Hazard Assessment Testing of the SM-3 Block IA Missile

Presentation for the

NDIA 23rd Annual National Test and Evaluation Conference

13 March 2007

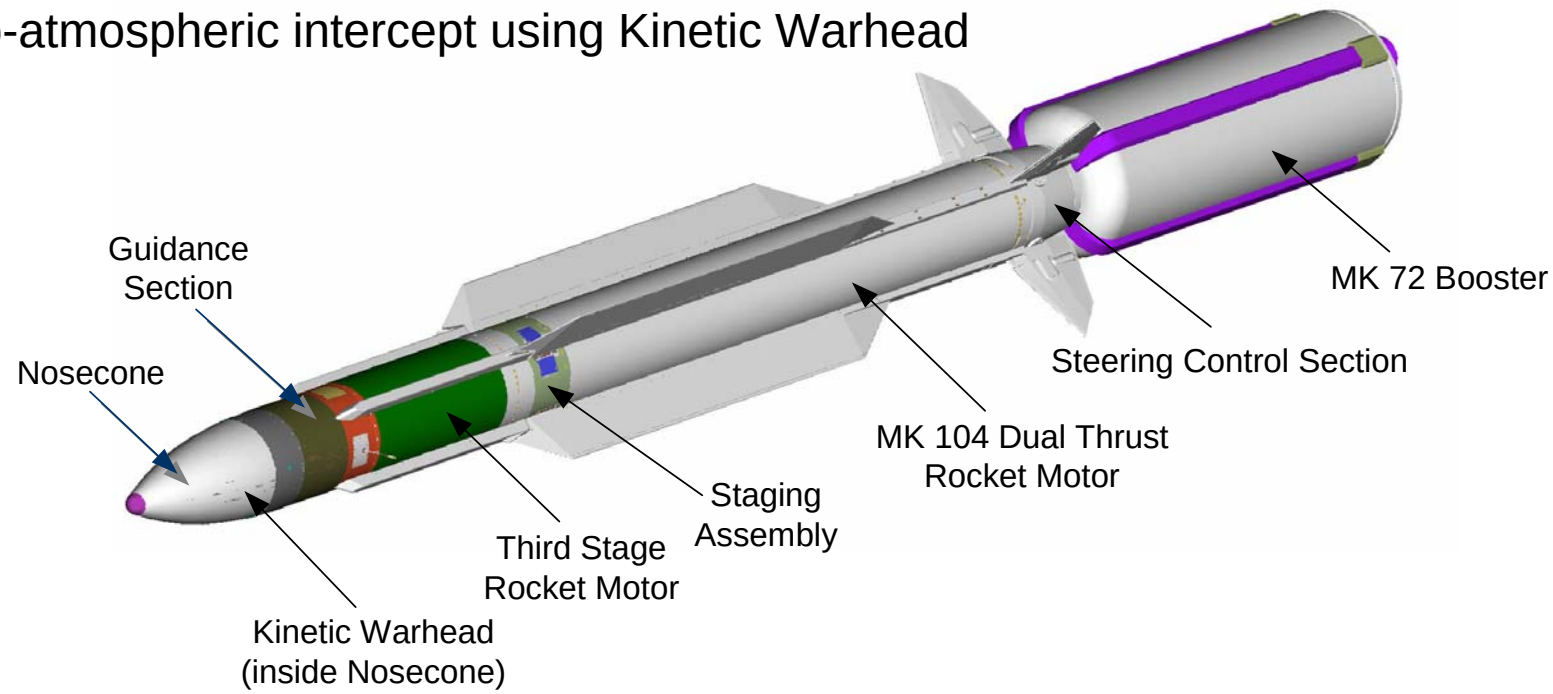
Dave Houchins
Dahlgren Division, Naval Surface Warfare Center
Test & Evaluation Division (Code G60)

Outline

- Description of SM-3 Block IA missile
- Hazard Assessment Test Program
- Test methodologies
- Summary of results
- Lessons-learned

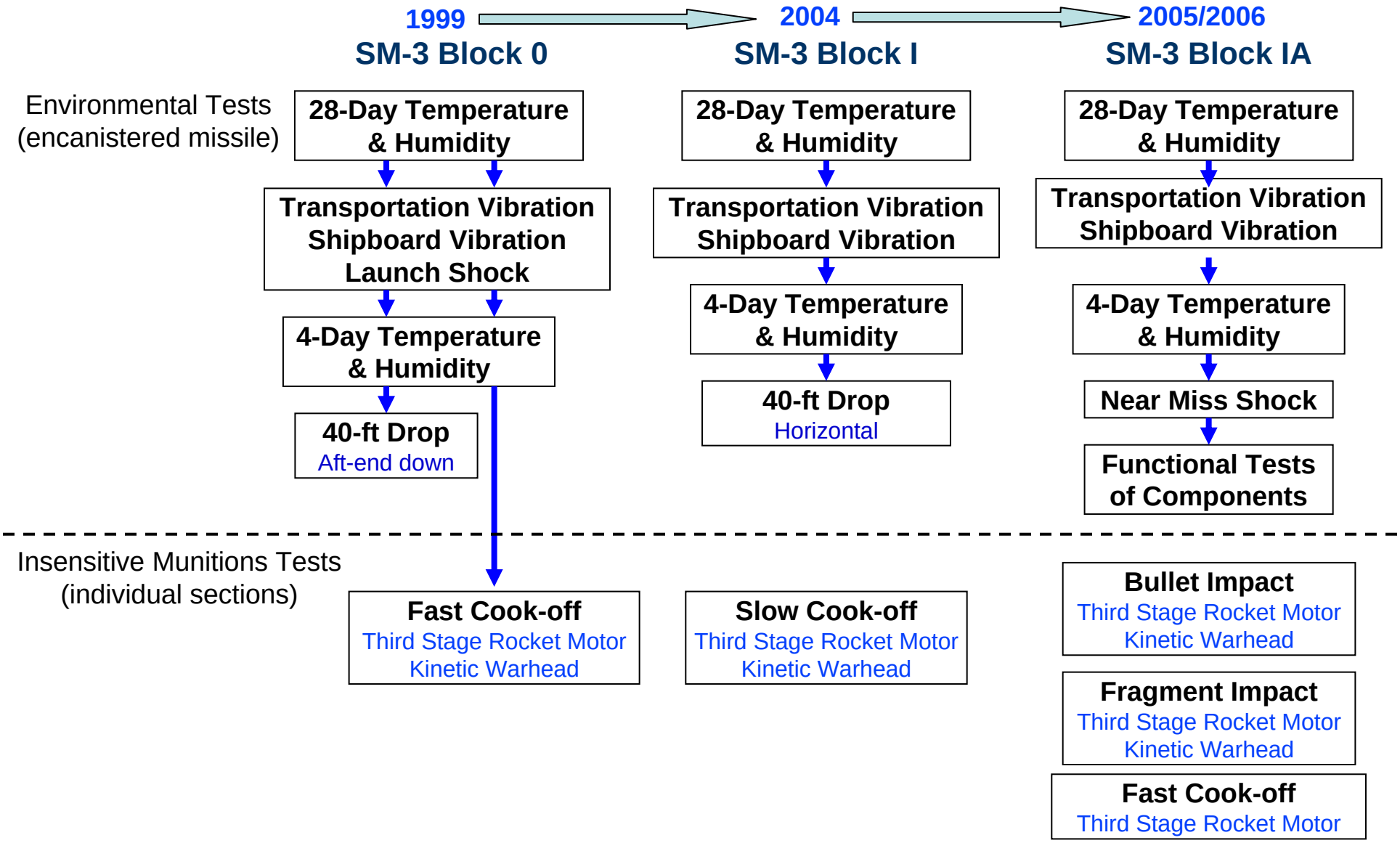
SM-3 Block IA Missile

- Sea-based component of the Ballistic Missile Defense system
- Launched from Vertical Launching System of DDG-class ships
  - Approximately 22 ft length x 13.5 in diameter
    - MK 72 booster ~21 in diameter
  - Contains ~2065 lbm propellant
  - Designed for MK 21 MOD 2 VLS canister
    - Total mass of all-up round ~6300 lbm (i.e., missile and canister)
- Exo-atmospheric intercept using Kinetic Warhead



