RDECOM

Analysis of Throw Distance Produced by a Sub-detonative Munition Response

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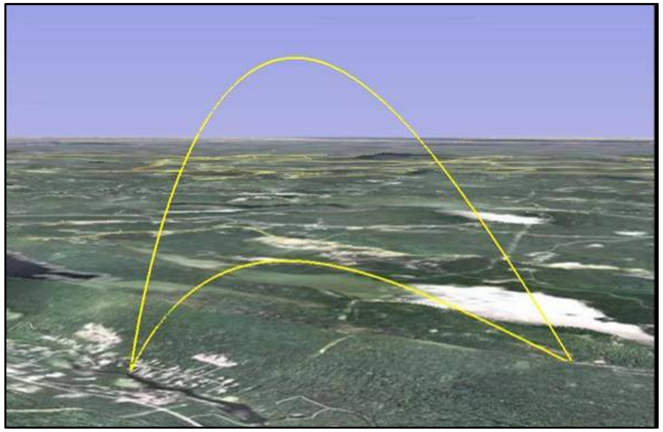
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



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Outline

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- Technical Analysis
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  - High Rate Continuum Modeling
  - Aeroballistics Analysis
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Introduction

- IM type III response (explosion): “Metal cases are fragmented (brittle fracture) into large pieces that are often thrown long distances”.
- The interpretation of “long distances” has recently been a question of concern to ARDEC.
- Discussions with the IM technical community have indicated that quite often an interpretation is that this references distances significantly greater than 15 meters, one of the criteria used to differentiate between type V and IV and distances of a hundred meters or more have been observed.

- Be aware: Fragment throw to much longer distances, on the order of at least two kilometers is possible and has occurred for the case of sub-detonative munitions response.
- The statistical occurrence of such long fragment throw distances for sub-detonative munitions response is not currently known.

Incident Description

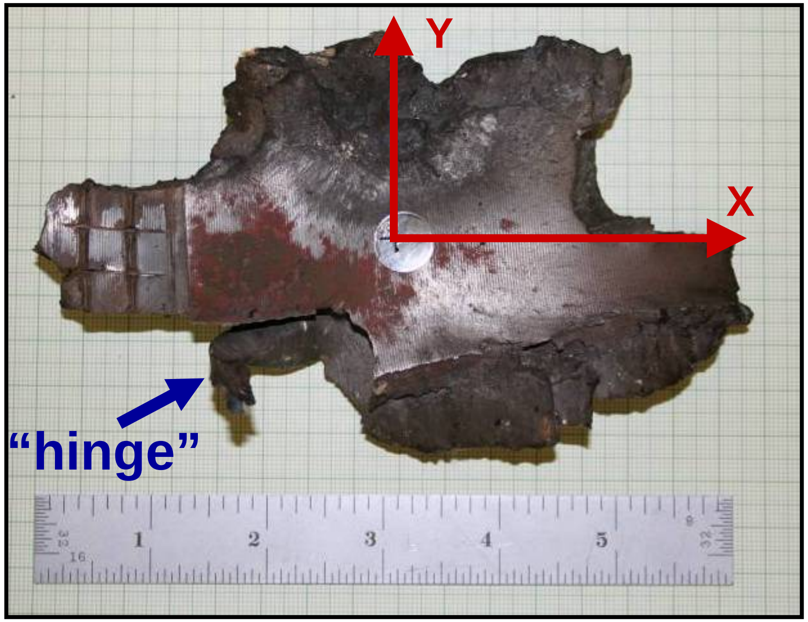
Tests in support of Explosive Ordnance Disposal (EOD) research and development activity. The purpose of the tests was to develop methods for disposal of unexploded munitions. Projectile was purposely subjected to non-standard initiation using a shaped charge directed at the projectile.

