Modeling of Gas Flow and Heat Transfer in Small Arms Weapons Systems

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Laurie A. Florio, Ph.D.
US ARMY ARDEC
Picatinny Arsenal, NJ
laurie.florio@us.army.mil
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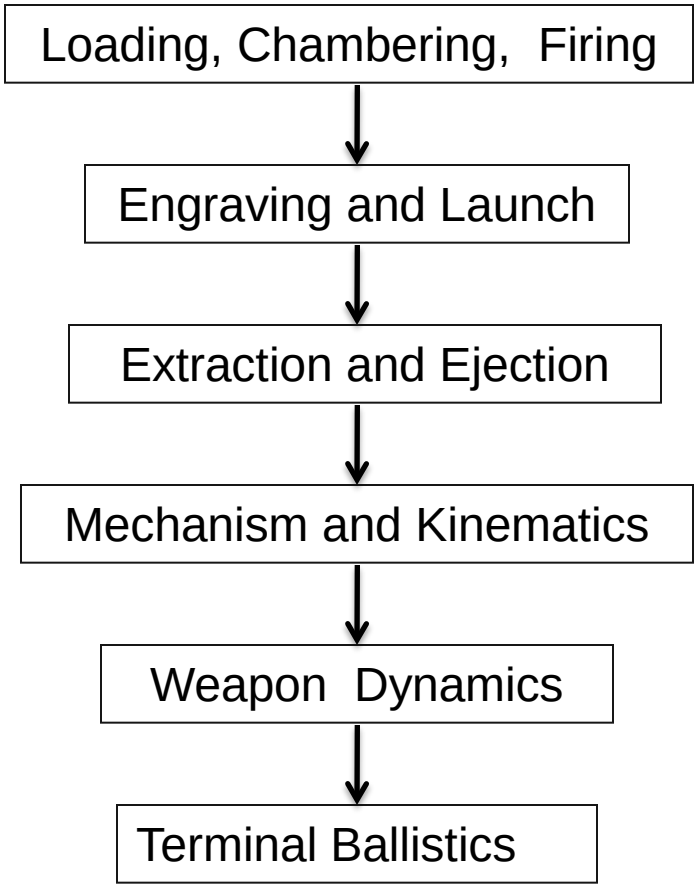
Topics Covered

- Modeling and simulation in small arms systems
  - Goals and capabilities
  - Advantages
- Gas flow and heat transfer in small arms systems
  - Barrel heating
  - Muzzle devices
  - Gas flow internal to weapon systems
- Conclusions
- Future work

Virtual analysis of weapon function



Fluid flow and heat transfer are involved in all of these functions

Modeling and Simulation of Small Arms Systems

- Advantages of modeling
  - Test concepts before building prototype
  - Isolate certain effects and understand how they influence system operation
  - Computational fluid dynamics (CFD) advantages
    - Visualization of the velocity, temperature, pressure
    - Measurements at any location without restrictions

Current capabilities of fluid flow and heat transfer modeling in small arms systems

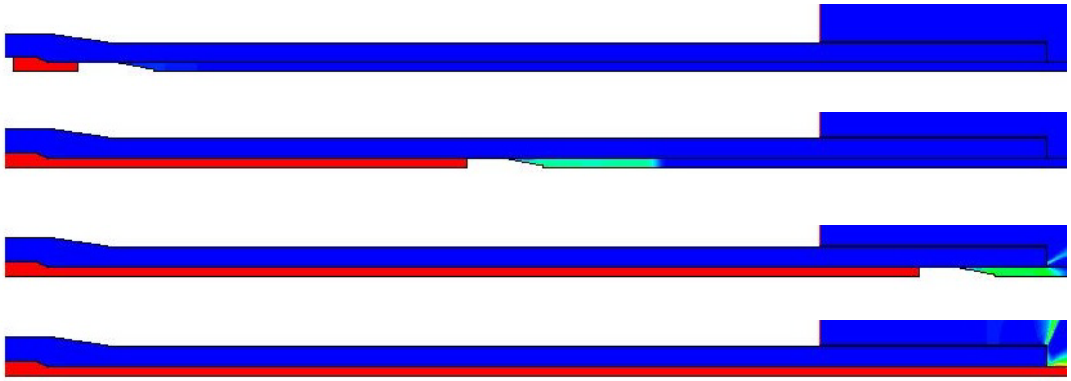
- 1. Barrel heating
- 2. Muzzle devices
- 3. Gas flow internal to the weapons system

1. Barrel heating

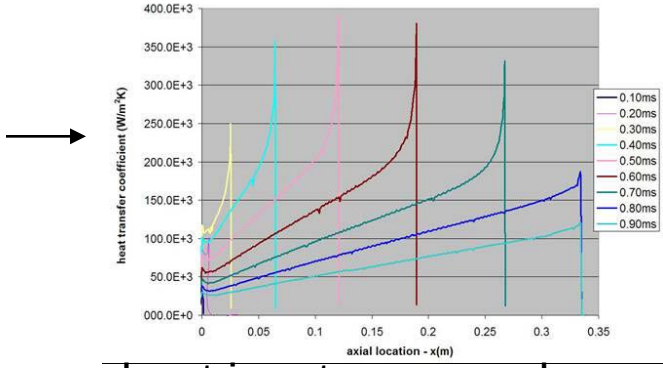
1. Modeling barrel heat transfer

Used to estimate the barrel temperature for a given firing schedule

- a. CFD model determines gas conditions as bullet moves along the barrel



CFD gas flow model

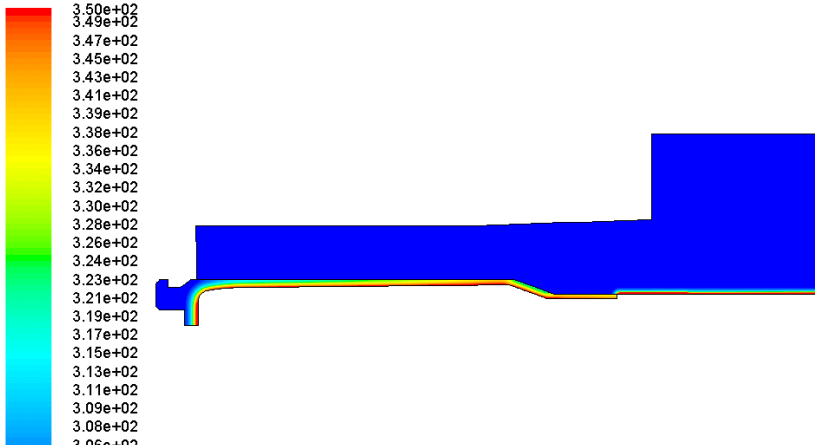


heat input per round

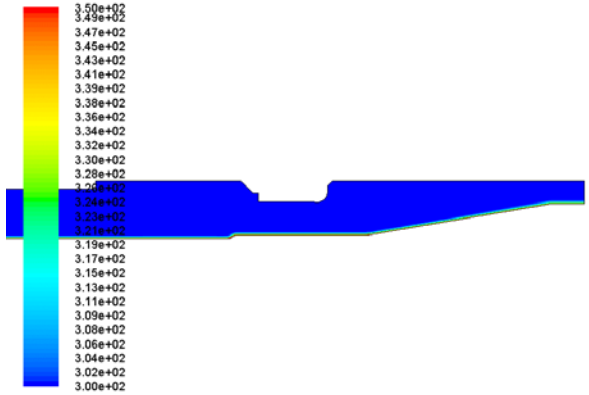
- b. Results used to estimate heat transfer to barrel during one shot
- c. Apply heat input per round to heat conduction model of barrel