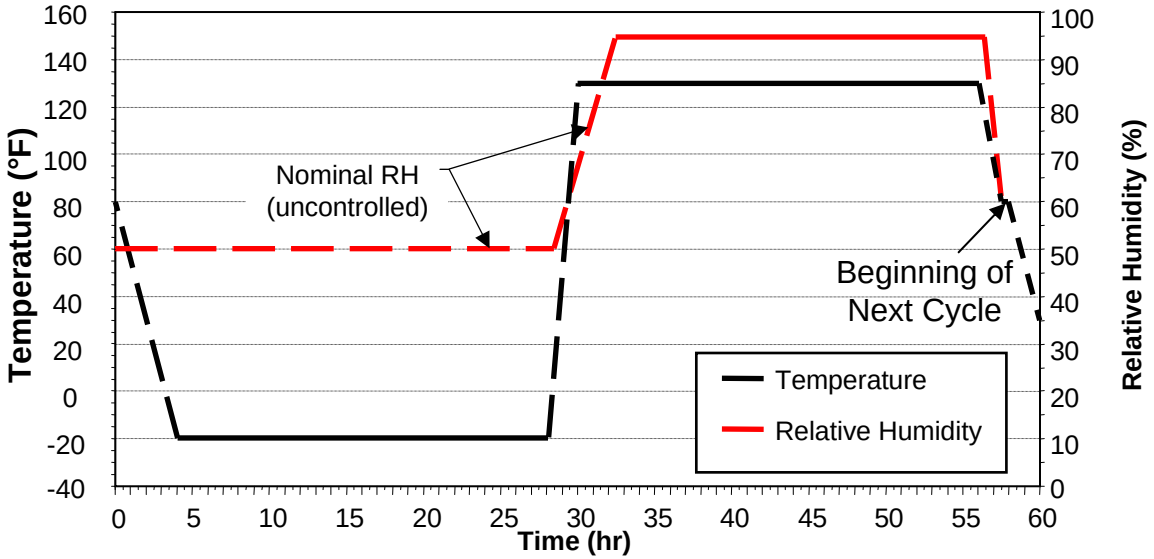
Hazard Assessment Testing of the SM-3 Block IA Missile

Hazard Assessment Test Program for SM-3



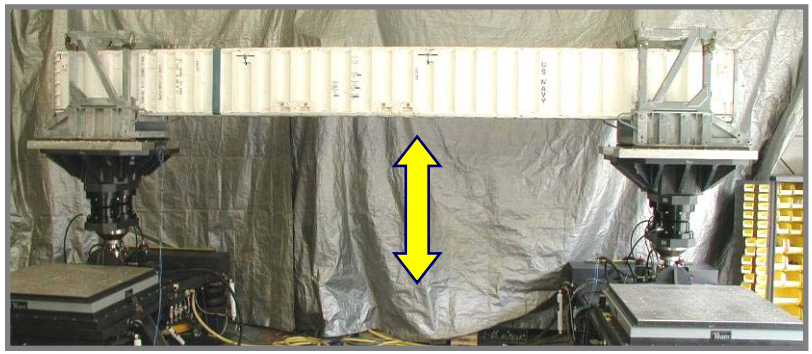
28-Day / 4-Day Temperature and Humidity (T&H) Test Method

- Encanistered missile cycled between hot/humid and cold environments
  - Conditions based on environmental profile for logistics life-cycle
    - +130F with 95% RH for hot/humid environment
    - -20F for cold environment
  - 1 cycle includes 24-hr (min) exposure to each environment
- Tests conducted using programmable environmental chamber
- Test methods identical except for duration
  - 14 cycles for 28-day T&H; 2 cycles for 4-day T&H

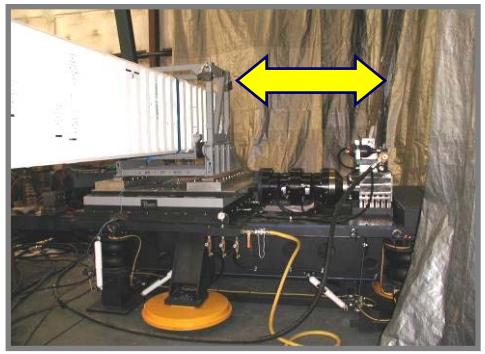


Transportation Vibration Test Method

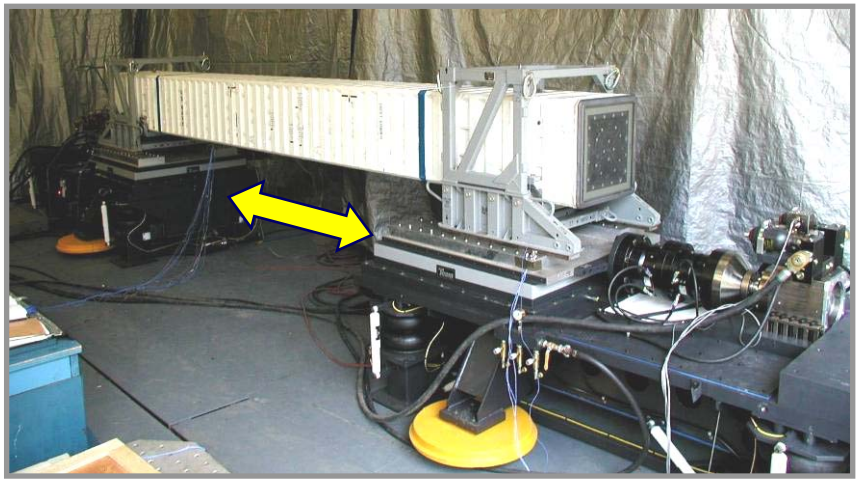
- Encanistered missile subjected to random vibration IAW MIL-STD-810
  - Simulate transportation by truck over improved roads
  - Input applied through 3 orthogonal axes; 1 axis at a time
  - 3 hr/axis duration to simulate 3000 miles over-the-road transport
- 2 hydraulic actuators used to provide input at each PHS&T skid