- Testing on unfuzed, comp B loaded M107, 155mm, artillery projectile
- 1st shaped charge fired into M107 base
- No initiation/ignition of M107
- 2nd shaped charge fired into sidewall
- Sub-detonative response
- Generates 1lb 14oz fragment
- Fragment travels ~1824 meters (5984 ft)
- Greatly exceeds established safety distance zone (SDZ)


Fragment

Fragment Analysis

- Metallurgical tests of the fragment
  - 1046 alloy, failed in shear with a tensile component (hinge)
- Fragment Solid Model
  - laser scan of the fragment
  - generated CAD solid model
- Physical Properties
  - Calculated and measured the fragment's physical properties



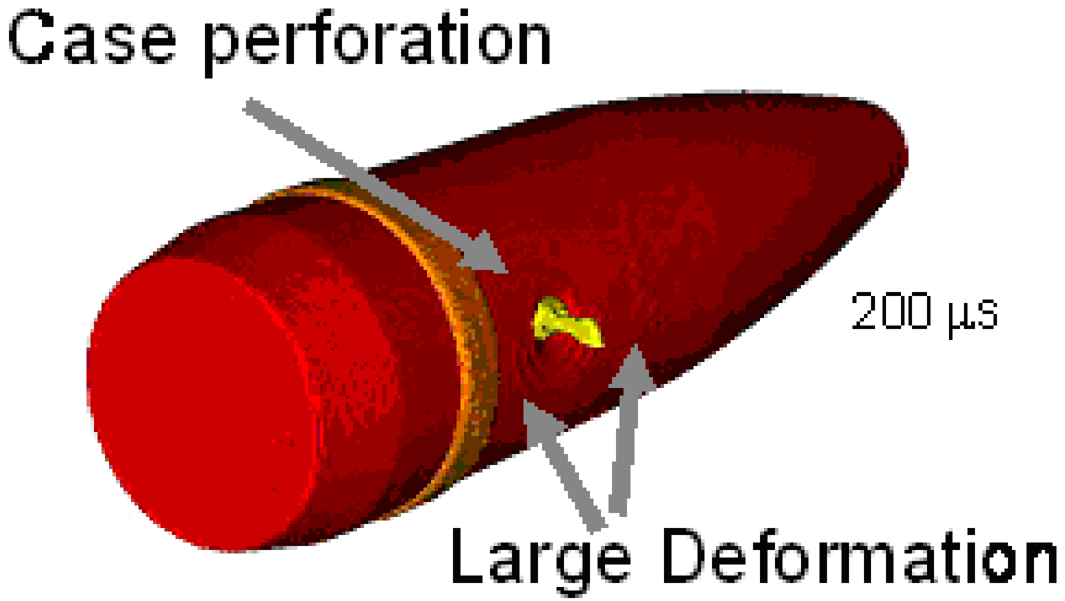
CAD physical properties		
Mass	1.902	Lbs
Ixx	1.005	lbs-in.^{2}
Iyy	3.264	lbs-in.^{2}
Izz	4.118	lbs-in.^{2}

measured physical properties		
Mass	1.854	Lbs
Ixx	1.011	lbs-in^2
Iyy	3.183	lbs-in^2
Izz	3.995	lbs-in^2