1. Barrel heat transfer

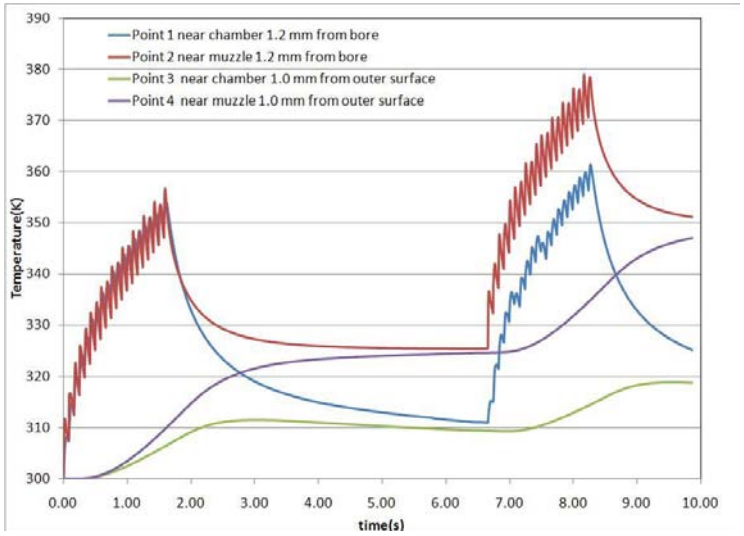
- Simulate:
  - Any number of rounds
  - Evaluate barrel performance
  - Evaluate heat mitigation concepts
- M4/ M240



Temperature near chamber



Temperature near muzzle



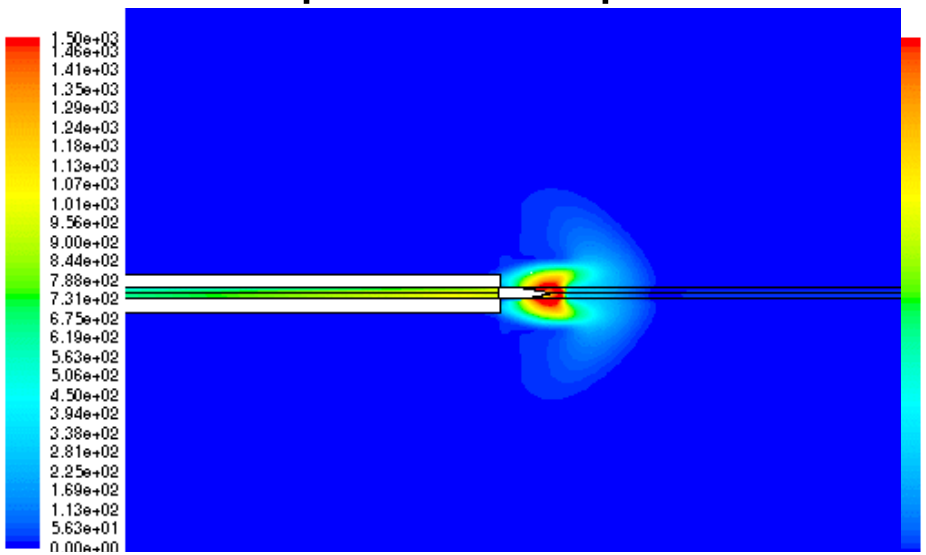
Temperature at a point vs. time

2. Gas flow through muzzle devices

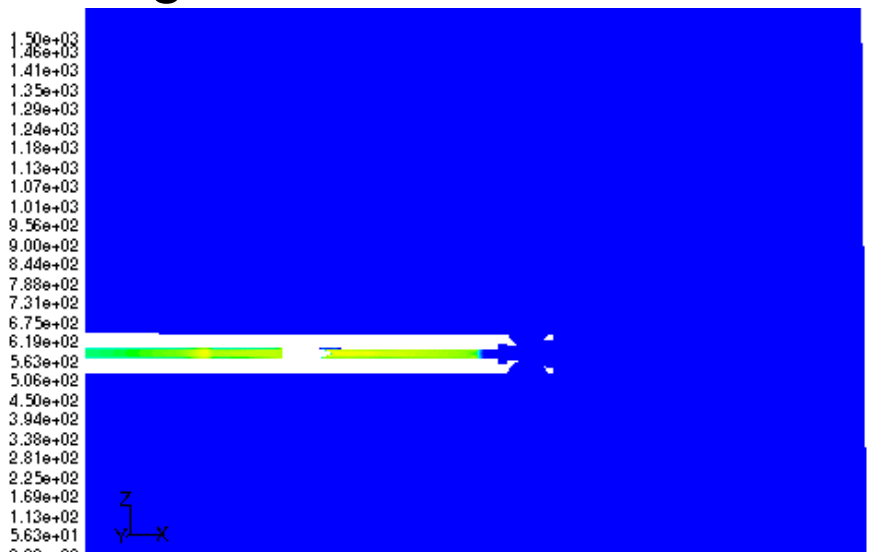
2. Models of gas flow through muzzle devices

Simulate movement of bullet along barrel and through muzzle device

- Determine gas velocity, temperature, and pressure distributions
- Compare blast patterns, resulting forces



