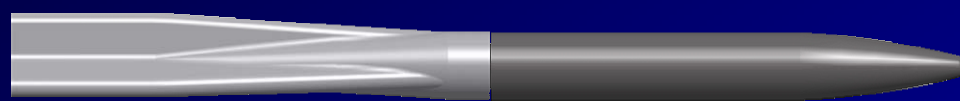
Development of a Unique Penetrator Warhead for Rocket or Missile Delivery



Presented to:
National Defense Industrial Association 40th Annual Armament Systems: Guns - Ammunition - Rockets – Missiles (GARM) Conference & Exhibition

25 – 28 April 2005

Roger W. Melin

Lockheed Martin Missiles and Fire Control
roger.melin@lmco.com
(972) 603-1769

Topics

Missiles and Fire Control

- I-NAIL™ Penetrator Concept
- I-NAIL™ Penetrator Design
- Recent Testing
  - Penetration Tests
  - Static Expulsion Tests
  - Wind Tunnel Expulsion Tests

I-NAIL™ Project Introduction

Missiles and Fire Control

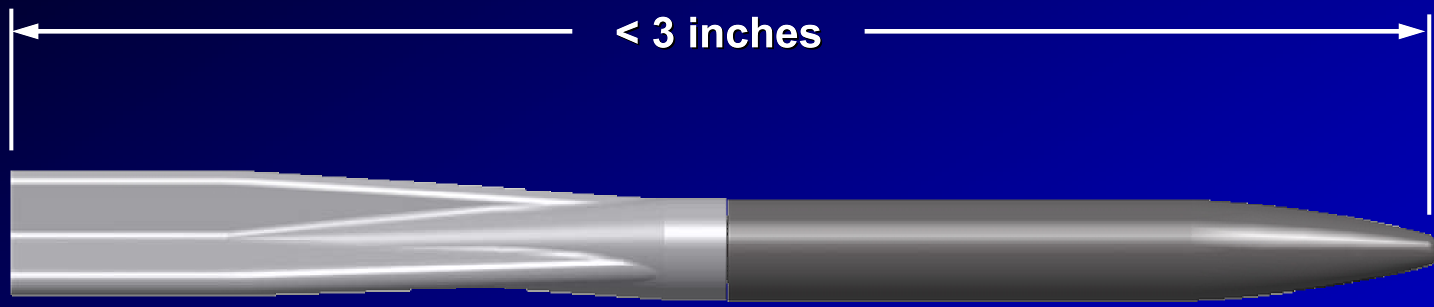
- **Project began as alternate GMLRS/HIMARS payload**
  - ✓ Zero dud rate
  - ✓ Inexpensive
  - ✓ Increased lethality
  - ✓ Limited zone of effects

- **Alternate platforms & applications**
  - ✓ Hydra-70
  - ✓ APKWS
  - ✓ AC –130 Gunship (105 mm cannon)

I-NAIL™ Penetrator

Missiles and Fire Control

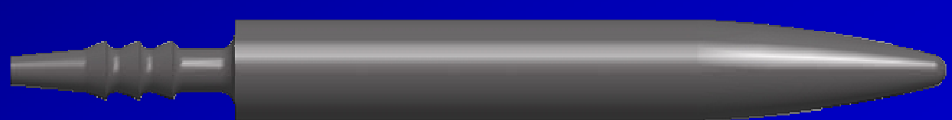
Assembled Configuration



Tail
Injected molded plastic

Forebody
Tungsten Alloy

Forebody



I-NAIL™ Penetrator Design Trades

Missiles and Fire Control

Testing

Forebody Materials
- Ceracom 2
- Ceracom 3 hipped
- Ceracom C116
- Ceracom - not hipped
- French Sintered Rod
- French Swaged Bar
- Hawk (Formulas 1 – 3)
- HD17 Tungsten Bar
- HD17D Tungsten Bar
- Liquid Metal
- Sintered Tungsten
- Tungsten Welding Rod

Tail Materials
- Aluminum
- Magnesium
- Plastic
- Mischmetal (cerium & lanthanum)

Penetrator Masses
- 150 – 300 grains

Target Materials
- Al 5083
- Al 6061T6
- A36 Steel
- High Hard Armor
- Cast Iron Engine Manifold
- Concrete block
- Cinderblock Wall Simulant
- Flak Jacket
- Ballistic Gelatin

Impact Velocities
- 750 – 2000 f/s

Analysis

Penetrator Masses
- 150 – 300 grains

Forebody Geometry
- Nose Shape
  - Circular Ogive
  - Von Karman (3:1 - 1:1)
- Shaft Cross Section
  - Circular
  - Hexagonal
- Tip Radii
  - Flat
  - Hemispherical

Impact Velocities
- 750 – 2000 f/s

Penetration Testing

Business Development / Demo Tests

- Performed in conjunction with tungsten evaluations
- Variety of targets, penetrator designs, and impact conditions

Engineering Tests

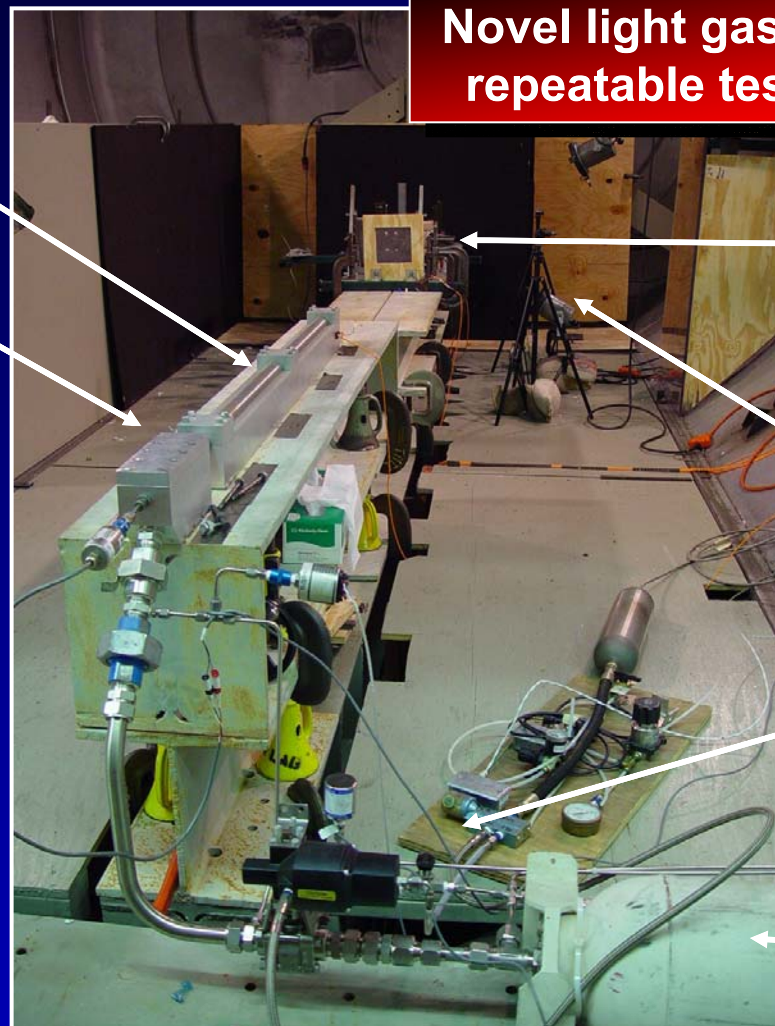
- Performed to develop structured database
- Design of Experiments techniques used to design test matrix
- Results used to develop regression-based penetration predictors

LMMFC Light Gas Gun Facility

Missiles and Fire Control

Novel light gas gun provides repeatable test conditions.