Vertical Axis

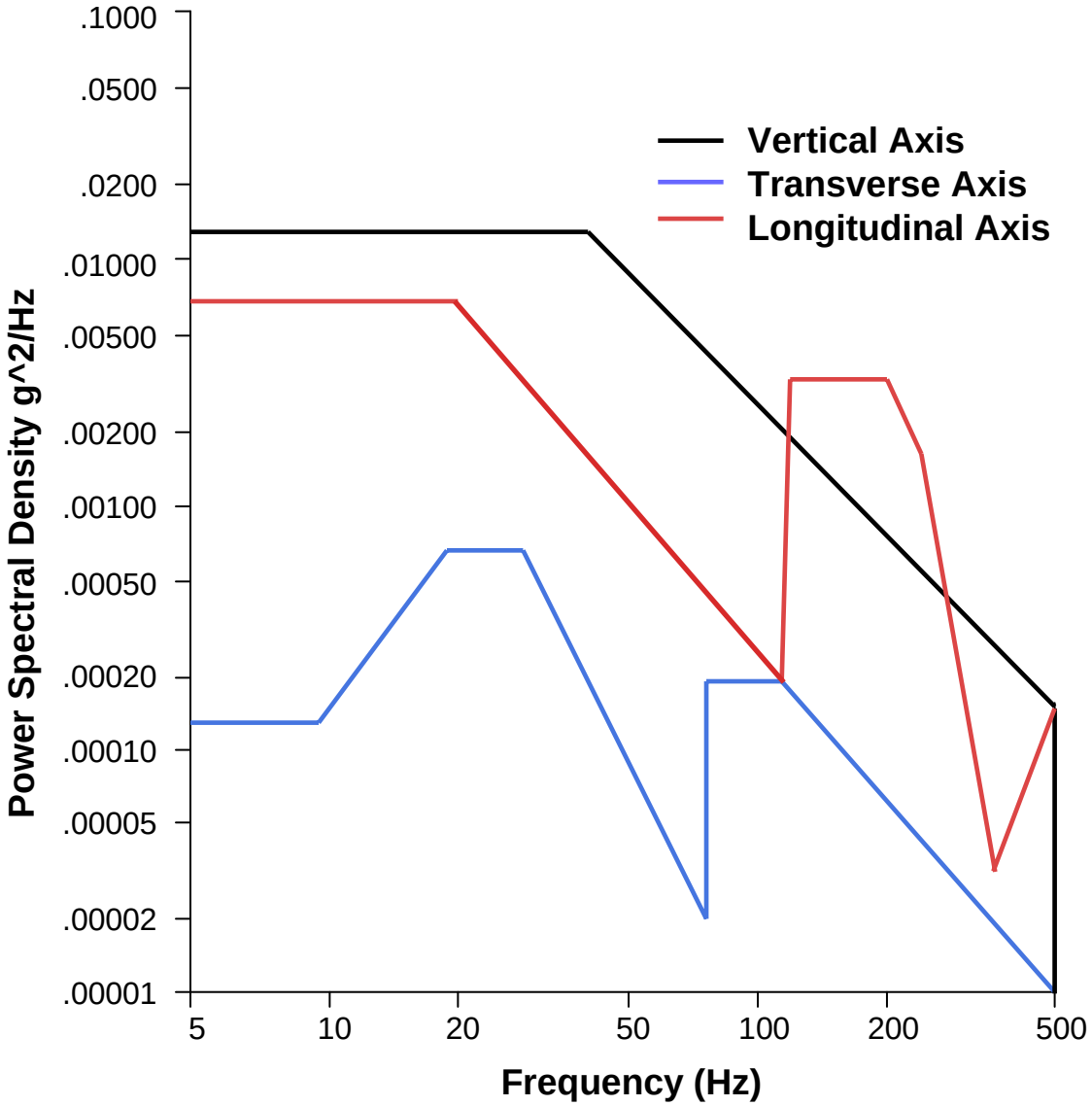


Transverse Axis



Longitudinal Axis

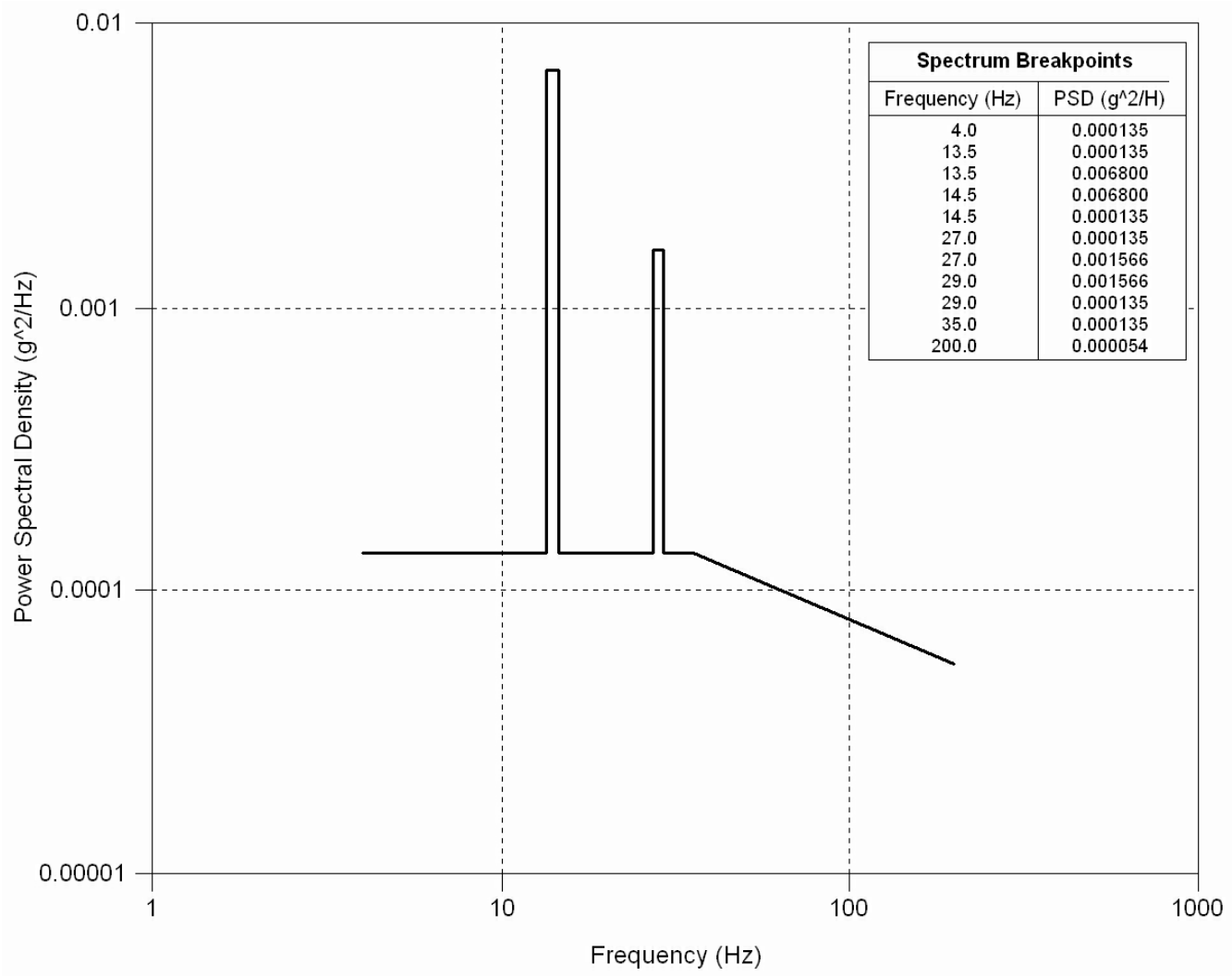
Transportation Vibration Input Profile



Shipboard Vibration Test Method

- Encanistered missile subjected to random vibration to simulate shipboard environment
  - Input profile and duration based on shipboard measurements in VLS cells
    - 4 – 200 Hz frequency range
    - Input spectrum encompasses full range of ship speeds and sea states
    - 39-hr/axis to simulate anticipated deployment durations
  - Input applied through 3 orthogonal axes; 1 axis at a time
- System-specific tailored test requiring approval from NAVSEA 05T
  - Most systems tested IAW MIL-STD-167
    - Sinusoidal vibration across 5 – 50 Hz frequency range
- Accomplished using UD-4000 electrodynamic shaker
  - Special fixtures used to provide input at correct interfaces with canister

