# The Rarefaction Wave Gun Program

## A Government and Industry Collaboration to Develop 21st Century Cannon Systems

**Presented by :**
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# 21st Century Cannon Systems

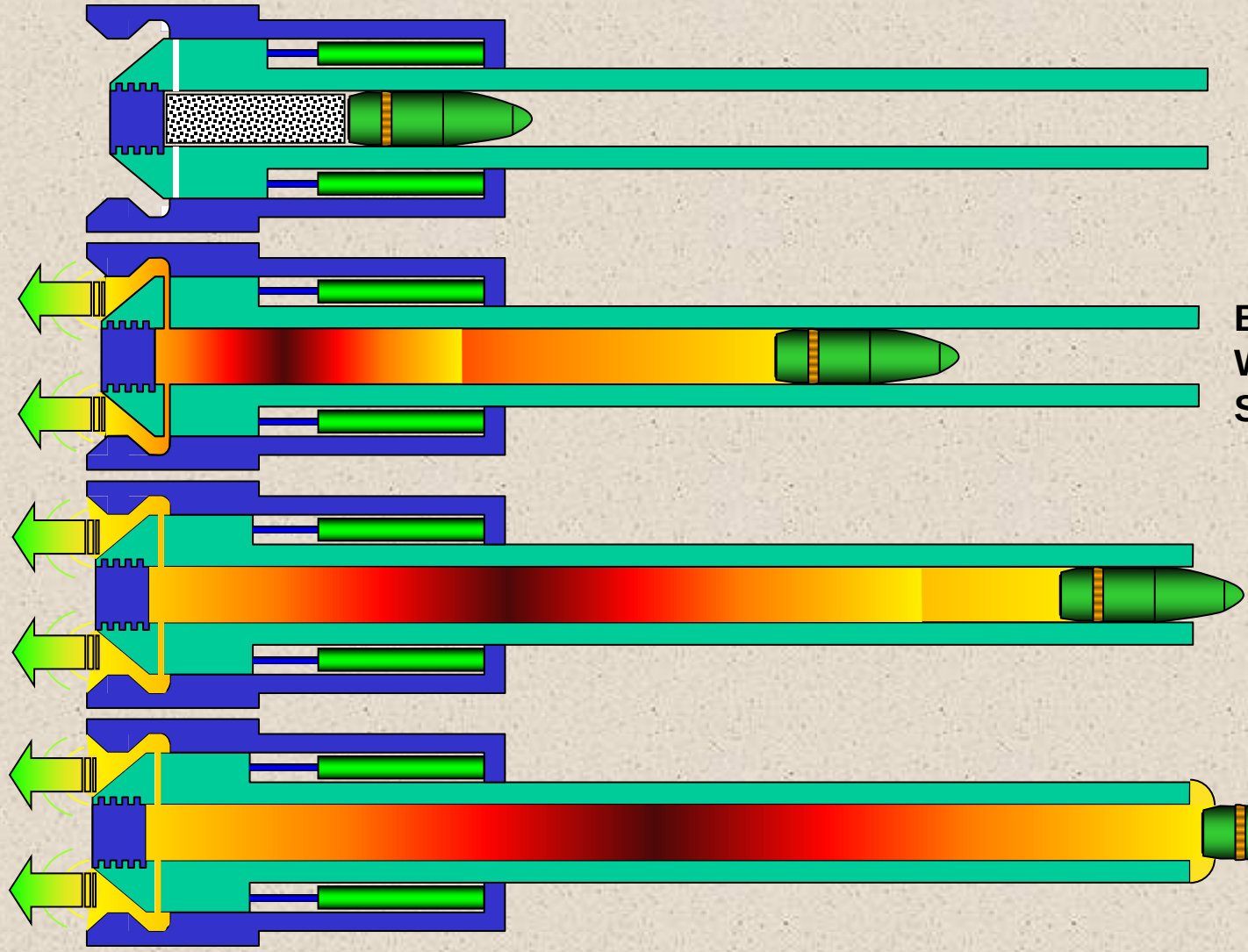
- LW vehicles w/ large caliber guns
  - Considerable momentum and kinetic energy imparted to system
- Engineering barriers
  - Mitigate recoil
  - Reduce weight
- RArefaction waVE guN (RAVEN)
  - Army After Next project (1999)
  - Dr. Eric Kathe - doctoral thesis (2001)
  - Engineering & demo. (2005 – 2010)