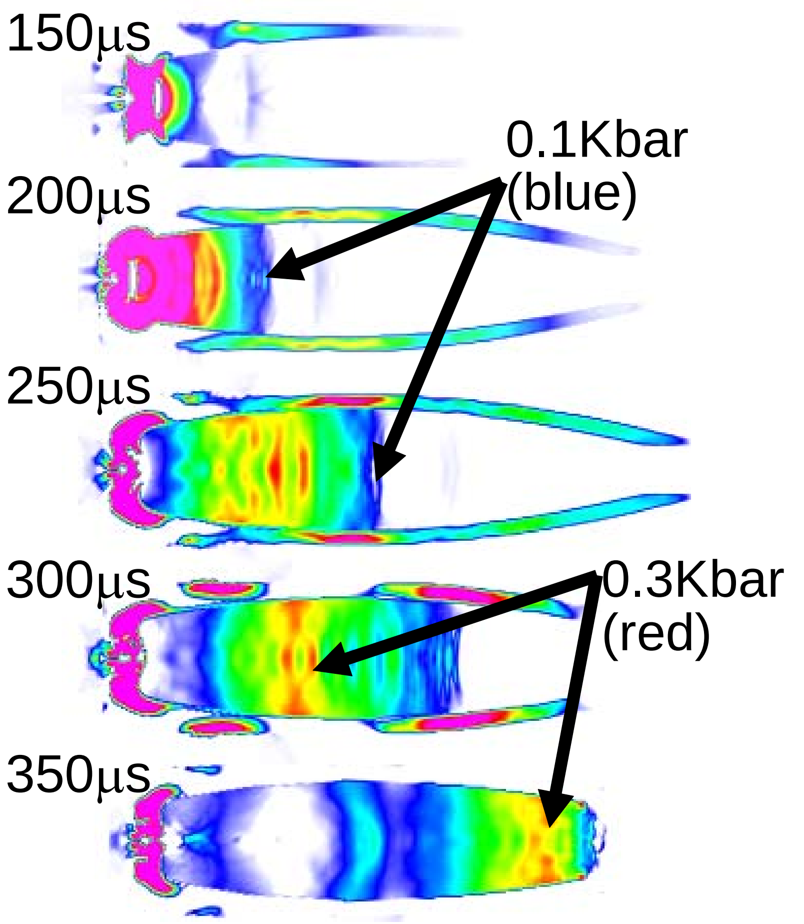
Close agreement: difference attributed to small voids

High Rate Modeling ALE3D

- Modeled shaped charge shot into base
  - damaged projectile base not sidewall
  - damaged cast Comp-B explosive
- Modeled shaped charge shot into sidewall
  - did not form large fragment
  - significant momentum transfer

