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14. ABSTRACT
Two projectile IGES geometry files are provided by ONR. Finite element models have been developed for both projectiles in HyperMesh which will be used in different FEA simulations.
Quarter-symmetric model is used in AutoDyn to simulate DoP experiments on aluminum targets and ceramic-faced aluminum targets with .30cal AP M2 projectile using SPH.
Future work will provide model validation runs based on the DoP experiments described in reference - ARL-TR-2219, 2000.

15. SUBJECT TERMS
.30cal AP M2 Projectile, 762x39 PS Projectile, SPH, Aluminum 5083, SiC, DoP Expeminets, AutoDyn Simulations

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MONTHLY REPORT

JULY 2013

MODELING AND SIMULATION OF CERAMIC ARRAYS TO IMPROVE BALLAISTIC PERFORMANCE

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MONTHLY REPORT FOR JULY 2013

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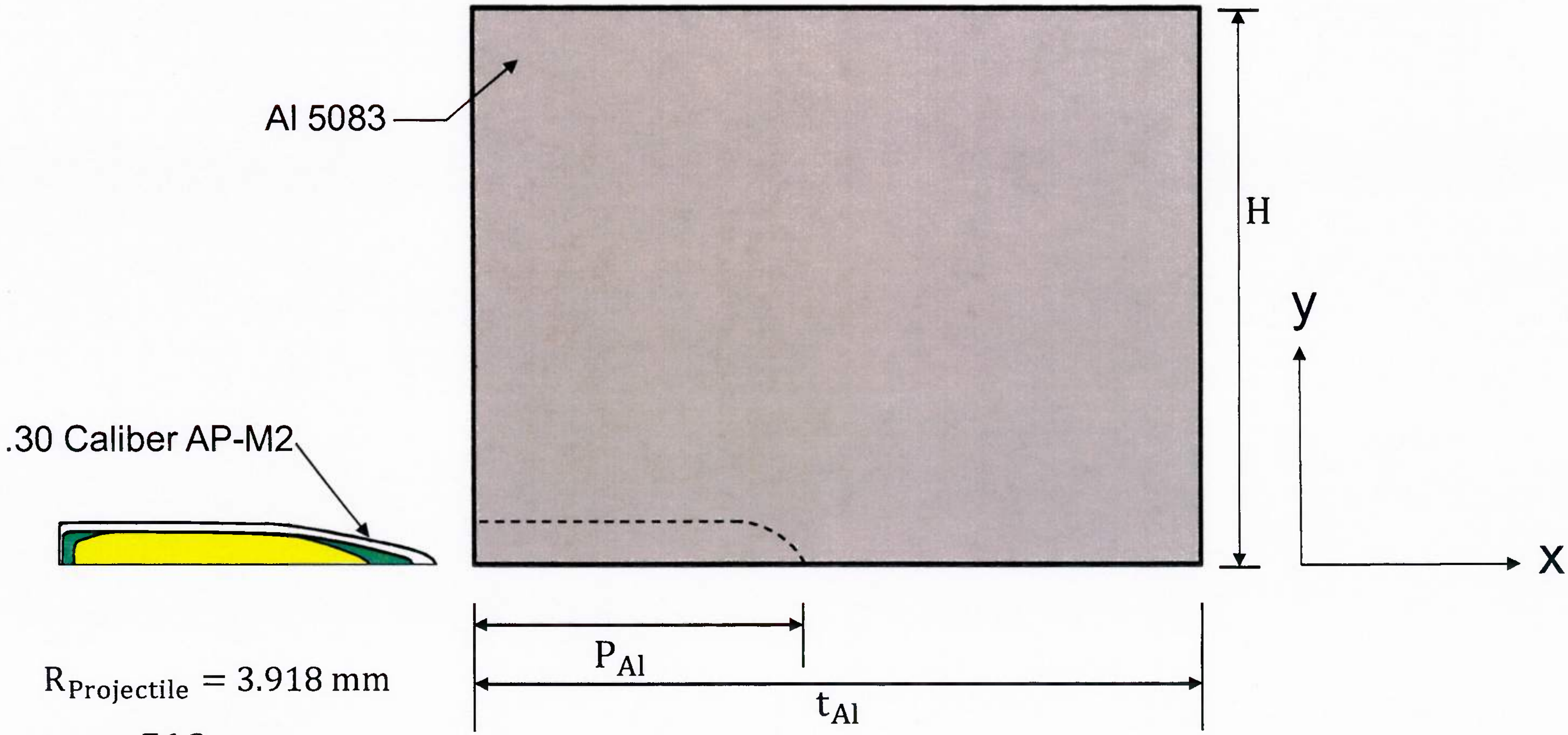
DOP OF .30cal PROJECTILE INTO MONOLITHIC ALUMINUM (Ref: ARL-TR-2219, 2000.)



$R_{Projectile} = 3.918$ mm

$t_{Al} = 76.2$ mm

$H = 20.0$ mm

$V_P = 400 - 900$ m/s

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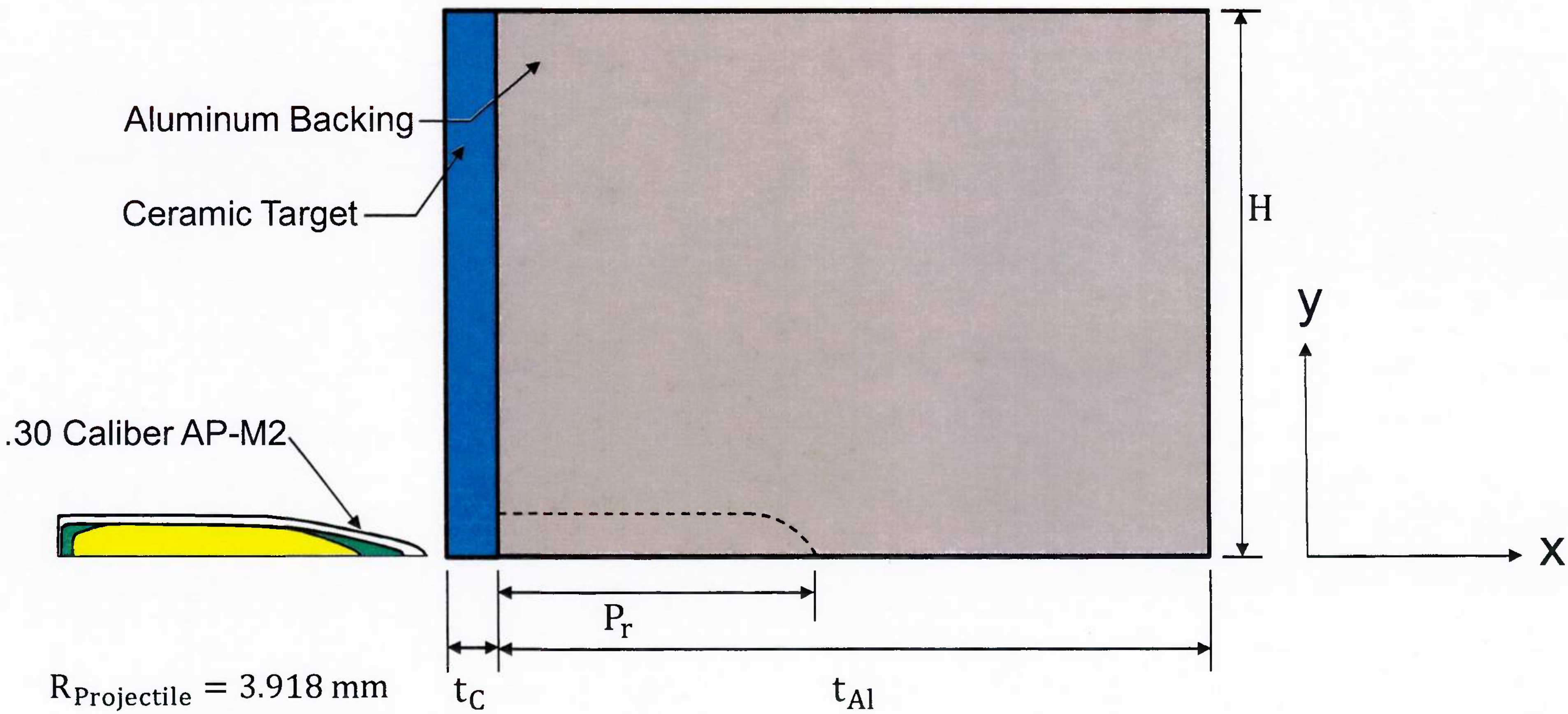
DOP OF .30cal PROJECTILE INTO CERAMIC-FACED TARGET (Ref: ARL-TR-2219, 2000.)



