

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE (DD-MM-YYYY) 02/18/201403/21/2014		2. REPORT TYPE Interim Research Performance Report (Monthly)		3. DATES COVERED (From - To) February 1, 2014 - February 28, 2014	
4. TITLE AND SUBTITLE Expeditionary Light Armor Seeding Development				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER N00014-13-1-0219	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Nichole Cicchetti, Bazle Haque, Shridhar Yarlagadda				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) UNIVERSITY OF DELAWARE OFFICE OF THE VICE PROVOST FOR RESEARCH 220 HULLIHEN HALL NEWARK, DE 19716-0099				8. PERFORMING ORGANIZATION REPORT NUMBER MONTHLY-11	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Research 875 North Randolph Street Arlington, VA 22203-1995				10. SPONSOR/MONITOR'S ACRONYM(S) ONR	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for Public Release; distribution is Unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT -The effect of tile thickness at varying gap sizes was explored, finding that a center impact DOP can on be achieved if at a gap size of 0.508 mm -In simulation the adhesive layer improves the ballistic efficiency of the target, experimental tests will confirm or deny this -A step ladder seam design was designed and tested, results are positive -Monolithic Aluminum base curve was re ran at 0.2 SPH and compared to ARL data, material properties may need to be adjusted					
15. SUBJECT TERMS Adhesive Layer Effect, .30cal AP M2 Projectile, 762x39 PS Projectile, SPH, Aluminum 5083, SiC, DoP Expeminets, AutoDyn Sin					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			UU
					19b. TELEPHONE NUMBER (include area code) 302-831-4941

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

20150925061



PROGRESS REPORT

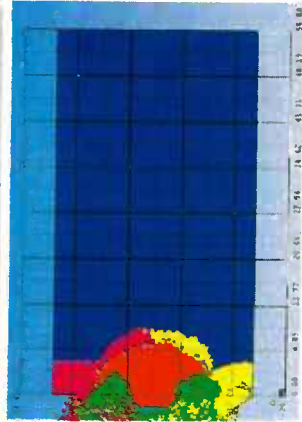
Nicole A. Cicchetti, Bazle Z. (Gama) Haque,
Shridhar Yarlagadda

MODELING AND SIMULATION OF CERAMIC ARRAYS TO IMPROVE BALLISTIC PERFORMANCE

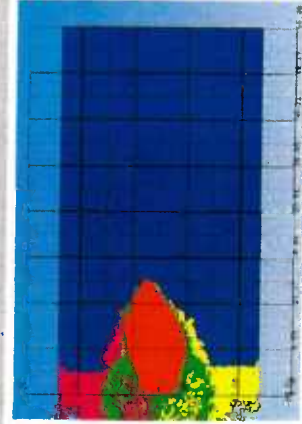
EFFECT OF TILE THICKNESS ON DOP AT 850m/s GAP SIZE 0.508mm