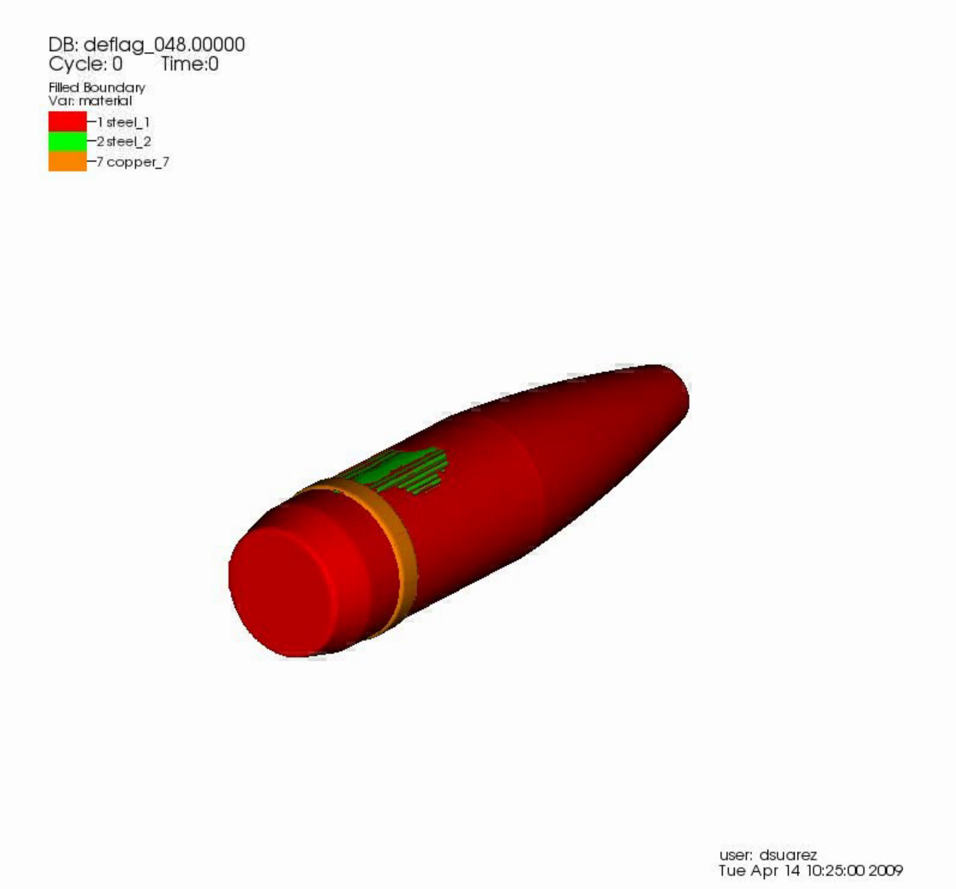


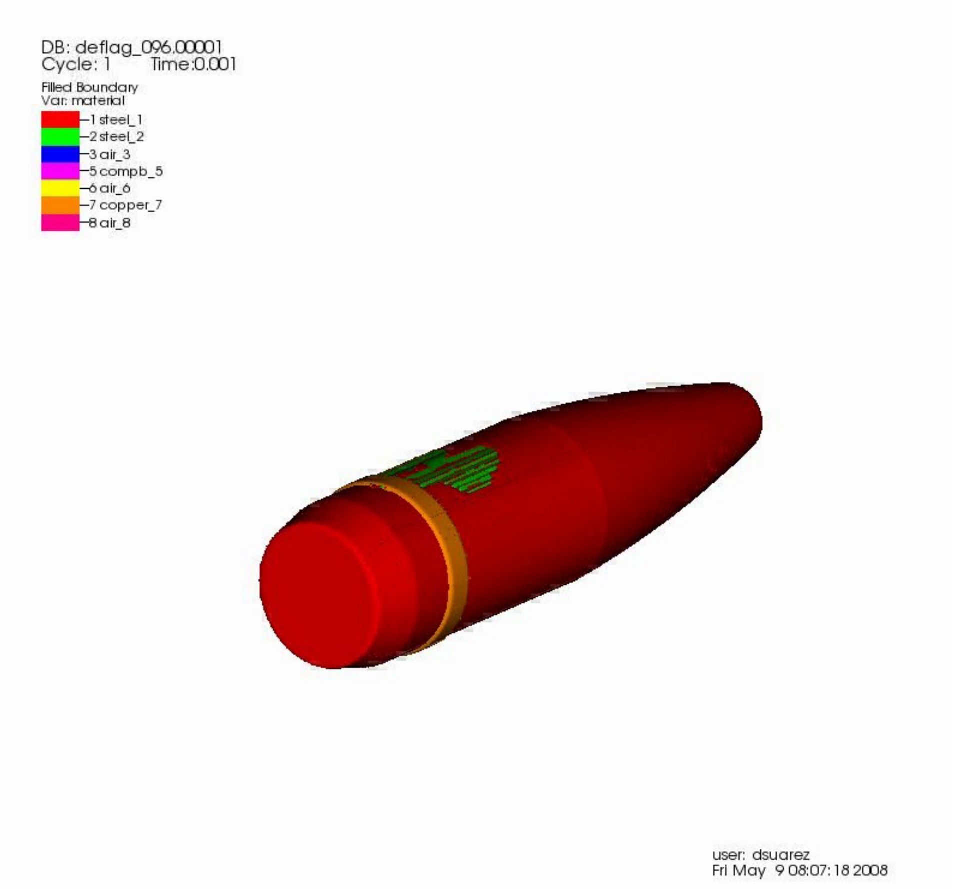
M107 Shaped Charge Attack



Pressure profile plots from SC base attack

High Rate Modeling
ALE3D





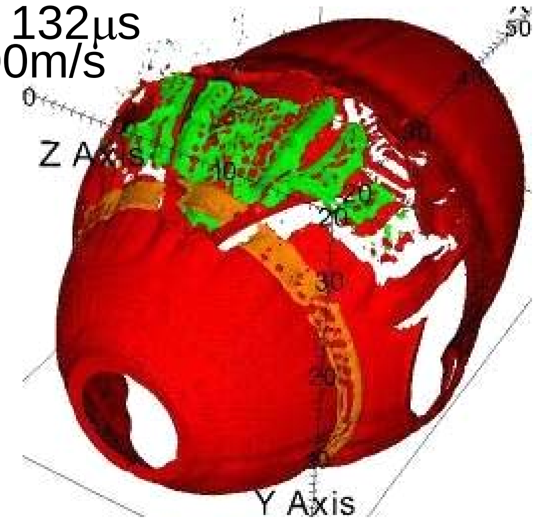
Detonation
(fragment breaks-up)

Deflagration

High Rate Modeling ALE3D

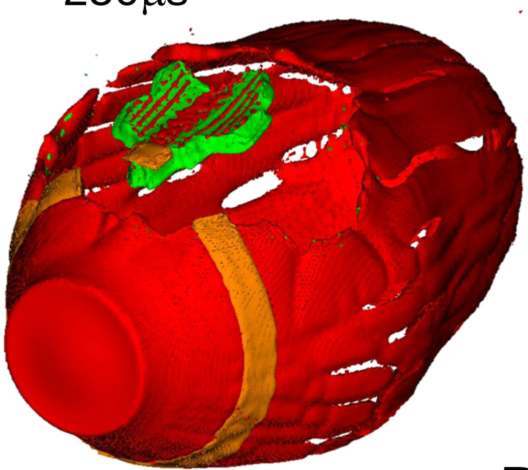
- Explosive response modeling
  - high order detonation generates smaller fragments
  - sub-detonation response formed large fragment
  - sub-detonation response can invert fragment
  - sub-detonation response produces a lower initial velocity

132μs
~1500m/s



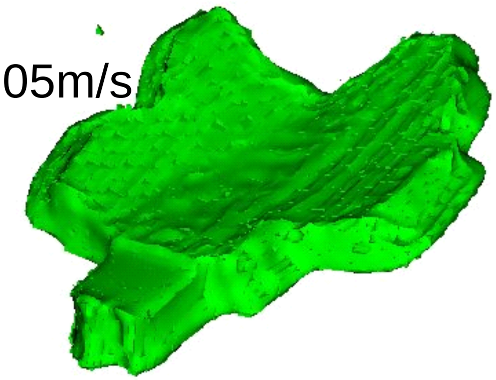
Detonation
(fragment breaks-up)

