Dynamic Measurements of Multi-Layer Target Perforation at Enhanced Velocities

24 May 07

APPLIED RESEARCH ASSOCIATES, INC.

An Employee-Owned Company

Program Overview

- *Nine Instrumented Tests into Multi-Layered Target @ Velocities to 2800'/sec*
- *AOI's to 70 degrees*
- *AOA's to 1.5 degree*
- *Acceleration and Strain Gage Instrumentation*
- *Extensive Photo-metrics*

Program Goals

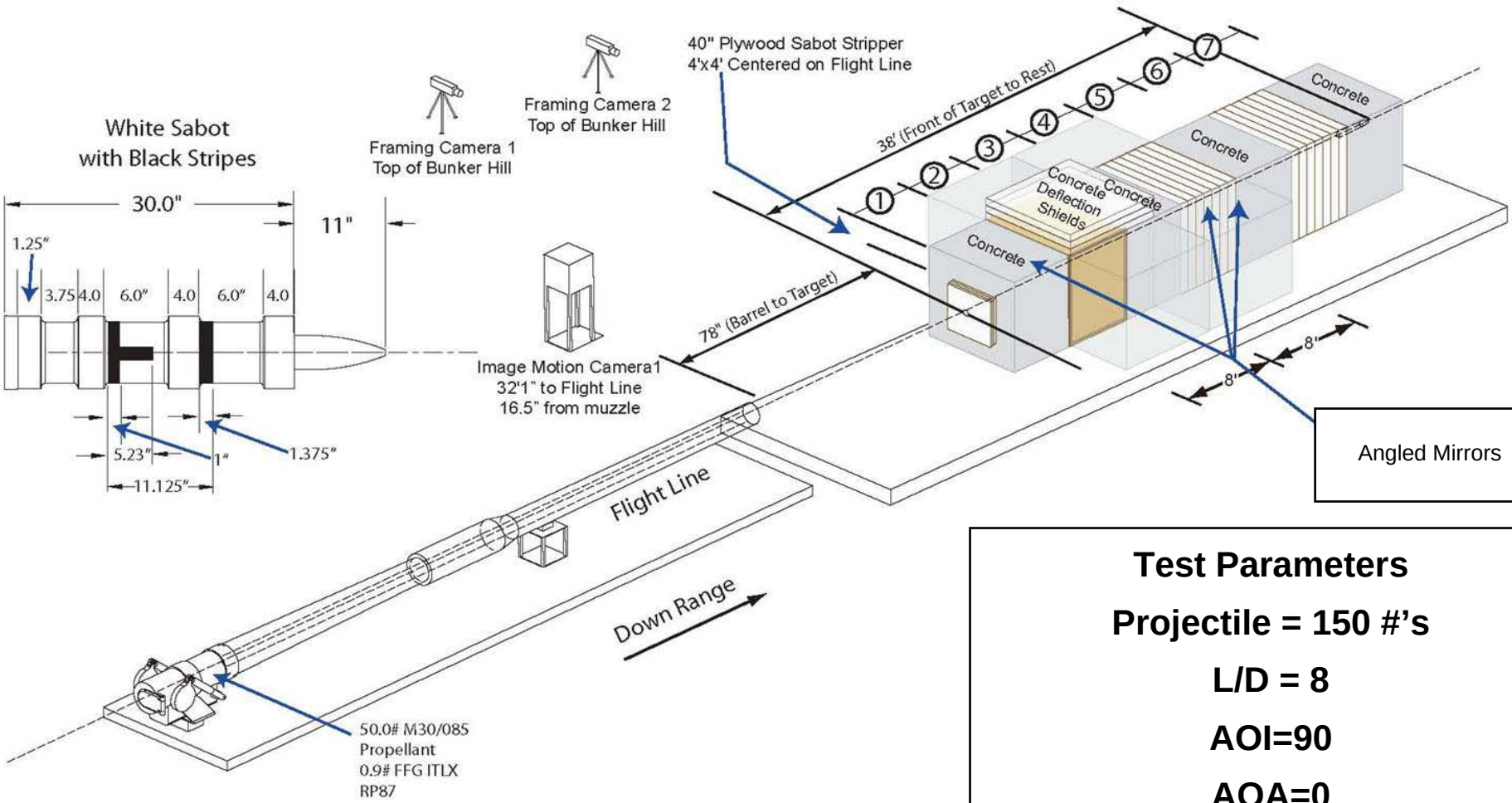
- ***Develop robust data recording packages to obtain high velocity deceleration of penetration through multi-layered targets***
- ***Determine peak 'g' vs: velocity relationship***
- ***Determine minimum detectable concrete thicknesses in calibers***
- ***Determine lateral loading influences on layer detection algorithms***
- ***Measure projectile rigid body angular features***
- ***Develop real time projectile position-time tracking algorithms***