$R_{Projectile} = 3.918\ \mathrm{mm}$

$t_C = 1.25, 2.50, 3.75, 5.00\ \mathrm{mm}$

$t_{Al} = 76.2\ \mathrm{mm}$

$H = 20.0\ \mathrm{mm}$

$V_P = 841 \pm 15\ \mathrm{m/s}$

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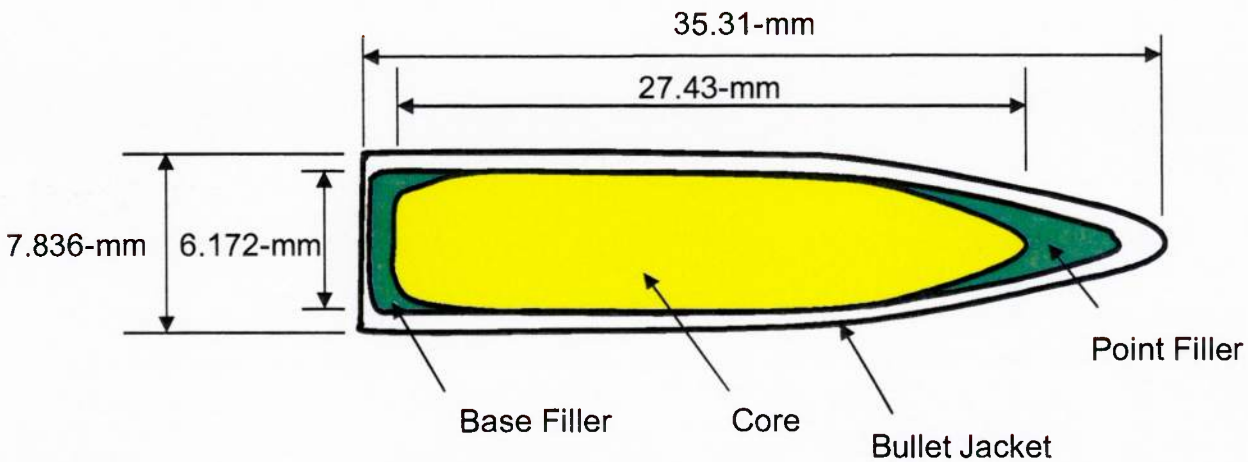
30AP-M2 PROJECTILE MASS PROPERTIES



Component	Material	Weight (g)
Jacket	Gilding Metal	4.2
Core	Hardened Steel - RC 63	5.3
Point Filler	Lead	0.8
Base Filler	Lead	0.5
Total Weight		**10.8**

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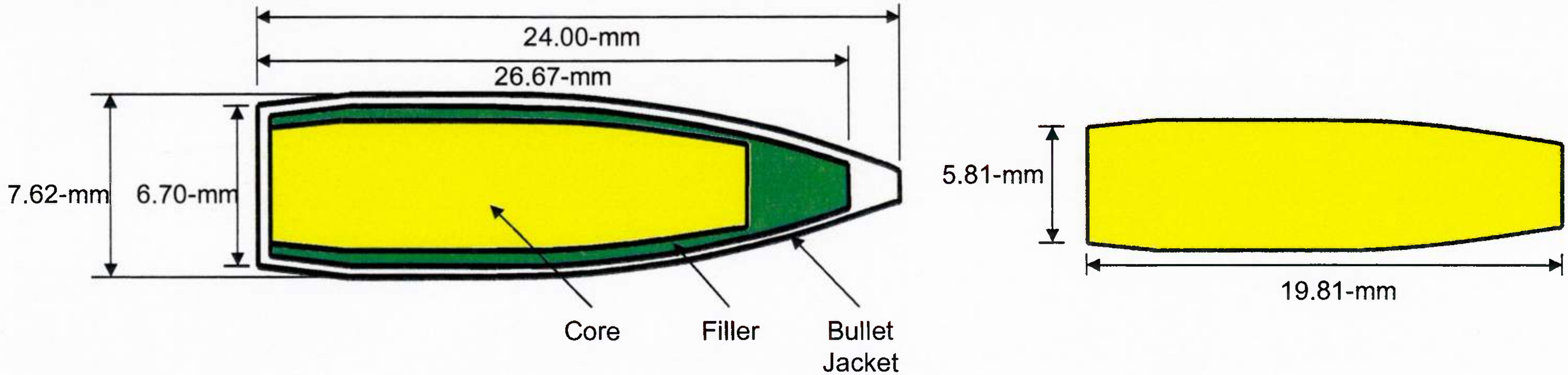
7.62x39 PS PROJECTILE PROPERTIES



