline HIPEP propellant)

	Impact ERL (50%)	ABL Friction	Electrostatic Discharge
ESP	>158.5cm (2.5kg)	20/20 NO GO (8000N)	>0.25J
PETN	13.9cm	142N	
RDX	29.8cm	1870N	

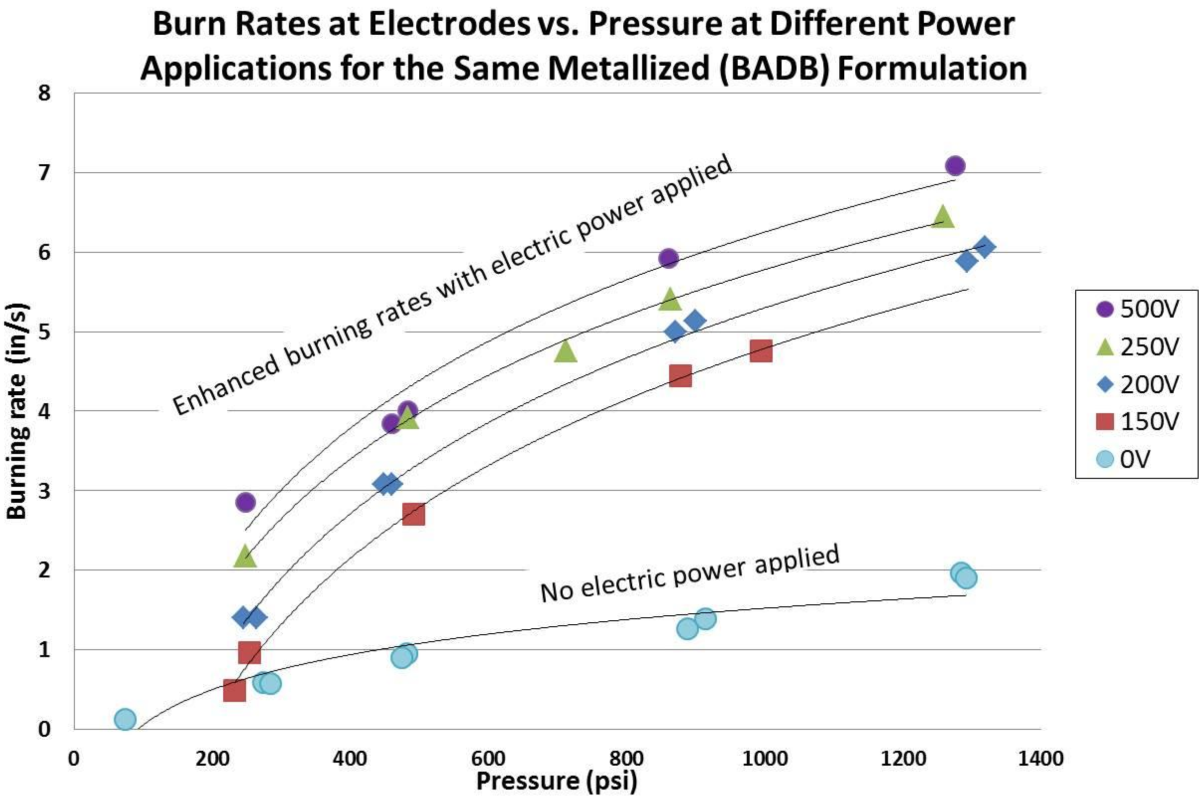
Type VI reaction to bullet impact
Type VI reaction to NOL Card gap Test at Zero Cards
Type V reaction to fast cook off

Energy content

Propellant	Impetus (J/g)
JA2	1153
JAX	1209
Gun Propellant ESP	1100-1150

- Energetic additives may improve impetus (slight reduction in IM properties).
- Higher volumetric loading may counter deficit in impetus.