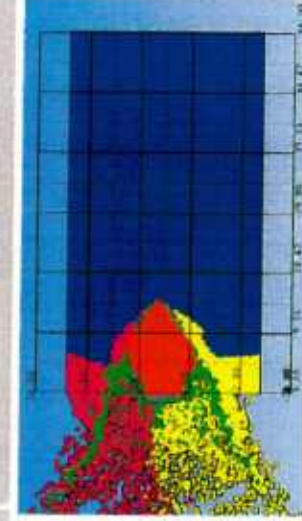
No Gap, DOP 10.33 mm



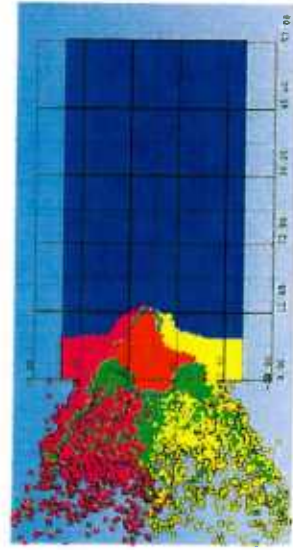
5 mm Thick, DOP 17.19 mm



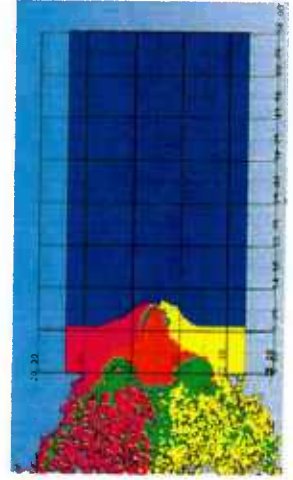
6 mm Thick, DOP 14.00 mm



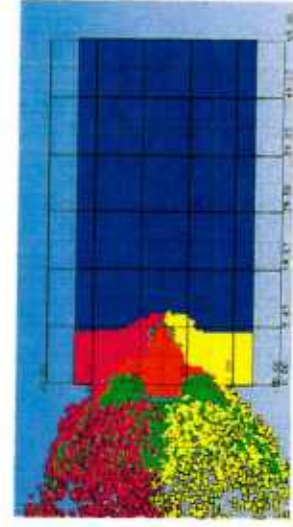
7 mm Thick, DOP 11.40 mm



8 mm Thick, DOP 10.80 mm



9 mm Thick, DOP 9.83 mm



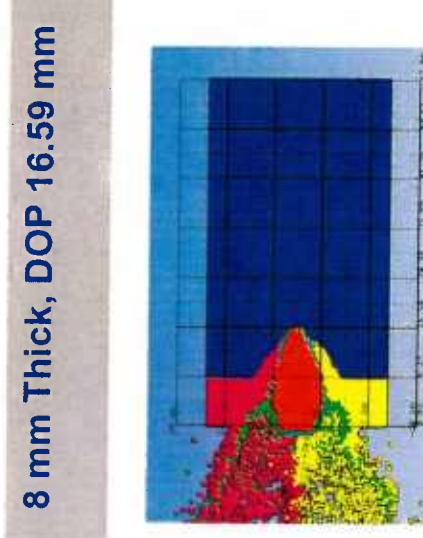
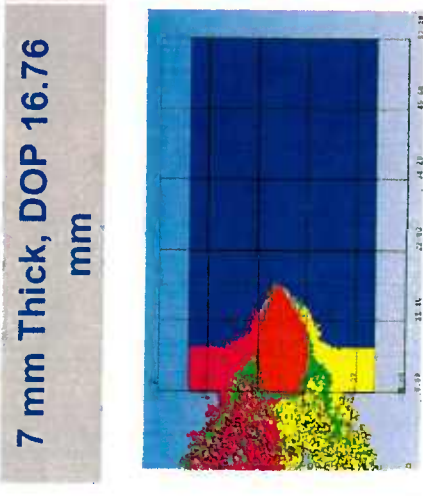
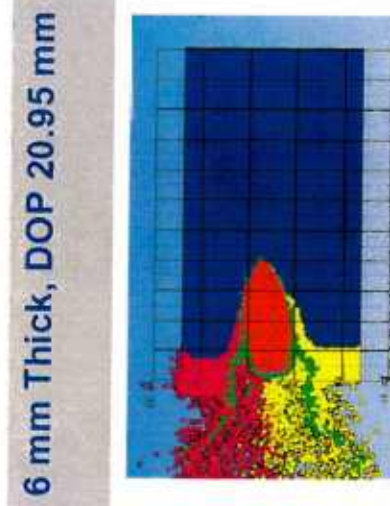
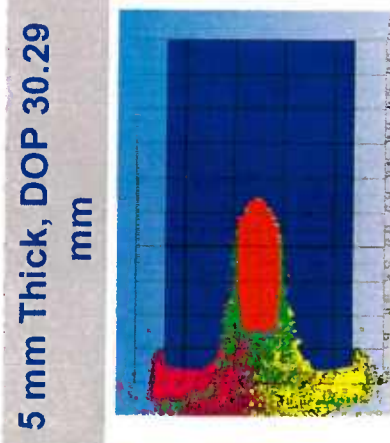
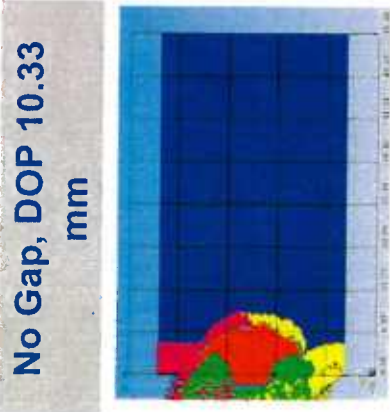
Depth of Penetration on Baseline Tiles and Modified Tiles at 850 m/s, Gap Size 0.508 mm