Data Acquisition/Data Reduction System



Gas (He) Gun

Breech

Make Screens/ Target

Lighting/High Speed Cameras

Gas Retention Valve

Gas Plenum

Representative Targets

Missiles and Fire Control

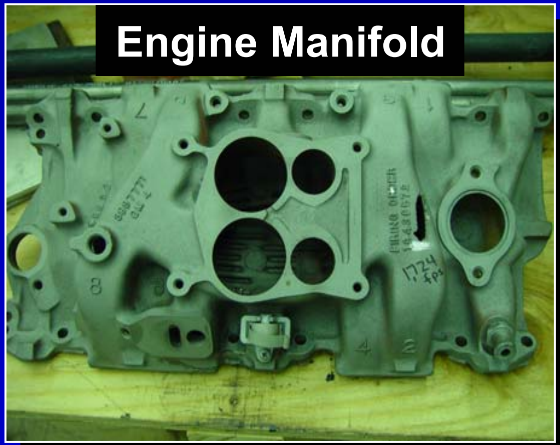
Light Armor

Ballistic Gel

Flak Jacket

Cinder Block

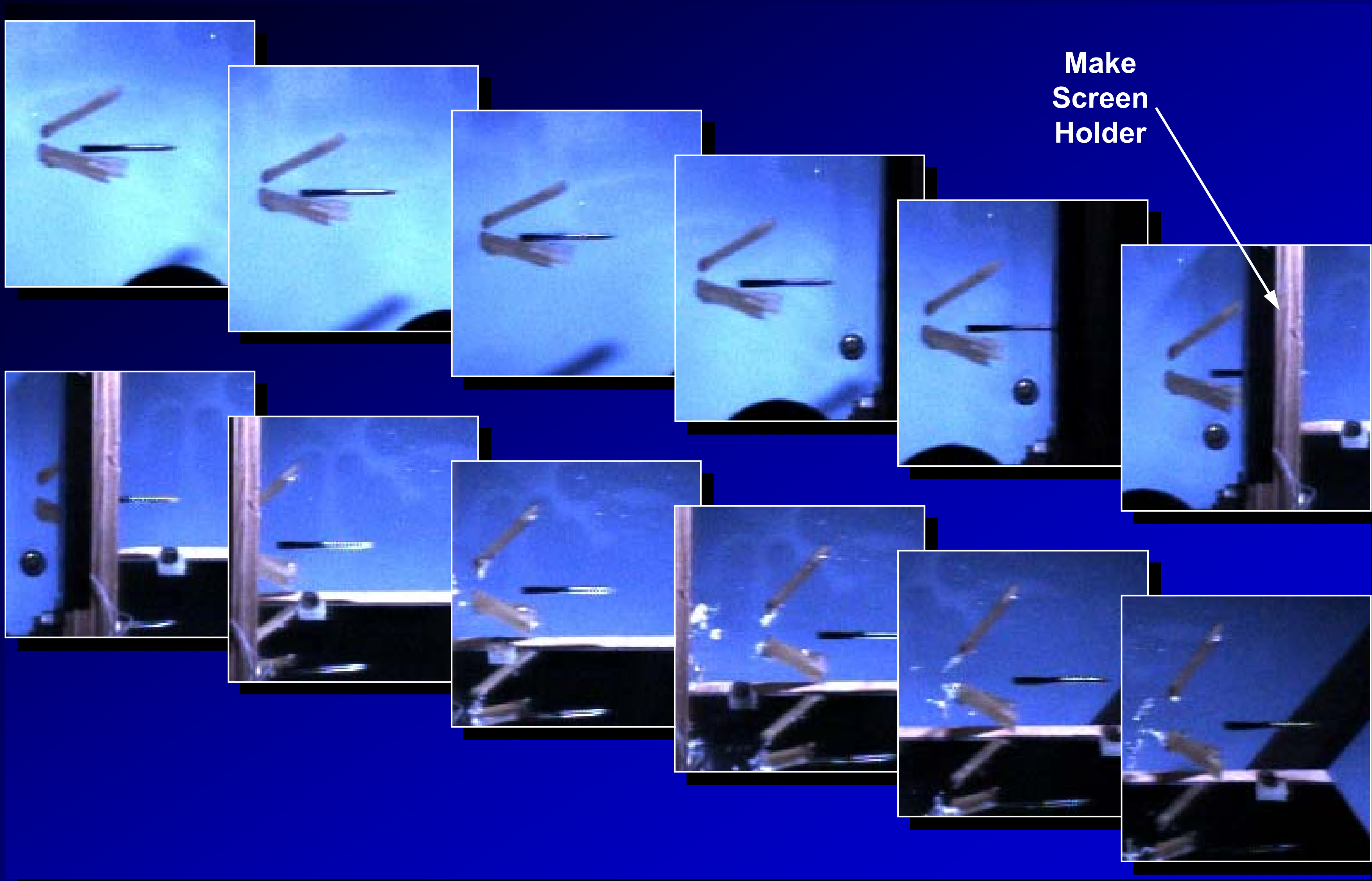
Concrete



Engine Manifold

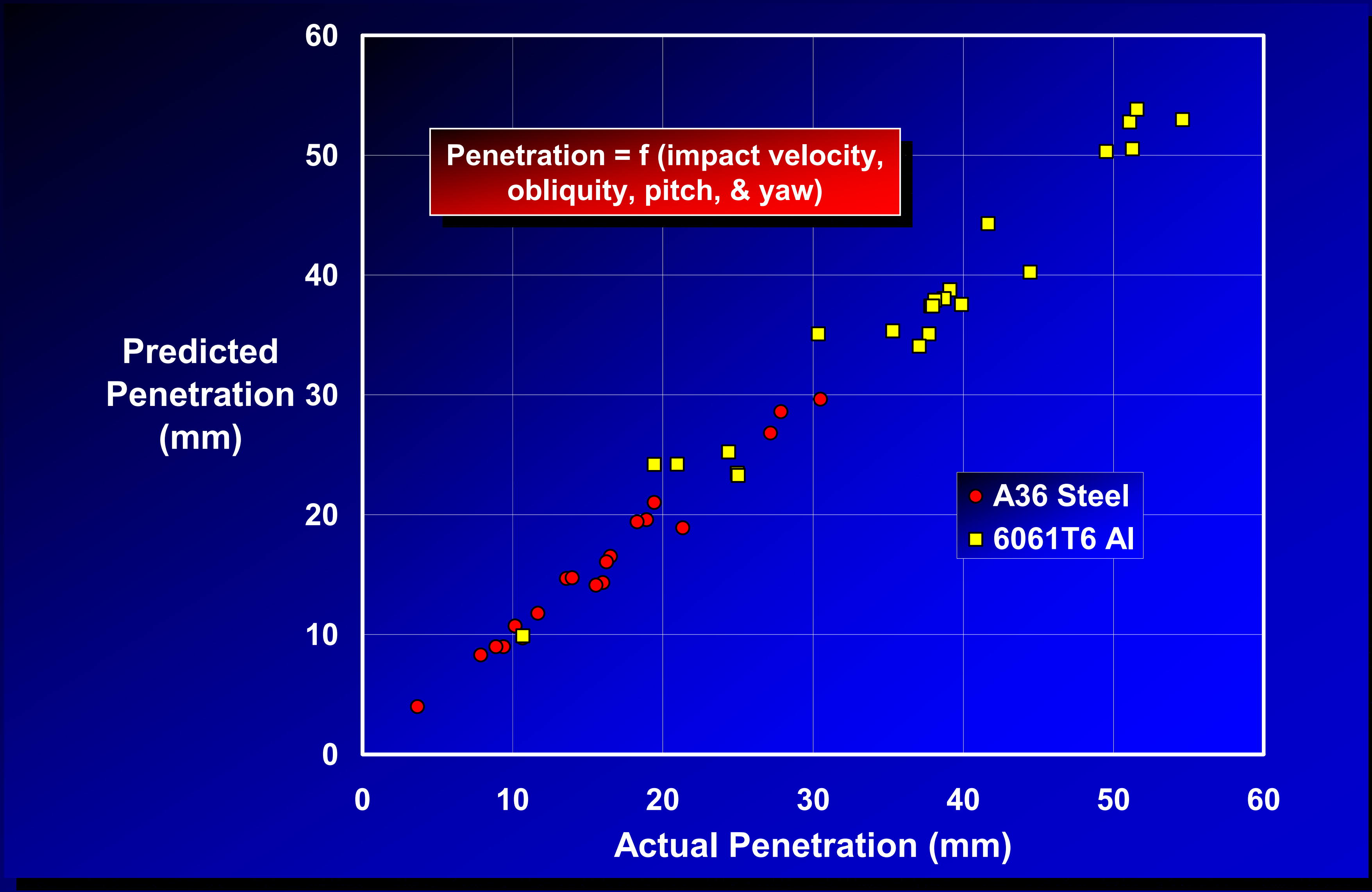
I-NAIL™ Sabot Separation

Missiles and Fire Control



I-NAIL™ Penetration Modeling

Missiles and Fire Control



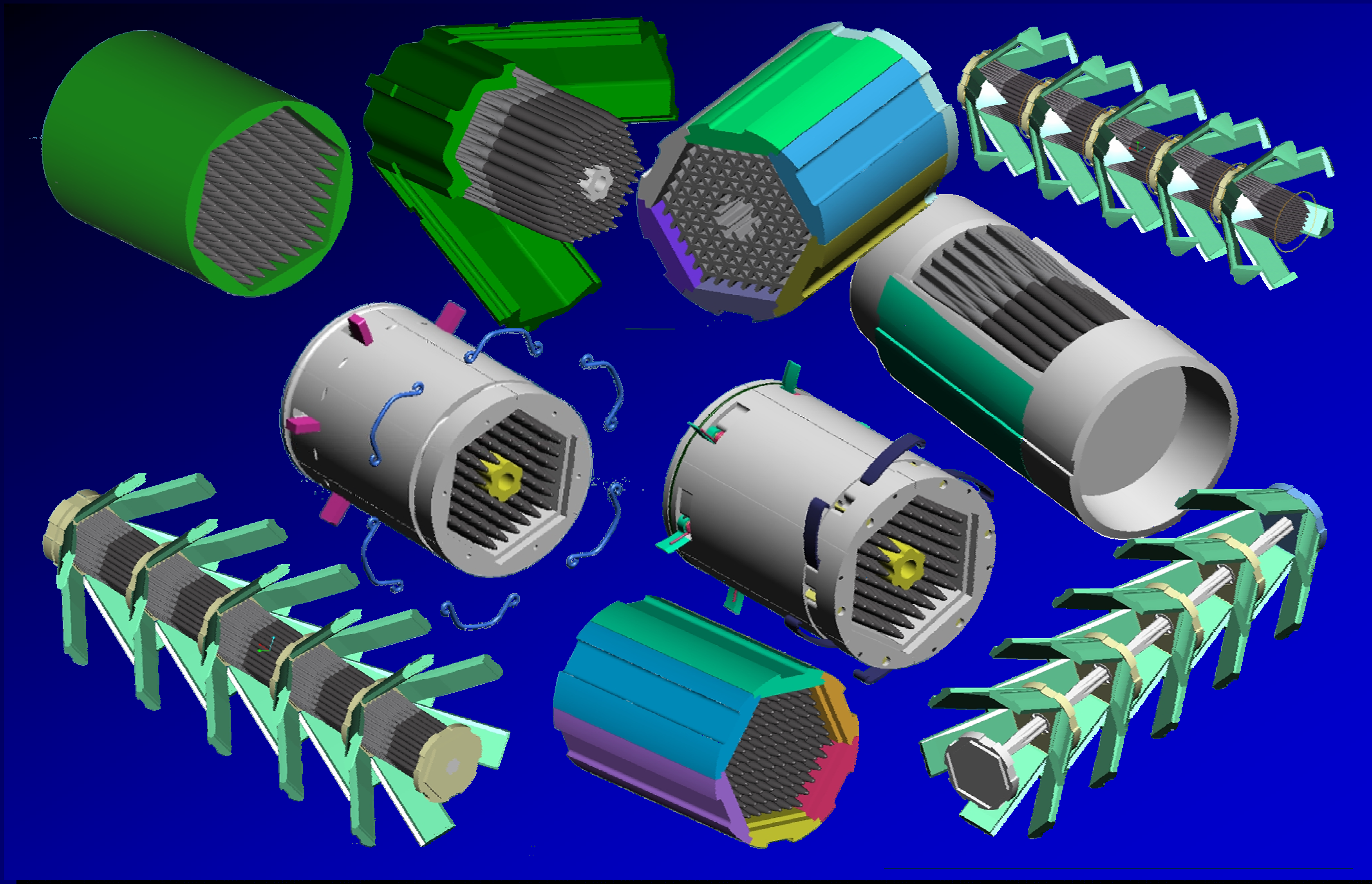
I-NAIL™ Integration into Hydra

Objectives:

- Package maximum loadout of I-NAIL™ penetrators maintaining HYDRA-70 weight / CG requirements
- Design and demonstrate performance of dunnage / penetrator support mechanism
- Demonstrate successful expulsion of I-NAIL™ penetrator payload with Hydra-70 expulsion charge
- Expulsion velocity ~150 f/s

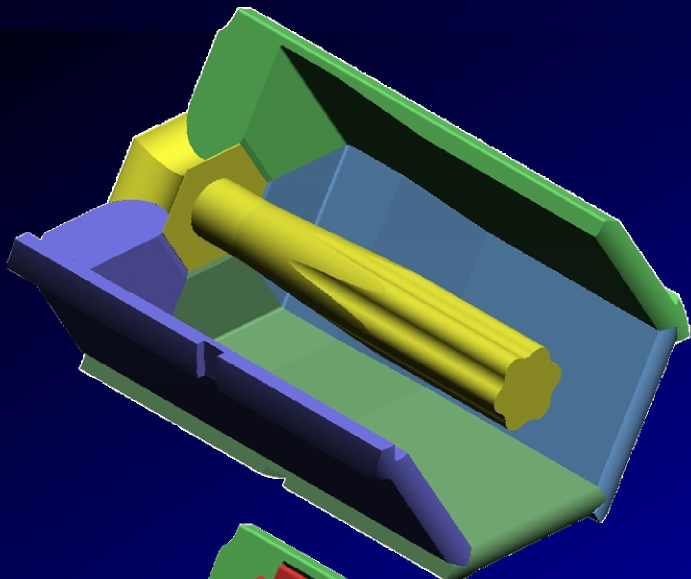
I-NAIL™ Penetrator Dunnage Concepts

Missiles and Fire Control

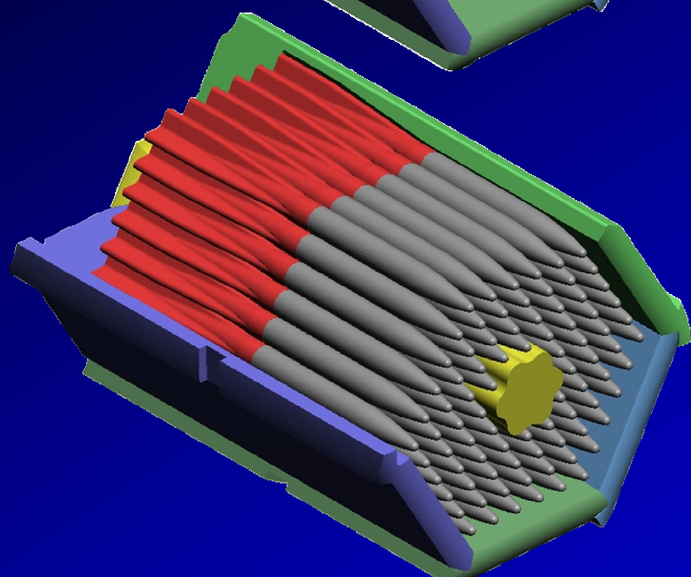


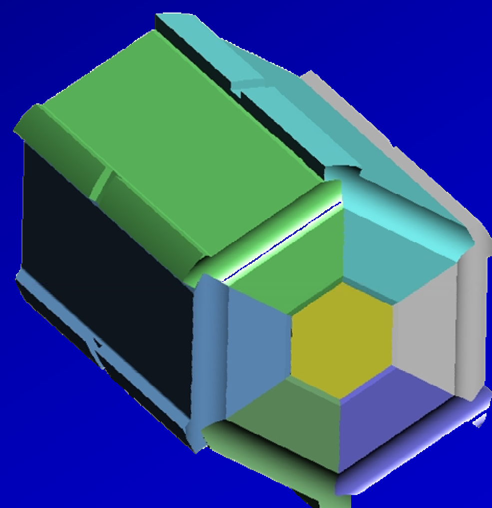
Selected Hydra-70 Dunnage Concept

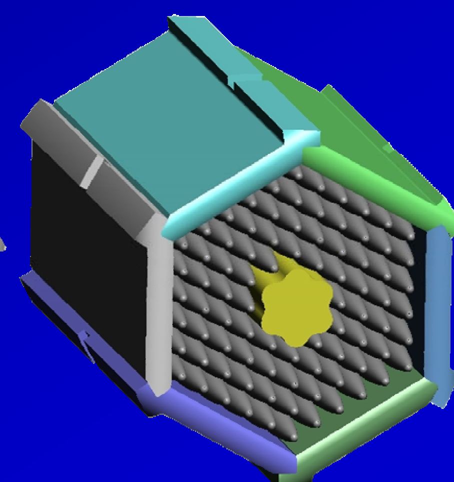
Missiles and Fire Control



- 6-petal design
- Peels apart like banana
- Center post takes loads of adjacent penetrator stacks
- Injection molded plastic

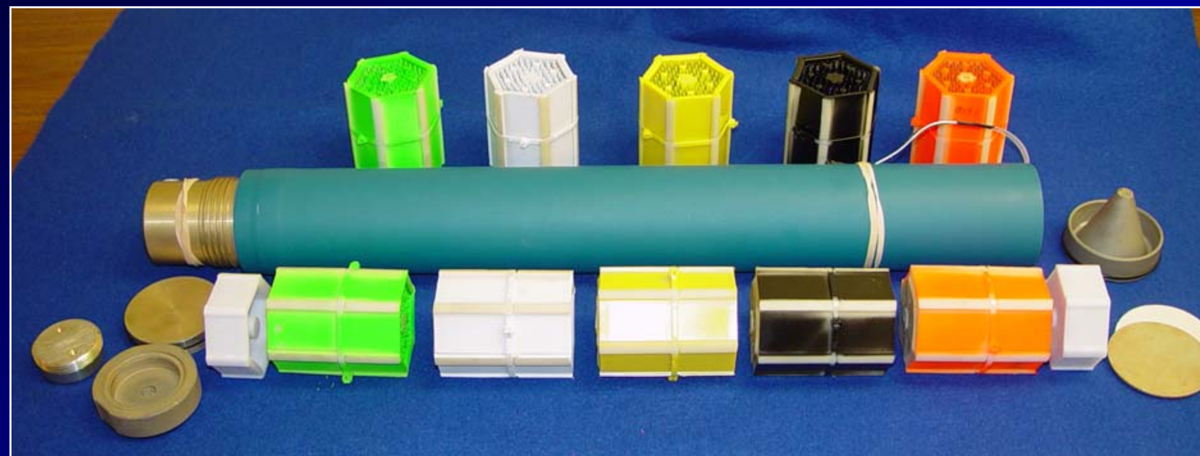






Expulsion Test Hardware


Forward end of Cup




Aft end of Cup

- 390 I-NAIL™ penetrators/warhead + 30 simulants for mass matching
- Fore & aft spacers added for CG match
- 6-Petal dunnage design for support and penetrator release
- GFE Hydra-70 expulsion charge
- Special SAF to allow static function

