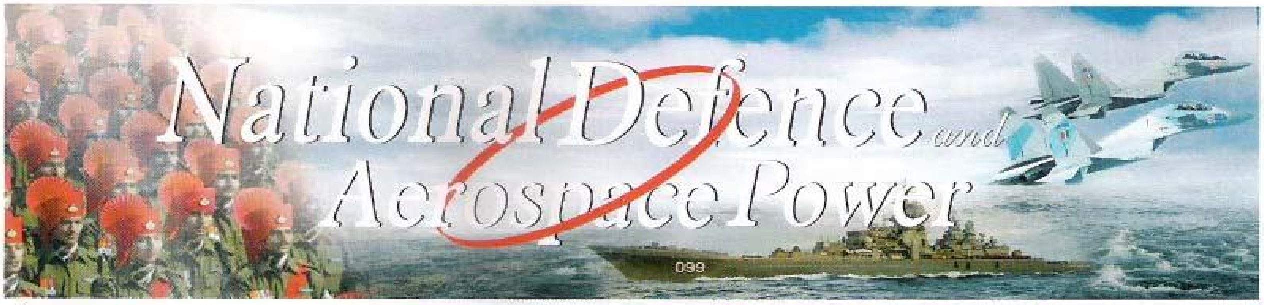

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INDIGENOUS ADVANCED TECHNOLOGY DEVELOPMENT: DRDO'S BALLISTIC MISSILE DEFENCE SYSTEM

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Introduction

India, since 1947, has consistently worked on development of indigenous capability to develop and field advanced weapons required for her security. For a variety of reasons that are beyond the scope of this brief these efforts at development of advanced technology weapons and associated equipment have not always met up to the expectations of the intended end users. Despite several failures and shortfalls in their final output, India's Research and Development (R&D) personnel and establishments have not lost heart and have continued to strive to develop equipment comparable to that available with the leading technologically advanced countries. Some R&D efforts have been aimed at relatively mundane equipment such as small arms and ammunition, building up towards artillery and armoured vehicles. Similarly, attempts have been made to design and develop aircraft – both fixed wing and rotary wing – and to design and build naval vessels ranging from small patrol boats to frigates, destroyers and even aircraft carriers. Design and development of more advanced weapons that are often classified in the media as 'strategic weapons' in the form of ballistic missiles of various ranges from a few hundred kilometers (km) to over 5,000 km has also been undertaken. The country's ballistic missile program is one that has met with a high level of success. The country's R&D community saw quite early that while it had been successful in developing sophisticated ballistic missiles, India too faced a credible ballistic missile threat from across her western as well as northern borders. The ballistic missile threat from the west was expected to feature nuclear warheads aboard the missiles while the northern threat could field a mix of nuclear payloads as well as very precise conventional warheads delivered by ballistic missiles. While nuclear payloads would definitively need to be stopped to avoid heavy damage to India's population and territory, the conventional warheads aboard accurate ballistic missiles could bypass the nation's conventional defence systems and would, therefore, also need to be countered effectively.

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Such a realisation appears to have led the R&D community to explore means of putting in place an effective ballistic missile defence (BMD) system.