Component	Material
Jacket	Copper-Plated Steel
Core	Steel
Filler	Lead

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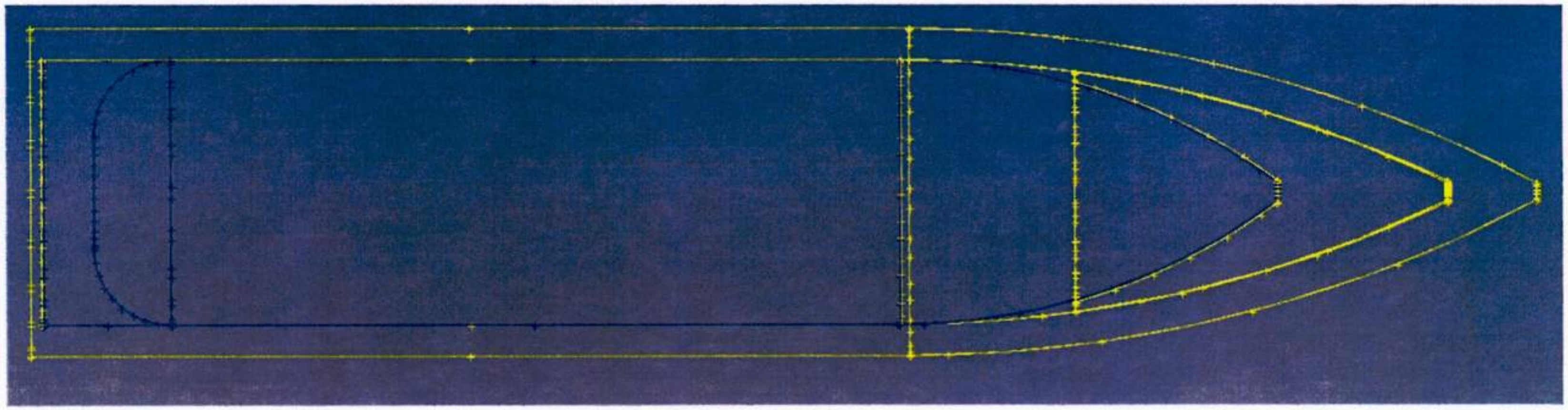
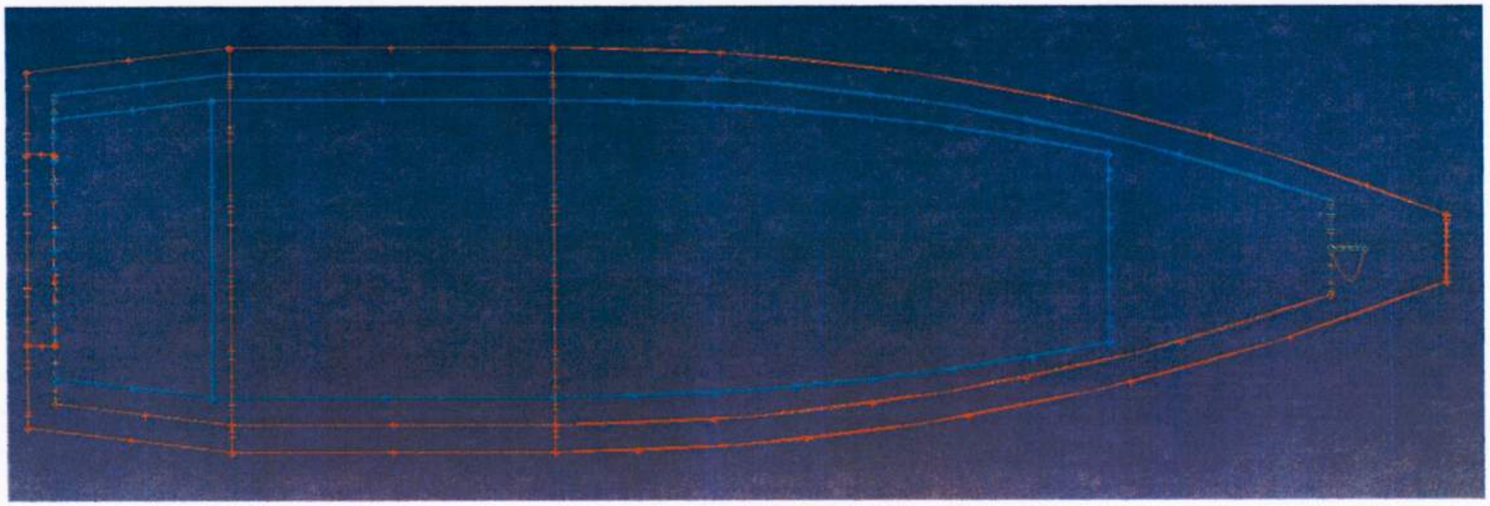
PROJECTILE GEOMETRIES (Ref: ONR, 2013.)

.30cal AP M2



7.62x39 PS



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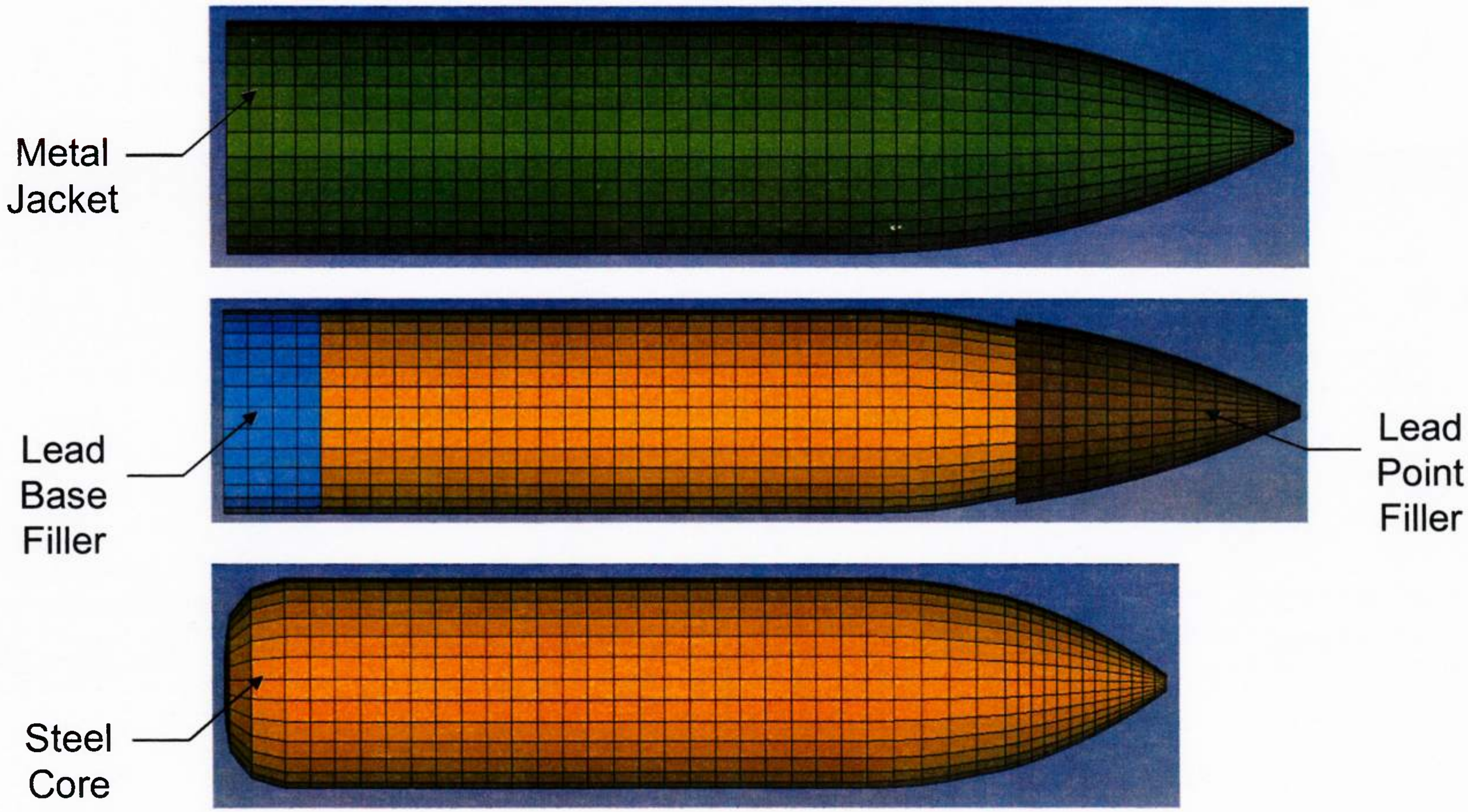
SOLID MODEL OF .30cal AP M2 PROJECTILE