Expulsion Testing

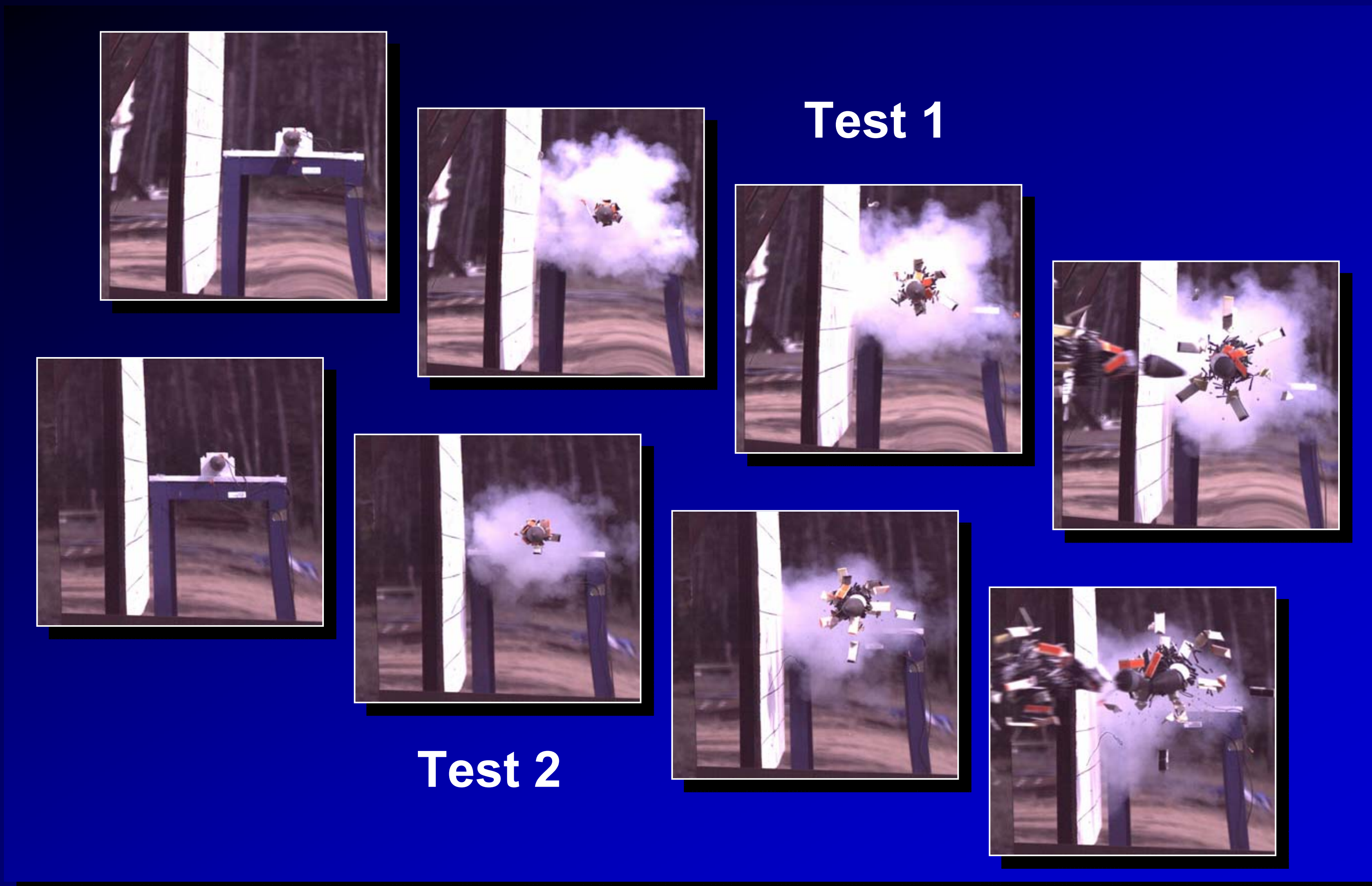
- **Two Hydra-70 warhead casings loaded at Camden, AR facility with I-NAIL™ penetrators**
- **Two warhead tests performed on 20 October 2004 at National Technical Systems site in Camden, AR**
- **Static fired two warheads**
  - **No representative rocket airflow**
  - **No spin**
- **Three high-speed digital cameras used for data acquisition (2.1K frames/sec)**
- **Celotex package positioned down range for possible pattern data**