Bare Muzzle

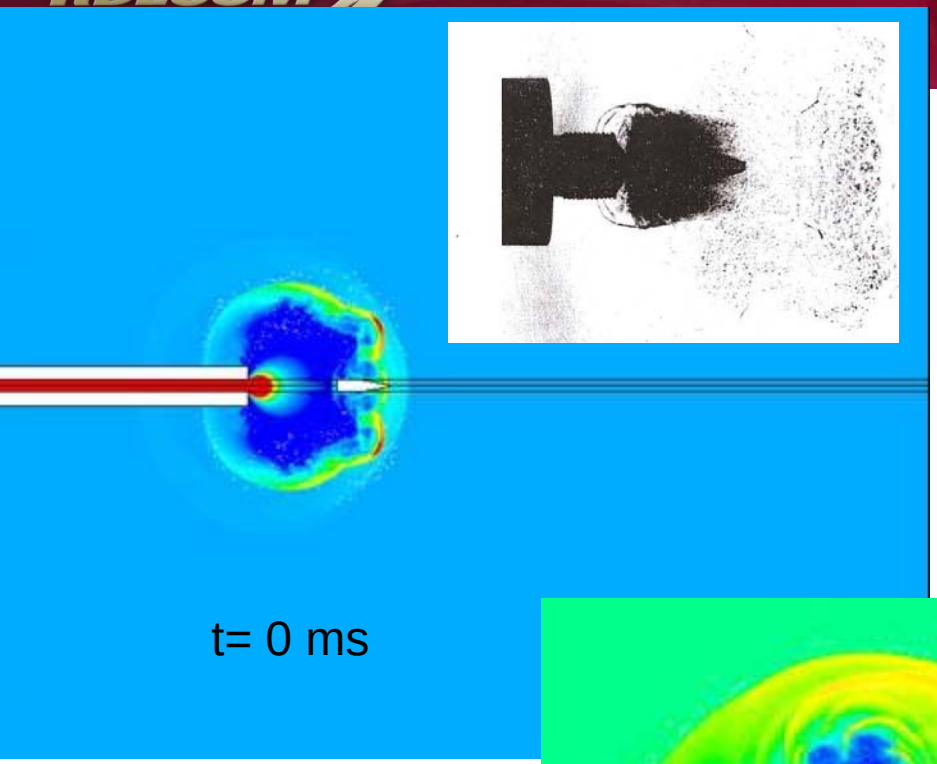


Flash Suppressor

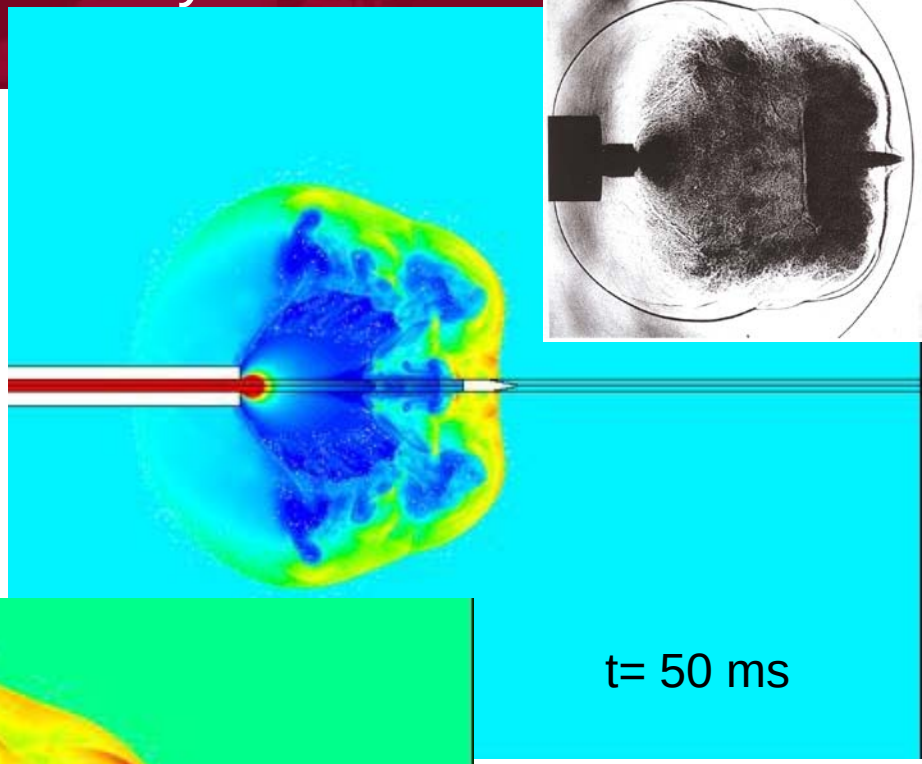
Velocity Contour Animations

A. Comparison to Shadowgraphs and System with and Without Muzzle devices

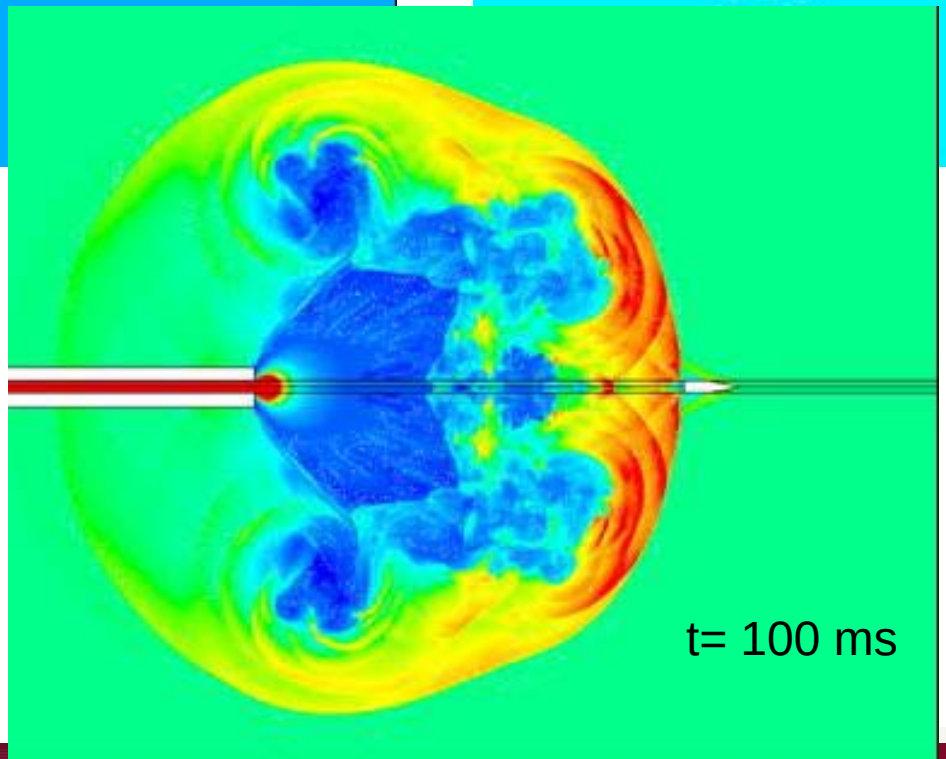
Bare Muzzle – Density Contours



t= 0 ms



t= 50 ms

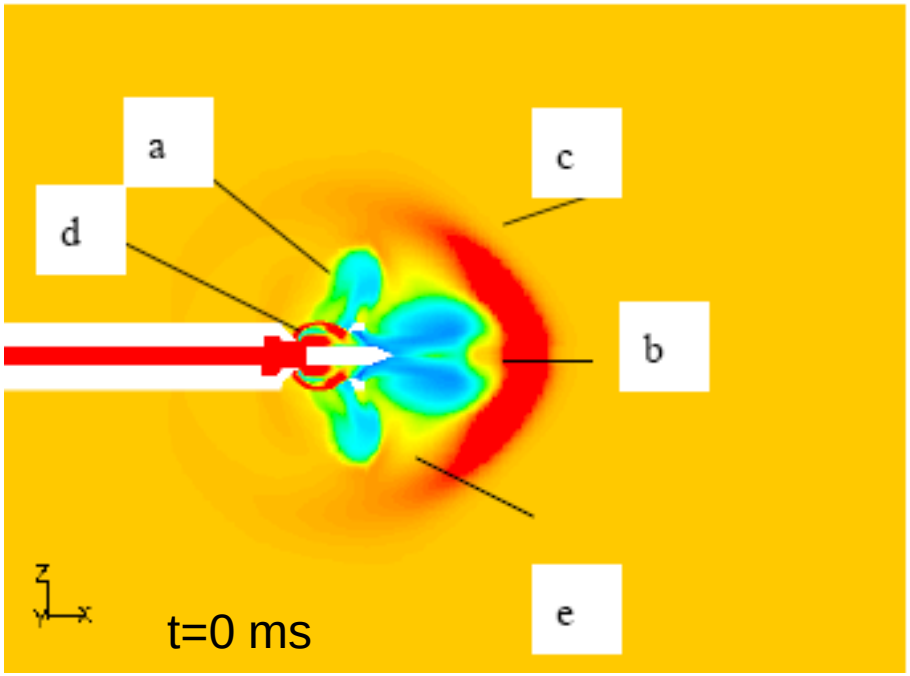