250μs



Deflagration

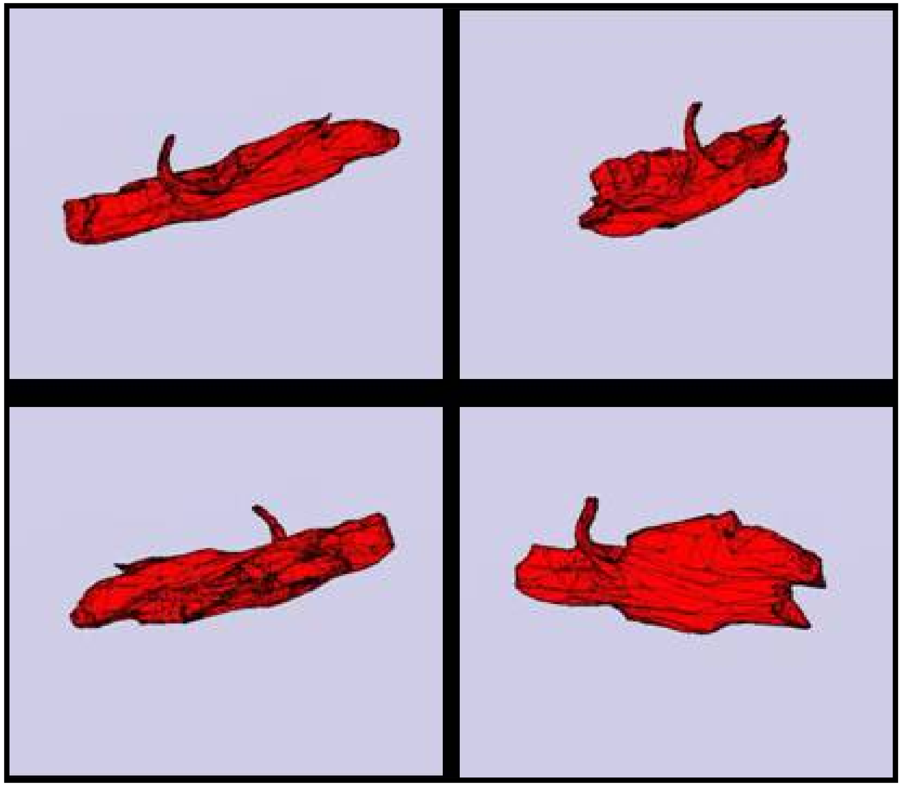
605m/s



Deflagration fragment
(upward curvature)