Gap Size t_{gap} (mm)	Tile Thickness H_c (mm)	Depth of Penetration d_p (mm)
Baseline (0)	5	10.3
0.508	5	17.2
0.508	6	14.0
0.508	7	11.4
0.508	8	10.8
0.508	9	9.8

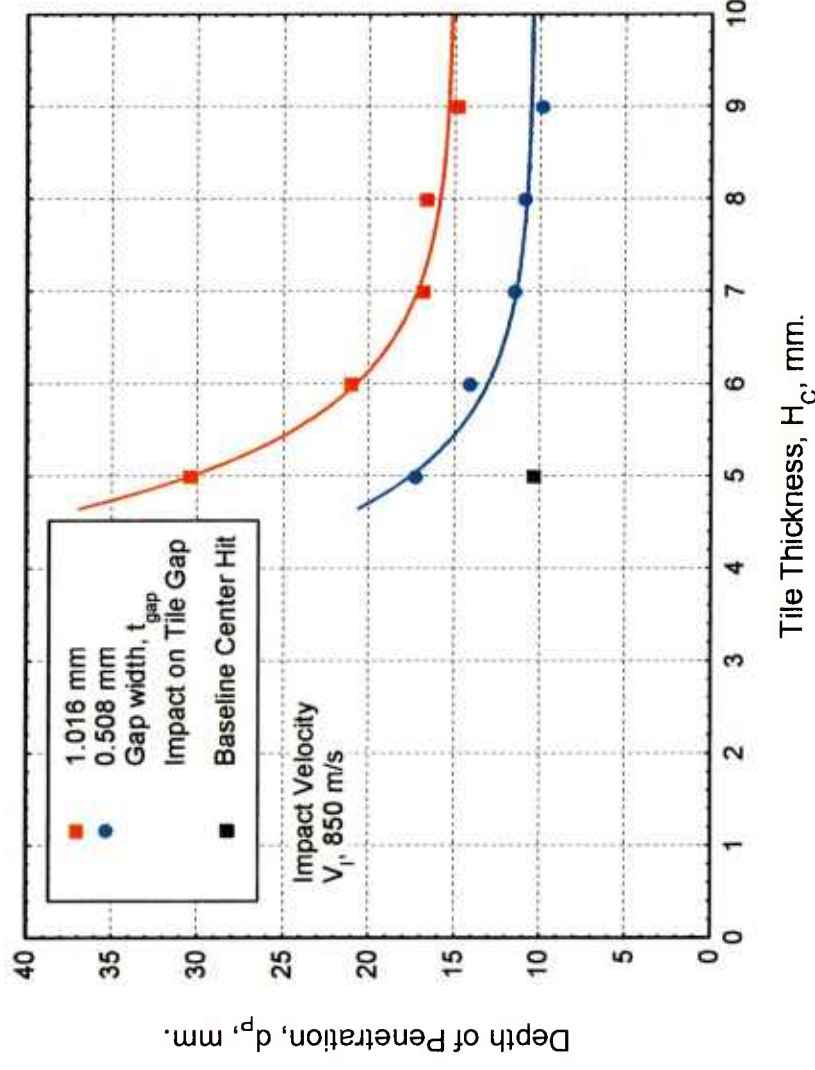
EFFECT OF TILE THICKNESS ON DOP AT 850m/s GAP SIZE 1.016mm



Depth of Penetration on Baseline Tiles and Modified Tiles at 850 m/s, Gap Size 1.061 mm			
Gap Size t_{gap} (mm)	Tile Thickness H_c (mm)	Depth of Penetration d_p (mm)	
Baseline (0)	5	10.3	
1.016	5	30.3	
1.016	6	21.0	
1.016	7	16.8	
1.016	8	16.6	
1.016	9	14.8	