V=2825 fps

MD1 Test Results

Test Date: 5/7/2004

Shot Time: 2:26 PM MST



Angled Mirrors

Test Parameters

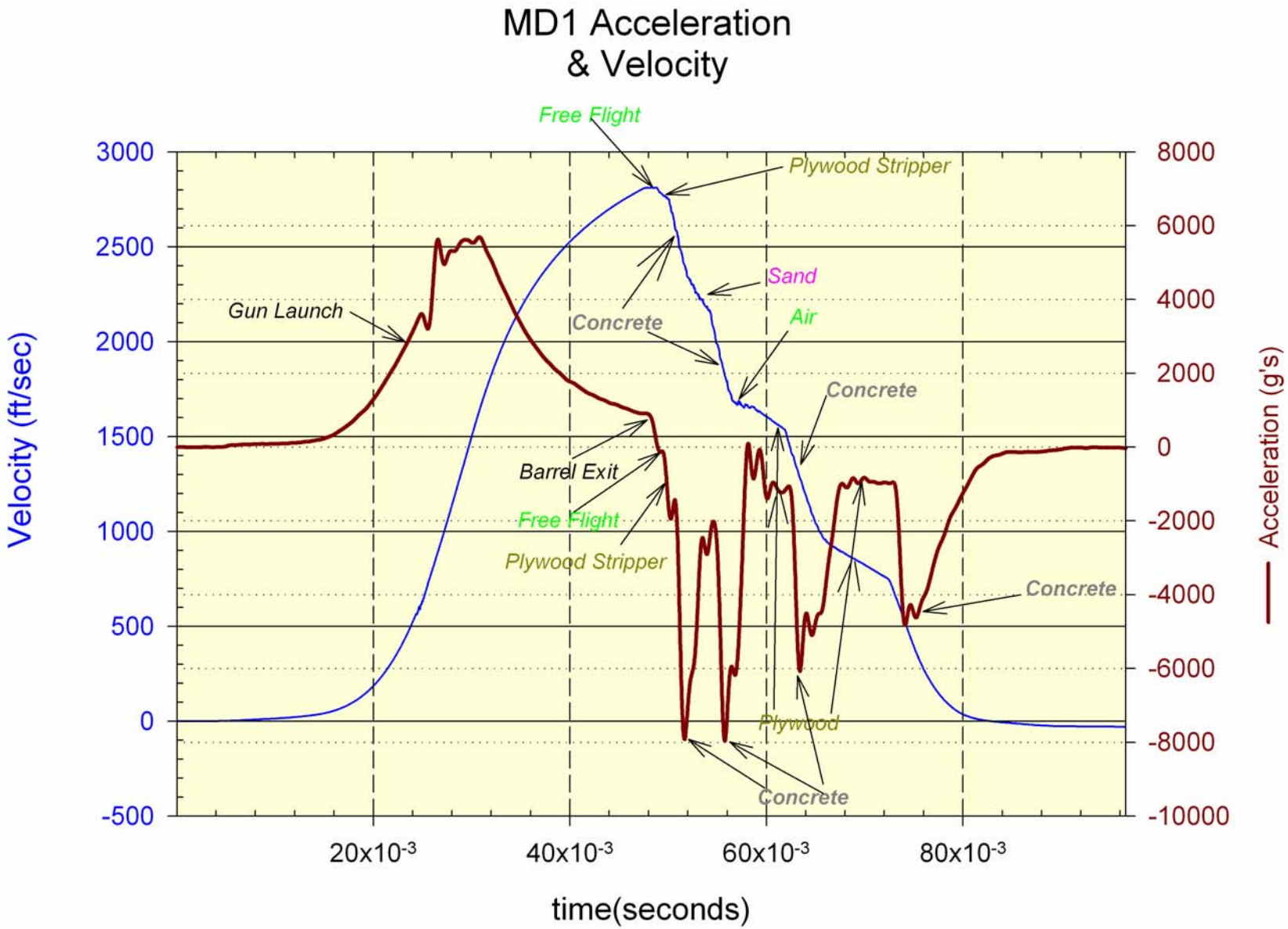
Projectile = 150 #'s

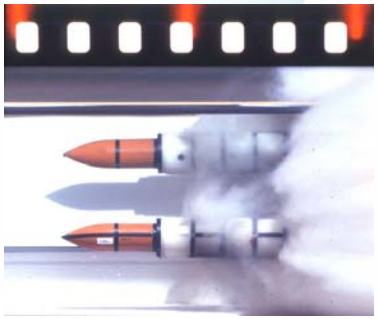
L/D = 8

AOI=90

AOA=0

TEST MD1 – 42’ Flight Path

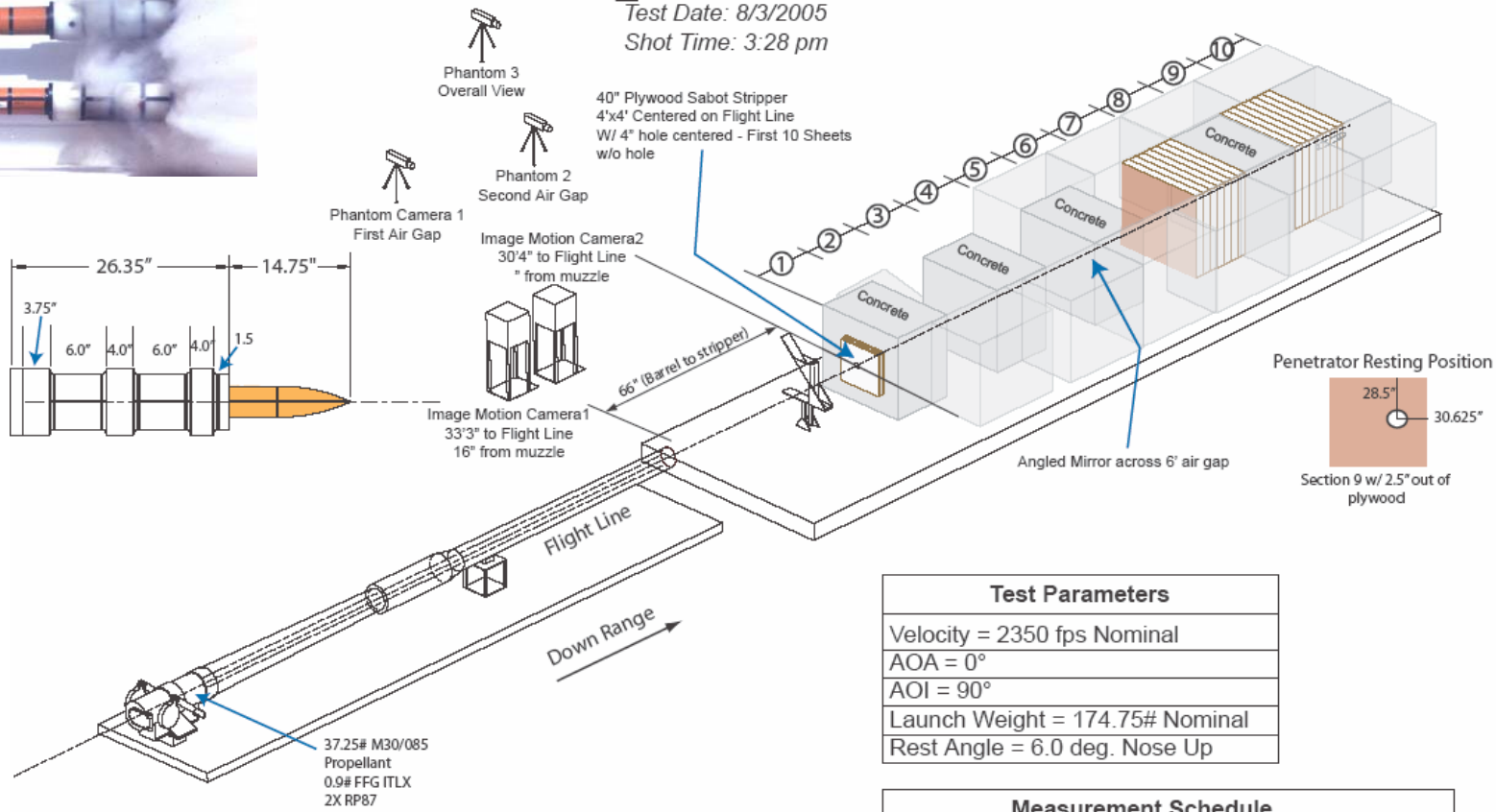

MD1 Acceleration
& Velocity
Free Flight
Plywood Stripper
Sand
Air
Concrete
Gun Launch
Concrete
Barrel Exit
Free Flight
Plywood Stripper