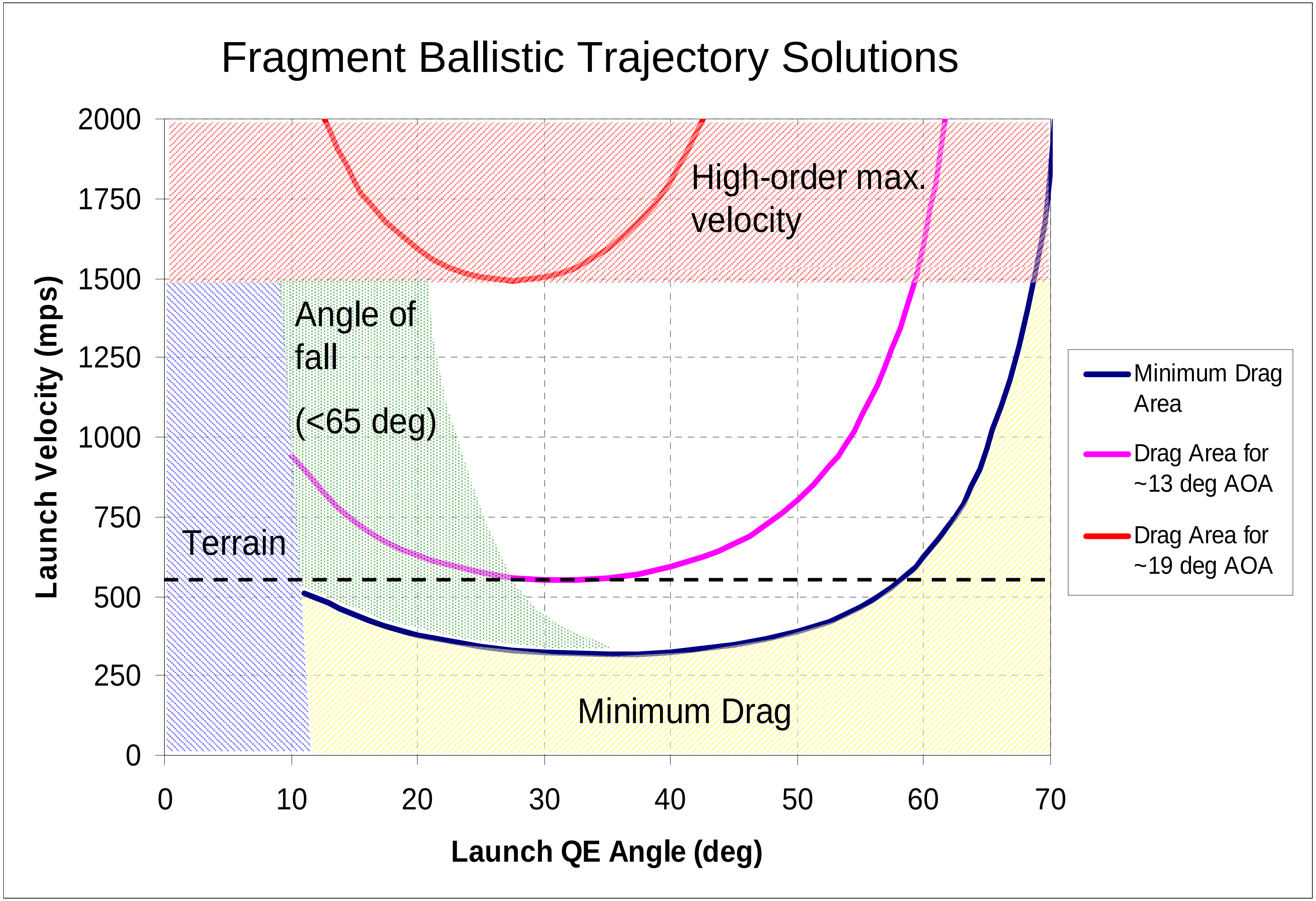
Aeroballistics Analysis

- Aeroballistics Analysis
  - characterized fragment's aeroballistics properties
  - established range of possible fragment trajectories
  - established fragment achieved low drag, edge on orientation
  - determined a significant spin rate was required to maintain low drag edge on orientation
  - tumbling fragment could not have achieved this range even with a high order detonation
  - supports initial velocities generated from sub-detonative response