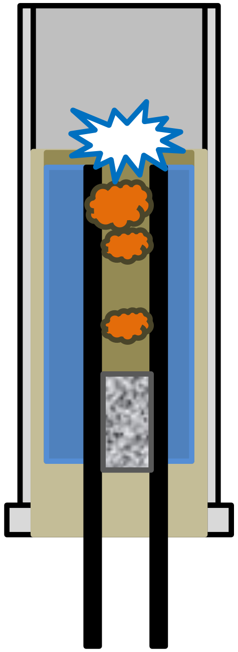
Why Electric Smart Propellants II



Electrical Properties

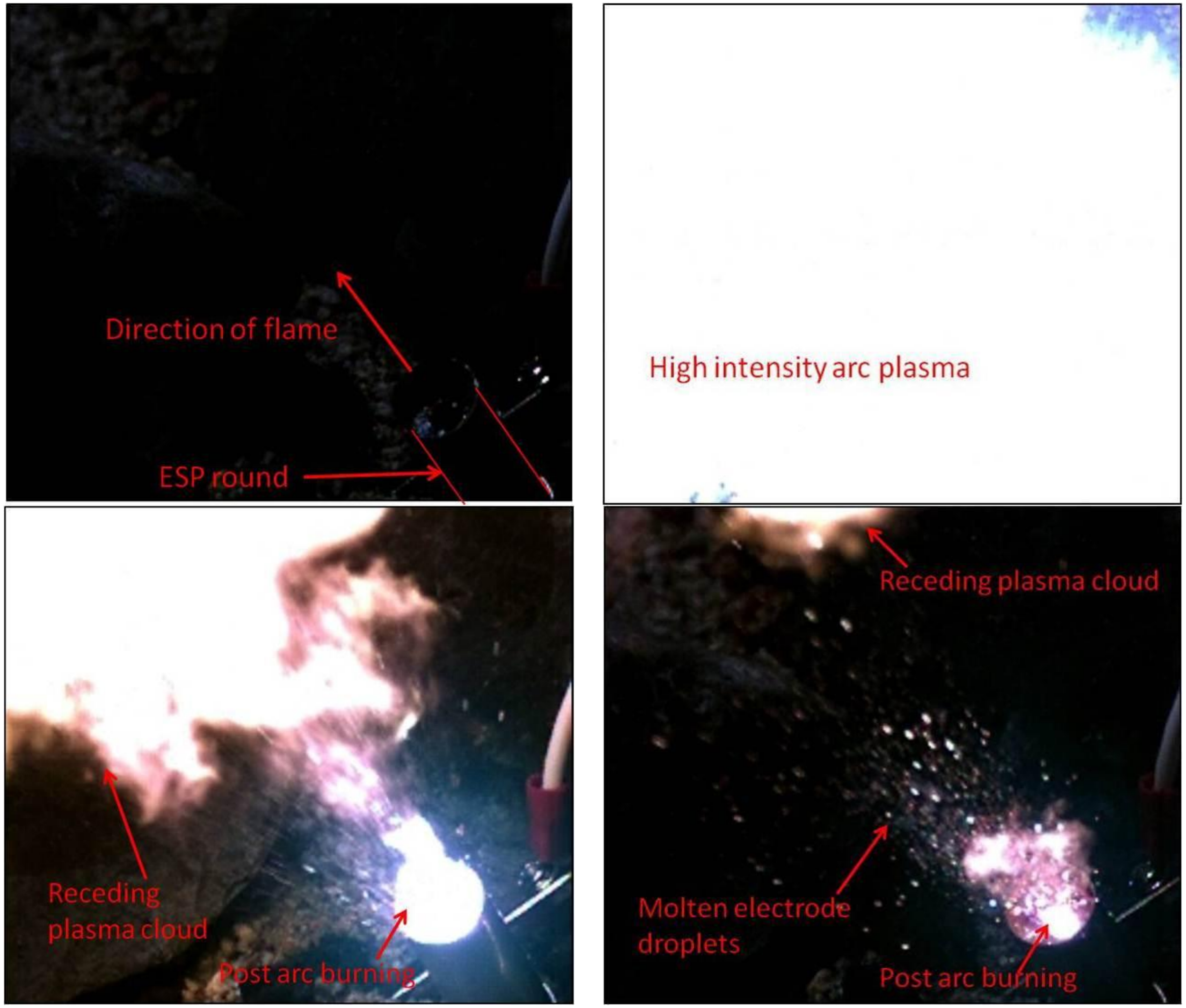
- Conductive
- Ignited by applied electrical power
- Electrical burn rate enhancement (grain morphing) for higher propellant loading
- Low voltage plasma production