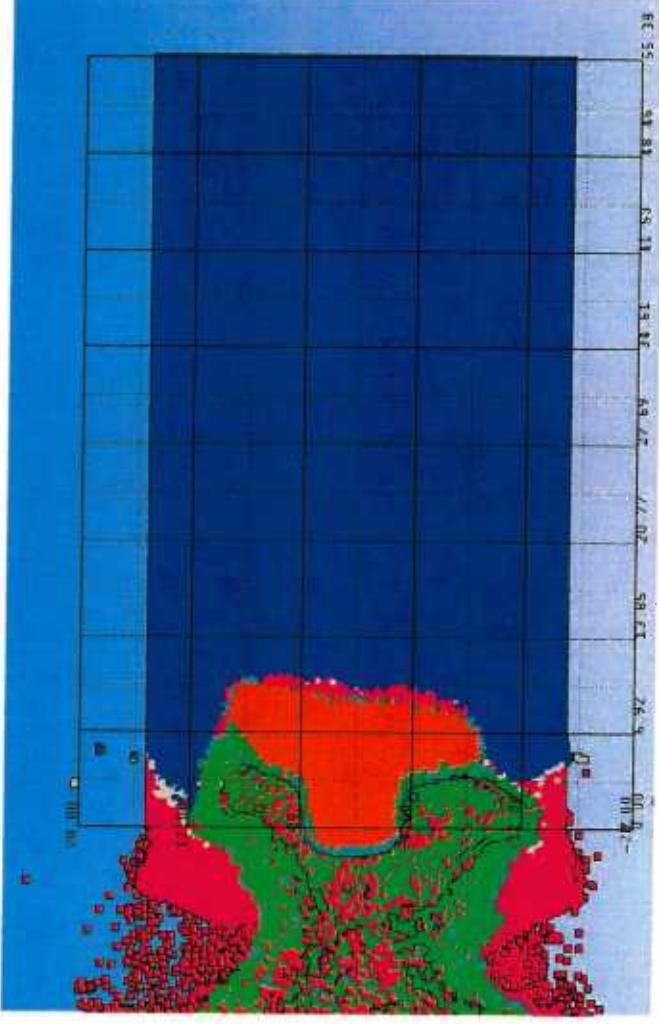


AUTODYN SIMULATION DOP VS TILE THICKNESS



- When the gap is held at 1.016 mm the baseline DOP of a center impacted tile cannot be effectively achieved
- A gap size of 0.508 mm allows the baseline to be achieved and gap size of 0.508 mm will be the gap size in use moving forward