Concrete
Plywood
Concrete
Velocity (ft/sec)
Acceleration (g's)
time(seconds)
3000
2500
2000
1500
1000
500
0
-500
8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
20x10-3
40x10-3
60x10-3
80x10-3



MD_A Test Results

Test Date: 8/3/2005

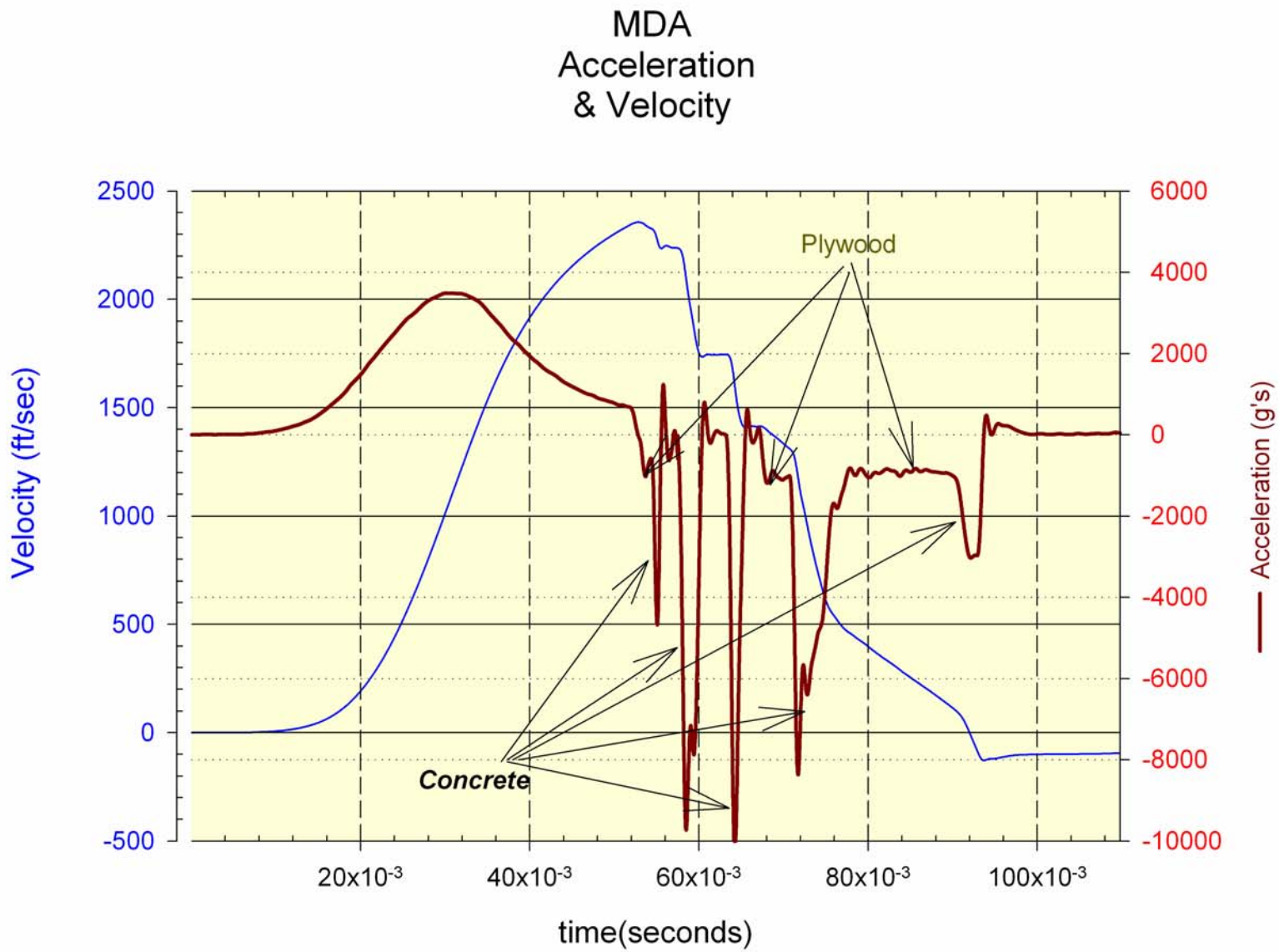
Shot Time: 3:28 pm



Test Parameters
Velocity = 2350 fps Nominal
AOA = 0°
AOI = 90°
Launch Weight = 174.75# Nominal
Rest Angle = 6.0 deg. Nose Up