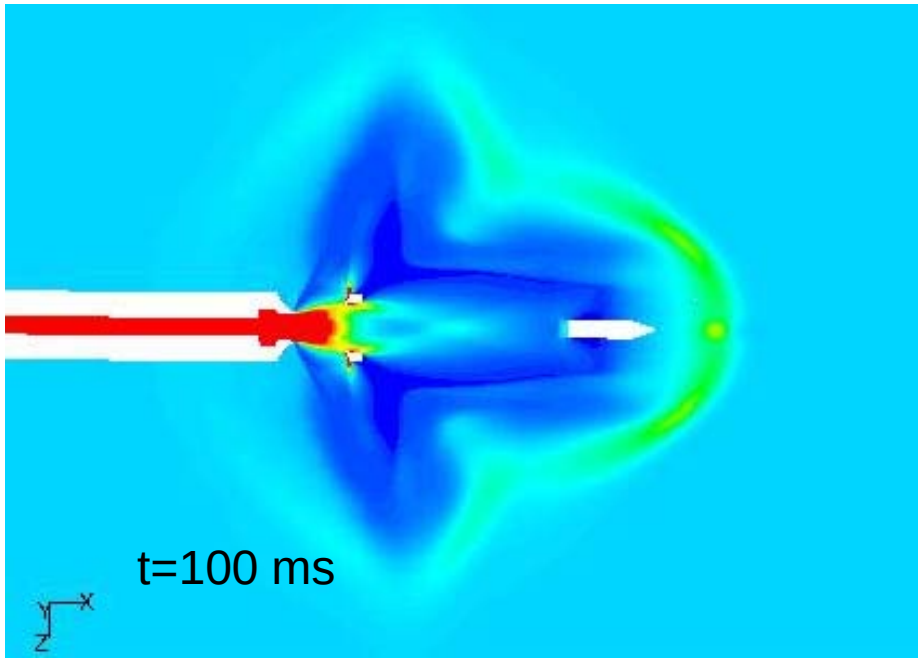
t= 100 ms

Shadowgraphs from Schmidt ARBRL-TR-02373, 1981.

Compared well with additional shadowgraphs from Baur and Schmidt BRL-MR-3513, 1986.

M16 Muzzle Device – Density Contours

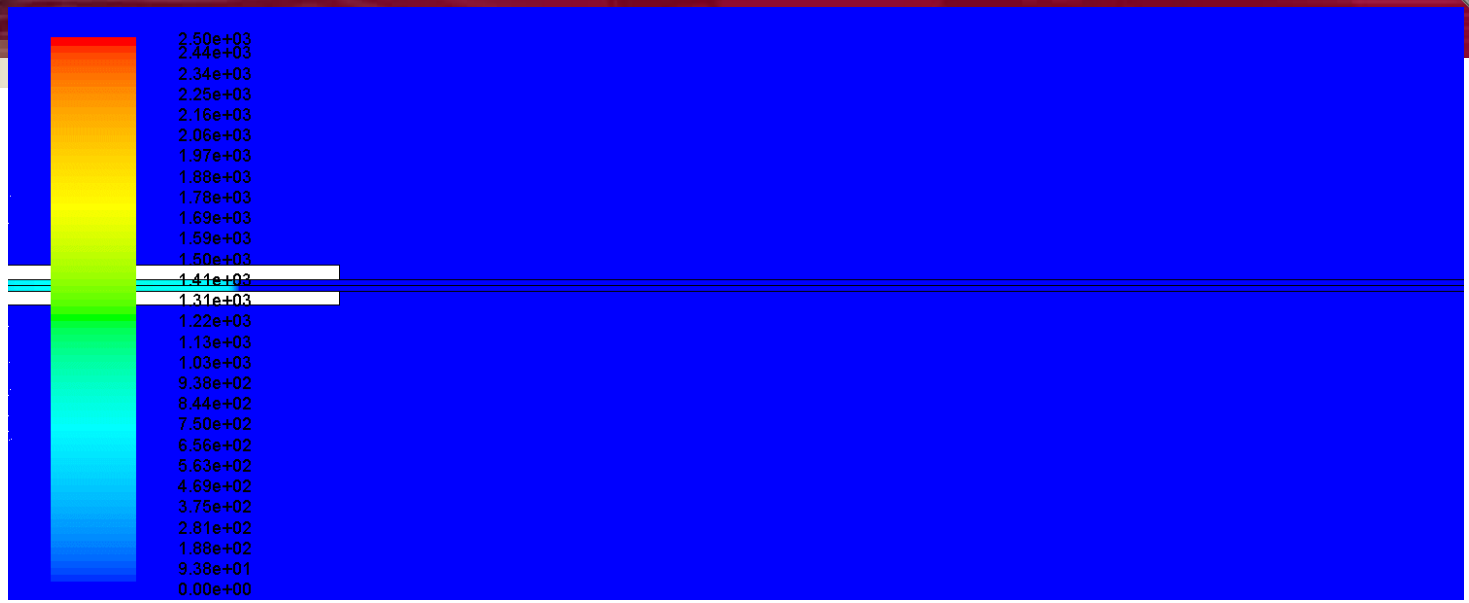




Compared well with shadowgraphs from Baur and Schmidt BRL-MR-3513, 1986.