ADHESIVE LAYER EFFECT ON CENTER IMPACTED 5mm THICK TILE

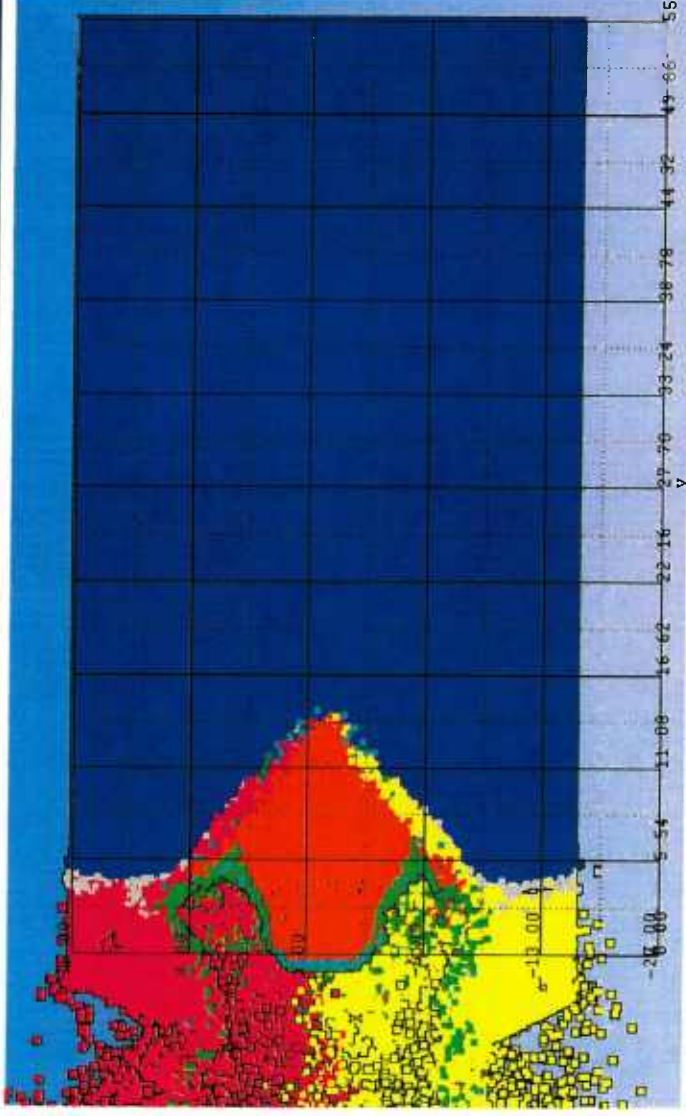


**Adhesive Layer DOP
Compared to No Adhesive
Layer DOP, Gap 0.508 mm**

Adhesive Layer DOP (mm)	Baseline Center Impact DOP (mm)
10.1	10.3

- An adhesive layer of Epoxy Resin was added in between the SiC tile and the Al backing
- The tile remained 5 mm thick

ADHESIVE LAYER EFFECT GAP SIZE 0.508mm 5mm THICK TILE

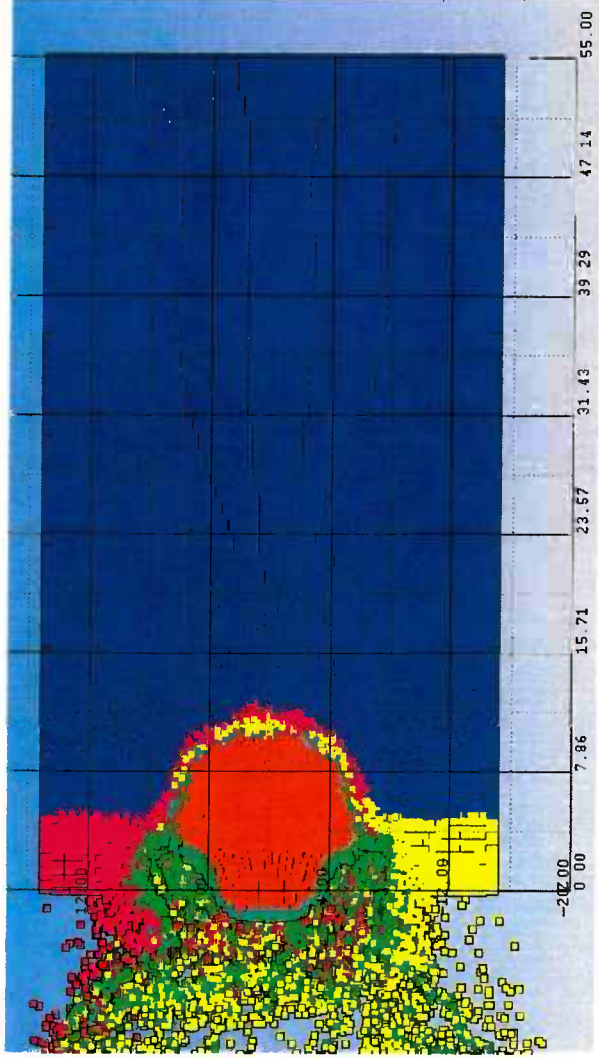


**Adhesive Layer DOP
Compared to 0.508 mm Gap
with No Adhesive DOP**

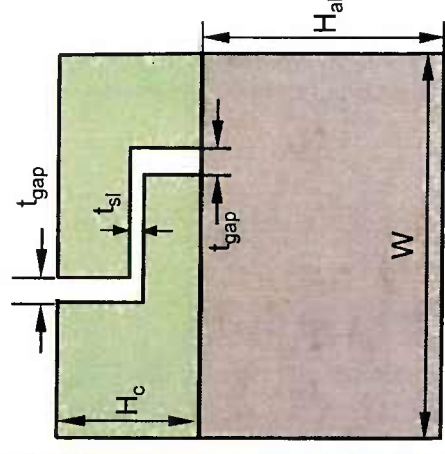
Adhesive Layer DOP (mm)	Tile Gap 0.508 mm with No Adhesive DOP (mm)
13.9	17.2

