Size of Boost-Phase Region of Ballistic Missile Flight

Location of Objects
Shown Every 20 Seconds

$\theta_0 = 22.55$ degrees
$V_0 = 7.177, 7.1935, \text{ and } 7.21 \text{ km/s}$

Altitudes Where ICBM is in Powered Flight (200 to 300 seconds)

Altitudes Where Reentry Effects May Be Observable (60 to 90 seconds)
Engagement Region of Trident II First-Stage + Kick-Stage Interceptor Against North Korean 250 Second Burn-Time ICBM

- Intercept Points If GBI is Launched 125 Seconds After ICBM is Launched
- Intercept Points If GBI is Launched 100 Seconds After ICBM is Launched
- End of North Korean ICBM Powered Flight
- Interceptor Burnout Speed: ≈ 6.2 km/sec
First-Stage Trident II Plus Kick-Stage Interceptor Timelines Against Powered Flight Profiles of 250 and 320 Second Burn-Time ICBMs
Boost-Phase Kill Vehicle Capable of 10 G Maximum Divert Acceleration and 2 km/sec Total Divert Velocity

- Total Propellant Weight = 230 lbs
- Propellant Density = 72 lb/ft³
- Total Propellant Volume = 3.2 ft³
- Motor Weight = 80 lbs
- Thrust = 4610 lbs
- Weight of Tanks and Structure = 46 lbs
- Overall Vehicle Weight = 460 lbs
- Payload Weight = 100 lbs
- Propellant = N₂O₄/MMH
- Vacuum Steady State Real Engine Performance
  - Specific Impulse (lbf-s/lbms) = 295
  - Throat Diameter = 5.2 inches (.13 meters)
  - Exit Diameter = 23.2 inches (.59 meters)
  - Area Ratio = 20
  - Chamber Pressure = 125 psia
  - Motor Length = 50 inches (1.27 meters)
  - Chamber Diameter = 13.5 inches (.35 meters)
  - Spherical Fuel/Oxidizer Tank Diameters = 18 inches
  - Barrel Tank
    - Barrel Diameter = 10 inches (.26 meters)
    - Overall Length = 38.5 inches (.98 meters)
    - Barrel Lenght = 28.5 inches (.73 meters)

Telescope for Homing on Illuminated Targets

Neodymium YAG Laser
Characteristics of the Navy Theater-Wide Interceptor that Make It Unsuitable for Anti-ICBM Boost-Phase Interceptor

Navy interceptor Needs:

- To be much bigger and heavier to do the job
- A Much Higher booster burnout speed for Adequate Area Coverage
- Much more divert capability to deal with accelerating targets
- Much higher resolution sensors for homing on the target

These requirements lead to a much bigger and heavier booster to do the Job

Such a Bigger and Heavier Booster is NOT compatible with storage and launch systems on standard Navy combat ships.

Navy Upper Tier Interceptor Weight = 3,100 lbs
GBI Interceptor Weight = 30,000 – 40,000 lbs
Size, Weight, Payload and Velocity Characteristics of Booster Variants Needed to Launch Kill Vehicles
Mass Ratios for 70 Second Burn-Time Two and Three-Stage Boosters for Launch of Boost-Phase Kill Vehicles
Basic Dimensions of Vertical Launch System Components
Basic Dimensions of Vertical Launch System Components

61-Missile Magazine
Vertical Launch System “Compatible” Variant of a Boost-Phase Two-Stage Navy Interceptor

- First Stage Minuteman
  - Weight: 51,000 lbs

- VLS “Compatible” Boost-Phase Interceptor
  - Weight: 16,900 lbs

- BPKV Weight = 400 lbs
- $V_0 = 6.65$ km/sec
- Shroud Weight = 75 lbs

- Stage Weight = 11,290 lbs
- Fuel Weight = 10,105 lbs
- $I_p = 272$ sec

- Stage Weight = 5,422 lbs
- Fuel Weight = 4,989 lbs
- $I_p = 300$ sec
Vertical Launch System “Compatible” Variant of a Boost-Phase Two-Stage Navy Interceptor