B. Differences in flow and pressure field with muzzle device with four expansion chambers

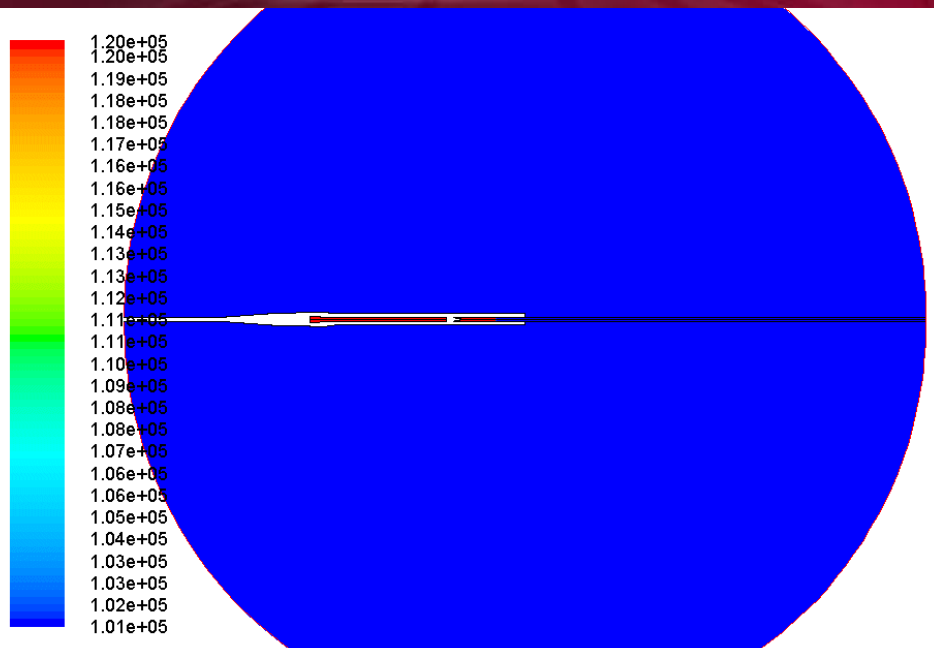
Velocity Contours



Baseline – bare muzzle

Four expansion chambers

Pressure Results



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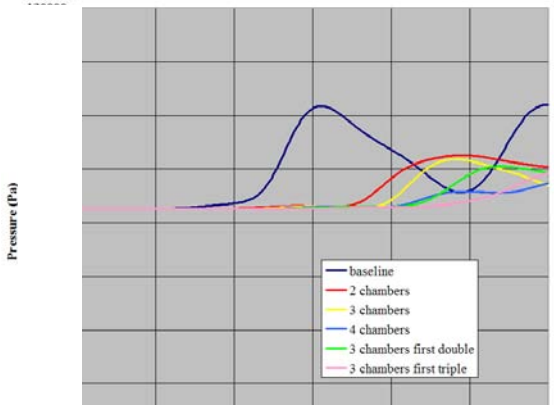
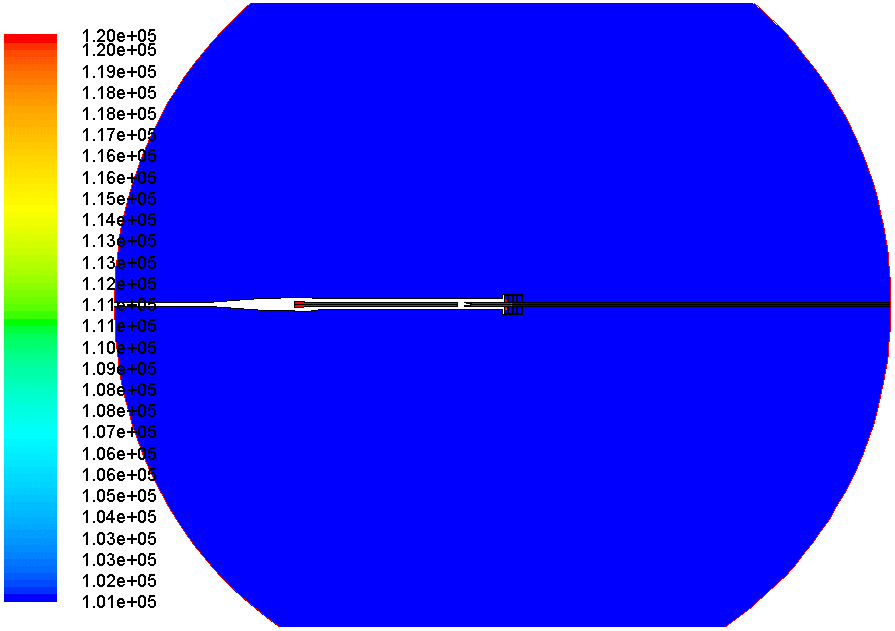


Pressures at point vs. time different arrangements



Four expansion chambers

3. Gas flow through weapon system and mechanism actuation

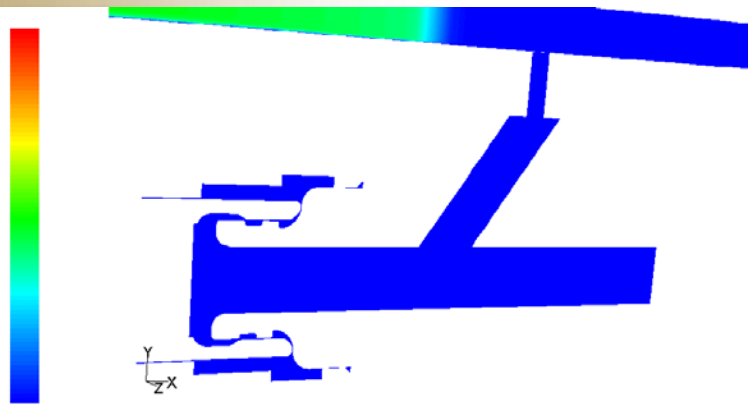
3. Gas flow internal to weapon system

Model:

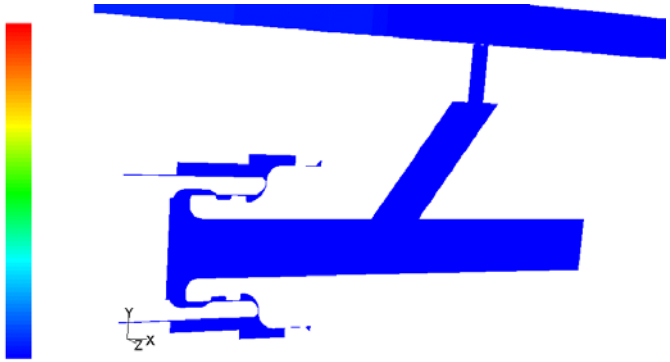
- From start of bullet motion to time bolt unlocking is approached
- Motion of bullet and operating group included
- Used to :
  - Visualize the flow field
  - Estimate pressures, temperatures, flow rates at important locations in the system
  - Estimate acting fluid forces
  - Estimate bolt/bolt carrier velocities
  - M4, M16, M249