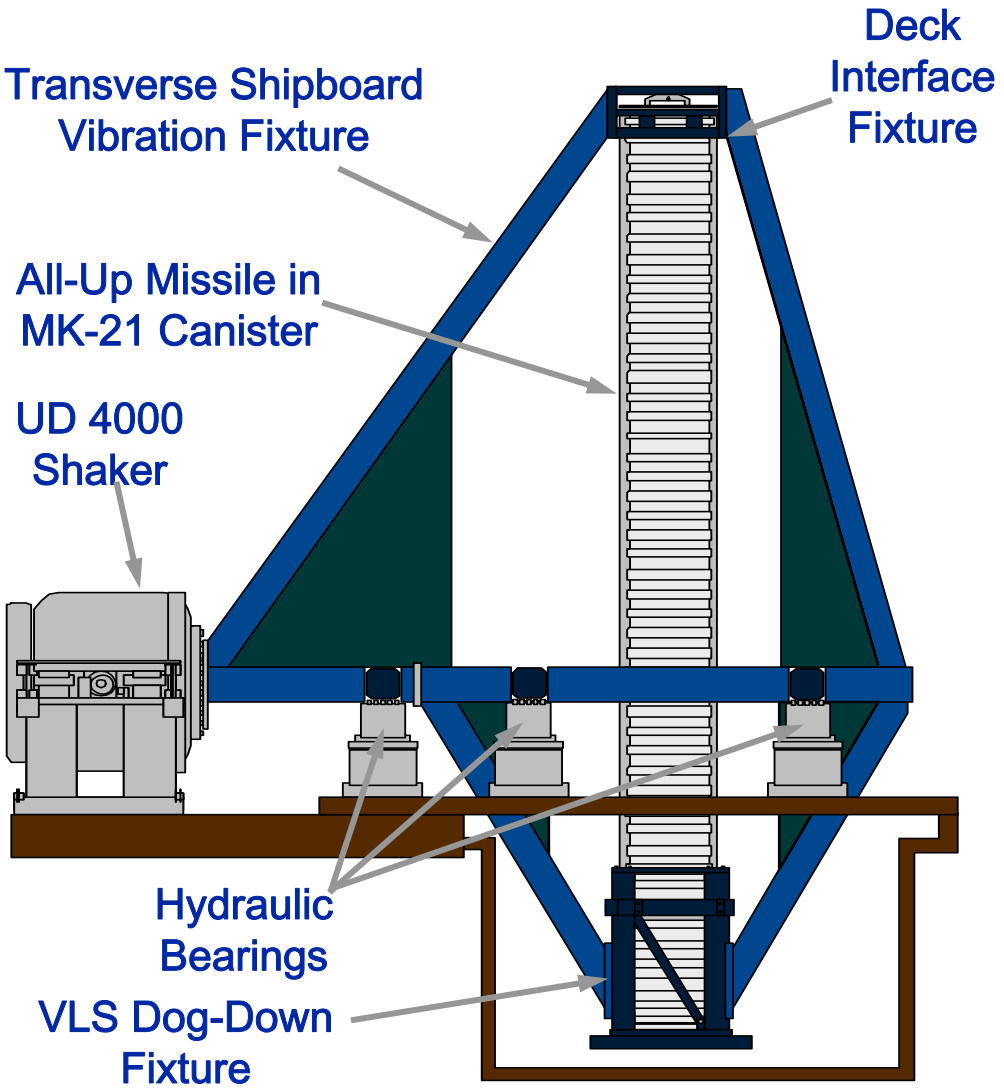
Shipboard Vibration Input Spectrum



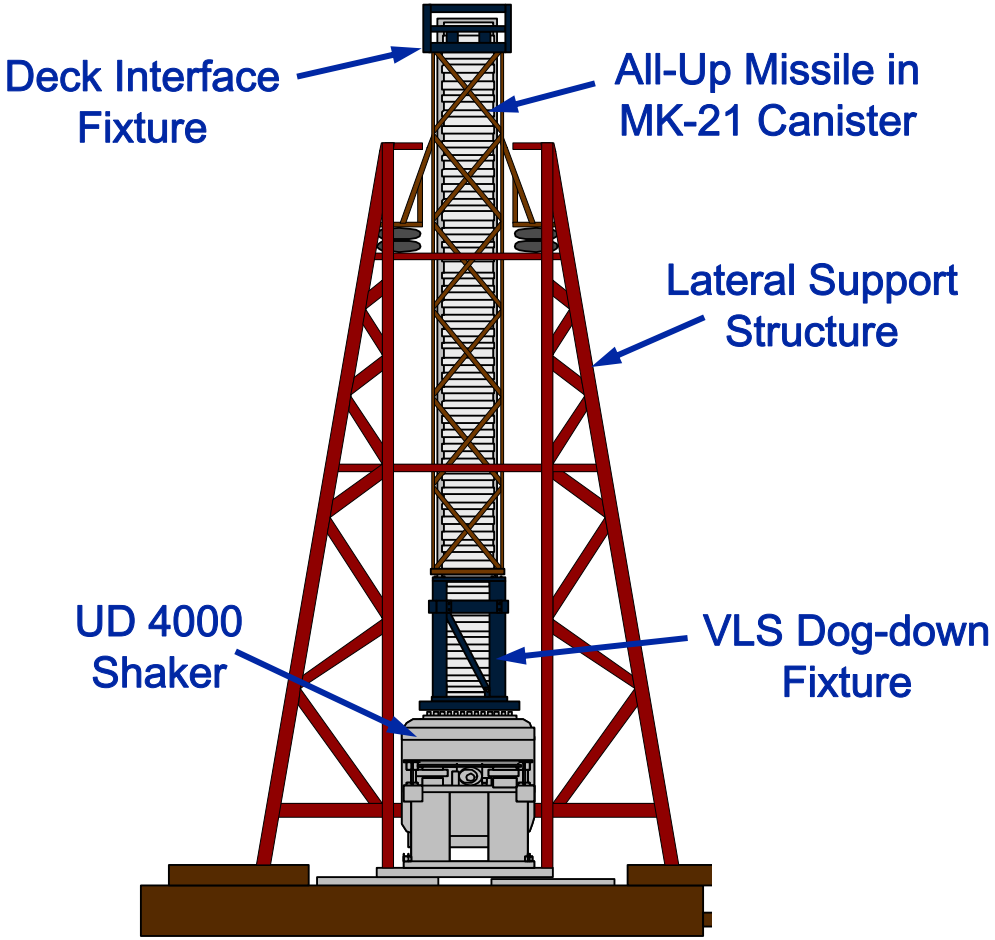
Spectrum Breakpoints

Frequency (Hz)	PSD (g^2/H)
4.0	0.000135
13.5	0.000135
13.5	0.006800
14.5	0.006800
14.5	0.000135
27.0	0.000135
27.0	0.001566
29.0	0.001566
29.0	0.000135
35.0	0.000135
200.0	0.000054

Shipboard Vibration Test Setup (Transverse Axis)



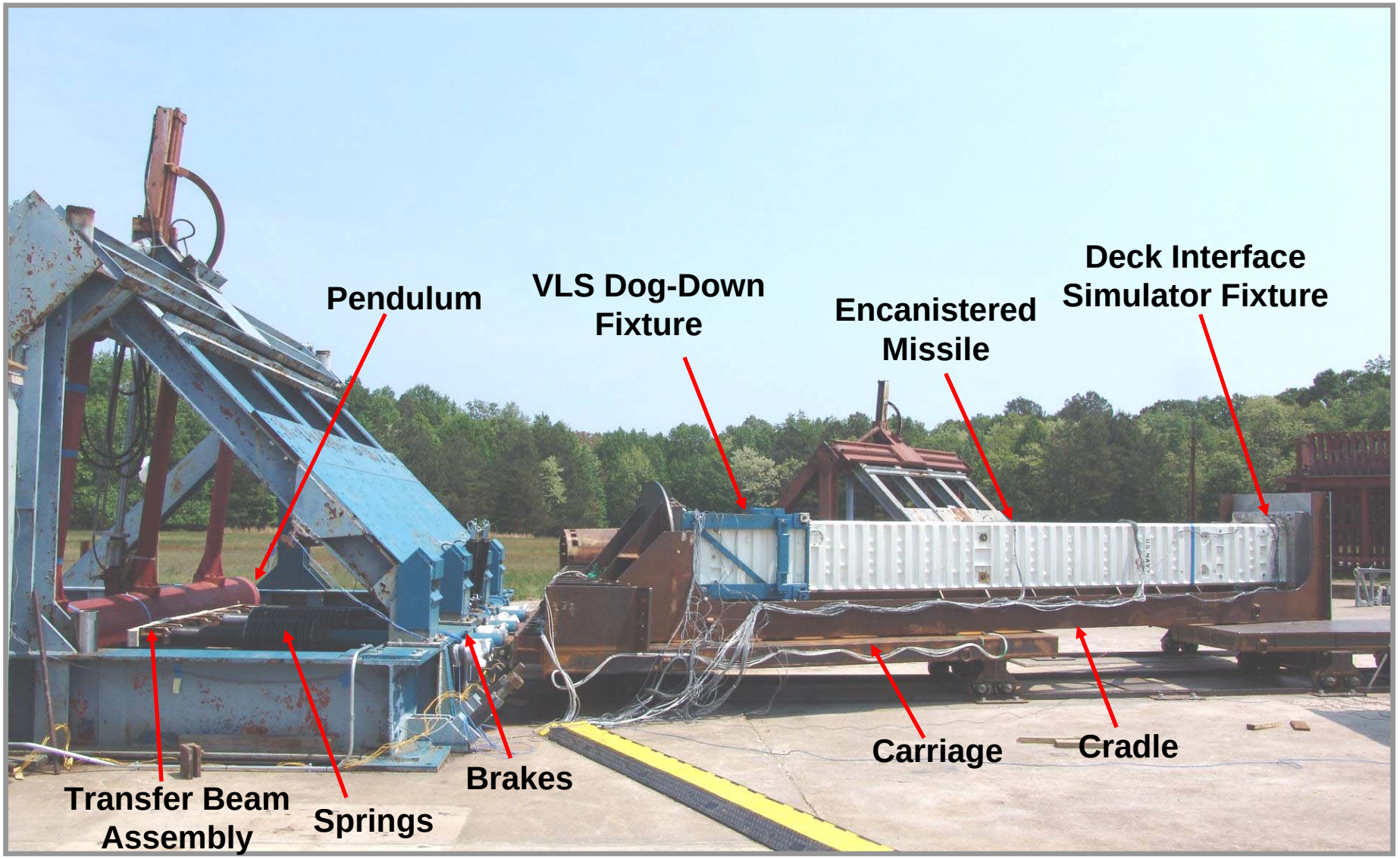
Shipboard Vibration Test Setup (Longitudinal Axis)



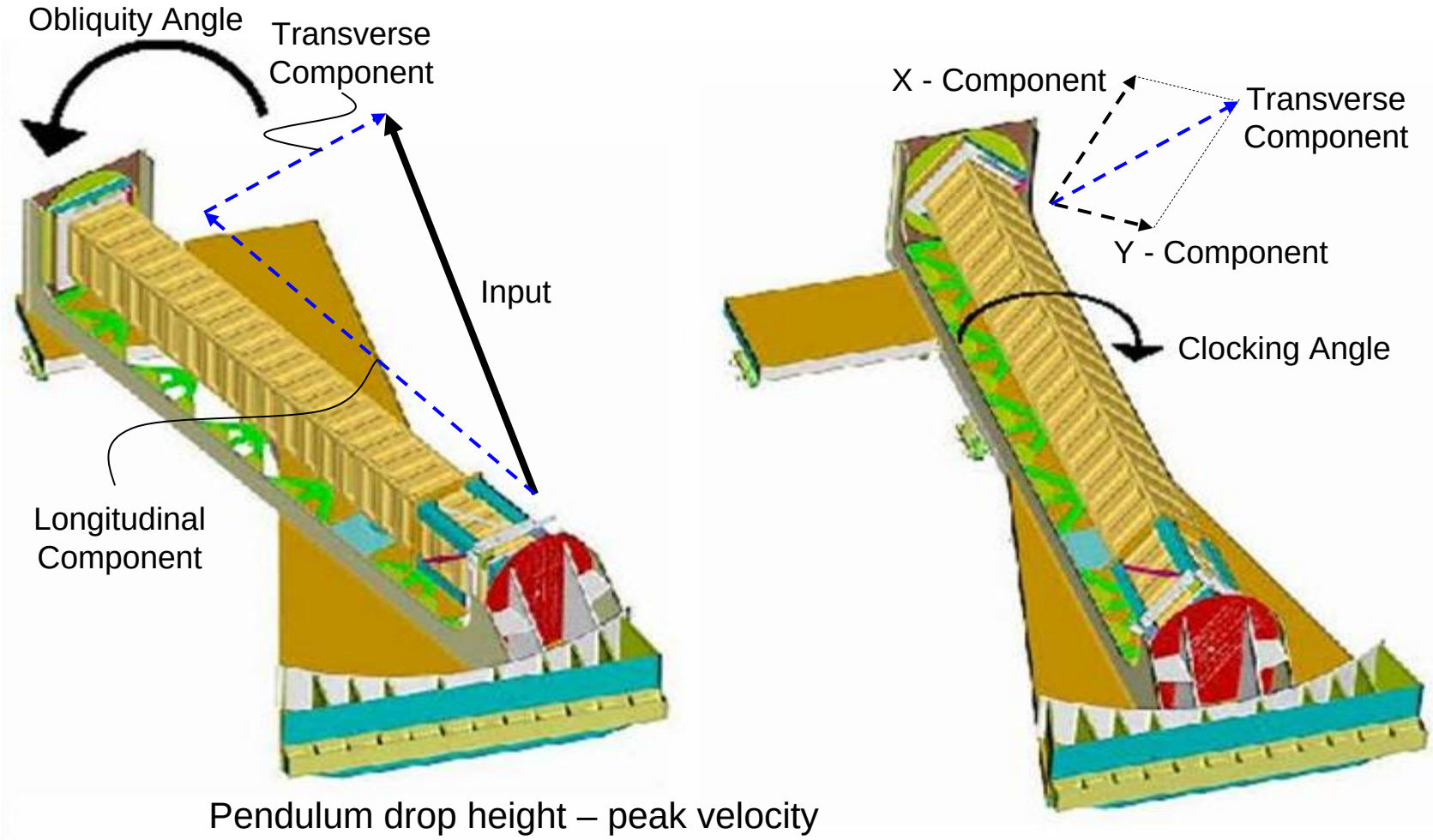
Near Miss Shock Test Method

- Accomplished using DS-3 Shock Machine
  - Large-displacement, pendulum-type impact shock machine
  - Highly-tunable design
    - Continuously adjustable pendulum impact velocity
    - Unique adjustable fixture permits input through 3 principal axes of item
- System-specific tailored test requiring approval from NAVSEA 05P3
  - Alternative to Heavyweight Test (i.e., “Barge Test”) of MIL-S-901
  - Input levels tuned to actual field measurements