First Stage Minuteman

51,000 lbs

VLS "Compatible" Boost-Phase Interceptor

38,100 lbs

Stage Weight = 12,200 lbs
Fuel Weight = 11,224 lbs
I = 300 sec

Shroud Weight = 100 lbs

BPKV Weight = 400 lbs, 300 lbs, 200 lbs

V = 7.6 km/sec, 7.8 km/sec, 8 km/sec

Stage Weight = 25,400 lbs
Fuel Weight = 22,860 lbs
I = 272 sec

Stage Weight = 12,000 lbs
Fuel Weight = 11,224 lbs
I = 300 sec
Notional Two-Stage Boost-Phase Interceptors Relative to the First Stage of the Minuteman ICBM

**Stage 1**: Weight = 51,000 lbs
- Minuteman
- VLS "Compatible" Boost-Phase Interceptor
- Weight = 38,100 lbs
  - BPKV Weight = 400 lbs, 300 lbs, 200 lbs
  - \( V_m = 7.6 \text{ km/sec}, 7.8 \text{ km/sec}, 8 \text{ km/sec} \)
  - Stage Weight = 12,200 lbs
  - Fuel Weight = 11,224 lbs
  - \( I_p = 300 \text{ sec} \)
- VLS "Compatible" Boost-Phase Interceptor
- Weight = 16,900 lbs
  - BPKV Weight = 400 lbs
  - \( V_m = 6.65 \text{ km/sec} \)
  - Stage Weight = 11,290 lbs
  - Fuel Weight = 10,106 lbs
  - \( I_p = 272 \text{ sec} \)

**Stage 2**: Weight = 51,000 lbs
- Minuteman
- VLS "Compatible" Boost-Phase Interceptor
- Weight = 38,100 lbs
  - BPKV Weight = 400 lbs, 300 lbs, 200 lbs
  - \( V_m = 7.6 \text{ km/sec}, 7.8 \text{ km/sec}, 8 \text{ km/sec} \)
  - Stage Weight = 12,200 lbs
  - Fuel Weight = 11,224 lbs
  - \( I_p = 300 \text{ sec} \)
- VLS "Compatible" Boost-Phase Interceptor
- Weight = 16,900 lbs
  - BPKV Weight = 400 lbs
  - \( V_m = 6.65 \text{ km/sec} \)
  - Stage Weight = 11,290 lbs
  - Fuel Weight = 10,106 lbs
  - \( I_p = 272 \text{ sec} \)

**Boost-Phase Interceptor**: Weight = 75,000 lbs
- Weight = 60,000 lbs
- Weight = 30,000 lbs
- Weight = 15,000 lbs
Boost-Phase Interceptor Based on the Trident II First-Stage Rocket Motor

- **Trident II First-Stage Rocket Motor** (87,000 lbs, 64 Second Burn Time)
- **Kick-Stage Motor** (1,000-1500 lbs, 10 Second Burn Time)
- **High-Divert and Acceleration Homing Boost-Phase Kill Vehicle** (250-500 lbs)
- Velocity of Homing Boost-Phase Kill Vehicle at Burnout:
  - ≥ 8.1-8.5 km/sec (Kick-Stage)
  - ≥ 6.1-6.5 km/sec (No Kick-Stage)
Appendix
Ballistic Missile Plumes
Short and Medium Wavelength Missile Plume Characteristics Relevant to Hard-Body Homing

Ballistic Missile
Plume Radiance Characteristics
at Intermediate Altitudes
(50 to 90 Kilometers)
Notes: Observation Bandwidth 3.4 – 3.7 µm
Laser Illuminator Bandwidth Could be << .001 nm
Frame-to-Frame Subtraction Should Give Edge Enhancement Effects
Use of Shorter Wavelength Illuminators May Allow for Uncooled CCDs
Will Very Large Number of Elements > 1000 x 1000
Shape and Radiance Characteristics of Ballistic Missile Exhaust Plumes at Different Altitudes

(a) Low Altitudes
   Axisymmetric non-interacting plumes

(b) Intermediate Altitudes
   3-D interaction region
   Non-axisymmetric shock structure

(c) High Altitudes
   Plume structure well-approximated by equivalent single nozzle
Variation of Apparent Ballistic Missile Exhaust Plume Intensities With Altitude

Enhancement

- Afterburning, $D \sim 10-100$ m
- Continuum flow regime, $D \sim 0.1-1$ km
- Molecular flow regime, $D \sim 1-10$ km
- Vacuum limit, $D \sim 1-10$ m

Log intensity

Altitude (km)

0 20 40 60 80 100 120 140 160 200 300 400 500

Booster
Intrinsic-core
Sustainer
Limited FOV
Total
MIRV bus
Vacuum limit
Short and Medium Wavelength Radiance of the Titan IIIB at 18 and 118 Kilometers Altitude

Fig. 5.5. SWIR and MWIR station radiances at 18 km.