# RAVEN Propulsion – Objectives

- High lethality weapons on lightweight vehicles
- Mitigate recoil
  - Recoilless early venting achievable
- Reduce thermal load
  - Reduced gas density
  - Reduced gas temperature
  - High rate-of-fire capability
  - Sustainable fire
- Maintain ballistic efficiency
- Maintain muzzle velocity
- Minimize impact to vehicle
- Lightweight materials to reduce system weight

Notional RAVEN Cannon Mounted upon a Lightweight Robotic Vehicle

# RAVEN Propulsion – Operation



**Ignition**

**Breech Vent Opens While Projectile is Still In-Bore**

**Synchronized Rarefaction Wave Catches Projectile At the Gun Muzzle**

**No Velocity Loss**

# RAVEN Propulsion - Challenges

- Vent method and mechanics
  - Blow-back bolt
  - Recoil actuated
  - Rupture disk
- Back blast
  - Overpressure
- Ammunition loading
- Gun system integration

Notional 45mm RAVEN Automatic Cannon Mounted upon a RIPSAW Robotic Vehicle

# RAVEN Program – Accomplishments

- Proof-of-Principle
  - 35mm demonstrator
    - RAVEN propulsion validation
    - Vent mechanics experimentation
- System Advancements
  - 105mm demonstrator
    - Converted FCS_MRAAS cannon w/cased telescoped ammunition
    - Inertial breech vent
    - Ammunition handling system
  - 45mm demonstrator
    - Converted COMVAT automatic cannon
    - Blow back bolt & ammunition based vent
    - Ammunition development

# RAVEN Program – Accomplishments

- Firing Tests
  - 105mm Demonstrator
    - Synchronized rarefaction wave demonstrated
  - 45mm Demonstrator
    - Closed breech baseline
    - Pre-synchronized venting (recoilless operation)