Expulsion Test Layout

Missiles and Fire Control

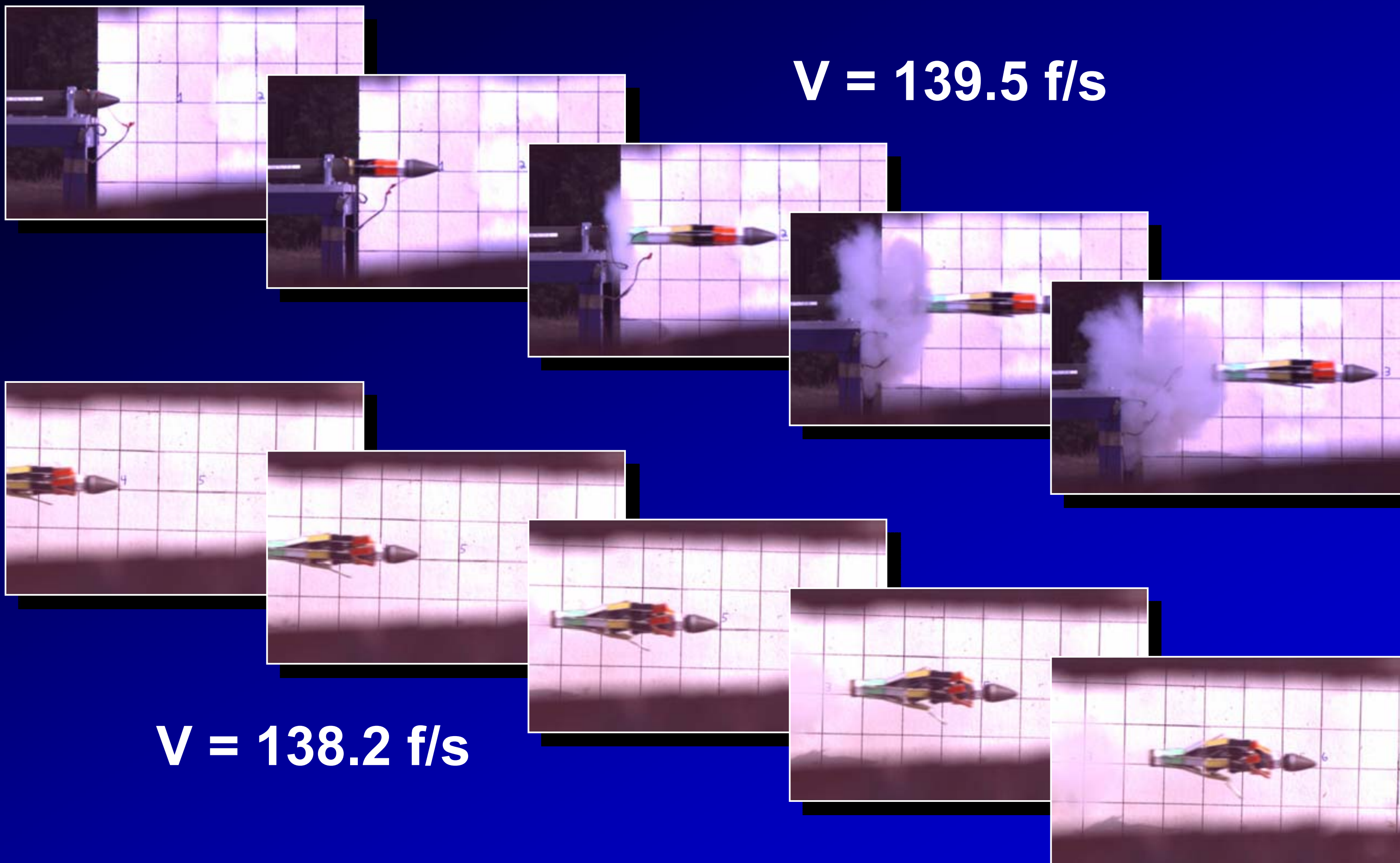
Down-Bore Views

Missiles and Fire Control



Side View – Test 2

Missiles and Fire Control



V = 139.5 f/s

V = 138.2 f/s

Expulsion Test Results Summary

Missiles and Fire Control

- Both payloads successfully ejected
- Nominal ejection velocities achieved in both tests

  Test 1: Camera 1 – no data
  Camera 2 – 138.3 f/s
  Test 2: Camera 1 – 139.5 f/s
  Camera 2 – 138.2 f/s
- Most penetrator damage occurred from sideways impacts as opposed to expulsion event
- Actual flight conditions will minimize such effect since penetrators will have time to align correctly
- Penetrator ballistics as expected

Wind Tunnel Tests

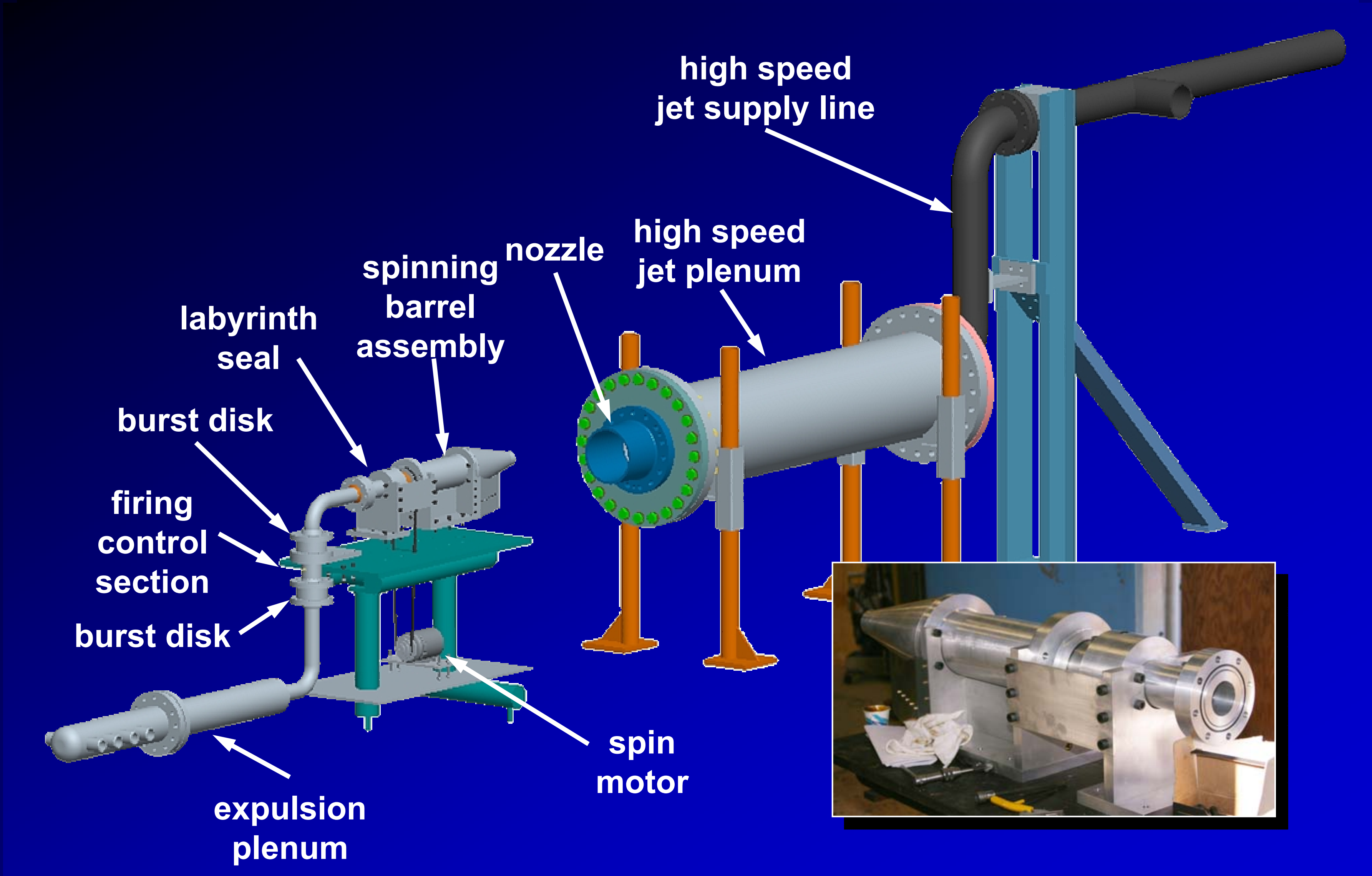
Objectives:

- Demonstrate separation cleanliness of two potential I-NAIL™ dunnage designs
  - 6-Petal Design (Hydra-70)
  - 3-Compartment Design (APKWS)
- Gather initial conditions for possible use in future dispense and pattern simulation studies