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MATERIAL PROPERTIES – Al 5083

Experimental Al 5083

	Al 5083
Density (g/cm^3)	2.65
Tensile Strength (MPa)	377.1
Yield Strength (MPa)	318.5
Elongation (%)	9.3

Ref:
MTL TR-86-14, 1986.
ARL-TR-2219, 2000.

AutoDyn Al 5083

Equation of State	**Linear**
Reference density	2.70000E+00 (g/cm3)
Bulk Modulus	5.83300E+11 (ubar)
Reference Temperature	2.93000E+02 (K)
Specific Heat	9.10000E+06 (erg/gK)
Thermal Conductivity	0.00000E+00 ( )
Strength	**Johnson Cook**
Shear Modulus	2.69200E+11 (ubar)
Yield Stress	1.67000E+09 (ubar)
Hardening Constant	5.96000E+09 (ubar)
Hardening Exponent	5.51000E-01 (none)
Strain Rate Constant	1.00000E-03 (none)
Thermal Softening Exponent	8.59000E-01 (none)
Melting Temperature	8.93000E+02 (K)
Ref. Strain Rate (/s)	1.00000E+00 (none)
Strain Rate Correction	1st Order
Failure	**None**
Erosion	**None**
Material Cutoffs	-
Maximum Expansion	1.00000E-01 (none)
Minimum Density Factor	1.00000E-05 (none)
Minimum Density Factor (SPH)	2.00000E-01 (none)
Maximum Density Factor (SPH)	3.00000E+00 (none)
Minimum Soundspeed	1.00000E-04 (cm/s)
Maximum Soundspeed (SPH)	1.01000E+20 (cm/s)
Maximum Temperature	1.00000E+16 (K)

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MATERIAL PROPERTIES - SiC

Experimental SiC

	SiC
Density (g/cm^3)	3.20
Elastic Modulus (GPa)	455
Shear Modulus (GPa)	195
Longitudinal Wave Velocity (km/s)	12.3
Poisson's Ratio	0.14
Hardness (kg/mm^2)	2700
Compressive Strength (MPa)	3410

Ref:
ARL-TR-2219, 2000.

AutoDyn SiC

Equation of State	**Polynomial**
Reference density	3.21500E+00 (g/cm3)
Bulk Modulus A1	2.20000E+12 (ubar)
Parameter A2	3.61000E+12 (ubar)
Parameter A3	0.00000E+00 (ubar)
Parameter B0	0.00000E+00 (none)
Parameter B1	0.00000E+00 (none)
Parameter T1	2.20000E+12 (ubar)
Parameter T2	0.00000E+00 (ubar)
Reference Temperature	2.93000E+02 (K)
Specific Heat	0.00000E+00 (erg/gK)
Thermal Conductivity	0.00000E+00 ( )
Strength	**Johnson-Holmquist**
Shear Modulus	1.93500E+12 (ubar)
Model Type	Segmented (JH1)
Hugoniot Elastic Limit, HEL	1.17000E+11 (ubar)
Intact Strength Constant, S1	7.10000E+10 (ubar)
Intact Strength Constant, P1	2.50000E+10 (ubar)
Intact Strength Constant, S2	1.22000E+11 (ubar)
Intact Strength Constant, P2	1.00000E+11 (ubar)
Strain Rate Constant, C	9.00000E-03 (none)
Max. Fracture Strength, SFMAX	1.30000E+10 (ubar)
Failed Strength Constant, ALPHA	4.00000E-01 (none)
Failure	**Johnson Holmquist**
Hydro Tensile Limit	-7.50000E+09 (ubar)
Model Type	Segmented (JH1)
Damage Constant, EFMAX	1.20000E+00 (none)
Damage Constant, P3	9.97500E+11 (ubar)
Bulking Constant, Beta	1.00000E+00 (none)
Damage Type	Instantaneous (JH1)
Tensile Failure	Hydro (Pmin)

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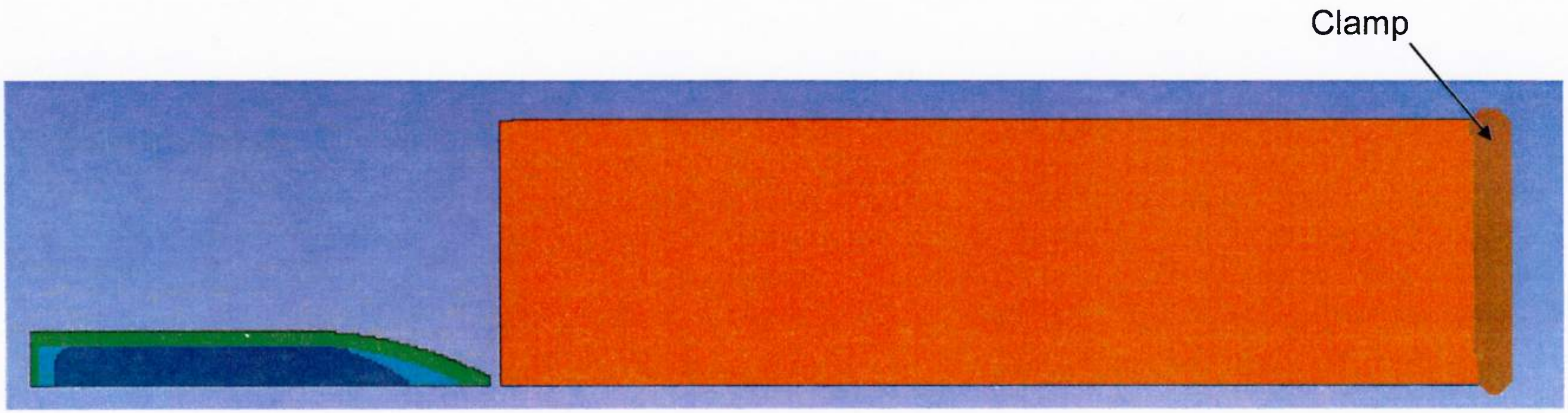
AUTODYN QUARTER-SYMMETRIC MODEL



