Introduction to missiles

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Global Nuclear Politics and Strategy

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Weapon system requirements

• Delivery to the target
• Targets may be at varying distances
• Launch from undisclosed locations
• Must achieve the target with accuracy
• Should be difficult to intercept
• Should perform in a reliable and repeatable fashion
• Should be capable of performing in all weather, all location and all year round
Target Distances
Missile Classification

Surface to Surface

>5500 km
- ICBM

2400 - 5499 km
- IRBM

800 - 2399 km
- SRBM
- SLBM
- CM (Cruise Missile)

Surface to Air

Air to Air
- AAM

Air to Surface
- ASM
Missile Classification

- **Type**
  - (Ballistic/Cruise)

- **Function**
  - (ATM/SAM/Surface to sea/air to surface/surface to surface / sea to sea/sea to surface)

- **Range**
  - (Short, Medium, Intermediate and Intercontinental)

- **Propulsion**
  - (SPR, LPR, ABR)

- **Guidance**
  - (Wire, terrain comparison, inertial, laser, RF+GPS)
Basics

• Figure of merit called *Specific Impulse*
• Thrust produced per unit mass flow of propellant ie $I_{sp} = F/(dm/dt)$
• Mass Ratio: $MR = M_i/M_f,$
  \[ M_i = M_{prop} + M_{inert} + M_{payload} \]
  \[ M_f = M_i - M_{prop} \]
  \[ v_{bo} = g_0 I_{sp} \ln MR \]
Trajectory of Short Range Missiles
Ballistic Missile Path
# Typical Ballistic Missile Trajectory Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 km</td>
</tr>
<tr>
<td>Burn time, s</td>
<td>30</td>
</tr>
<tr>
<td>Initial $\theta$, deg</td>
<td>90</td>
</tr>
<tr>
<td>Final $\theta$, deg</td>
<td>40</td>
</tr>
<tr>
<td>Final accn, g</td>
<td>5.07</td>
</tr>
<tr>
<td>$V_{bo}$, km/s</td>
<td>1.30</td>
</tr>
<tr>
<td>Apogee, km</td>
<td>35.5</td>
</tr>
<tr>
<td>Range, km</td>
<td>101</td>
</tr>
<tr>
<td>Flight time, s</td>
<td>191</td>
</tr>
</tbody>
</table>
Growth in Ballistic Missile Weight
Missile subsystems
Rocket Power Plants
Prithvi Missile

- Technology driven mission
- Variable range 40-150 km
- Limited range – low stand-off distance
- Has to be necessarily placed near border
- Liquid propulsion requires longer preparation time
Agni series evolution
Agni Performance

Range, km


Agni 1  Agni 2  Agni 3  Agni 4  Agni 5

K 4  K 15  Nirbhay

Agni 6 MIRV
Range capability of Agni missiles
UNDER WATER LAUNCHED SYSTEMS

- HOT GAS GENERATOR
- SHOCK ISOLATED LAUNCHER
- UNDER WATER DYNAMICS
- UNDER WATER CONTROL
- MECHANISMS FOR UW APPLICATION
- SAFETY INTERLOCKS FOR SUBMARINE
- HYPERSONIC AERODYNAMIC CONTROL MANEUVER
Cruise Missiles

• Cruise missiles are attractive candidate systems for targeted delivery. They resemble aircraft in construction and operation. They can be designed for:
  - long range
  - long endurance
  - be equipped with stealth features
  - follow terrain hugging paths
  - precision targeting
  - multi-platform launch
  - Low cost and one-shot use
Cruise Missiles—Advantages

• Aircraft like profile and low altitude fight render it difficult for detection and tracking cruise missiles.

• Supersonic cruise missiles provide low reaction times

• Launch from land, ship, aircraft and submarines provide versatility

• Hypersonic cruise missiles are still in the development stage. When ready they will add immensely to the lethality
Cruise Missiles

TOMAHAWK
BLOCK IV

Specifications:
- Weight: 3000 lbs. 1360 kg with radio package
- Range: 1000 miles
- Warhead: 700 lbs. 640 kg insensitive
- Guidance: Inertial navigation with GPS, INS, and TERRAIN contour matching
- Rocketing: Ability to change Target or beam-ride via satellite communications

Rocketed Motor:
- Liquid Momentum
- Satellite Data Link Terminal for in-flight communications
- Programmable Rocket Motor
- 5000 lb thrust

Warhead Section:
- Titanium-Cased Warhead
- Inertial-Momentum plus GPS
- Guided by satellite communications

Main-Body Section:
- Main Fuel Tank - 5000 lb
- Wing and Wing Door Detach System: Wing and Door Detach System during wing deployment and store after wing deployment to provide it more aerodynamic shape.
- Wspar/landing gear

Fuselage Section:
- Fuel and Gas
- Inertial-Momentum plus GPS
- Guided by satellite communications