A. Gas flow and weapon system mechanism actuation

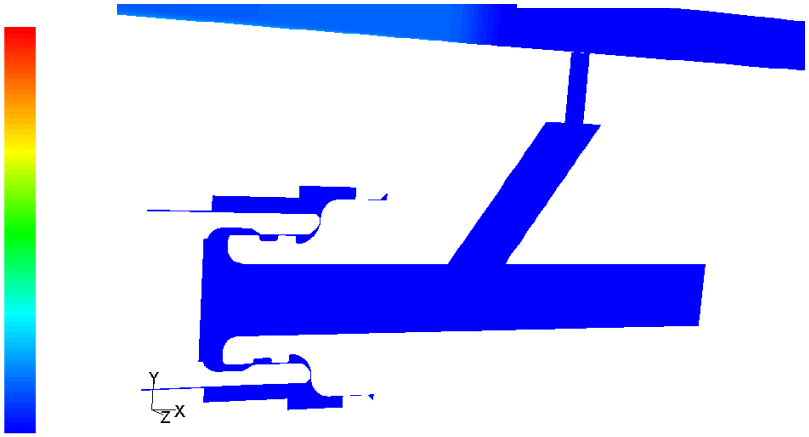
Animations M249



Velocity

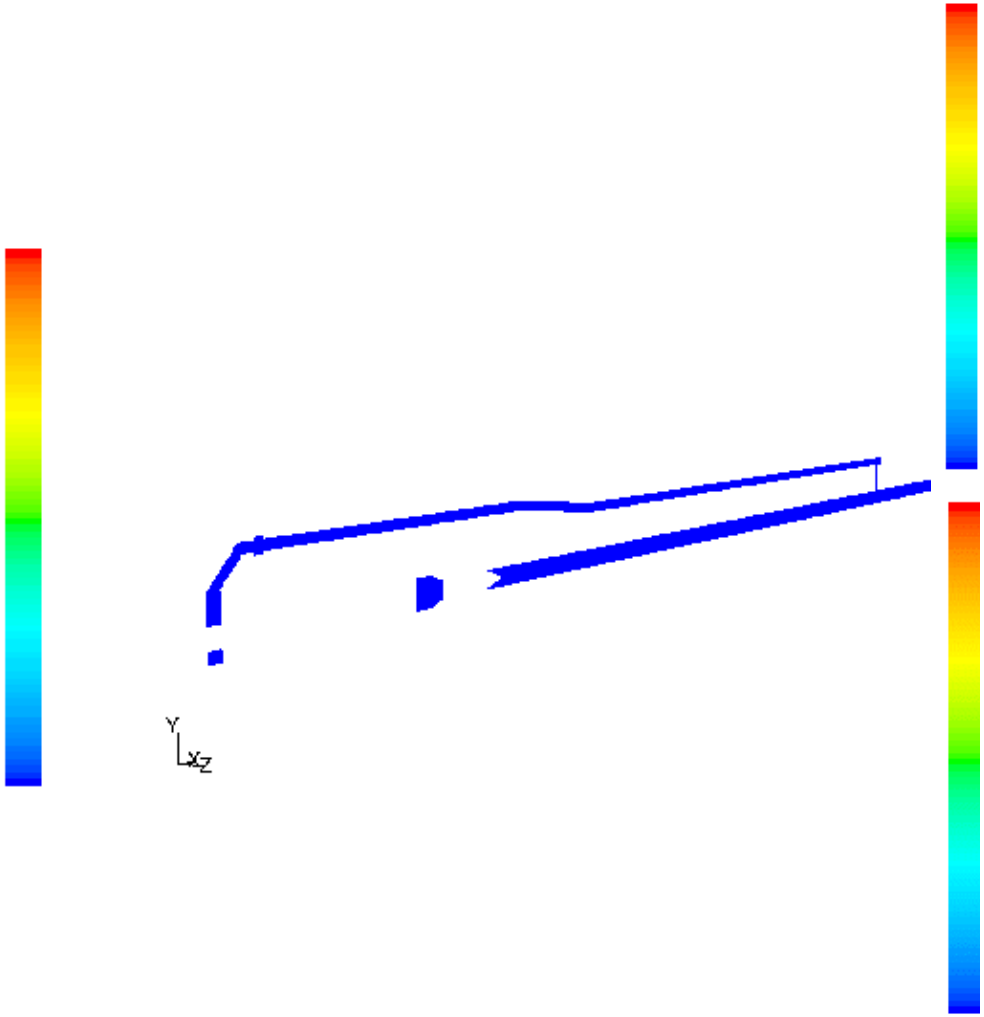


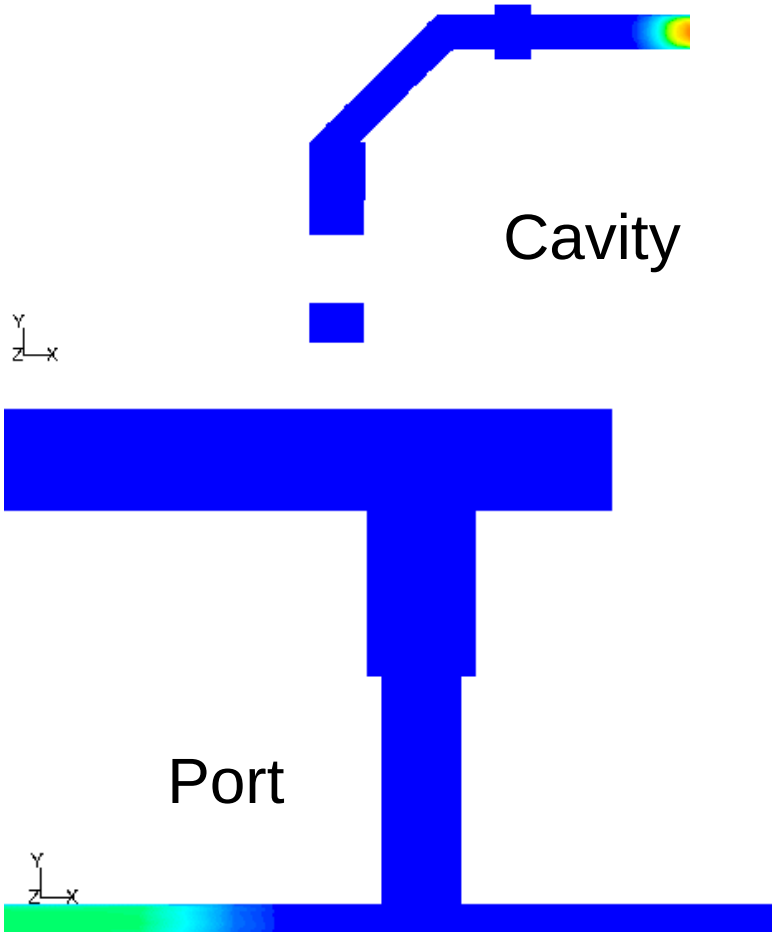
Pressure



Temperature

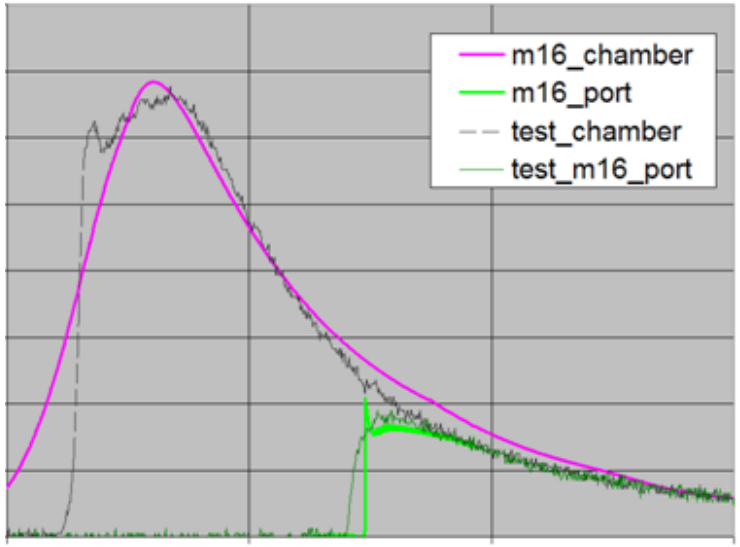