Near Miss Shock Test Setup

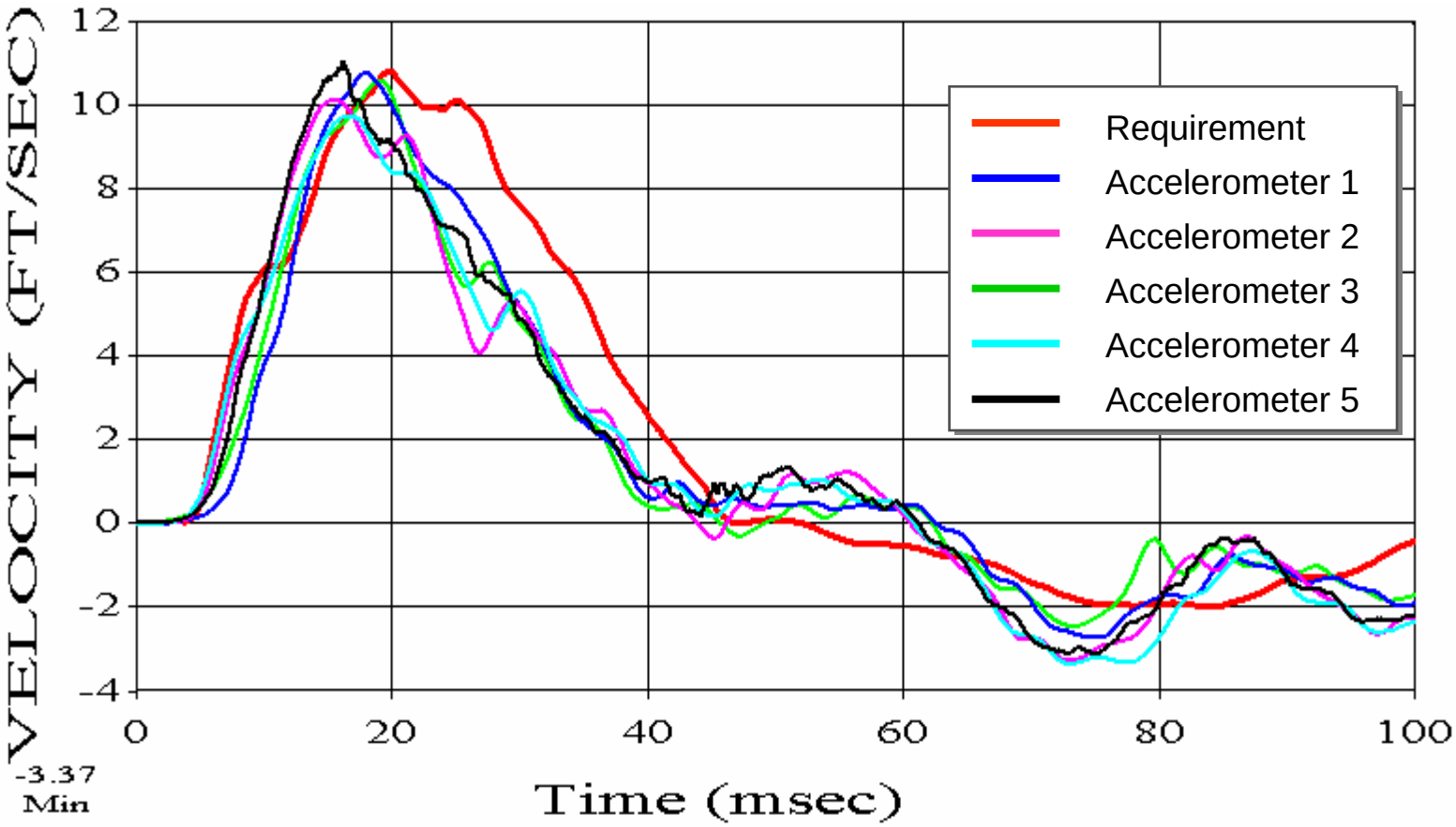


Tuning of Input for Near Miss Shock Test

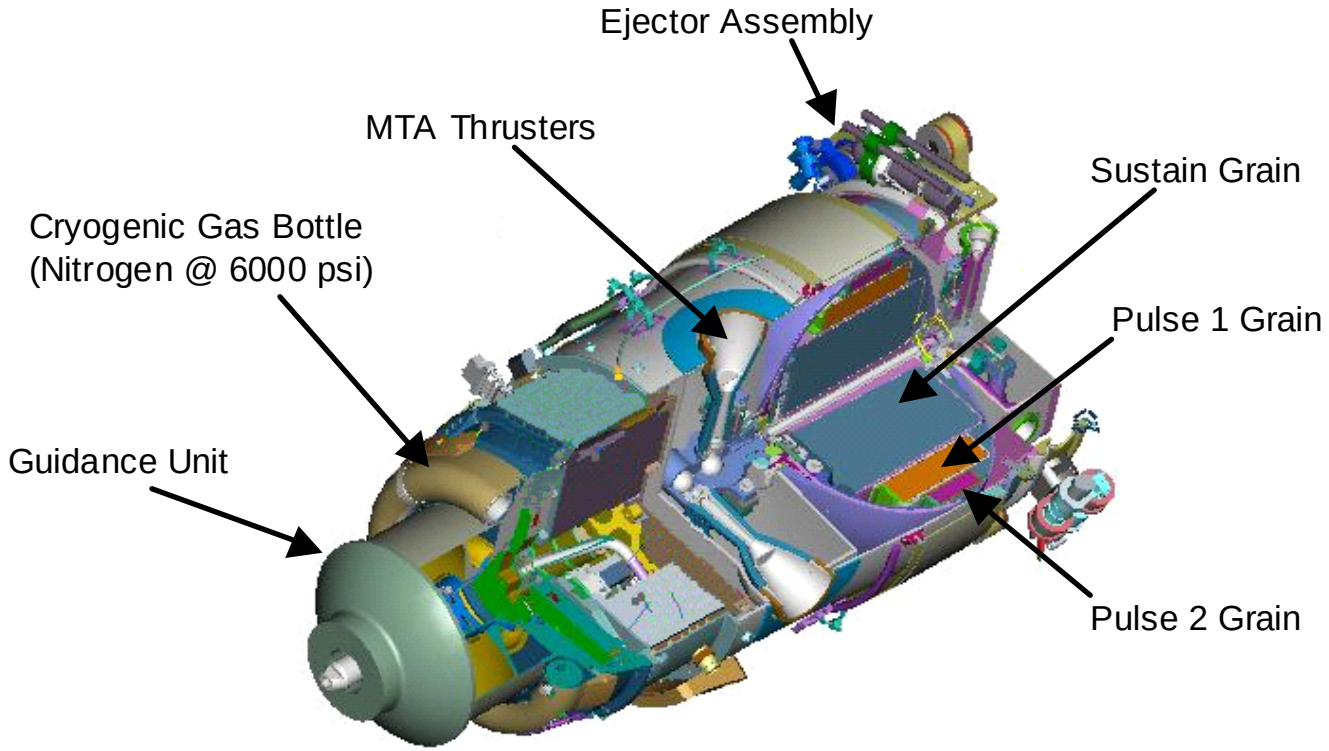


Pendulum drop height – peak velocity
Programmer pad thickness – initial acceleration
Brakes & Springs – initial pulse duration; magnitude of neg. velocity
Obliquity/clocking – Longitudinal and Transverse components