Wind Tunnel Tests

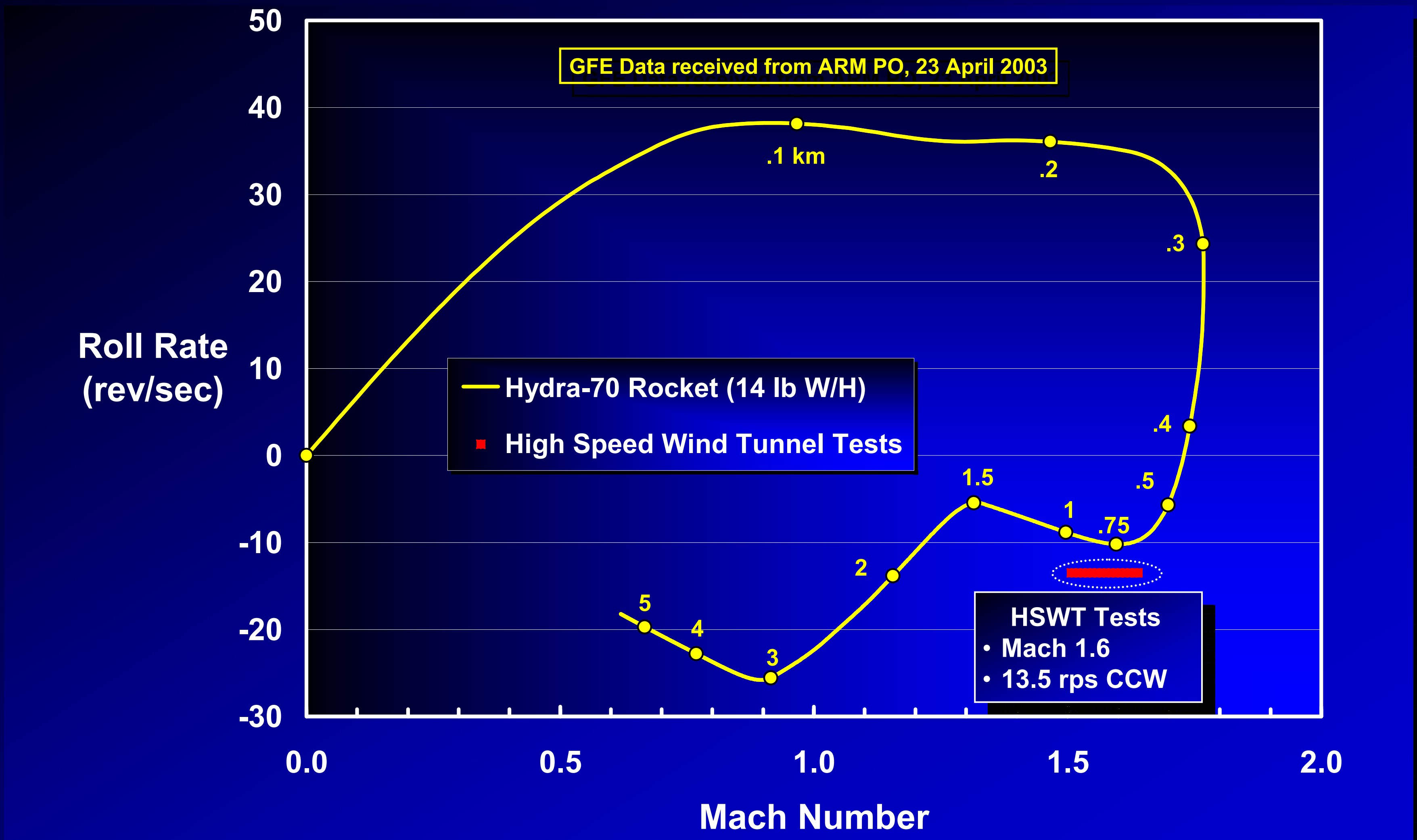
- Testing performed at LMMFC High Speed Wind Tunnel (HSWT) facility in Grand Prairie, TX on 18 December 2004
- "Backyard" Tests – High velocity flow ducted out of high pressure tanks to external test location
- Spinning air gun constructed to expel payload into high mass flow air stream
- Payloads represented two I-NAIL™ penetrator pack concepts
  - 5 packs present in M255-A1 Hydra-70
  - 3 packs present in APKWS

Wind Tunnel Test Setup



I-NAIL™ Wind Tunnel Test Conditions

Missiles and Fire Control

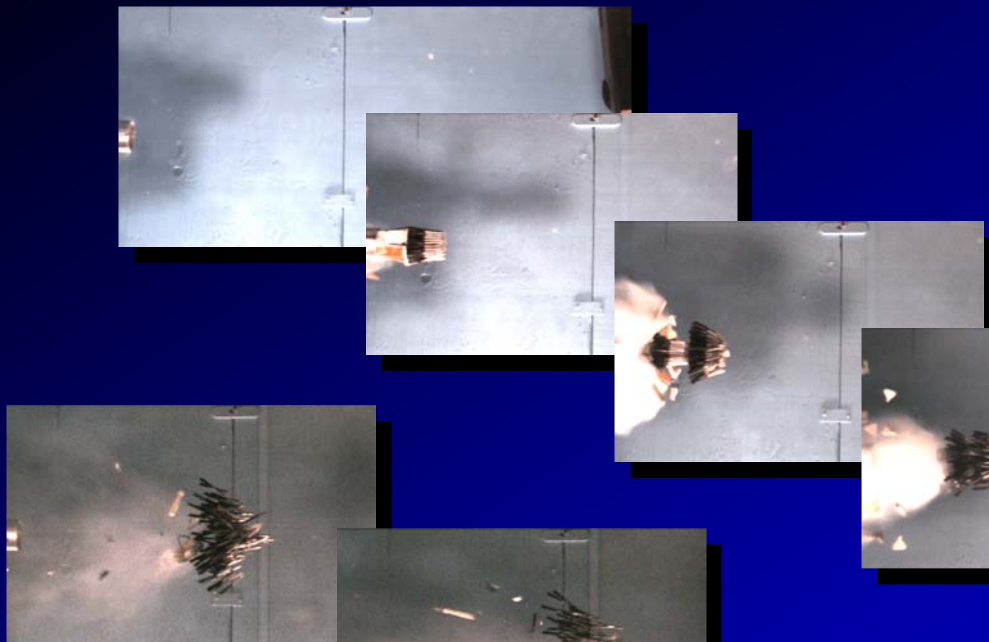
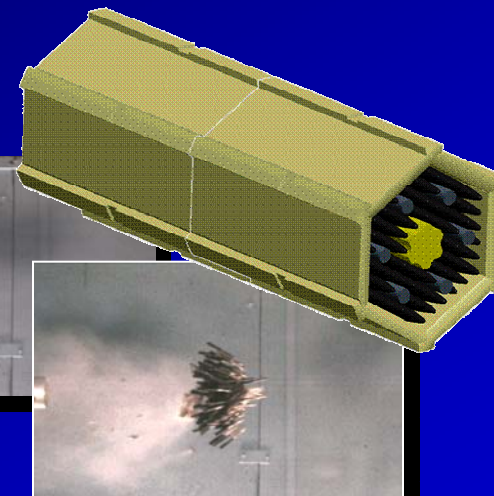
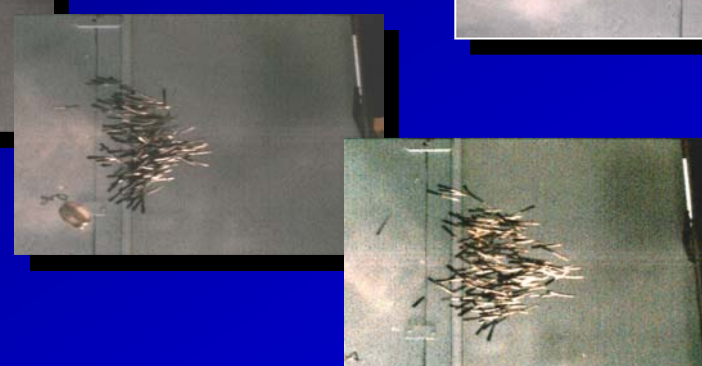