# Accomplishments – 35mm Demonstrator

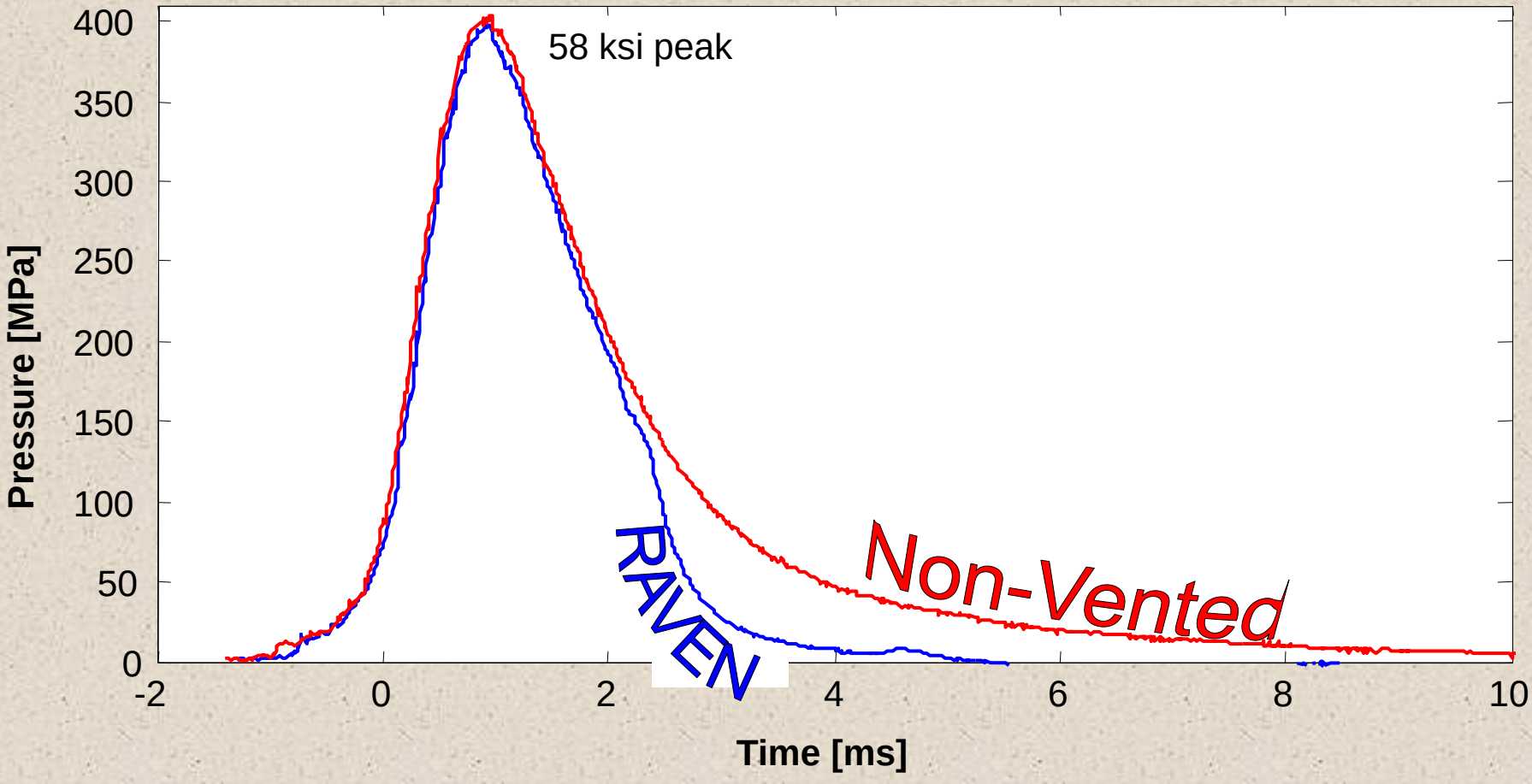
- Design
  - Based on Oerlikon KD series 35mm anti-aircraft gun
- Vent Method
  - Ammunition-based rupture disk
    - Intentionally ‘uncorks’ the breech
  - Blow-back bolt
    - Propelled rearward by impulse from propellant gases
  - Timing
    - Driven by same propellant gases as bullet
    - Governed by bolt mass bolt and distance to ‘uncork’

# Accomplishments – 35mm Demonstrator

- Proof-of-principle tests
  - Synchronized & pre-synchronous venting (60 shots)
    - Maintained muzzle velocity when synchronized
    - Recoilless when pre-synchronous
    - Significant reductions in
      - Barrel heating
      - Recoil momentum
  - Experimental results

| Measurement | Units | Closed Breech Baseline | RAVEN Results | % of CB Baseline |
|---|---|---|---|---|
| Muzzle Velocity | m/s | 1,135 | 1,131 | 100% |
| Barrel Heating ($\Delta T$) | K | 3.61 | 2.13 | 59% |
| Momentum | N-s | 1,031 | 402 | 39% |