- ❑ Smoothed-particle hydrodynamics (SPH) used for all parts
- ❑ Particle size = 0.30-mm totaling 351k elements
- ❑ Clamp boundary condition used at end of aluminum to secure the target
- ❑ Material strength and damage properties will be varied to validate ARL-DoP data in future

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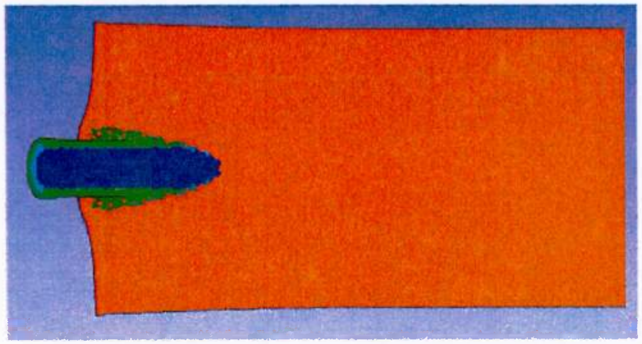
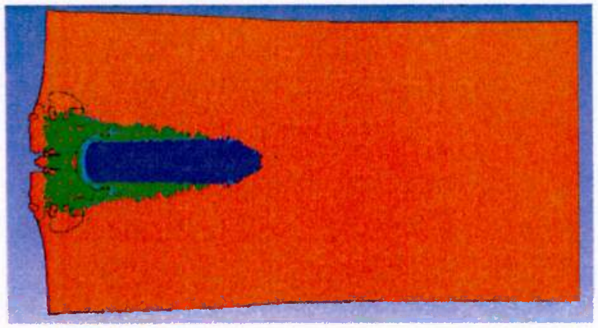
SHOT NO. 2802, V=701.6 m/s

$t = 0.0153$ ms



$t = 0.0402$ ms



$t = 0.0715$ ms

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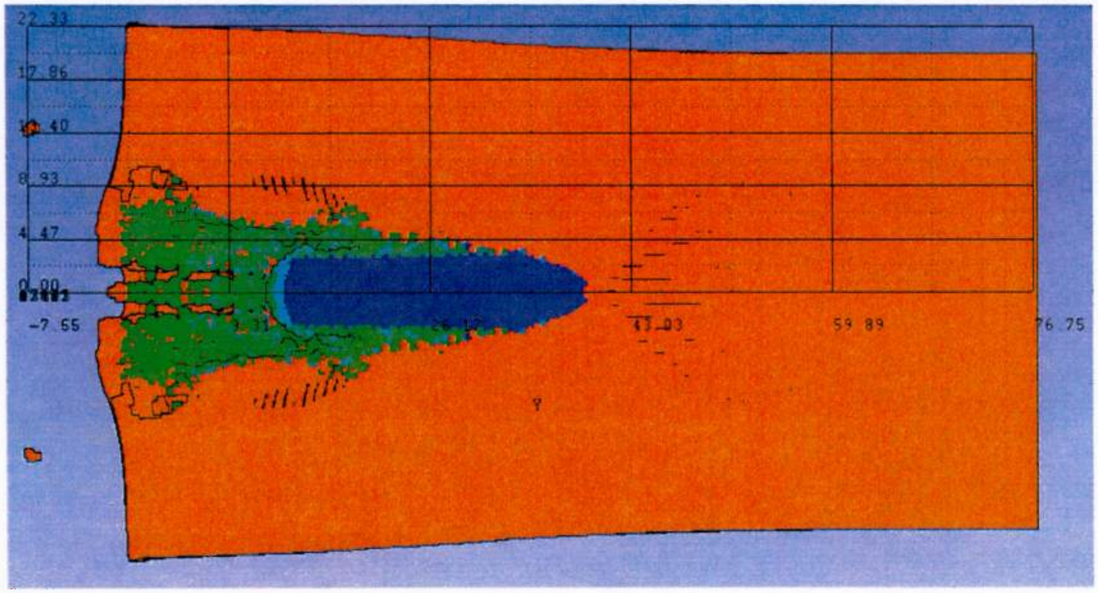
SHOT NO. 2802, V=701.6 m/s



$t = 0.1427\ \mathrm{ms}$

$\text{AutoDyn DOP} = 37.785\ \text{mm}$

$\text{Experimental DOP} = 33.8\ \text{mm}$

Conclusion: Reasonable result since yaw and pitch are not considered in AutoDyn run while present in experiment

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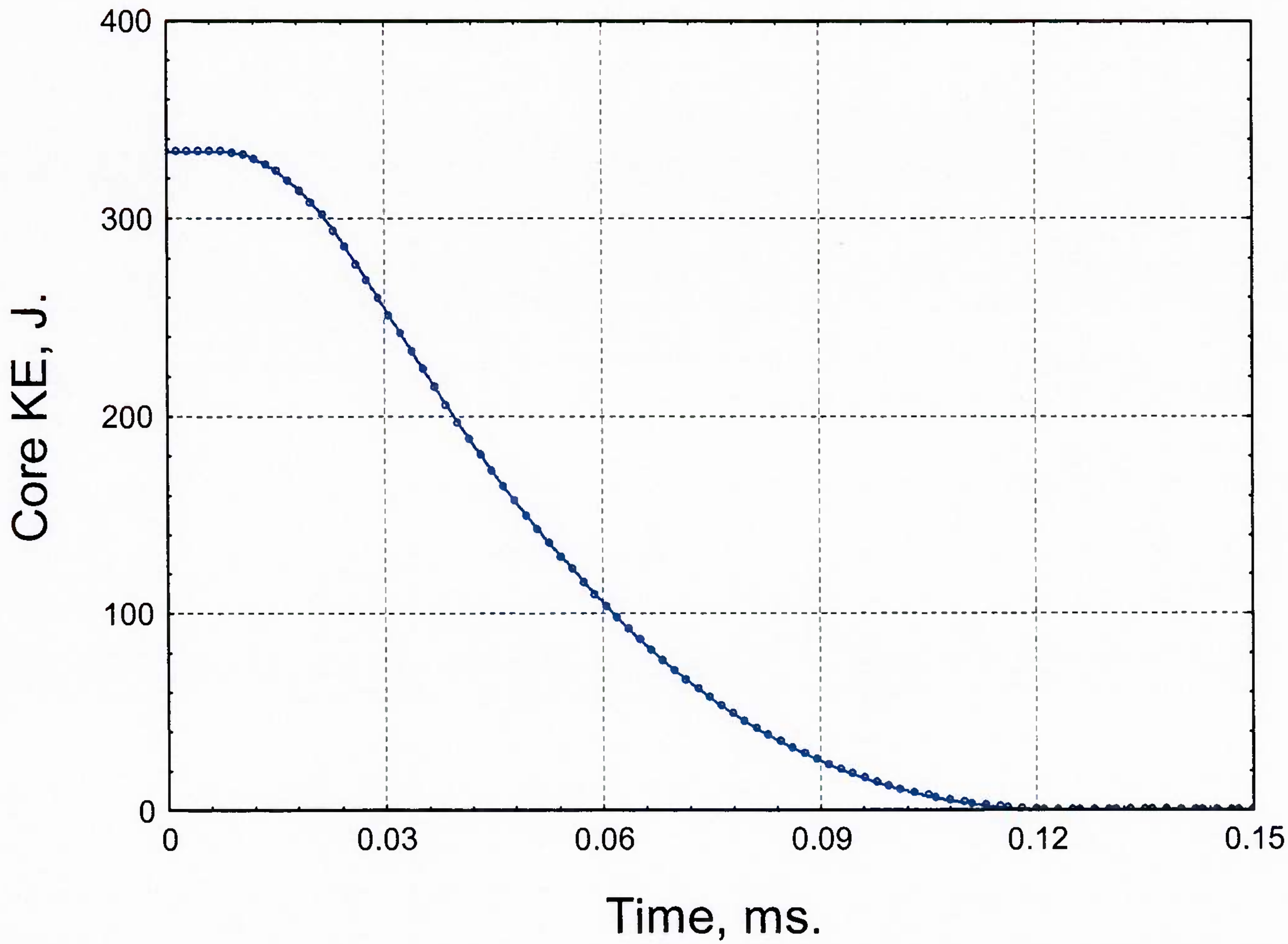
SHOT NO. 2802 PROJECTILE KINETIC ENERGY vs. TIME