Target Sections			
#	Type and Length	#	Type and Length
1	Concrete - 9"	6	Air - 3'
2	Air - 6'	7	Plywood - 5'
3	Concrete - 4.5'	8	Concrete - 5'
4	Air - 6'	9	Plywood - 5'
5	Concrete - 2'7"	10	Concrete - 5'

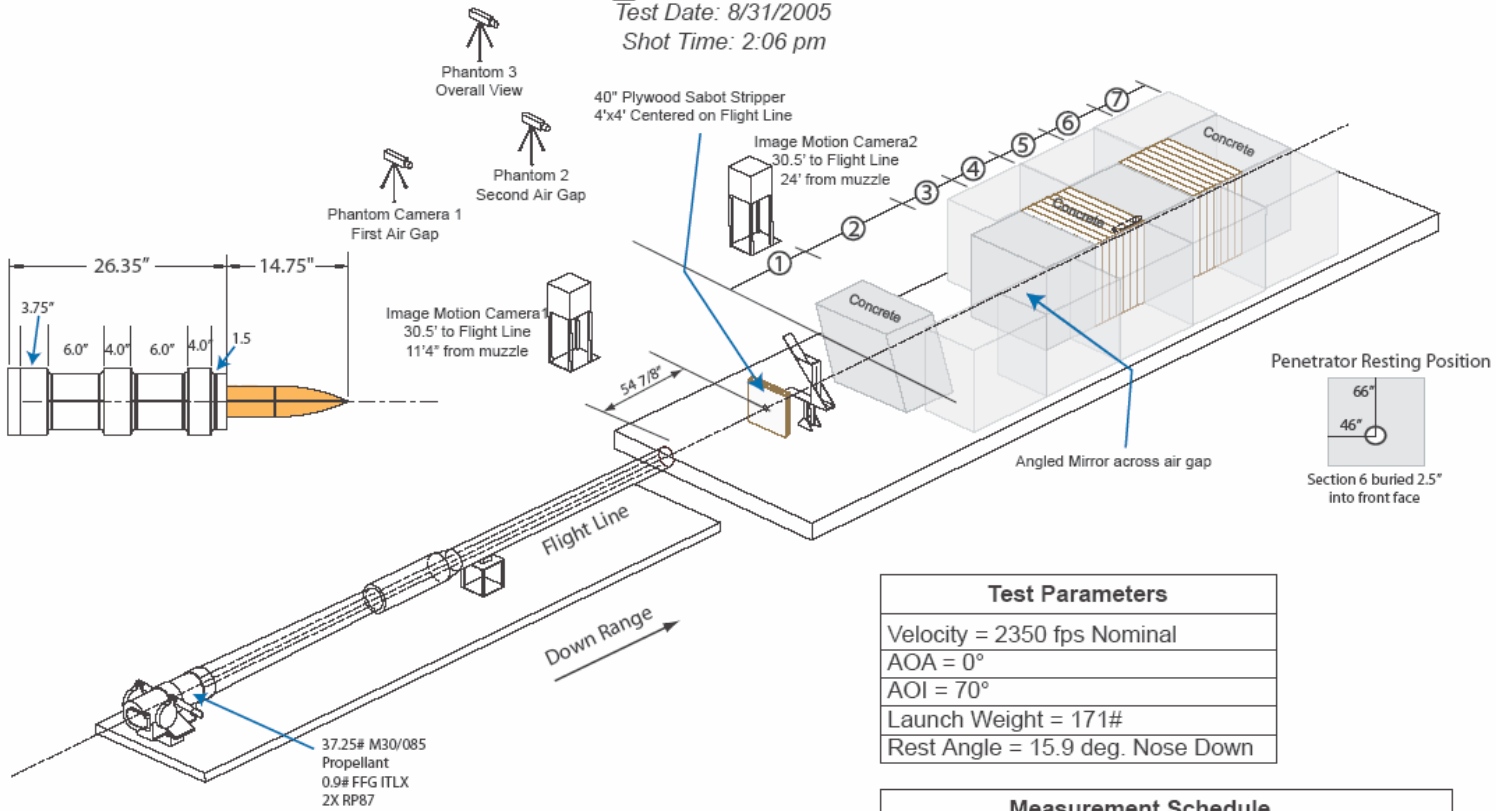
Measurement Schedule	
#	Measurement
1	Sabot Weight = 14.30#
2	Pusher Plate with Obturator Weight = 6.45#
3	Penetrator Weight = 154# before, 151.5# after
4	Penetrator Nominal Length & Diameter = 40", 5"
5	Projectile Seating Length = 90.75"
6	Projectile Barrel Travel = 48'1" Nominal


MDA
Acceleration
& Velocity
Velocity (ft/sec)
2500
2000
1500
1000
500
0
-500
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
Acceleration (g's)
Plywood
Concrete
20x10-3
40x10-3
60x10-3
80x10-3
100x10-3
time(seconds)