Plasma Production with Capacitor Discharge

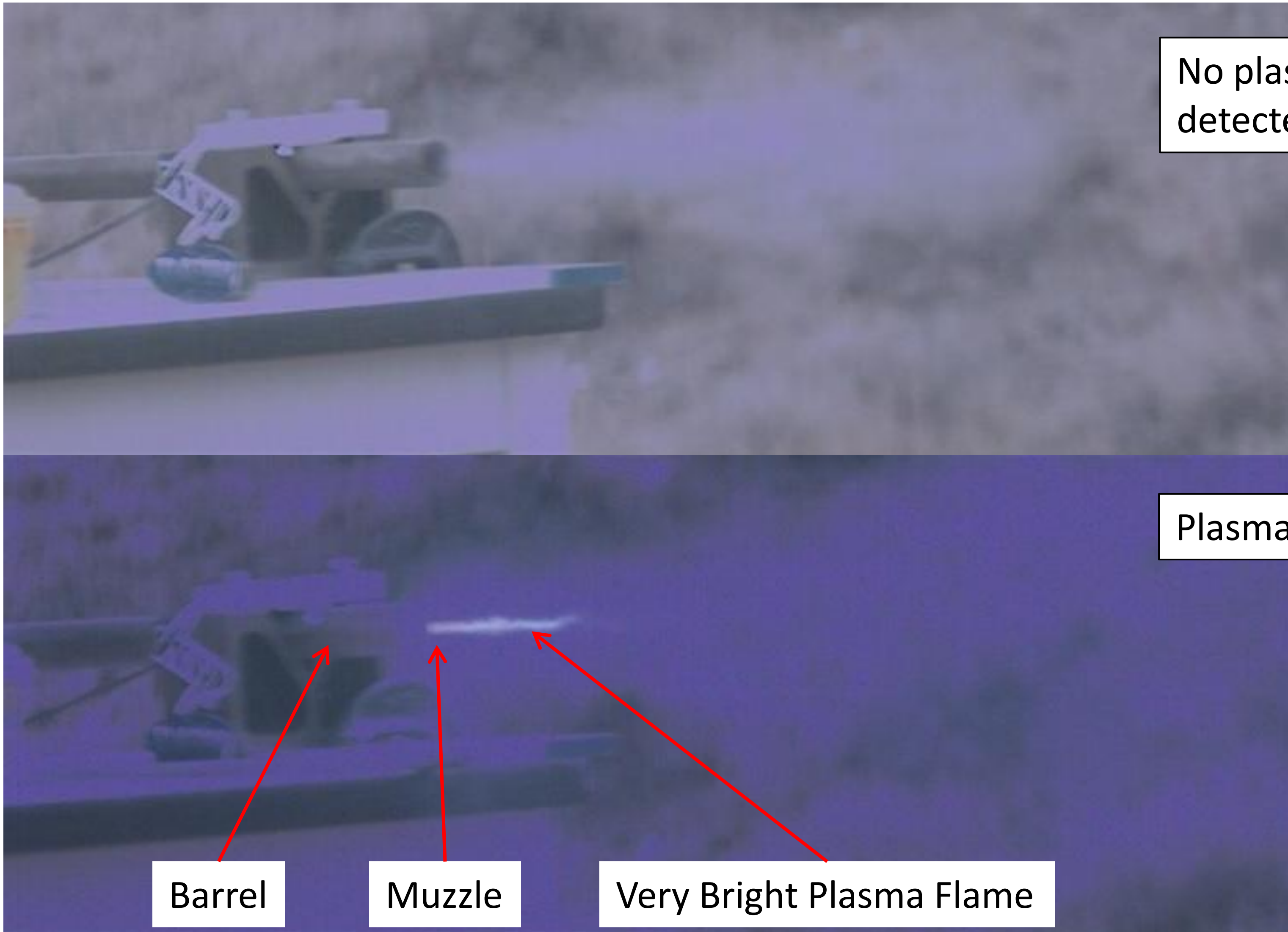


Recorded at 35Kfps, event lasts <1 ms

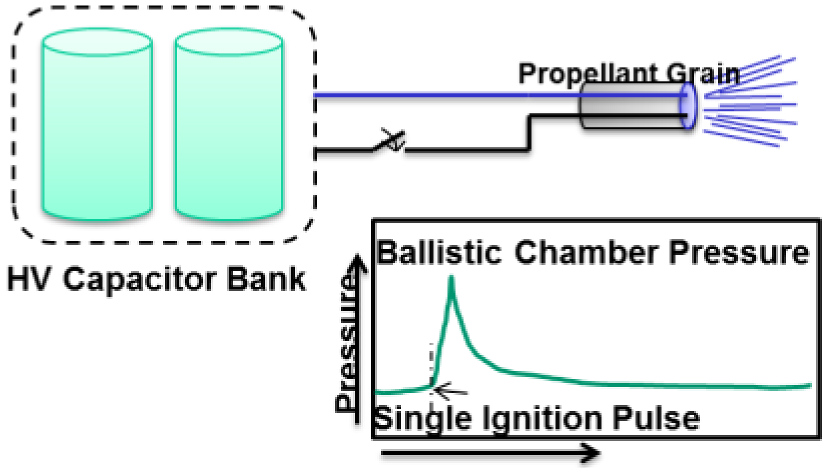
Videos were taken at 1 µsec exposure



Plasma Production Phenomenon In-Barrel