- ❑ An adhesive layer of Epoxy Resin was added in between the SiC tile and the Al backing
- ❑ The tile remained 5 mm thick and the gap size at 0.508 mm to compare when no adhesive was added

CENTER IMPACTED STEP LADDER



Step Ladder DOP Compared to Baseline Gap 0.508 mm DOP	
Step Ladder DOP (mm)	11.8
No Step Ladder DOP (mm)	17.2



Part	V_o	H_p	t_{gap}	H_c	t_{sl}	H_{al}	W
	850 m/s	35.31 mm	0.508 mm	5 mm	0.2 mm	50 mm	30 mm

- ❑ An Step Ladder was created at the seam according to the schematic at right
- ❑ The tile remained 5 mm thick and the gap size at 0.508 mm to compare to the baseline results



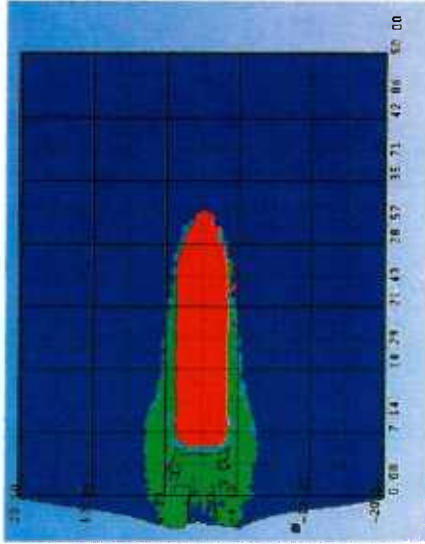
- Earlier DoP Simulations have been performed using SPH size 0.40-mm
- Recent DoP Simulations of (i) Step-Ladder Tiles and (ii) Center Impact with Adhesive Layers have been conducted with SPH size 0.20-mm
- This is why we reran the DoP of Aluminum with SPH size 0.20-mm to be consistent

DOP SIMULATION OF ALUMINUM TARGETS WITH 0.20mm SPH SIZE

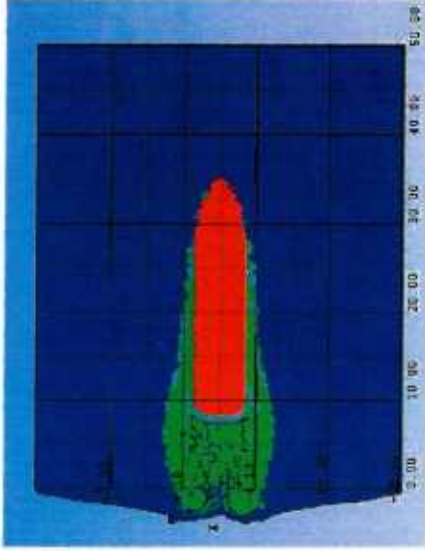
MONOLITHIC AI5083 DOP CALIBRATION AT SPH SIZE 0.2



