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THREE STAGES OF THE INTER-CONTINENTAL BALLISTIC MISSILE (ICBM) FLIGHT

This *Pathfinder* is a second in a series on ICBMs (refer #302) and will outline the three distinctly different phases of flight. An understanding of the characteristics of these different phases of flight is important to highlight the different missile operating environments and flight characteristics for guiding the designs for systems that provide operational responses within a ballistic missile defence system.

Conventional ICBMs typically follow a ballistic trajectory that can be divided into three separate phases as shown in *Figure 1*. The boost phase is the part of a missile's flight when its rockets are thrusting to accelerate the ICBM to the velocity needed to reach its target; the *mid-course phase* is the part of the trajectory that is usually outside the atmosphere where the missile ascends to its apogee height before descending towards its target; and finally, the *terminal phase*, where the missile is coasting, or freefalling through the atmosphere towards its terrestrial target.

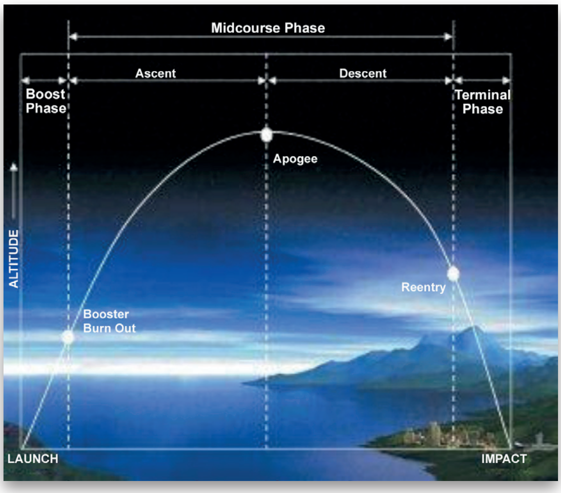

Figure 1 - Phases of an ICBM trajectory

The boost phase commences after launch and lasts about 3–5 miutes until the rocket engine(s) expire and is typically completed within the atmosphere. The booster rockets serve to accelerate the ICBM payload onto a ballistic trajectory. They also enable thrust vectoring to control flight and make corrections in order to steer the ICBM onto the planned trajectory towards the target. Depending on the missile, this phase can typically last between three to five minutes.

There may be more than one rocket motor stage in this phase in order to boost the ICBM payload to a higher apogee to ensure that it can ballistically reach a longer ground range. Each spent booster stage is jettisoned after expiring and freefalls back to Earth as uncontrolled debris. The ICBM can reach speeds of more than 24,000 kph before the boosters cease functioning when the propellant expires, and are jettisoned as debris, which will return to earth.

The booster rocket plume displays a significant infrared signature that contrasts against the surrounding atmospheric environment.

The mid-course phase is arbitrarily assigned to the part of the trajectory that commences after the boosters have expired. The booster rockets provide the momentum that makes the missile continue on a ballistic trajectory towards the planned ground impact position. Even though the missile is steered in flight throughout the boost phase, once the rockets are spent, there is no mechanism available to control and direct the movement of the conventional missile. Having been boosted to hypersonic speed to heights above the atmosphere, the aerodynamically heated ICBM exterior has a hot infrared signature that contrasts prominently against the background of cold space.

After the boosters have expired, the ICBM ascends to its apogee and the point of maximum potential energy, before descending toward Earth. Typically, ICBMs are not designed with adequate kinetic energy to accelerate into a stable Earth orbit and normally follow a sub-orbital trajectory.

The mid-course phase is the longest phase of the missile's trajectory and can last for up to 20 minutes. This phase provides the longest time and predictable opportunities for intercepting an incoming ICBM. Since the missile is neither powered nor in controlled flight during this phase, its predicted trajectory can be used to plan an exo-atmospheric intercept based on orbital dynamics and circular motion.

During the descent whilst still in space, the ICBM's mission payload (e.g. warheads and/or decoys) separate from the ICBM for each to follow their independent ballistic trajectories towards the target position.

The terminal phase commences when the ICBM's mission payload re-enters the Earth's atmosphere and continues until the warhead functions in an air burst or on ground impact, depending on the fuzing mechanism. The conventional payload is typically designed to follow a ballistic freefall trajectory path, in uncontrolled flight. This phase of flight can take about a minute for a typical strategic ICBM