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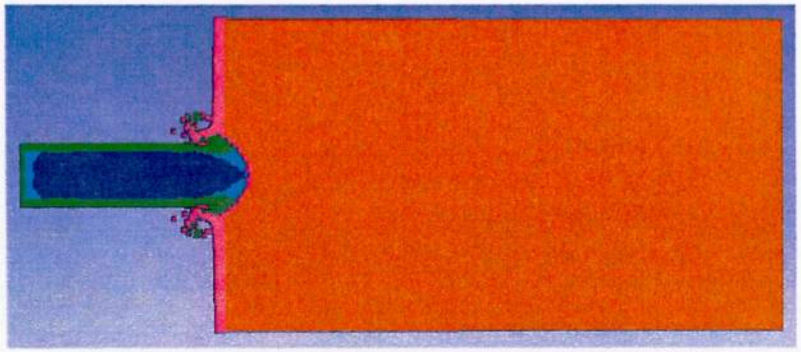
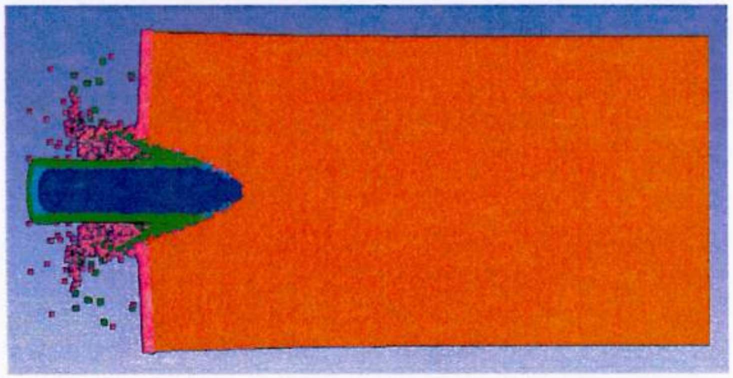
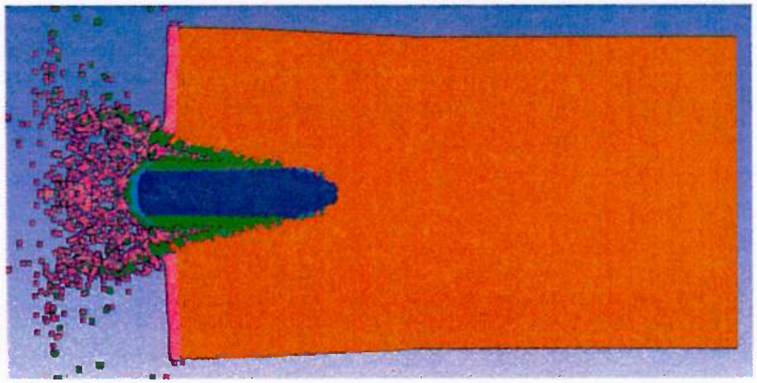
SHOT NO. 3002, V=834 m/s, t_c=1.25 mm



$t = 0.01587$ ms



$t = 0.03314$ ms



$t = 0.04902$ ms

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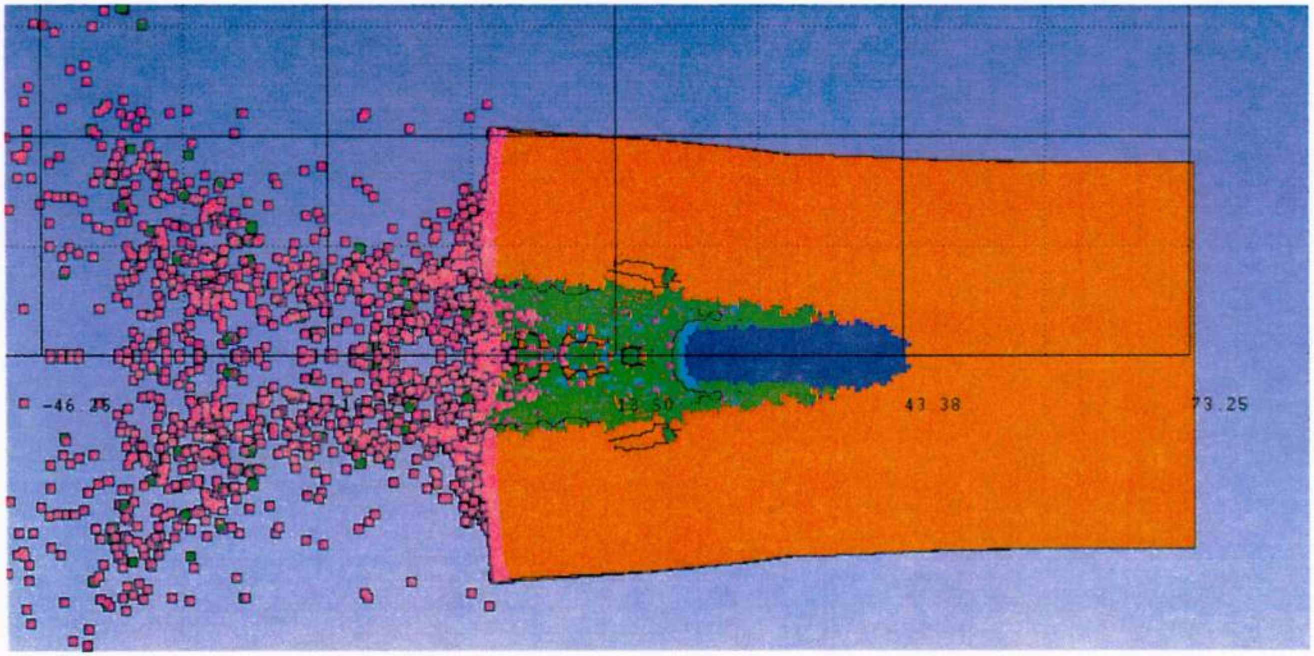
SHOT NO. 3002, V=834 m/s, t_c=1.25 mm