# Accomplishments – 35mm Demonstrator




Chamber Pressure Data

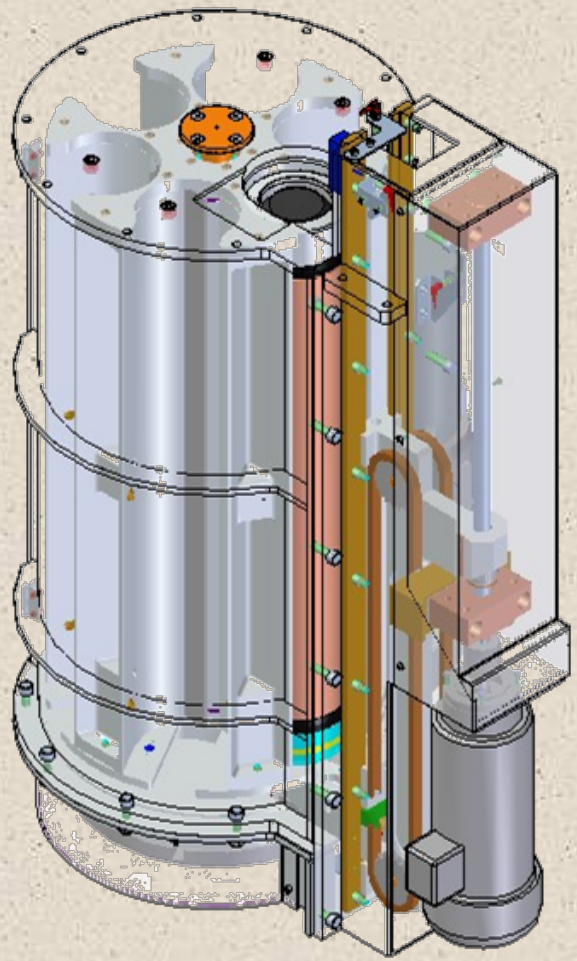
Vented and Non-vented Rounds w/ Same Muzzle Velocity

# Accomplishments – 105mm Demonstrator

- Design
  - FCS_MRAAS 105mm smooth bore swing chamber cannon
- Vent method
  - Bolt face nose, integrated blow-back bolt, and exhaust nozzle
    - Impulse acts on bolt face
    - Combined inertia of bolt and exhaust nozzle delay venting
  - Timing
    - Governed by mass of inertial breech and required travel distance of bolt face seal to vent

# Accomplishments – 105mm Demonstrator

- Ammunition Handling System
  - Design
    - Based on 75mm XM274 autoloader
  - Vertical carousel
    - 6 rounds
    - Rotary motor driven Geneva indexing mechanism
  - Feeder
    - Ball screw driven
  - Rate of fire
    - 15-20 shots/min (targeted range)
    - 17 shots/min (designed)



# Accomplishments – 105mm Demonstrator

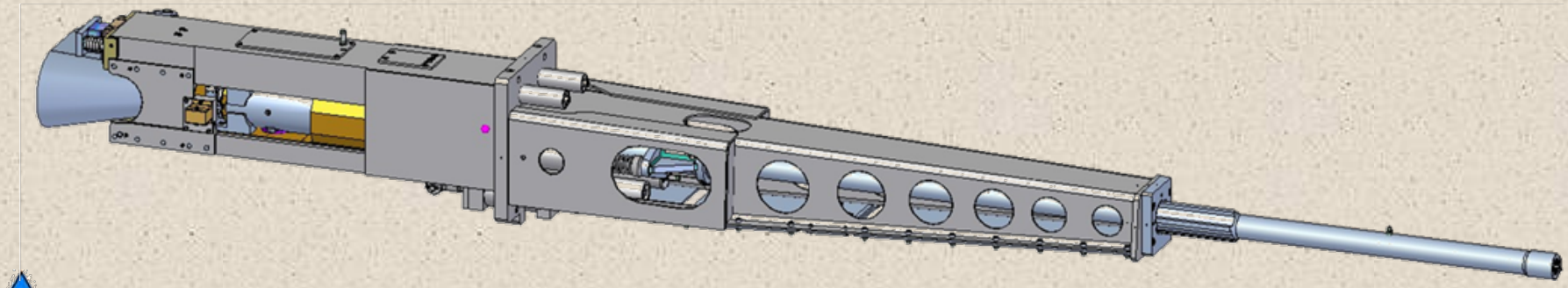
- Firing tests
  - Synchronized & pre-synchronous vent (14 shots)

  - Experimental results

| Measurement | Units | RAVEN Results | |
|---|---|---|---|
| | | Predicted | Actual |
| Muzzle Velocity | km/s | 1.49 | 1.37 |
| Momentum | kN-s | 14.0 | 12.7 |