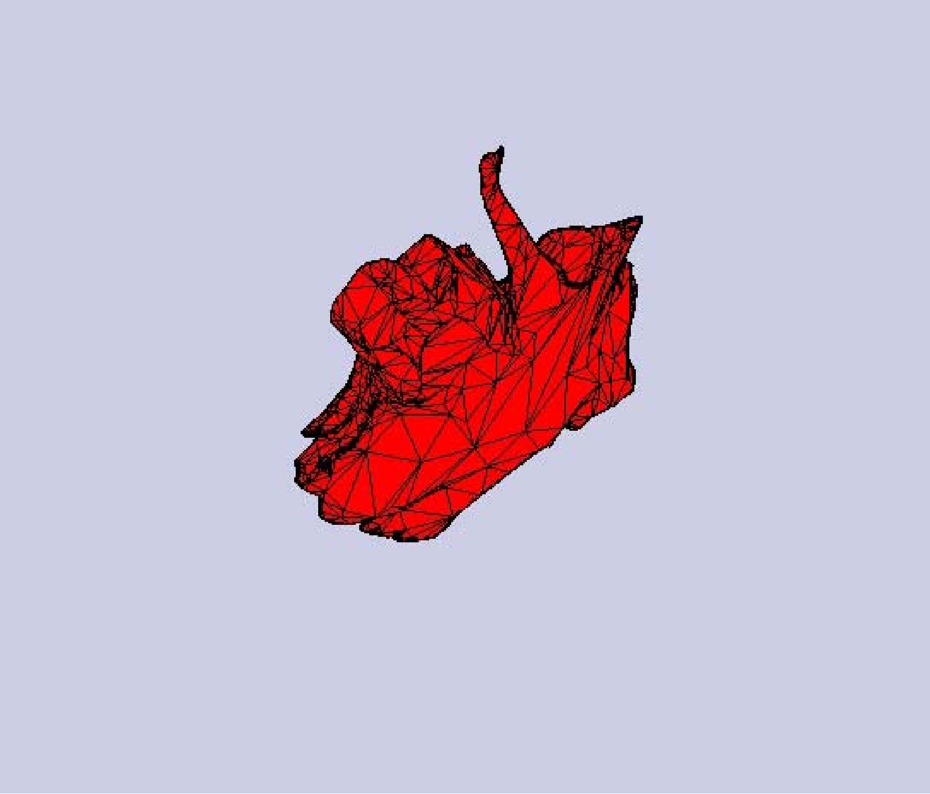


Flight Simulation Snapshots

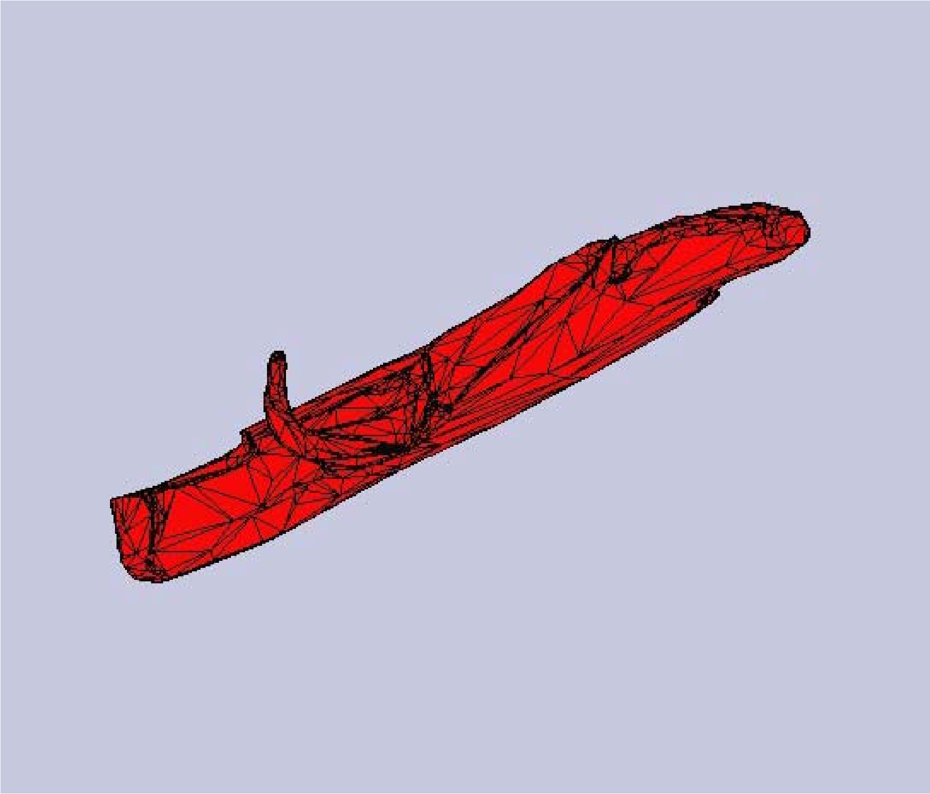
Aeroballistics Results



Aeroballistics Analysis



Lower Spin Rate
(fragment tumbles)



Higher Spin Rate
(fragment stable)

Standard assumption for fragment aeroballistics calculations is random orientation (fragment tumbles)

Technical Findings

- During investigation, learned of and conducted evaluation on other fragments exceeding established HFDs
  - Only 4 identified events
  - 2 of the events with fragments that look fairly similar to the ARDEC fragment: large flat fragments
  - Non-standard initiations have caused large flat fragments
  - Standard initiation has also caused large fragments …but not as large as non-standard initiation

Fragment

large, fairly flat

Technical Findings

- 3 Main factors (high likelihood)
  - Reaction within the M107 was deflagration, creating a relatively large and aerodynamically stable fragment (A plastically yielding "hinge" held onto a large, flat fragment reducing likelihood of tumble)
  - Fragment flew aerodynamically-stable rather than tumbling
  - Generally accepted methods for calculating HFD assume fragments tumble rather than fly aerodynamically stable

Conclusions

- IM testing commonly produces sub-detonative muntions response: fragment throw to much longer distances than would be predicted using established hazard fragment distance (HFD) analysis is possible
- Aeroballistics analysis determined fragment was capable of achieving the demonstrated range (1824 meters, 5,984 ft) and greater
  - low drag, edge on orientation with spin required
  - many possible combinations of launch quadrant elevations and velocities
- Sub-detonative response
  - formed large fragment with hinge
  - provided spin to stabilize fragment orientation
  - provided required fragment initial velocity