Fig. 5.6. SWIR and MWIR station radiances at 118 km.

Fig. 5.3. Spectra of Titan IIIB at 18 km and viewing aspect of 48 deg.

Fig. 5.4. Spectra of Titan IIIB at 118 km and angle-of-attack of 7.4 deg.
Short and Medium Wavelength Radiance Maps of the Titan IIIB at 18 and 118 Kilometers Altitude

Fig. 5.7. SWIR radiance map at 18 km.

Fig. 5.8. MWIR radiance map at 18 km.

Fig. 5.9. SWIR radiance map at 118 km.

Fig. 5.10. MWIR radiance map at 118 km.
Flight Profile and Initial Plume Intensities of the Titan IIIB

**Fig. 5.11.** Flight profile for Titan IIIB.

**Fig. 5.2.** Model calculations of the plume intensity of a Titan IIIB.
Short and Medium Wavelength Radiance of the Titan IIIB at 18 and 118 Kilometers Altitude

~1500 KW/sr

~20 KW/sr

~.005 × 100 KW/sr = 500 W/sr

~1500 KW/sr

~.001 µm × 500 W/sr/µm = .5 W/sr?

~200 – 500 W/sr over distances of meters?

~.001 µm/500 W/sr/µm = .5 W/sr?

~20 KW/sr

Fig. 5.3. Spectra of Titan IIIB at 18 km and viewing aspect of 48 deg.

Fig. 5.4. Spectra of Titan IIIB at 118 km and angle-of-attack of 7.4 deg.

Fig. 5.5. SWIR and MWIR station radiances at 18 km.

Fig. 5.6. SWIR and MWIR station radiances at 118 km.
Narrow Band Infrared Target Measurements Combined with Frame-to-Frame Subtraction

TUNDRA BACKGROUND
8-10 μm
64x64 8-BIT PIXELS
21 IMAGES

CAMERA ID - 00
8-BIT LINE NUMBER

HALO / IRIS SIMULATION SCENES
3.4-3.7 μm
128x128 12-BIT PIXELS
50 IMAGES

CAMERA ID - 10
8-BIT LINE NUMBER

TUNDRA BACKGROUND & SOLID BOOSTER
4.2-4.4 μm &
8.0-10.0 μm
256x256 10-BITS
101 IMAGES

CAMERA ID - 01
8-BIT LINE NUMBER

FOUR UNIFORM NOISE SETS
DATA RANGES:
• 0-255
• 1792-2047
• 3840-4095
• 0-4095
1024x1024 12-BITS
40 IMAGES

CAMERA ID - 11
16-BIT LINE NUMBER
### TABLE 19. TEST RESULTS SUMMARY

<table>
<thead>
<tr>
<th>TEST SET</th>
<th>DESCRIPTION</th>
<th>COMPRESSION (Data Only)</th>
<th>COMPRESSION (With Header)</th>
</tr>
</thead>
<tbody>
<tr>
<td>256 x 256 x 10</td>
<td>Boost vehicle against a tundra background. 4.2 - 4.4 μm</td>
<td>9.1:1</td>
<td>6.4:1</td>
</tr>
<tr>
<td>128 x 128 x 12</td>
<td>HALO/IRIS simulation scene. 3.4 - 3.7 μm</td>
<td>3.8:1</td>
<td>3.2:1</td>
</tr>
<tr>
<td>1024 x 1024 x 12</td>
<td>Noise uniformly distributed 0.255</td>
<td>1.4:1</td>
<td>1.4:1</td>
</tr>
<tr>
<td>1024 x 1024 x 12</td>
<td>Noise uniformly distributed 1792-2047</td>
<td>1.4:1</td>
<td>1.3:1</td>
</tr>
<tr>
<td>1024 x 1024 x 12</td>
<td>Noise uniformly distributed 3840-4095</td>
<td>1.4:1</td>
<td>1.4:1</td>
</tr>
</tbody>
</table>