Multiple Pulsed Capacitors

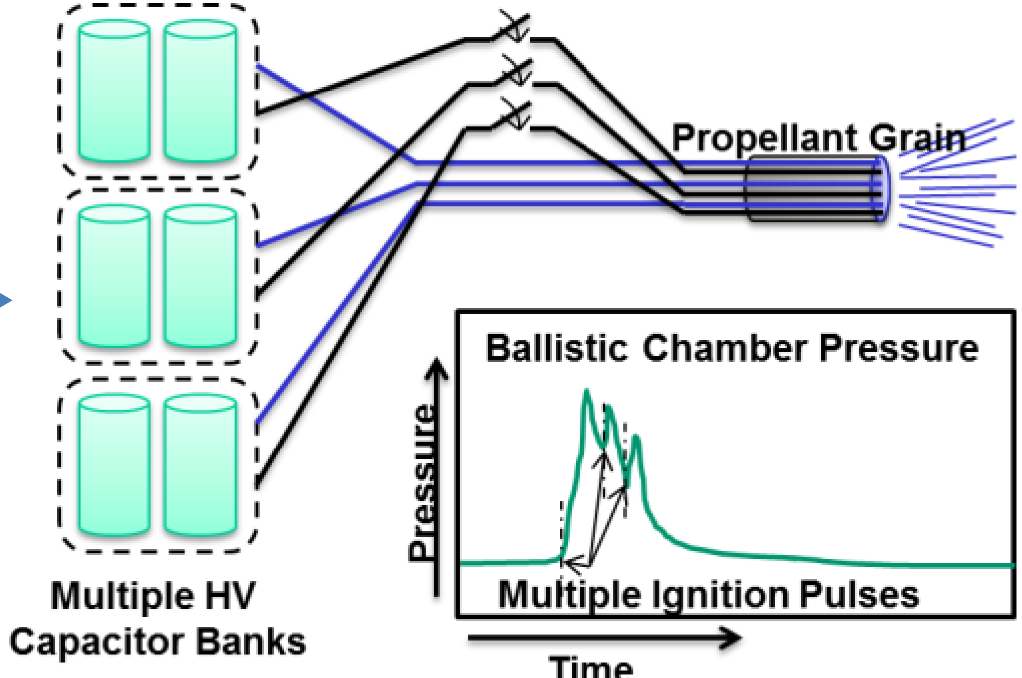


Single Pulse- Cap discharge

- Fast ignition
- High Amperage
- Single energy source devoted to ignition, grain morphing, *or* plasma production