Representative Response Data

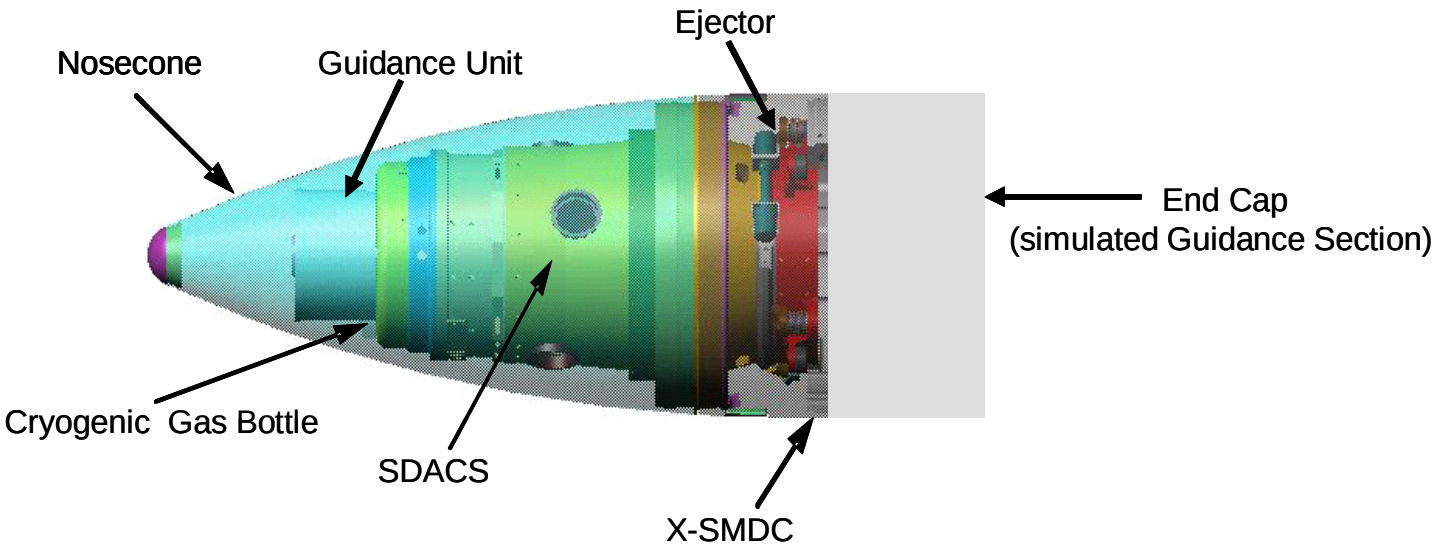


Configuration of Kinetic Warhead



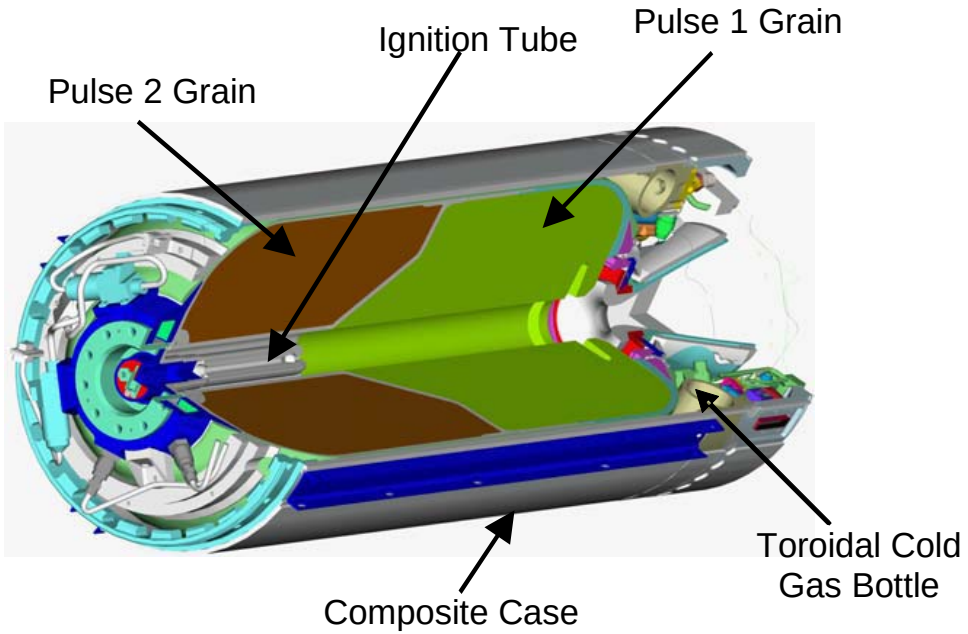
- 3 propellant grains in Solid Divert and Attitude Control System (SDACS)
  - Pulse I grain is TP-H-3510 propellant
  - Pulse 2 grain is TP-H-3511 propellant
  - Sustain grain is TP-H-3512 propellant
- SDACS case is graphite-epoxy composite

Configuration of Kinetic Warhead for Insensitive Munitions Tests



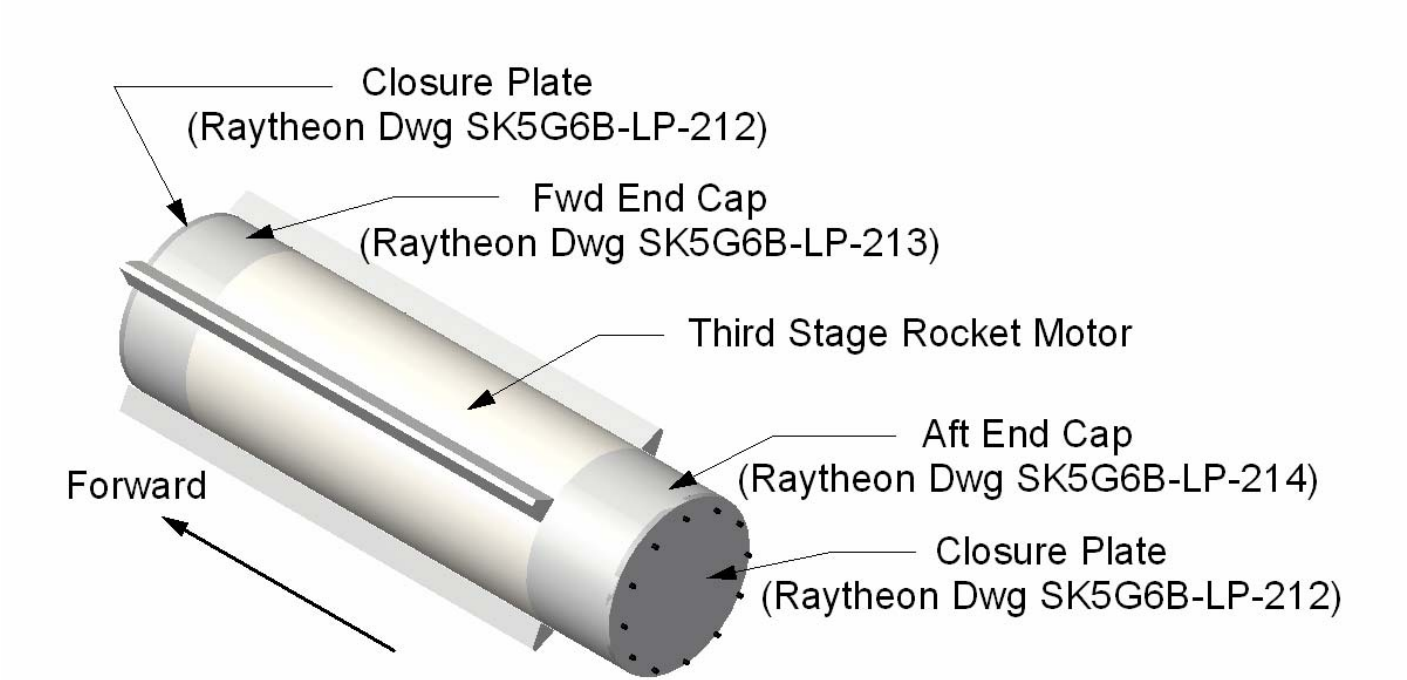
- Kinetic Warhead assembled to simulated Guidance Section shroud
  - 13.625-in OD annular aluminum cylinder with ½-in thick aluminum closure plate
  - Guidance Unit simulated using high-fidelity mass model
  - Cryogenic gas bottle present and fully-charged
- Block IA Nosecone installed over Kinetic Warhead
  - Secured to simulated Guidance Section shroud in same manner as tactical missile
  - All Nosecone explosive components present

General Configuration of Third Stage Rocket Motor



- 2 propellant grains
  - Pulse I grain is TP-H-3518A propellant
  - Pulse 2 grain is TP-H-3518B propellant
- Case sidewall is filament-wound graphite-epoxy composite
- Toroidal cold gas bottle contains pressurized nitrogen