Conditions most representative of 750 – 1000 m Hydra-70 range.

I-NAIL™ Wind Tunnel Test 1

Missiles and Fire Control

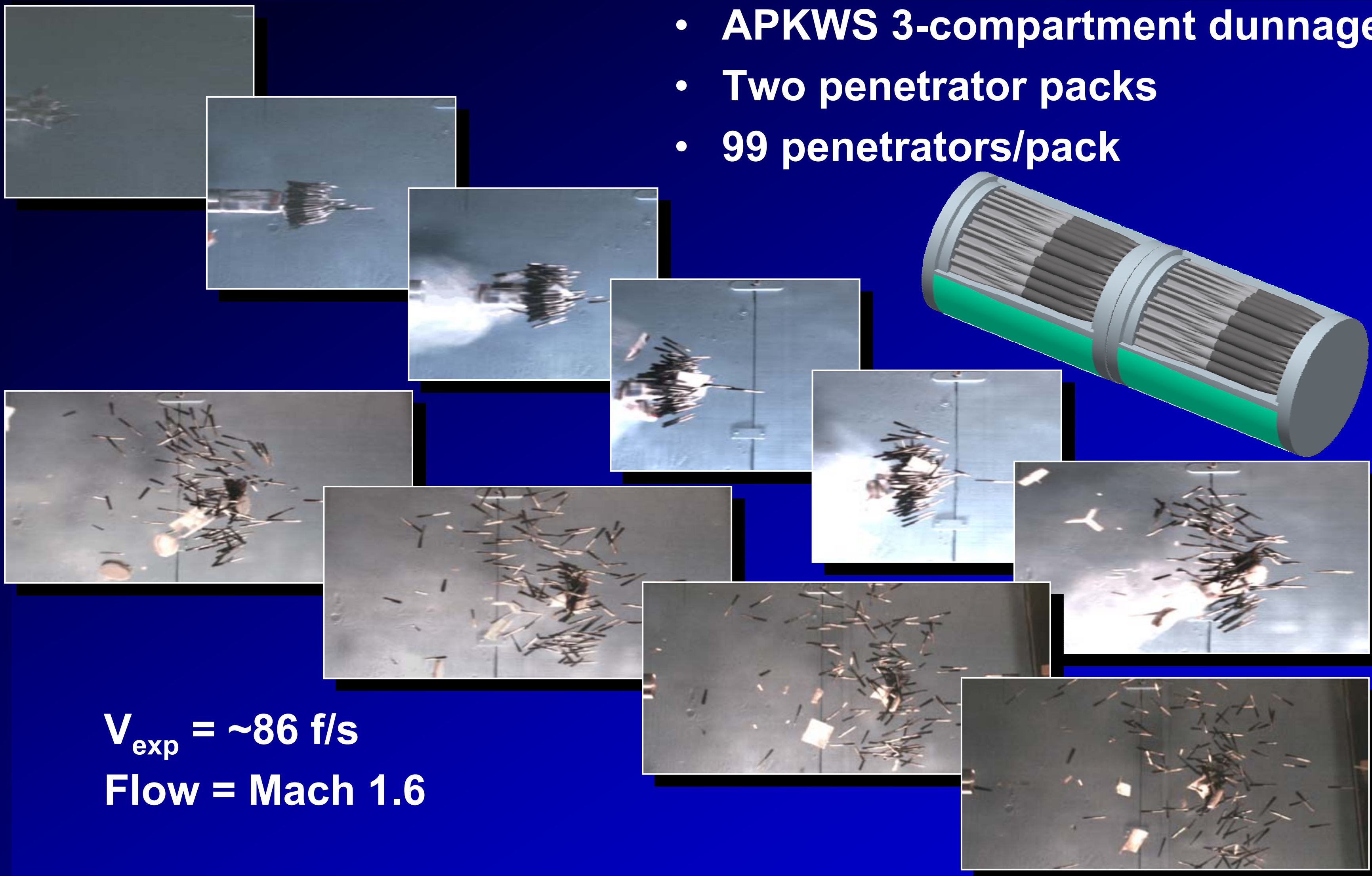
- Hydra-70 6-petal dunnage
- Two penetrator packs
- 84 penetrators/pack

- Vexp = ~86 f/s
- Flow = Mach 1.6

I-NAIL™ Wind Tunnel Test 2

- **APKWS 3-compartment dunnage**
- **Two penetrator packs**
- **99 penetrators/pack**



V_{exp} = ~86 f/s

Flow = Mach 1.6

I-NAIL™ Dunnage Comparison

Missiles and Fire Control

6-Petal Dunnage Concept

- Good release achieved
- Petals broke in a desired fashion and moved away quickly

3-Compartment Dunnage Concept

- Center structure interferes with radial dispense of penetrators
- Compartment covers and solid forward plate are pushed into penetrator cloud

Both Concepts

- Collisions occurred between two penetrator packs
- Second pack catches up to first mainly due to still being pushed by plenum gas; drafting effects may contribute
- Good penetrator dispersion and aerodynamics

Wind Tunnel Test Conclusions

Dunnage

- 6-Petal dunnage design preferred
  - Demonstrated better overall performance
  - Compatible with Hydra-70 and APKWS platforms
  - Utilizes existing M255-A1 components
  - Inexpensive solution for APKWS

Penetrators

- Design has been modified to strengthen weak point in tail attachment section to minimize breakage

Viable dunnage concept has been tested and is ready for integration and flight testing.

I-NAIL™ Summary

Missiles and Fire Control

- Mini-penetrator design developed
- Design provides significant behind-armor effects
- Highly lethal with no unexploded ordnance left on the battlefield
- System integration approach and implementation demonstrated
- Compatible with a variety of delivery systems