Multiple Pulse- Cap discharge

- Ignition, grain morphing, AND plasma production throughout ballistic cycle
- Banks can be individually sized based upon power requirements



ESPs making ETC systems more viable

SOA High Energy Chemical Propellant Potentially Hazardous

-ESPs are extremely low hazard; type V-VI reactions to most hazards

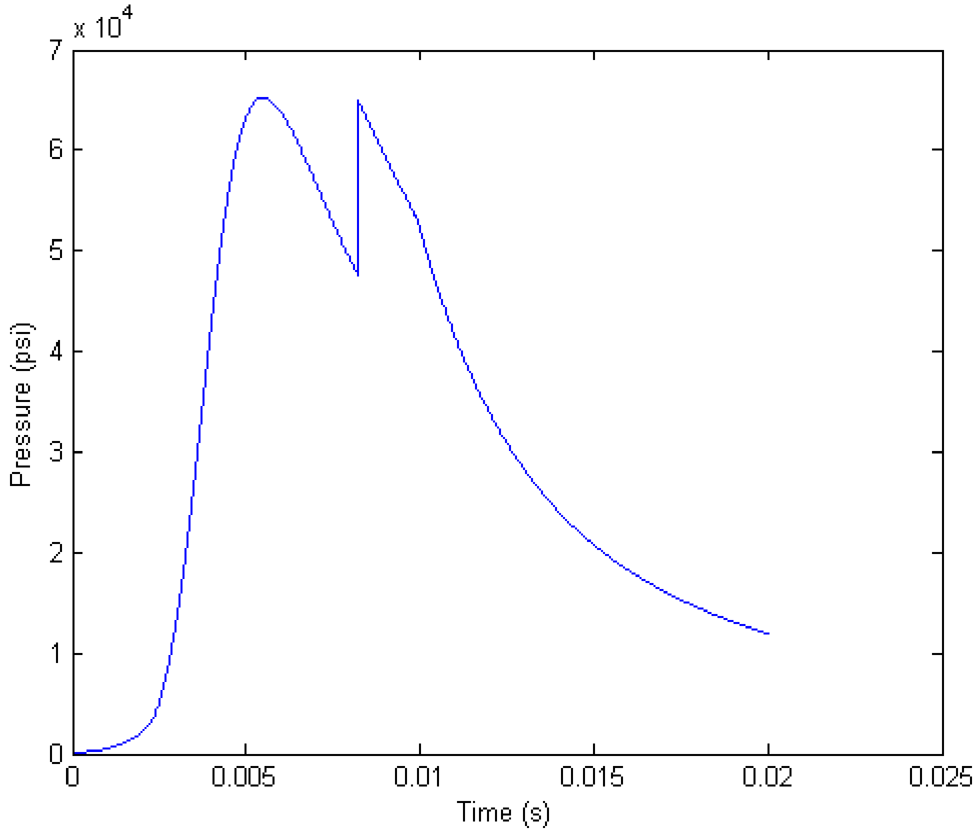
SOA Plasma donor is separate inert system- plasma created from exploding wire and then must be injected into the main grain

-Plasmas are created with the ESP main grain directly
-Voltages for chemical breakdown of ESPs into plasma is on the order of 100's of volts instead of 1000's of volts. Either lower power requirements needed or greater reaction strength and speed at same power levels.

Single plasma injection at ignition results in higher chamber pressures and temperatures leading to heavy barrel wear.