Configuration of Third Stage Rocket Motor for Insensitive Munitions Tests

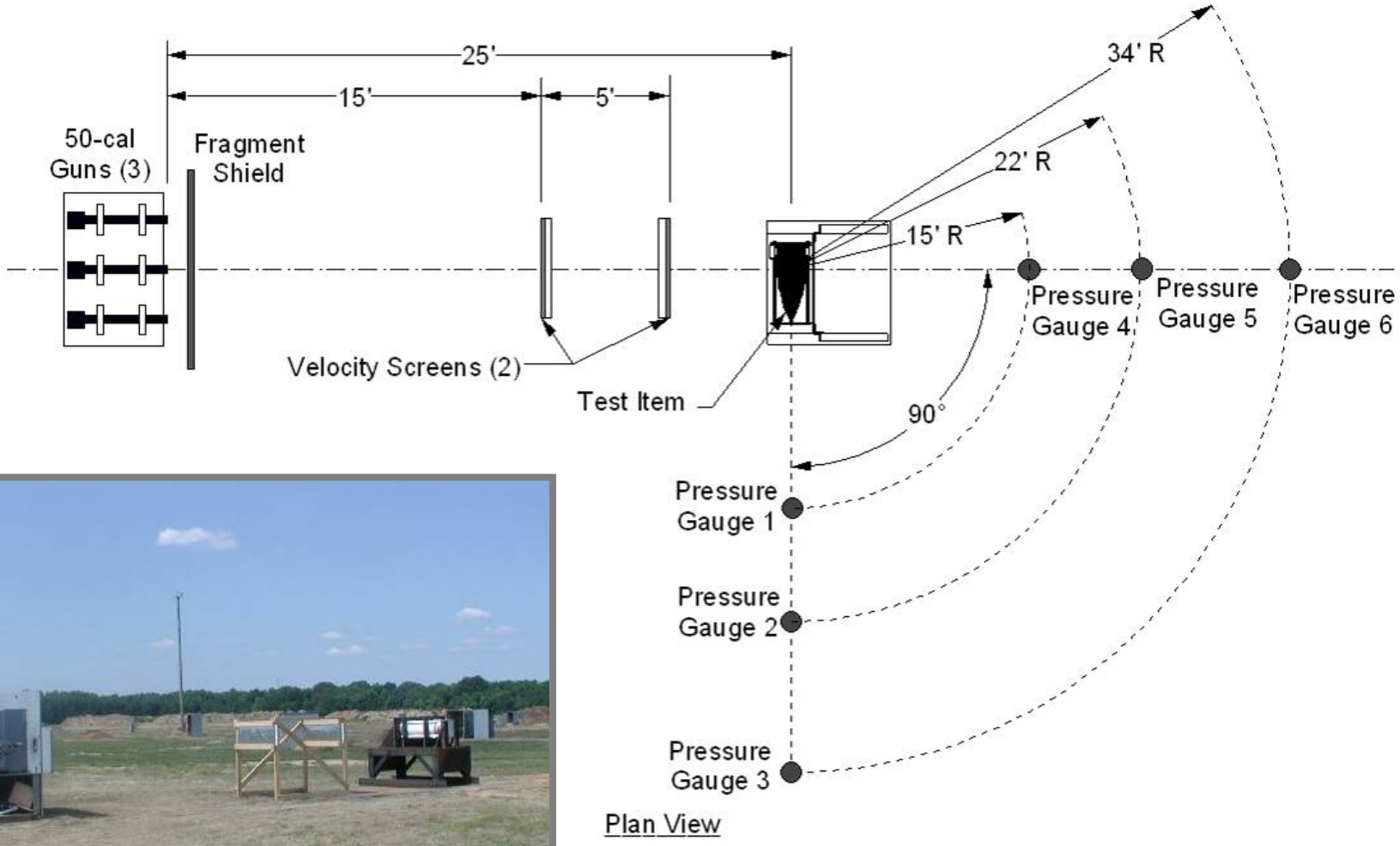


- TSRM assembled with end caps to simulate adjoining missile sections
  - Each end cap is 13.72-in OD annular aluminum cylinder with ½-in thick closure plate
  - Aft end cap secured using 4 explosive bolts
    - Replicate configuration of tactical missile

Bullet Impact Test Method

- Item impacted by three (max) 0.50-cal AP projectiles
  - Velocity of 2800 ± 200 ft/s
  - Bullets fired at 50 ms intervals using three 50-cal Mann barrels
- Trajectory of bullets perpendicular to longitudinal axis of test item
  - Bullets aimed to pass through center of SDACS propellant in KW
  - Bullets aimed to pass through Pulse II grain and ignition tube in TSRM
- Instrumentation and data collection IAW MIL-STD-2105B
  - Gun firing times
  - Bullet velocities
  - Air shock
  - High-speed video record of events
  - Post-test recovery and characterization of remains

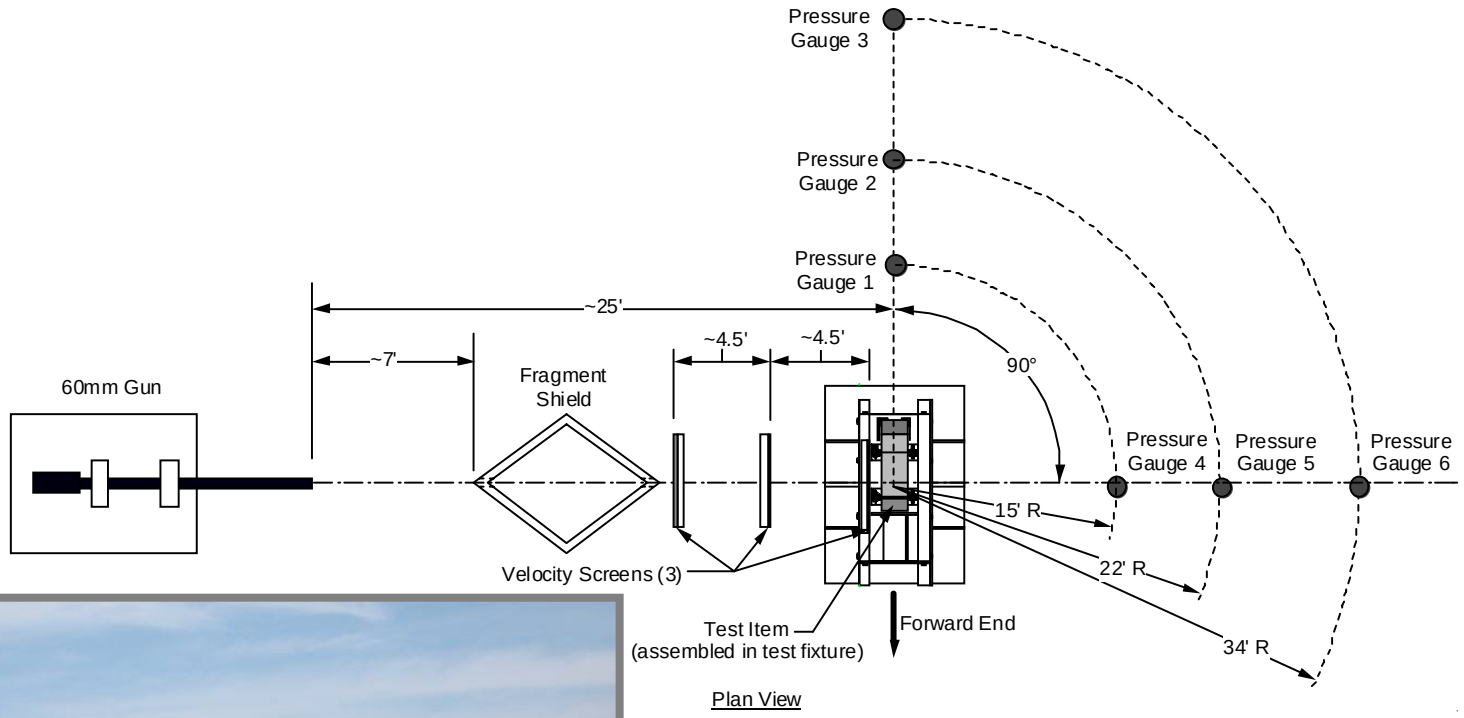
Bullet Impact Test Setup



Fragment Impact Test Method

- Item impacted by three ½-in mild-steel cubes
  - Velocity of 6000 ± 200 ft/s
  - Cubes launched using 60mm smoothbore gun and unique FRP sabot
- Trajectory of cubes perpendicular to longitudinal axis of test item
  - Aimed to pass through center of SDACS propellant in KW
  - Aimed to pass through Pulse II grain and ignition tube in TSRM
- Instrumentation and data collection IAW MIL-STD-2105B
  - Cube velocities
  - Air shock
  - High-speed video record of events
  - Post-test recovery and characterization of remains