MD_D Test Results

Test Date: 8/31/2005

Shot Time: 2:06 pm

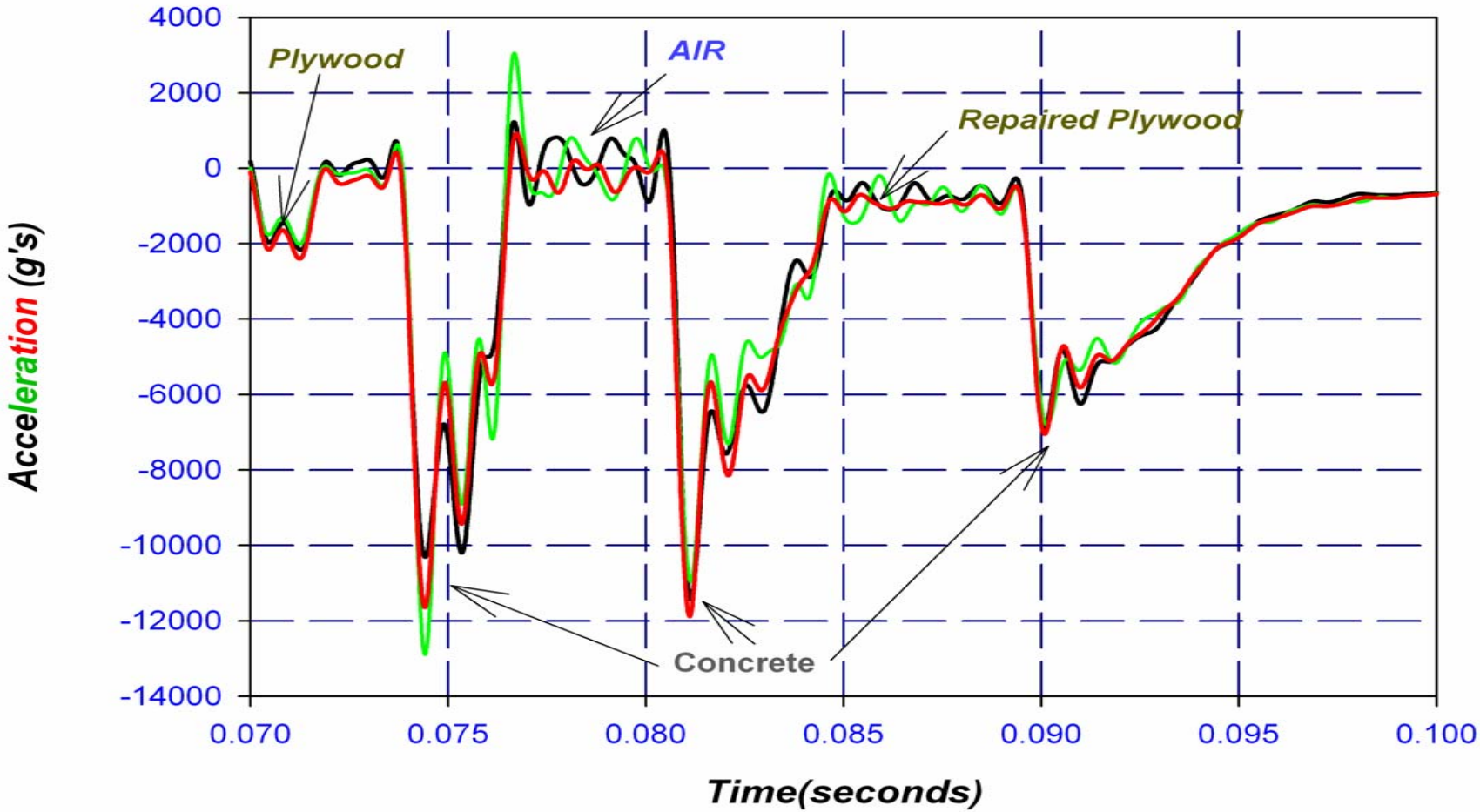


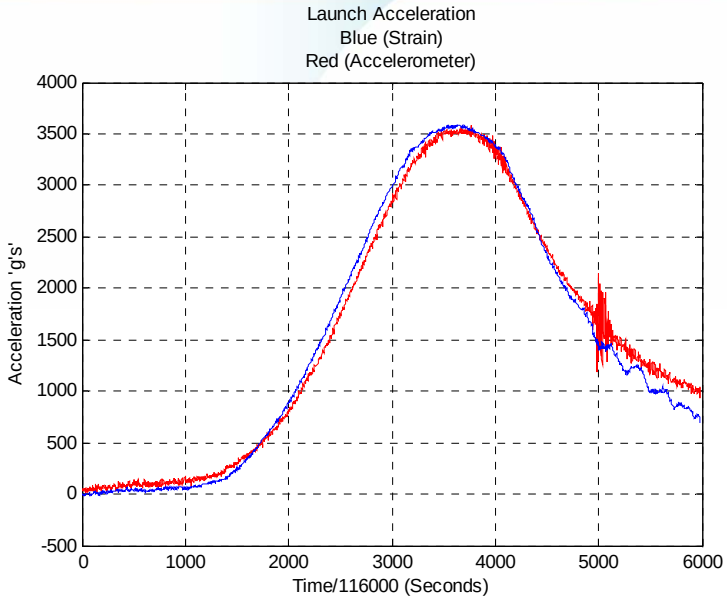
Test Parameters
Velocity = 2350 fps Nominal
AOA = 0°
AOI = 70°
Launch Weight = 171#
Rest Angle = 15.9 deg. Nose Down