M16 Velocity Contour Animations

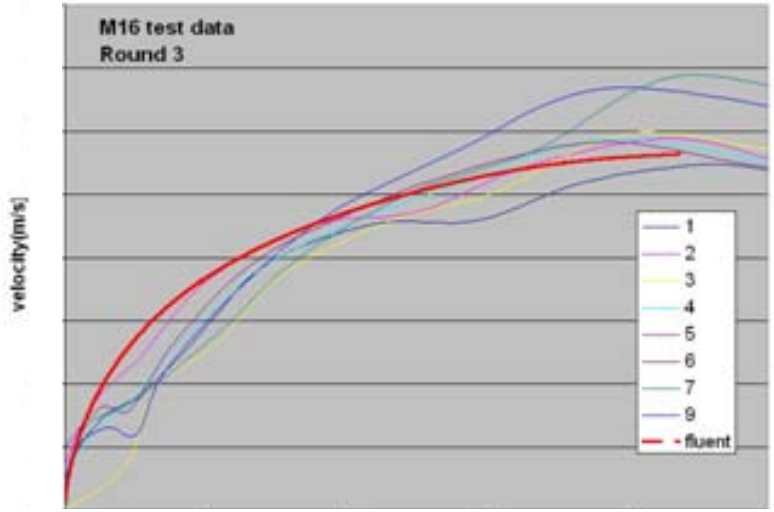




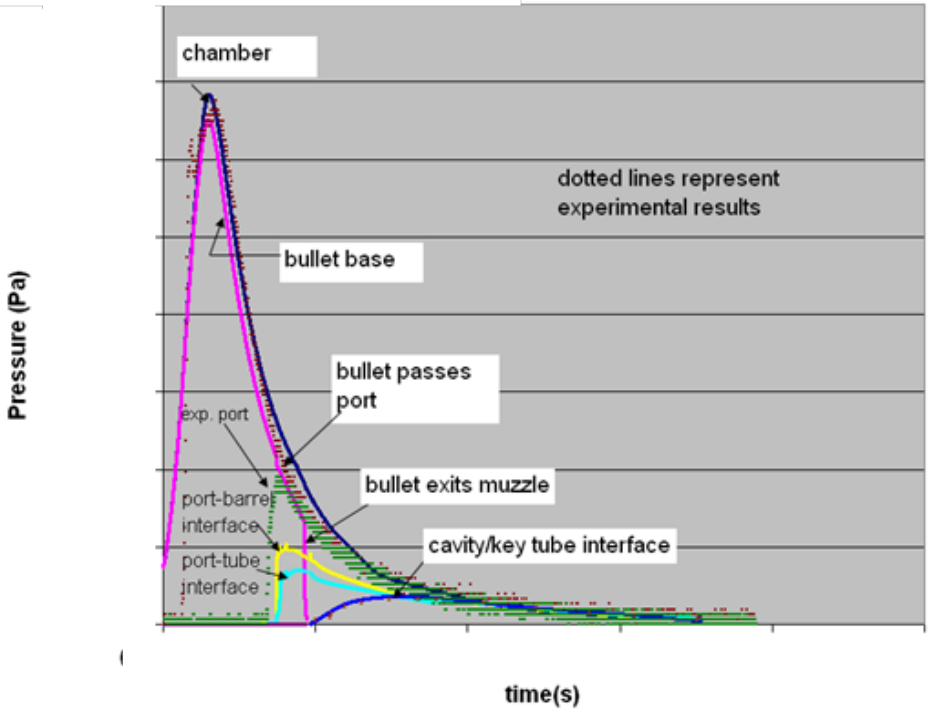
Velocity Contours

M16 data





Pressure results compared to experiment



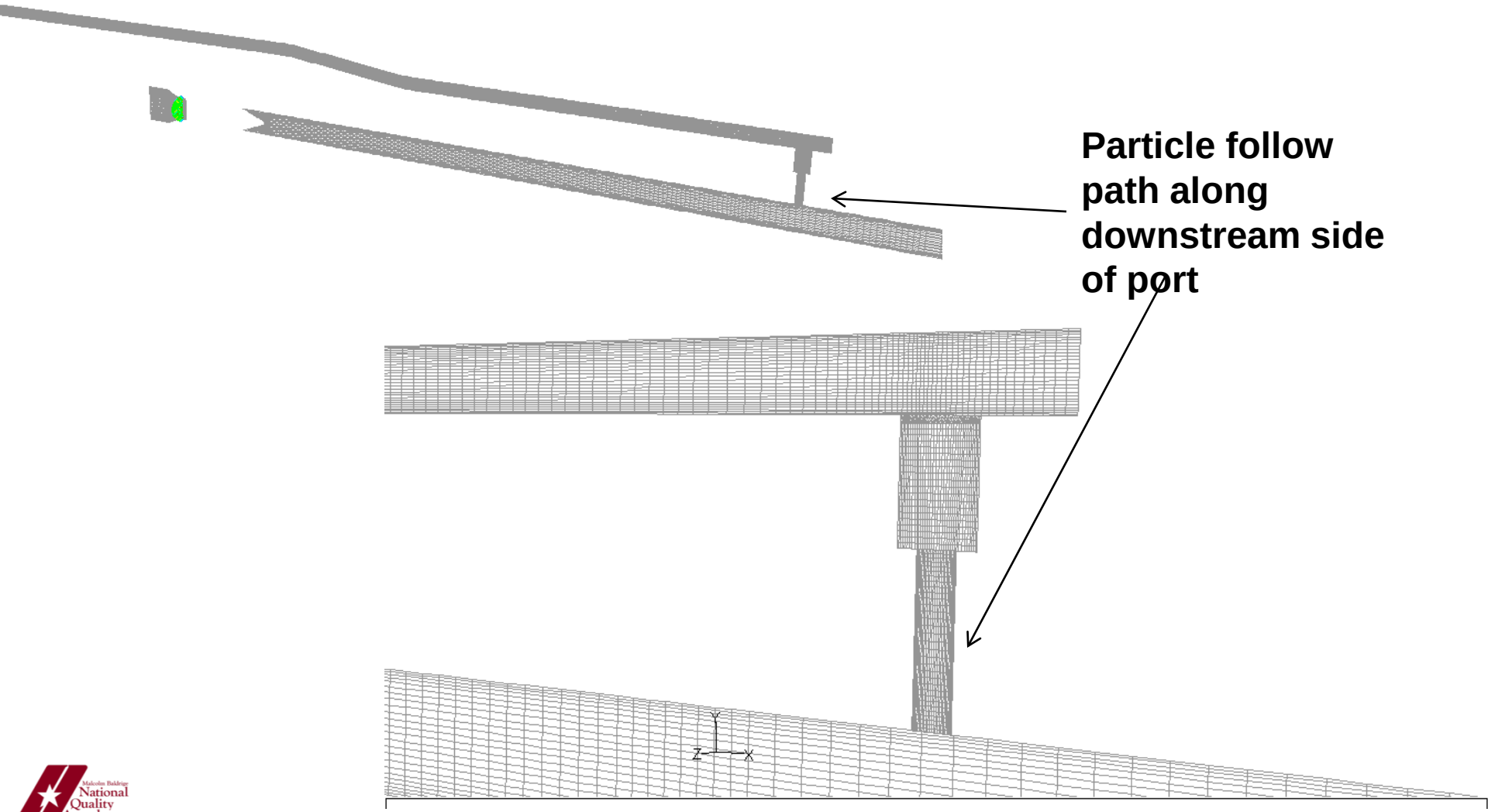
Bolt carrier motion results compared to experiment