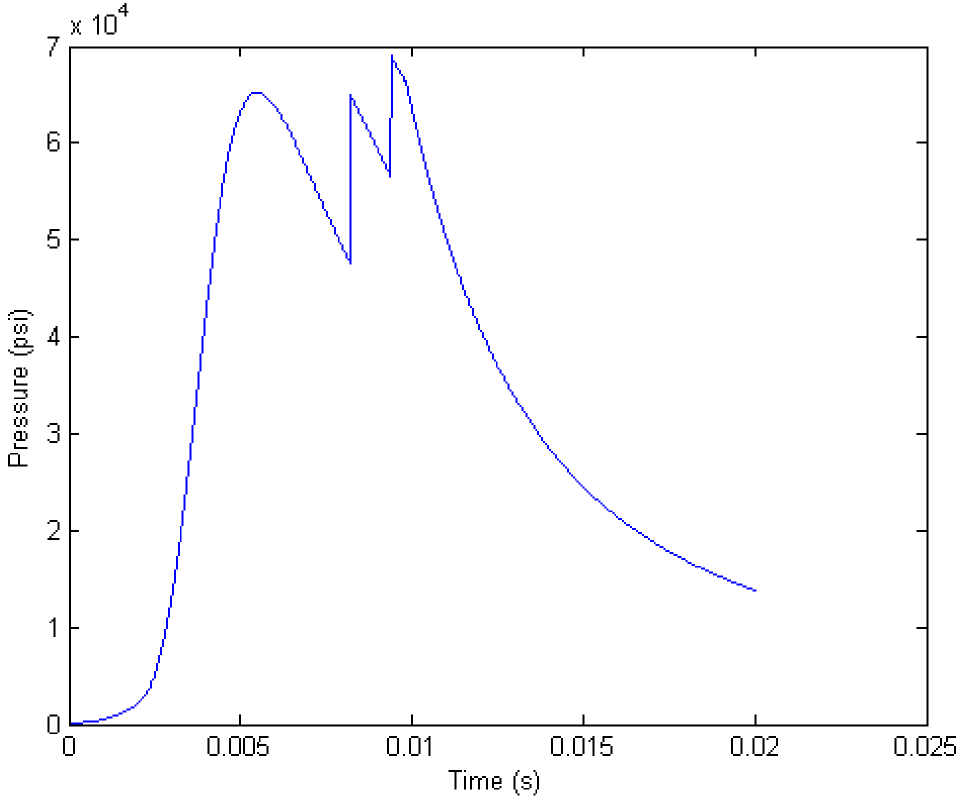
-Plasma injection multiple times during ballistic cycle reduces peak pressure but maintains higher overall pressure and keeps peak gas temperature lower as well.

Case-Study Mark 45 Mod 4/5" ETC Gun System Scenario 1



- Single 1kJ/g plasma pulse at 8.2ms from ignition
- Peak pressure: 65,300psi
- Peak Temperature 3400K
- Muzzle Velocity: 4610ft/s (31.75kg projectile)
- Range: ~34 nautical miles with conventional round
- PFN Requirements: 12MJ per shot.

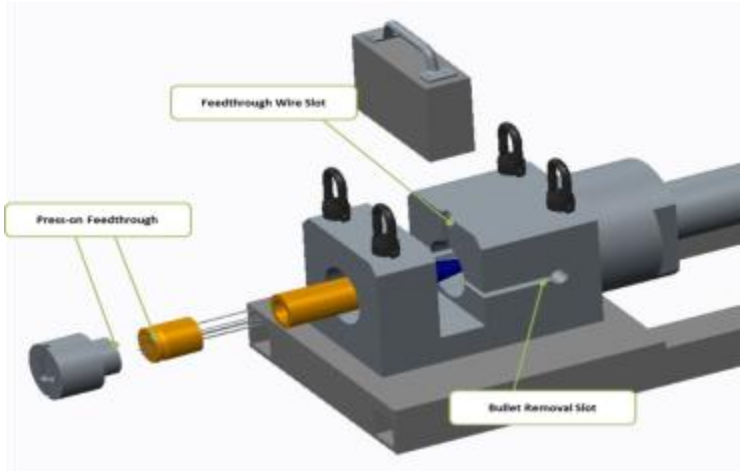
Case Study Mark 45 Mod 4/5" ETC Gun System- Scenario 2