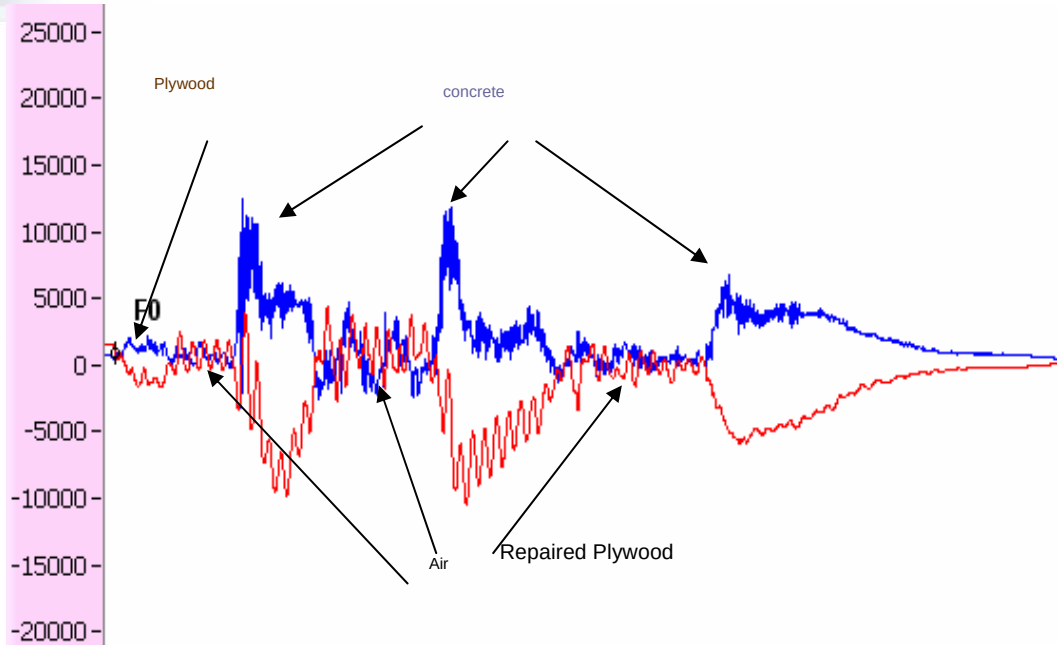
Target Sections			
#	Type and Length	#	Type and Length
1	Concrete - 4.5' 70 deg.	6	Plywood - 5'
2	Air - 7.5'	7	Concrete - 5'
3	Concrete - 5'		
4	Plywood - 5'		
5	Concrete - 5'		

Measurement Schedule	
#	Measurement
1	Sabot Weight = 14.30#
2	Pusher Plate with Obturator Weight = 5.45#
3	Penetrator Weight = 151.25# before, 148.5# after
4	Penetrator Nominal Length & Diameter = 39.5", 5"
5	Projectile Seating Length = 91 1/4"
6	Projectile Barrel Travel = 48'1" Nominal

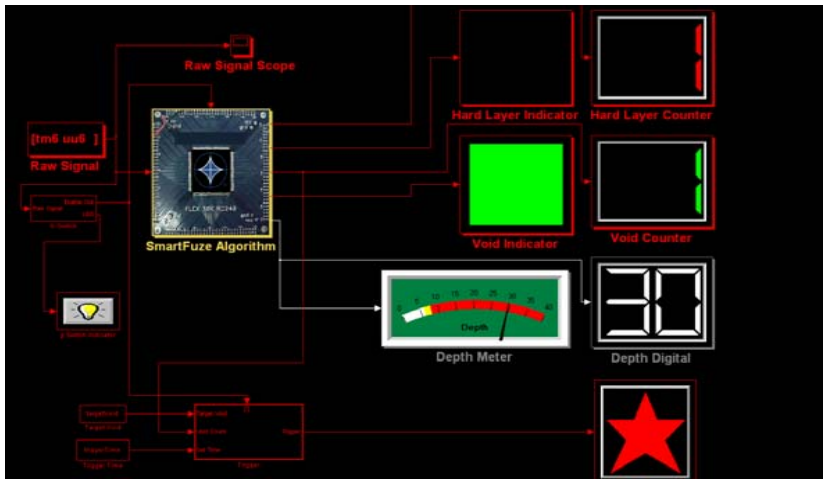
Three Planar Axial Accelerometers

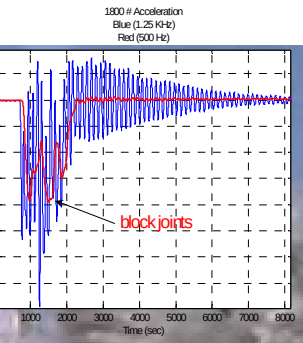



Launch Acceleration
Blue (Strain)
Red (Accelerometer)
Acceleration 'g's'
Time/116000 (Seconds)
4000
3500
3000
2500
2000
1500
1000
500
0
-500
0
1000
2000
3000
4000
5000
6000