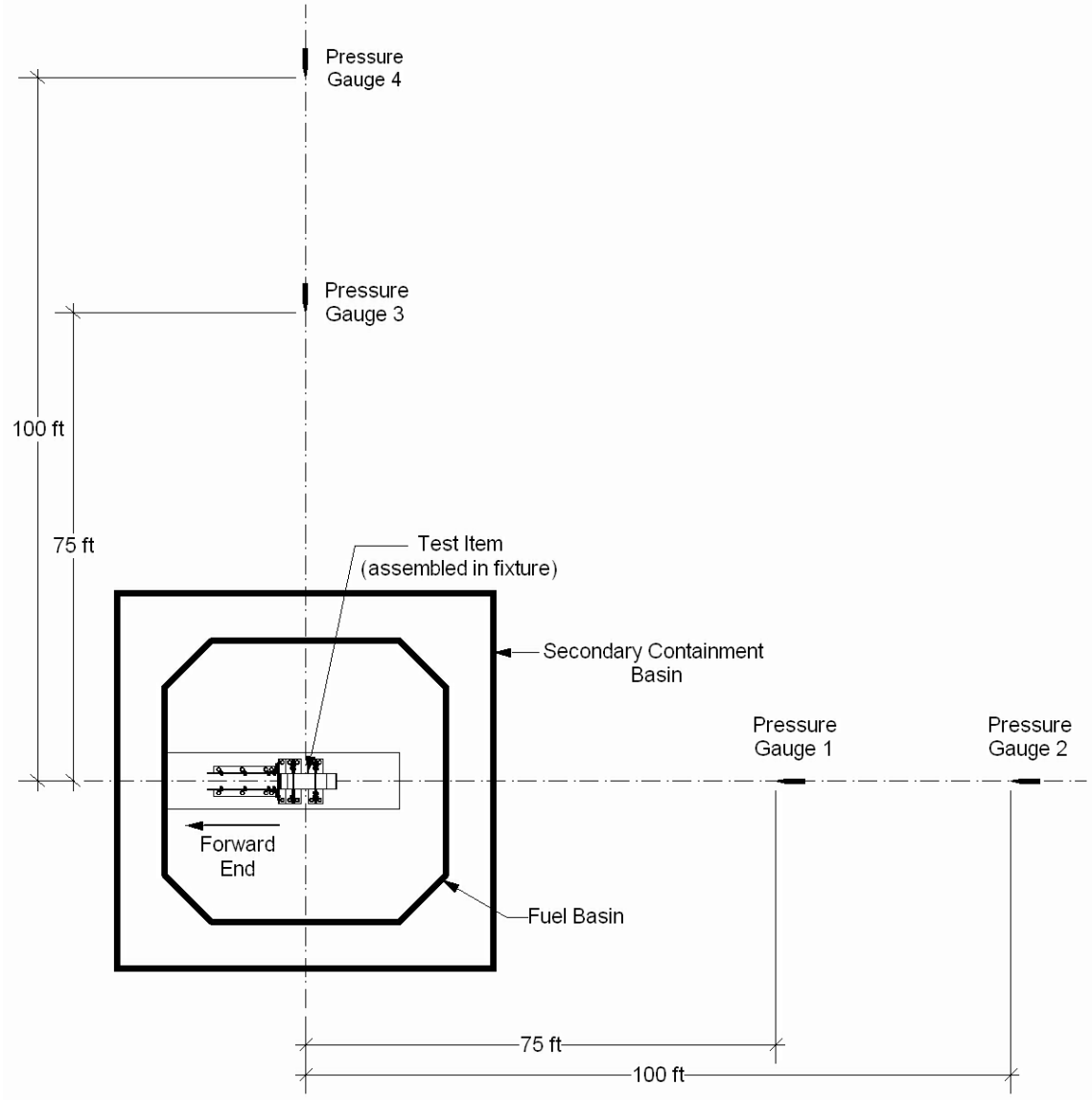
Fragment Impact Test Setup



Fast Cook-Off Test Method

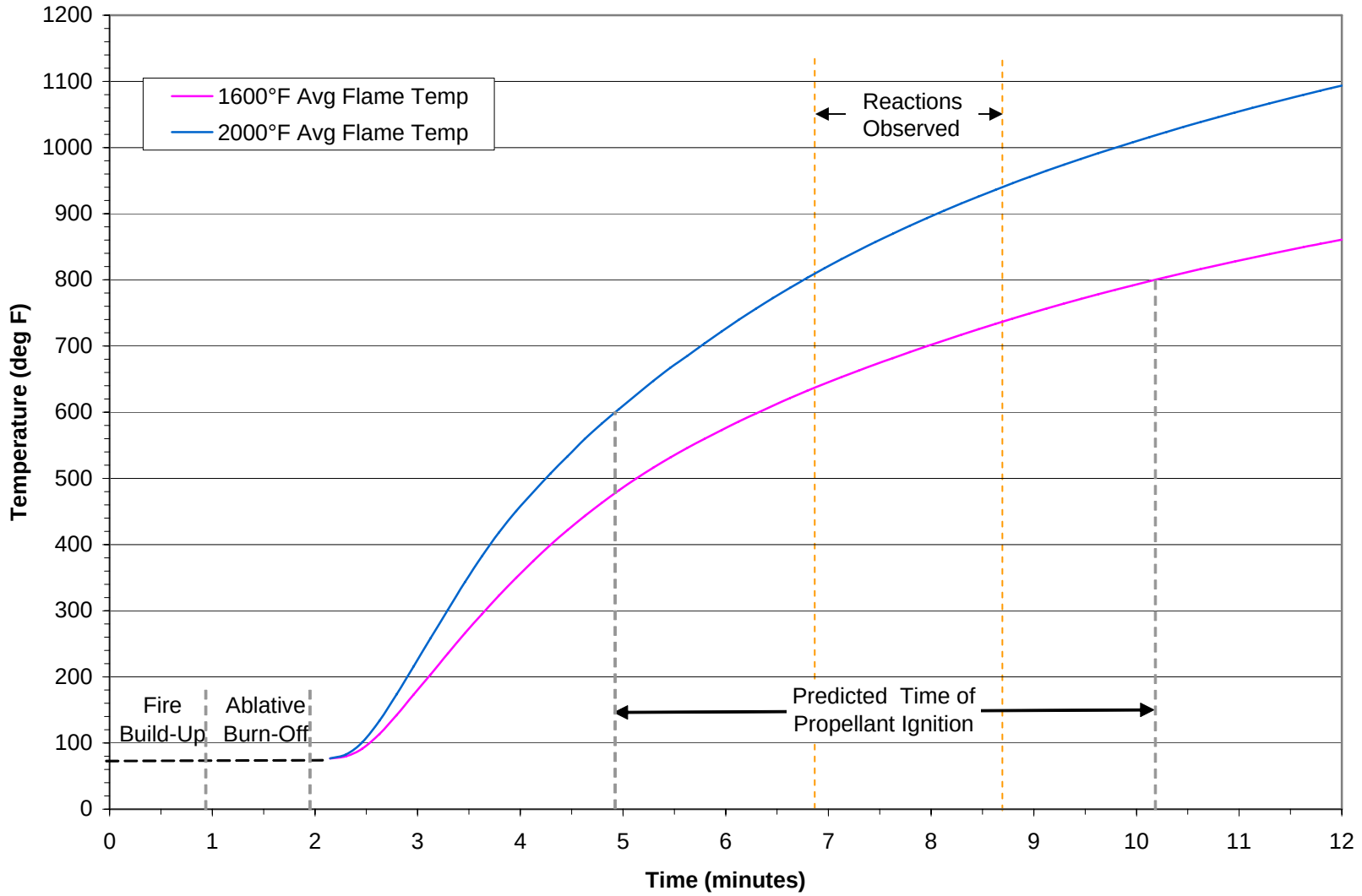
- Item suspended above pool of burning JP-5 aviation fuel
  - Average flame temperature >1600F
  - 30-ft x 30-ft fuel basin used to ensure complete immersion within flame
- Instrumentation and data collection IAW MIL-STD-2105B
  - Flame temperature
  - Air shock
  - Video record of events
  - Post-test recovery and characterization of remains
- Pretest modeling to predict time to reaction
  - 1-D model to examine radial heat transfer through case sidewall
  - Examined two bounding flame temperature conditions
    - 1600°F average flame temperature
    - 2000°F average flame temperature

Fast Cook-Off Test Setup



Fast Cook-Off Test Setup

Predicted Temperature at Liner/Propellant Interface During TSRM Fast Cook-Off



Summary of Test Results

Test	Result
28-Day Temperature & Humidity	No safety-related anomalies
Transportation Vibration	No safety-related anomalies
Shipboard Vibration	No safety-related anomalies
4-Day Temperature & Humidity	No safety-related anomalies
Near Miss Shock	No safety-related anomalies
Bullet Impact	Kinetic Warhead: Type IV reaction (deflagration) Third Stage Rocket Motor: Type III reaction (explosion)
Fragment Impact	Kinetic Warhead: Type IV reaction (deflagration) Third Stage Rocket Motor: Type III reaction (explosion)
Fast Cook-Off	Third Stage Rocket Motor: Type IV reaction (deflagration)

Lessons Learned

- Multi-shaker setup used for Transportation Vibration test introduces additional issues related to phase control
  - Currently not explicitly addressed in MIL-STD-810
  - Accepted / best practices still evolving
- Not possible to achieve same input levels at both ends of canister in Shipboard Vibration test due to fixture dynamics
  - Fact-of-life constraint for single-shaker setup using large, complex fixture
  - Problem most pronounced at higher frequencies
  - New state-of-the-art facility at NSWC/Dahlgren will enable multi-shaker testing in vertical orientation
- Near Miss Shock test demonstrated capability to replicate real-world triaxial shock input to large encanistered missile using pendulum-type shock machine
  - Potential alternative to “Barge Test” for some systems
    - Subject to approval by NAVSEA 05P5 on case-by-case basis
    - May reduce system design risks

More Info

- Test program documented in two NSWCDD technical reports
  - NSWCDD/TR-06/47, Standard Missile - 3 Block IA Hazard Assessment Test Results
    - Draft currently in final review
    - Expect publication and release within a few weeks
  - NSWCDD/TR-06/48, Standard Missile-3 Block IA Near Miss Shock Qualification Test Report