# Accomplishments – 45mm Demonstrator

- Design
  - 45mm COMVAT automatic CTA cannon
- Venting Method
  - Ammunition rupture disk
    - Consumable exhaust throat
  - Inertial bolt with brake
    - Controls vent displacement over time
  - Timing
    - Governed by material properties and geometry of rupture disk and bolt mass



# Accomplishments – 45mm Demonstrator

- Ammunition development
  - Converted from percussion primer
  - Challenges
    - Integrating electric ignition train into cartridge
    - Maintaining high pressure seals

45mm RAVEN Cartridge

# Accomplishments – 45mm Demonstrator

- Firing tests
  - Closed breech baseline (21 shots)
  - Pre-synchronous vented recoilless (4 shots)
    - Unimpeded baseline vent, bolt brake not included
    - Impeded vent, bolt brake included
  - Experimental Results

| Measurement | Units | Closed Breech (CB) Baseline | RAVEN (no brake) | % of CB Baseline | RAVEN (w/ brake) | % of CB Baseline |
|---|---|---|---|---|---|---|
| Muzzle Velocity | ft/s | 3,636 | 2,326 | 64% | 2,837 | 78% |
| Chamber Pressure | ksi | 54 | 45 | 83% | 49 | 91% |
| Barrel Heating (ΔT) | °F | 79 | 21 | 27% | 37 | 47% |
| Recoil Travel | in | 3.49 | 0.10 | 3% | 0.16 | 5% |

# RAVEN Program – Objectives

- Demonstrate RAVEN Propulsion Objectives
  - Reduce recoil impulse, thermal loads, and system weight
  - Maintain ballistic efficiency and velocity for synchronized venting
  - Demonstrate repeatability
    - Accurate vent timing predictability
- Model validation
  - Confirm interior ballistic performance
  - Verify heat transfer predictions
  - Verify gas discharge behavior
- Integrate RAVEN into lightweight vehicle platform
- Demonstrate minimum impact on vehicle dynamics
  - Vehicle movement

# RAVEN Program – Task Schedule

## Jun-Aug 2010

**Synchronization Tests**

- 45mm & 105mm
  - Fire single shots
  - Achieve synchronized vent

## Sep-Dec 2010

**Development Tests**

- 45mm & 105mm
  - Install AHS
  - Demonstrate rapid–fire with RAVEN propulsion

## Jan-May 2011

**Vehicle Integration**

- 45mm & 105mm
  - Build platform modifications
  - Install demonstrators onto lightweight vehicles

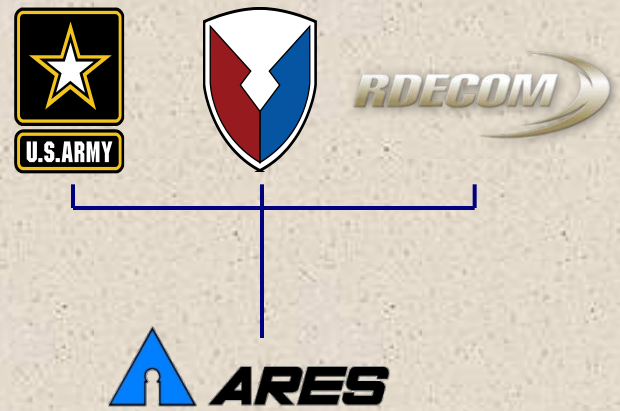
## Jun-Jul 2011

**Vehicle Firing Tests**

- 45mm & 105mm
  - Fire single shots
  - Demonstrate vehicle response

# RAVEN Program – Collaboration Benefits

- Government: WSEC, ARDEC, RDECOM
  - Obtains knowledge in 21st century weapon systems development
  - Gain access to ARES expertise
    - Case Telescoped Ammunition (CTA) design
    - Transitioning prototype designs to mature firing systems
- Industry: ARES, Inc.
  - Upgrades capabilities
    - Design and analysis
    - Manufacturing
    - Testing
  - Expands personnel and expertise



# The Rarefaction Wave Gun Program

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