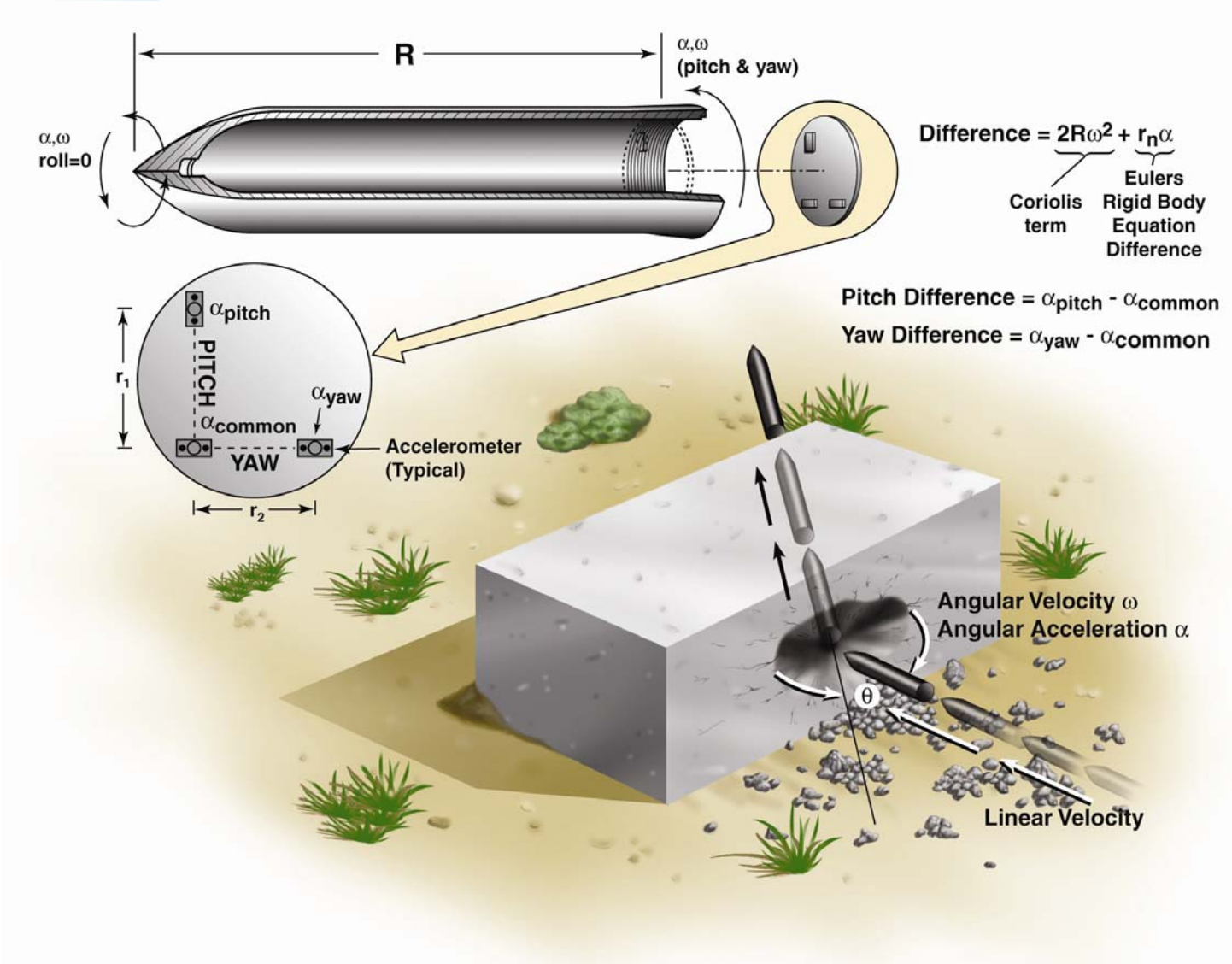

25000
20000
15000
10000
5000
0
-5000
-10000
-15000
-20000
Plywood
concrete
F0
Air
Repaired Plywood