t = 0.1144 ms

AutoDyn DOP = 42.38 mm

Experimental DOP = 40.1 mm

Conclusion: Reasonable result since yaw and pitch are not considered in AutoDyn run while present in experiment

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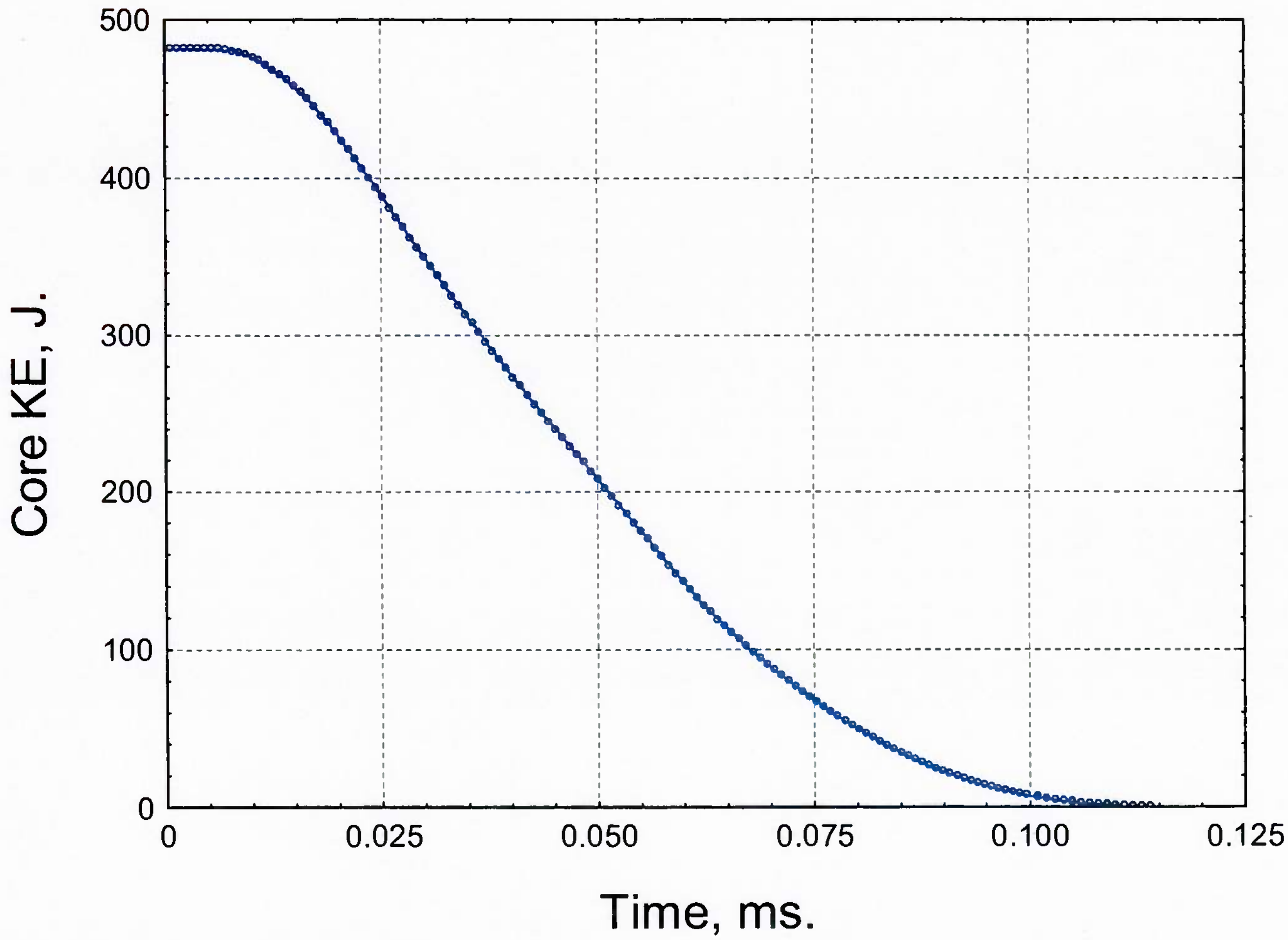
SHOT NO. 3002 PROJECTILE KINETIC ENERGY vs. TIME



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SUMMARY

- Quarter-symmetric model is used in AutoDyn to validate projectile model and ceramic properties using data from ARL-DoP experiments
- Both monolithic aluminum and ceramic-faced aluminum targets match results found in literature with reasonable accuracy
- Mesh size will be reduced and material properties (strength and damage) will be adjusted to improve results
- Further analysis will be done to validate the 7.62x39 PS projectile using a similar approach

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Experimental Results from REF: ARL-TR-2219, 2000