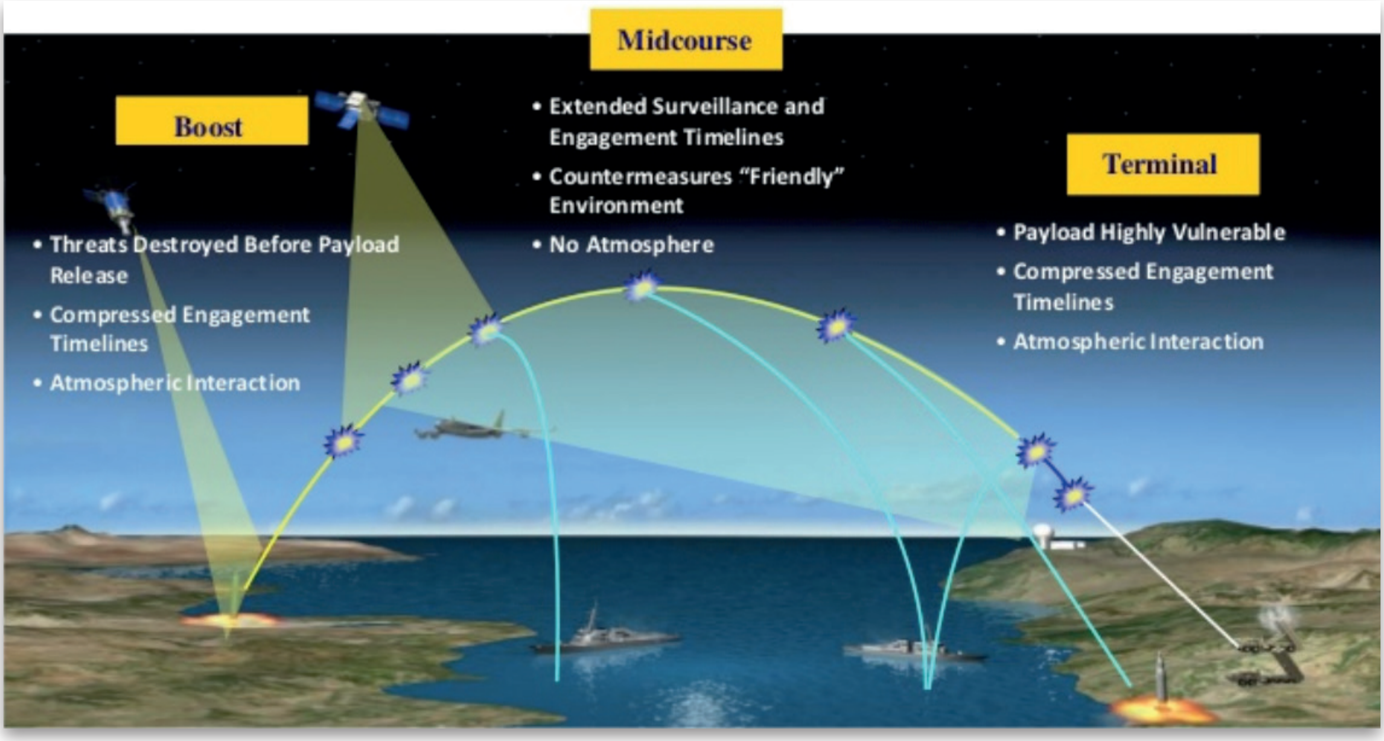

Figure 2 - Challenges faces by anti-missile defence systems during the different ICMB flight phases.

warhead, which might be travelling towards the ground at speeds of around 3,200 kph.

These characteristics of the three separate phases of flight of an ICBM are useful to highlight the different signatures and trajectories that could in turn drive the designs for systems to detect, track, and engage, the missile. The defence systems will have to take advantage of the contrast that ICBMs provide against the different backgrounds of being in space or being in the atmosphere, and while transitioning across the two different environments.

Anti-missile defence systems are challenged by the need to provide a quick response to engage the target missile—preferably close to its launch site—and also to consider the flight time to intercept a hypersonic target (See *Figure 2*). The interception of an ICBM in its relatively slow *Boost Phase* could end its mission, regardless of its range or intended aim-point, providing an operational response that defends nations and global areas. A *Mid-Course Phase* intercept provides an operational response to defend both a wide regional or localised area. A *Terminal Phase* defence intercept provides protection for a localised area or deployed task force.

The integration of different systems into a single integrated system-of-systems can provide response options to intercept an attacking ICBM in the different phases of its flight. Such a system would provide a layered defence capability that provides options to increase the probability of successfully disrupting the ICBM mission at different points in its trajectory. The achievement of a mission-kill does not negate the likely collateral damage through the warhead remnants and debris resulting from a successful intercept.

The operationalisation of hypersonic aerodynamic vehicles with flight controls, boosted from an ICBM and then aerodynamically flying an evasive trajectory to its target, is expected to force a change in the current approach to missile defences.

Key Points

- *Conventional ICBMs typically follow a ballistic trajectory that can be divided into three separate phases based on its mode of operation – boost, mid-course and terminal phases.;*
- *Typically, ICBMs are not designed with adequate kinetic energy to accelerate into a stable Earth orbit and normally follow a sub-orbital trajectory.*
- *The integration of different systems into a single integrated system-of-systems can provide response options to intercept an attacking ICBM during the different phases of its flight.*

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