2000 # Class Instrumentation

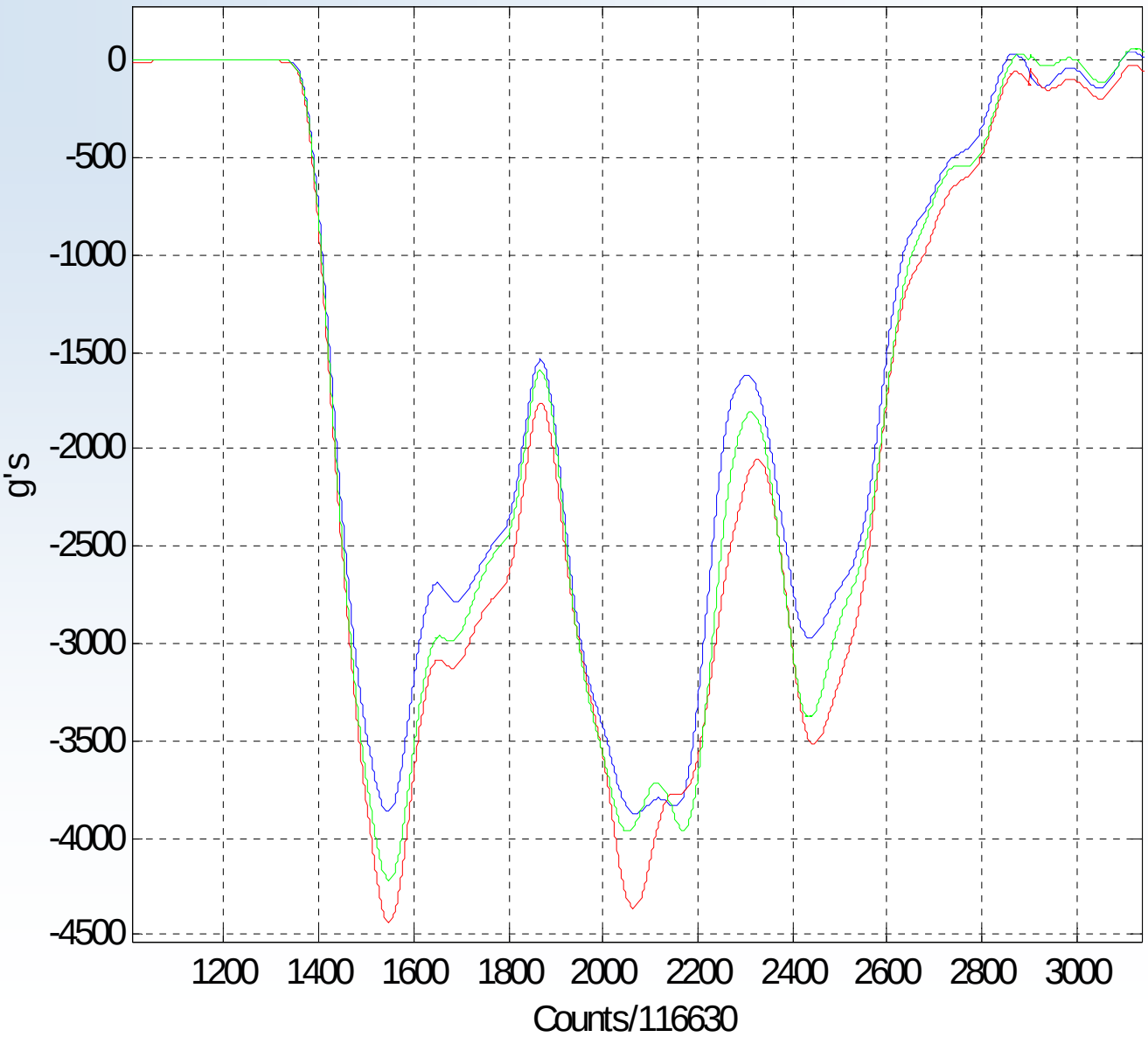


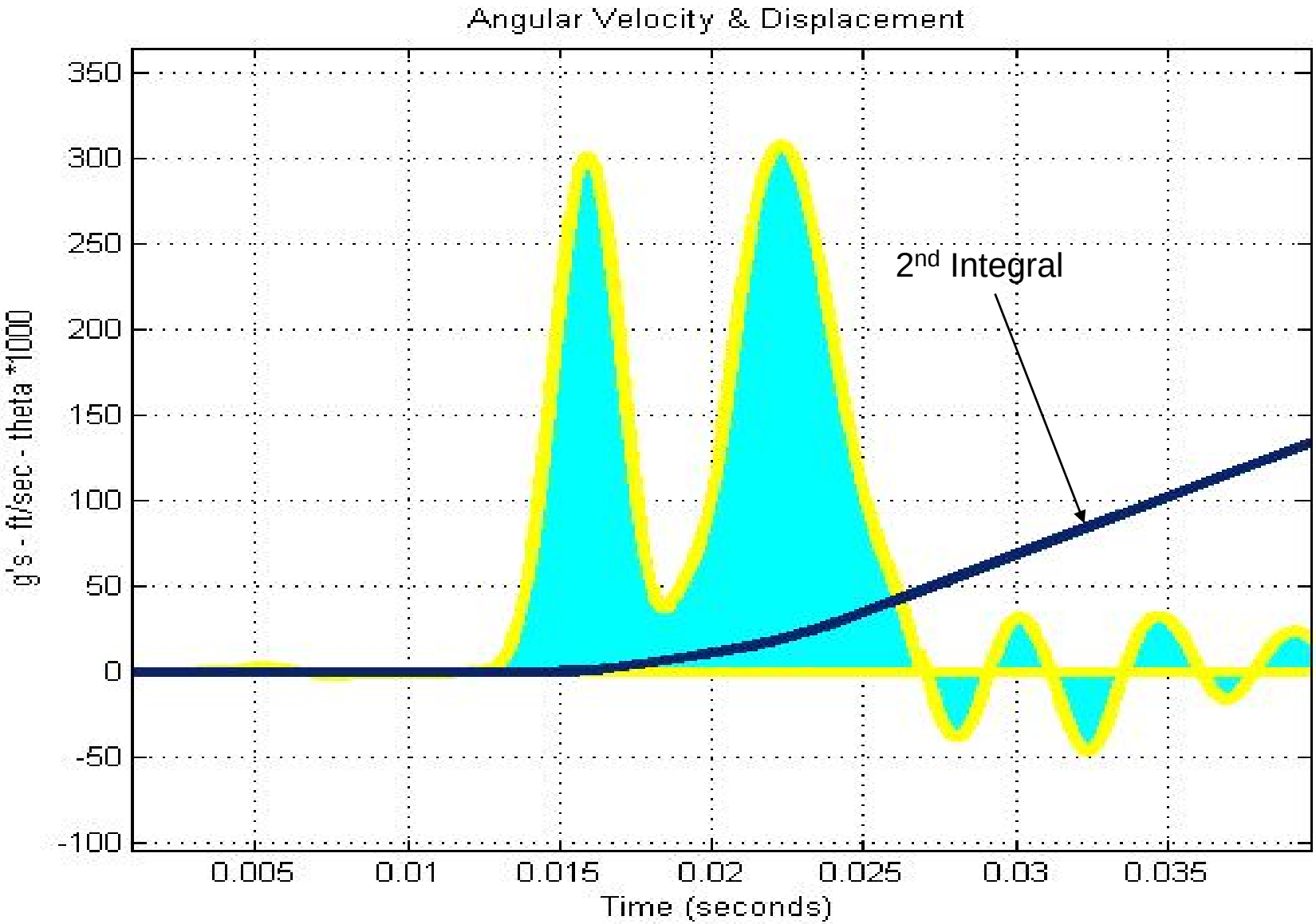



2000 # Class Acceleration
Blue (1.25KHz)
Red (500 Hz)
2000
0
-2000
-4000
-6000
-8000
-10000
gees
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
Time(sec)
Block Joints


R
α,ω
(pitch & yaw)
α,ω
roll=0
Difference = 2Rω² + rnα
Coriolis term
Eulers Rigid Body Equation Difference
Pitch Difference = αpitch - αcommon
Yaw Difference = αyaw - αcommon
αpitch
PITCH
αyaw
αcommon
YAW
r1
r2
Accelerometer (Typical)
Angular Velocity ω
Angular Acceleration α
θ
Linear Velocity

Accelerations x1 (red)
x2(blue) - x3(green)




Angular Velocity & Displacement
g's - ft/sec - theta *1000
350
300
250
200
150
100
50
0
-50
-100
0.005
0.01
0.015
0.02
0.025
0.03
0.035
Time (seconds)
2nd Integral

Program Results

- *Robust data recording packages were designed and constructed for 3000 fps impact velocities to survive rigid body g's to 25000*
- *The Dr. Forrestal penetration equations were verified. Peak g's are a soft function of impact velocity.*
- *The minimum detectable thickness for auto-correlation algorithms is 1/3 of a caliber*
- *At nominal impact conditions lateral contamination of axial signals does not impact detection algorithms*
- *A differencing technique allows the measurement of angular acceleration, velocity, and displacement*
- *An integration routine has been developed which allows the position-time of a projectile to be tracked during flight through a hard target*