Pressure results

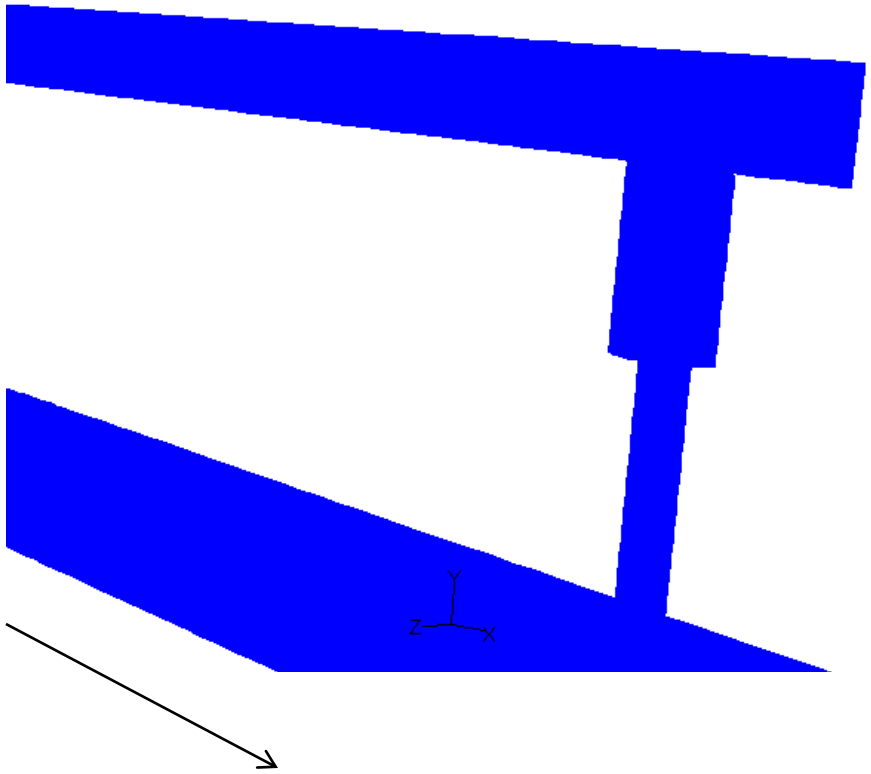
B. Particle flow carried by gas flow in M4

Flow of particles in weapon gas system

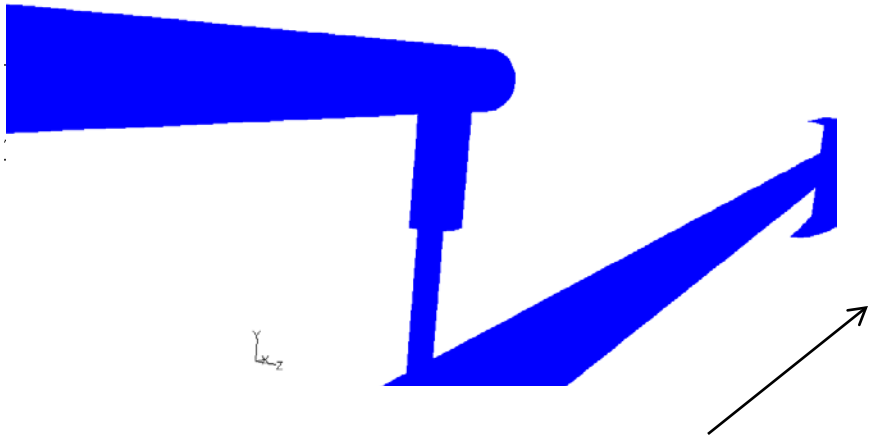
- Identify areas prone to erosion or build up



Flow of particles in weapon gas system



- Erosion most likely on downstream side of the port- corresponds to areas where port erosion has been noted
- Virtually investigate how changes in geometry alter characteristics

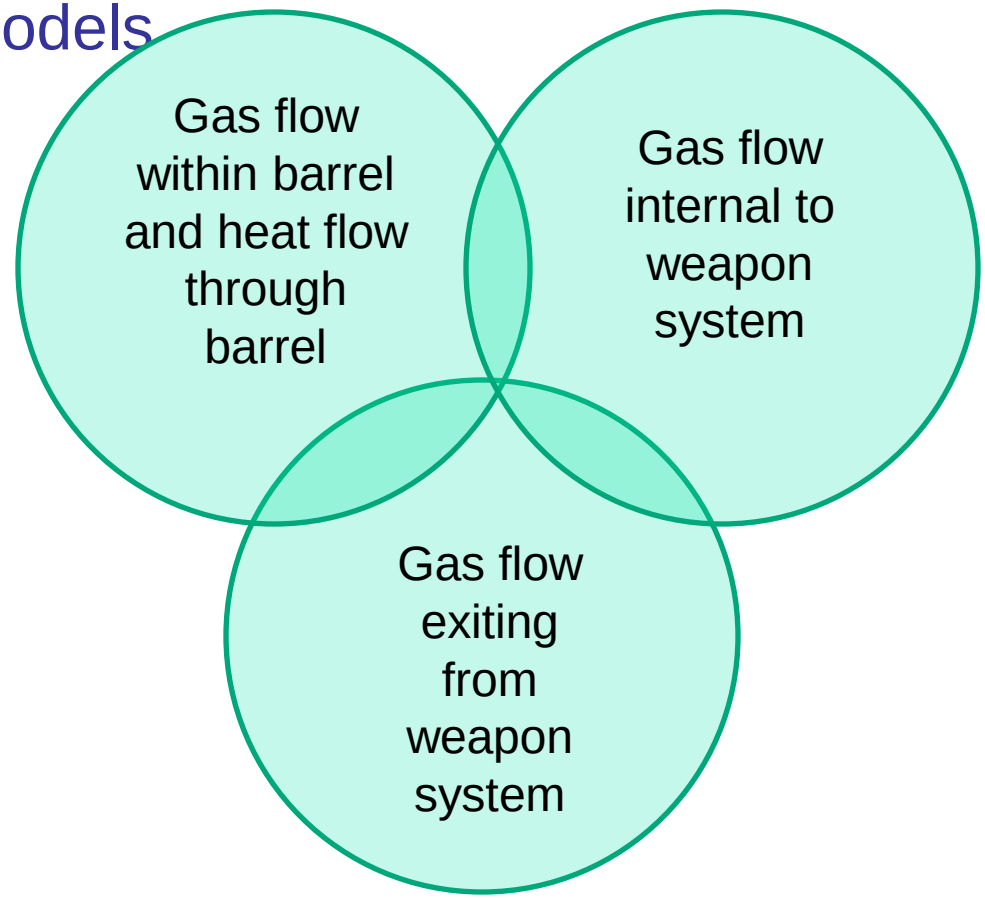


Conclusions

- CFD modeling can be used to “test” designs in virtual environment
  - Evaluate barrel temperature
  - Evaluate muzzle device designs
  - Understand and estimate gas flow through weapons systems
- Reduces number of physical tests
- Provides basis for design improvements and new designs
- Provides insight and understanding of current weapon system operation

Future Work

- Continue to develop and apply gas flow and heat transfer models



- Long term goals: Integrate fluid flow models directly with mechanism and stress analysis/dynamics

Laurie Florio, Ph.D.

US Army ARDEC

Technology Branch

Small and Medium Caliber
Armaments Division

laurie.florio@us.army.mil