ADDITIONAL SLIDES

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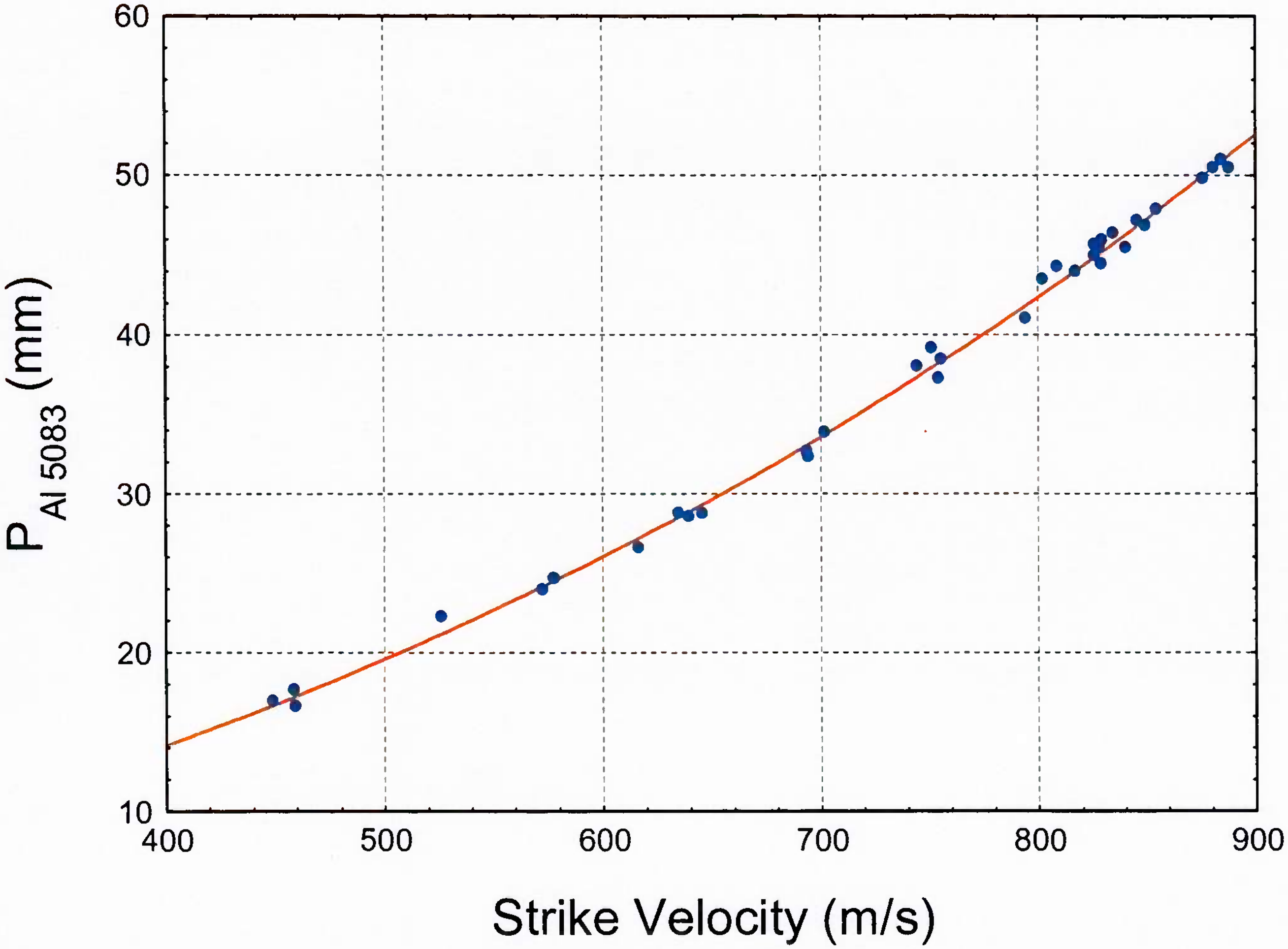
PENETRATION INTO MONOLITHIC ALUMINUM vs. STRIKE VELOCITY (Ref: ARL-TR-2219, 2000.)



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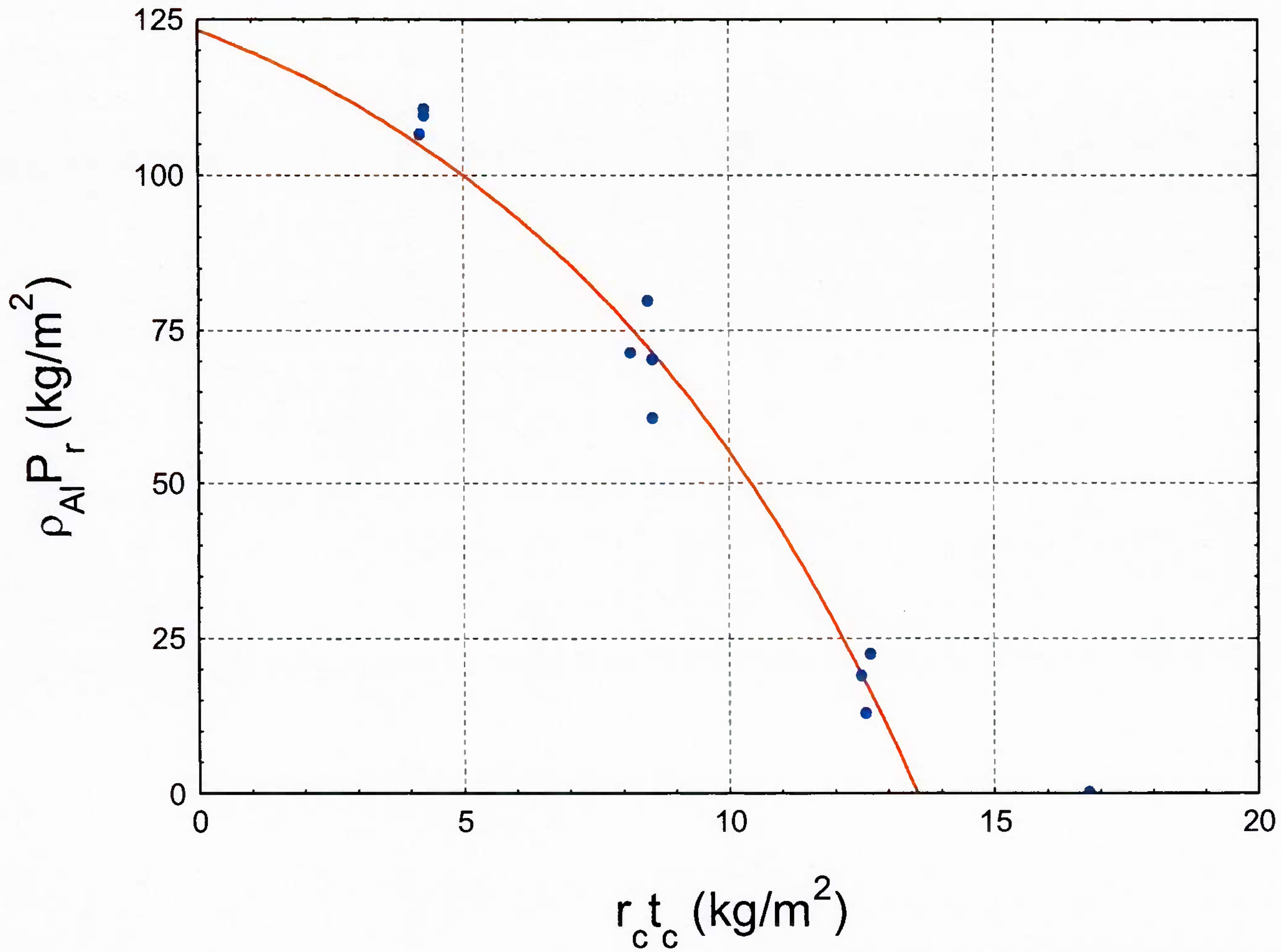
RESIDUAL PENETRATION AREAL DENSITY vs. CERAMIC AREAL DENSITY (Ref: ARL-TR-2219, 2000.)



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