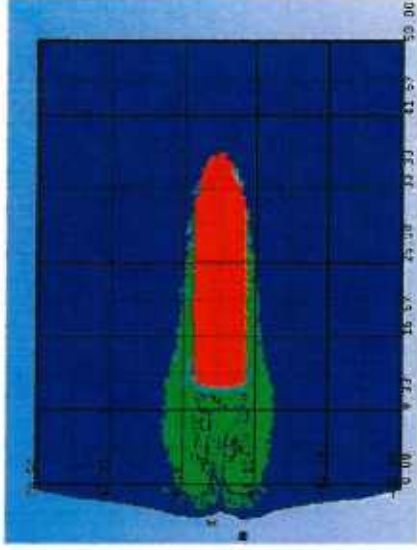
700 m/s



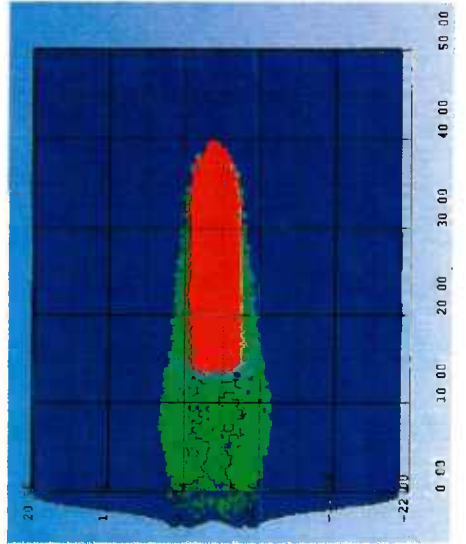
750 m/s



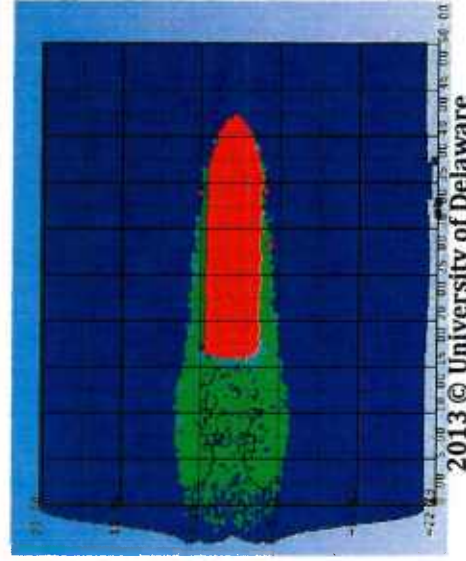
800 m/s



850 m/s



900 m/s



Monolithic AI5083 DOP

Velocity (m/s)	DOP (mm)
700	32.1
750	35.0
800	37.5
850	40.0
900	42.5

ARL MONOLITHIC AL5083 DOP

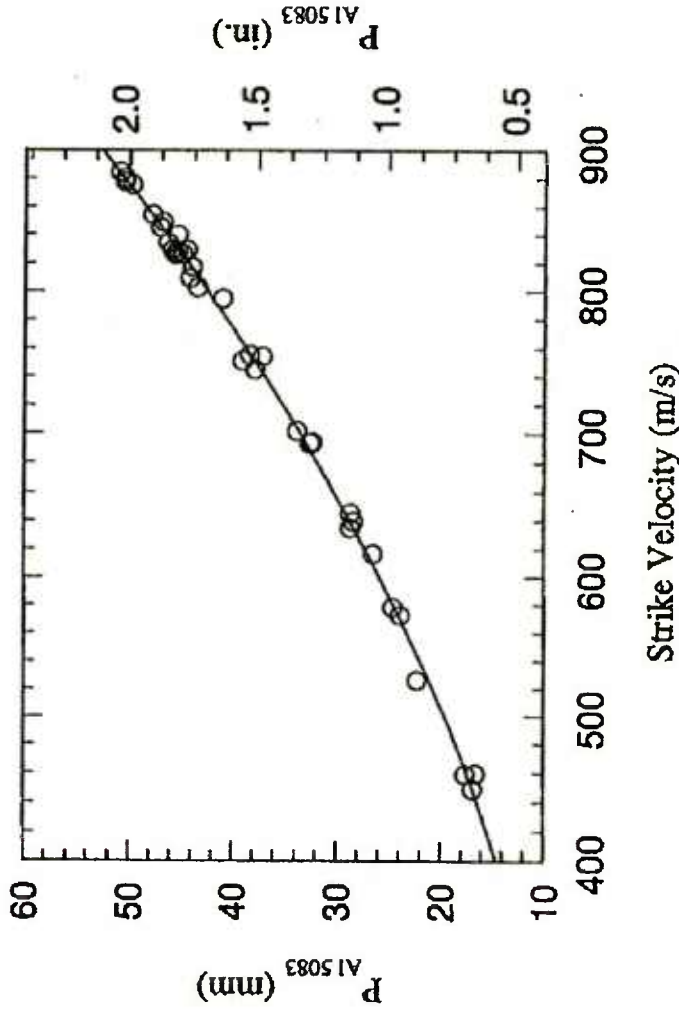


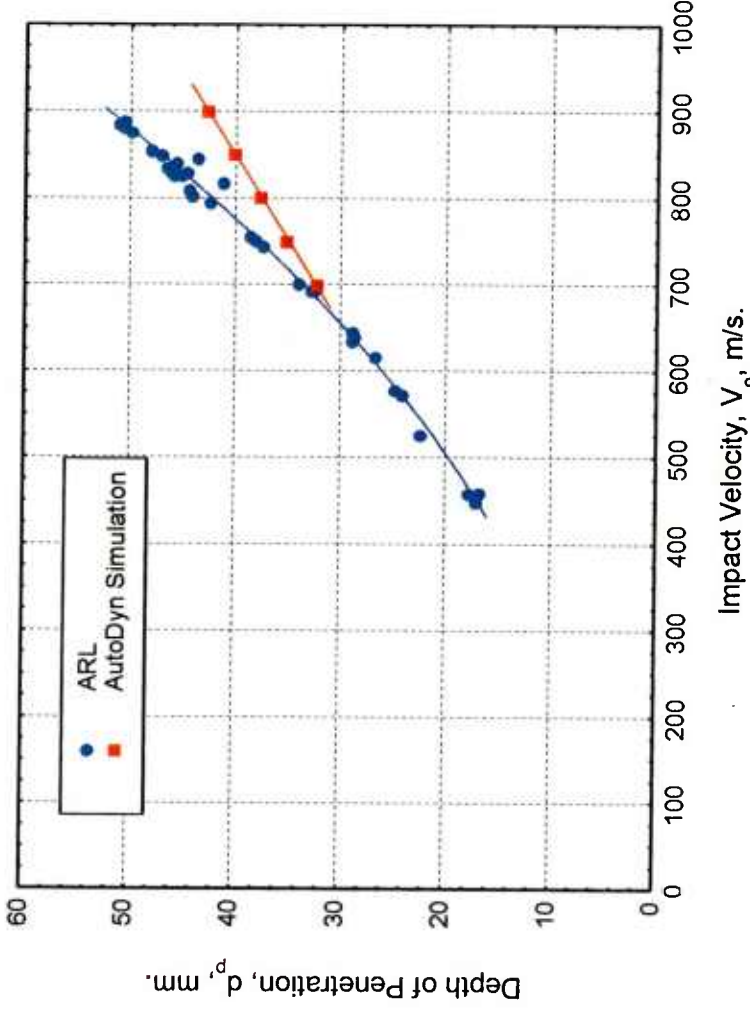
Figure 2. Penetration Into Monolithic Aluminum (Al 5083) vs. Strike Velocity.

- ARL ranged from 400 to 900 m/s, we will only be running experimental tests on 700 to 900.

Moynihan, Thomas J., Shun-Chin Chou, and Audrey L. Mihalcin. *Application of the Depth-of-Penetration Test Methodology to Characterize Ceramics for Personnel Protection*. Rep. Aberdeen Proving Ground, MD: Army Research Laboratory, April 2000. Print.
2013 © University of Delaware

^a Data point disregarded, due to excessive pitch/yaw.

AUTODYN AND ARL DOP VS IMPACT VELOCITY



- Simulation results do not show the same trend as the ARL experimental data
- Simulations will be extended over a larger range of Impact Velocities
- Material properties may be edited if the properties do not match the material properties used in the ARL experiments

SUMMARY



- The effect of tile thickness at varying gap sizes was explored, finding that a center impact DOP can on be achieved if at a gap size of 0.508 mm**
- In simulation the adhesive layer improves the ballistic efficiency of the target, experimental tests will confirm or deny this**
- A step ladder seam design was designed and tested, results are positive**
- Monolithic Aluminum base curve was re ran at 0.2 SPH and compared to ARL data, material properties may need to be adjusted**