Specifications:
- Weight: 3000 lbs. 1360 kg with radio package
- Range: 1000 miles
- Warhead: 700 lbs. 640 kg insensitive
- Guidance: Inertial navigation with GPS, INS, and TERRAIN contour matching
- Rocketing: Ability to change Target or beam-ride via satellite communications
Developments in India

**NIRBHAY**
- **Range**: 1000 km
- **Cruise Speed**: Subsonic
- **Cruise Altitude**: 100 m
- **Powerplant**: Small Turbofan Engine
- **Navigation**: INS
- **Terminal Homing**: RF / EO / IR Seeker
- **Versions**: Land attack/ship-borne

**BRAHMOS**
- **Cruise Speed**: Supersonic
- **Range**: 280 Km
- **Warhead**: 300 Kg
- **Navigation**: INS and OBC
- **Versions**: Land, Sea and Air
Anticipated Trends

Inventory build up for credible minimum deterrence

Inventory to match or exceed. Range for deep penetration

Ballistic Missile Defence

MIRV

Cruise Missiles
Layered Defence
Typical missile response times

Diagram:

1. Sensor
2. Sensor Cues
3. Defense interceptor assigned
4. Handover to interceptor system
5. Interceptor Launched
6. Interceptor Mid-Course Guidance
7. Intercept
8. Kill Assessment
9. Second, ..., nth shot if needed
10. Final Kill Assessment

Defended Asset

NIAS
## Typical ballistic missile flight times

<table>
<thead>
<tr>
<th>Max range, km</th>
<th>Ballistic flight time, minutes</th>
<th>Boost phase time, seconds</th>
<th>Total flight time minutes,</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>2.6</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>300</td>
<td>4.0</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>500</td>
<td>5.2</td>
<td>30</td>
<td>5.70</td>
</tr>
<tr>
<td>1000</td>
<td>7.4</td>
<td>50</td>
<td>8.23</td>
</tr>
<tr>
<td>1500</td>
<td>9.0</td>
<td>60</td>
<td>10.00</td>
</tr>
<tr>
<td>2000</td>
<td>10.4</td>
<td>65</td>
<td>11.48</td>
</tr>
<tr>
<td>2500</td>
<td>11.7</td>
<td>70</td>
<td>12.87</td>
</tr>
<tr>
<td>3000</td>
<td>12.8</td>
<td>75</td>
<td>14.05</td>
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</table>
Discriminate and target
Interception sequence

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sensor detects</td>
<td>The early warning sensor detects the launch of the threat missile. The sensor could be a satellite, radar or airborne IR system</td>
</tr>
<tr>
<td>2</td>
<td>Sensor cues</td>
<td>The early warning sensor performs one to three hits on the threat missile to determine its characteristics and direction</td>
</tr>
<tr>
<td>3</td>
<td>Defence interceptor assigned</td>
<td>Through a pre-planned command structure and battlefield protocol, a system is setup for deciding which interceptor system will be assigned to engage the threat missile</td>
</tr>
<tr>
<td>4</td>
<td>Handover to interceptor system</td>
<td>The threat data is transferred to the preferred interceptor system and its fire control radar</td>
</tr>
<tr>
<td>5</td>
<td>Interceptor system launched</td>
<td>The interceptor system is on alert. After the threat missile enters the FOV of the fire control radar the interceptor is launched. In some instances it might be possible to give midcourse guidance to the interceptor</td>
</tr>
<tr>
<td>6</td>
<td>Intercept</td>
<td>Interception takes place at an altitude based on the footprint analysis</td>
</tr>
</tbody>
</table>
## Comparative radar characteristics

<table>
<thead>
<tr>
<th>Radar</th>
<th>RCS</th>
<th>Detection Range</th>
<th></th>
<th></th>
<th>Range Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Surveillance</td>
<td>Tracking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Pine</td>
<td>1 m² /0.02 m²</td>
<td>825 km</td>
<td>1190 km/450 km</td>
<td></td>
<td>≈ 1m</td>
</tr>
<tr>
<td>FBX radar</td>
<td>1 m² /0.02 m²</td>
<td>1020 km</td>
<td>1600 km/600 km</td>
<td></td>
<td>≈ 0.15 m</td>
</tr>
<tr>
<td>PAVE/PAWS</td>
<td>1 m² /0.1 m²</td>
<td>3800 km</td>
<td>4250 km/2400 km</td>
<td></td>
<td>≈ 5m</td>
</tr>
<tr>
<td>EMR</td>
<td>1 m² /0.02 m²</td>
<td>2700 km</td>
<td>2700 km/1000 km</td>
<td></td>
<td>≈ 0.15 m</td>
</tr>
</tbody>
</table>

### THAAD

- ~2.7 km/sec Vbo
- 40 km min. intercept altitude

### SM-3 interceptor

- Block IA ~3 km/sec Vbo
- Block II ~4.5 km/sec Vbo
- 80-100 km min. intercept altitude

### 2-stage GBI

- ~6.5 km/sec Vbo
- 80-100 km min. intercept altitude
Thank you