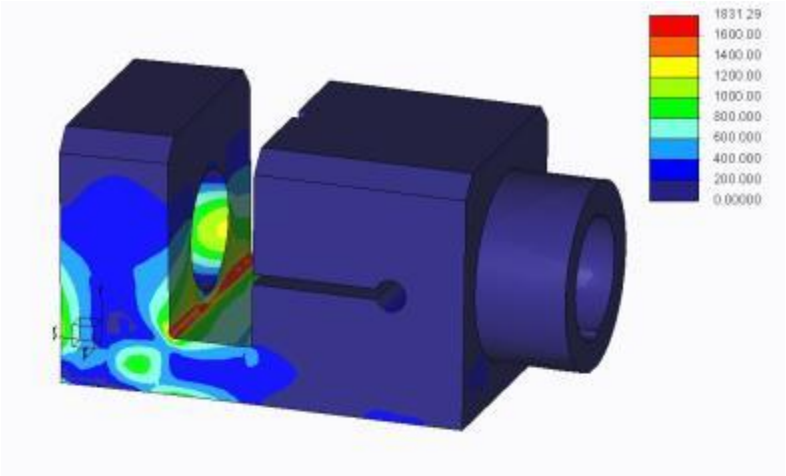


- Two- 1kJ/g plasma pulse at 8.2ms and 9.4ms from ignition
- Peak pressure: 69,000psi
- Peak Temperature 3500K
- Muzzle Velocity: 4870ft/s (31.75Kg projectile)
- Range: ~40 nautical miles with conventional round
- PFN Requirements: 24 MJ per shot

Current Efforts-30mm Scale Testing

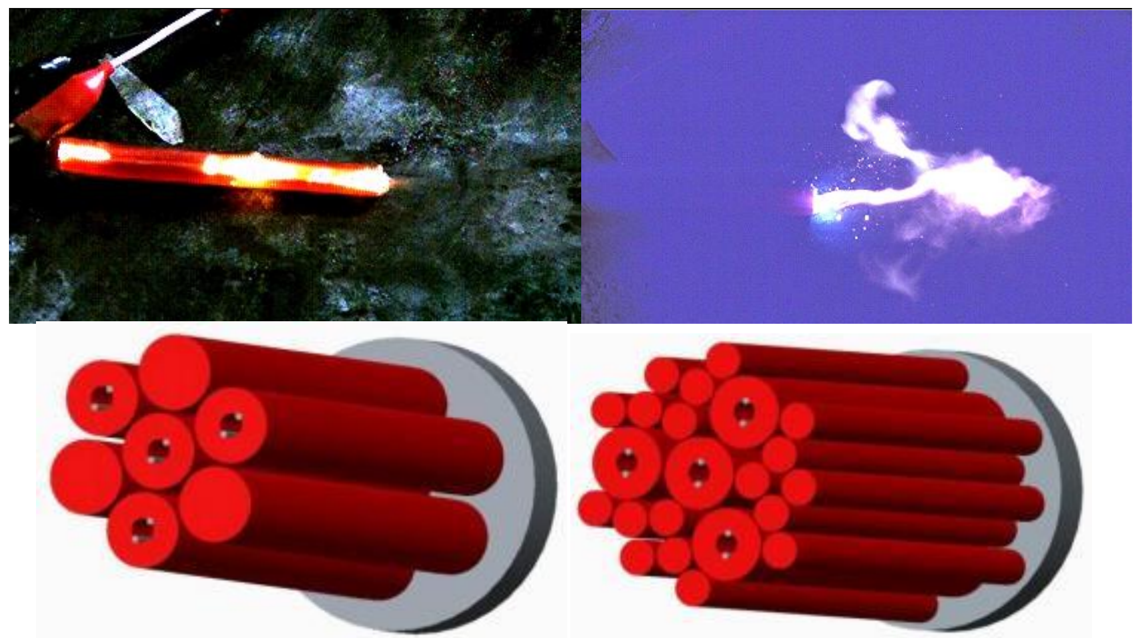
- Larger scale more tolerable to lower surface areas, higher propellant loading
- More space to explore form factors
- GAU-8 Avenger Barrel, Breech Designed in-house
  - Designed (backed by FEA analysis) to withstand chamber pressures up to 150,000psi





Current Efforts-30mm Scale Testing

- Begin with monolithic grain used for 0.50cal testing
- Once familiarity and safety measures locked down, will incrementally scale to 60-70% of full charge load.
- Plasma production seen at 600V with higher capacitance for 30mm single stick grain
- 30mm grains will be a series of sticks



THANK YOU!

Special thanks to DARPA for giving us this opportunity.