Essential Components and Working of a BMD System

A BMD system has a few essential components. These are the early warning long range radar that would pick up inbound threats at long range and warn of an imminent ballistic missile attack. Such radar should be able to acquire relatively small radar cross section (RCS) targets at slant ranges of several hundred km to over thousands of km. Ballistic missiles follow a parabolic or modified parabolic path from their launch point to their target. This path if plotted for missiles with ranges of 1500 to over 50000 km would place the path at several thousand km from the target, especially in the first part of the missile's trajectory. The incoming missile's path as seen from the radar site designed to locate the missile falls below the horizon initially, lifting to above the horizon as the missile climbs out towards space and tilts in the direction of its planned target. The missile warning radar would thus have to look out to very large ranges at low grazing angles to the surface of the earth going up to high elevation angles in later parts of the incoming missile's flight. Therefore the early detection radar requires having very large range capability. This radar would provide warning of attack and serve to activate the rest of the BMD system. In addition there needs to be separate radar – or a mode of the same radar – with the function of accurately tracking incoming threats. The accurate information provided by this radar or radar mode would provide the data needed for calculating and executing a successful interception of incoming ballistic missiles and their warheads. A robust command and control (C&C) system is the next requirement. A C&C system would get the data from the radars and compute the interception profile. Thereafter, based upon the design philosophy, it could either provide interceptor missile launch cues to human operators or it could, by itself, launch interceptor missiles at the optimum time. The final components of this basic BMD system are its interceptor missiles. These missiles would be launched to intercept and destroy incoming ballistic missile threats. Ideally, an incoming missile threat should be intercepted as far away from its target as possible. In case of ballistic missile defence this means that the incoming ballistic missile should be intercepted and destroyed in the exo-atmospheric region (outside the atmosphere, or above 75 to 80 km above mean sea level (AMSL)). 75 to 80 km AMSL is strictly the "near space" region, as the Karman Line – accepted to represent the boundary between the atmosphere and outer space – lies at approximately 150 km AMSL. Ballistic missiles typically eject their payloads in the exo atmospheric regime of flight to fall towards the intended targets. In order to defeat opposing BMD systems decoy warheads are at times included in the ballistic missile. The larger the range from the BMD system the lesser would be the resolution of potential targets on the BMD system's long range radar. Thus, differentiating between actual and decoy warheads may not be easy in exo-atmospheric engagements. The end result is that the possibility of some incoming warheads getting past the exo-atmospheric interceptors cannot be ruled out. This necessitates another layer of interception to be included. Given the very high speed of the warheads – in the range of several km per second –the second opportunity for interception would fall within the atmosphere, below 75 to 80 km AMSL, in the endo-atmospheric regime. The interception in this region is very different from that at higher altitudes. In the exo-atmospheric region there is no atmospheric buffeting and hence the target is usually on a steadier predictable path that is easier to compute and plot an interception course for. However, given the large distance and lead time required, very quick and accurate calculations of intercept geometries would be needed. The interceptor missile would require accelerating to very high velocities in order to execute the interception. However, given the large distance it has to travel it may have some time to carry out this acceleration. This time available to accelerate reduces the difficulties somewhat where design of the interceptor missile is concerned. Once it reaches the vicinity of the target, it has to search for the target in a relatively clutter free region. It could be expected that most ballistic missile warheads would have already separated from their carrying missile or would be in process of doing so at this stage. This separation would reduce the target RCS considerably, making accurate detection and tracking more difficult. However, given the expected kinetic friction heating undergone by the incoming ballistic missile and its warhead and absence of other similar heat sources in the out of atmosphere region – unless the sun is directly in the field of view – it would make target acquisition and homing relatively easier. In the endo-atmospheric region the incoming warhead would be long separated from its host ballistic missile and would present a small RCS, usually expected to be well under 1square meter. This small RCS would make acquisition and tracking more difficult. These difficulties would be exacerbated by the buffeting that the warhead is likely to experience due to atmospheric wind patterns. Moreover, there are likely to be several other phenomena that clutter the background affecting clear differentiation of the incoming warhead from background clutter. An interceptor missile designed for endo-atmospheric engagements would have lesser time to accelerate to very high speeds and so would require a motor with higher thrust output per unit time or specific impulse. This missile's seeker would require support from its launch system till it is able to distinguish the target against background clutter and to lock on reliably. Thus the interception in exo-atmospheric and endo-atmospheric phases is seen to present very different problems and demands upon the designer of a BMD system. These problems flow from basic physics and have been understood for quite some time. The crux of the matter is the efficiency with which designers are able to overcome them.

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BMD Systems Worldwide

Work towards the first BMD system to be developed and fielded was by the erstwhile Soviet Union and began in 1962-63 to defend the Moscow area. This ambitious project envisaged a chain or early warning radars along the Soviet Union's periphery along with more powerful radars located deeper inside the Soviet Union to control a planned 128 interceptor missiles to defend the Soviet Union's capital region from ballistic missile attack. However, the system was able to reach just 64 deployed interceptor missiles by 1969-70. In 1972 the USA and Soviet Union signed the ABM treaty limiting each country to just two sites totalling 200 interceptor missiles.[1] This figure was further reduced through signing of a protocol in 1974.[2] The US at this stage appears to have been lagging in BMD technology compared to the Soviet Union. Soviet attempts to upgrade the system were speculated about from the later 1970s into the 1980s but not much is known about these. The US attempted to steal a march over the Soviets with the Strategic Defence Initiative or 'Star Wars' program to put in place a modern BMD system able to target hostile missiles in boost, mid-course and terminal phases of flight. This project did not fructify but later led on to US research into theatre level BMD systems in order to deal with ballistic missile technology in the hands of smaller states that could target US forces in different parts of the world. In response to perceived progress in these more limited BMD systems, the US unilaterally withdrew from the ABM treaty in December 2001.[3] Since then the US has experimented with its Patriot anti-aircraft missile system to give it some degree of BMD capability, developed the Terminal High Altitude area Defence (THAAD), and is in the process of fielding it operationally after several years of testing and improvements. The THAAD uses an interceptor missile with a hit to kill or collision impact system. The more typical proximity fuze system, as is used in most air to air missiles was considered and abandoned in favour of hit to kill due to the need to ensure positive destruction of the incoming warhead. A proximity fused warhead may merely damage the incoming warhead and maybe just alter its trajectory to an extent. If the warhead is nuclear, a displacement of a few km from the originally intended target may not sufficiently mitigate the affect it will have on the ground. Hence hit to kill was chosen for assured destruction of the incoming warhead in the THAAD system[4]. The Soviet era S-300 air defence system – especially in its later variants such as the S-300PMU2 – is claimed to have a limited BMD capability. The more modern S-400 is said to have credible BMD capability while the under development S-500, which is due to commence field trials later in 2017, is claimed to include a more robust BMD capability. China claimed to have carried out a BMD flight trial on 11 January 2010 and a second one on 27 January 2013,[5] using a reconfigured version of either the DF-21C or DF-25, referred to in some circles as the KS/SC-19.[6] It is possible that in these two reported BMD tests, China used reverse engineered components from the S-300PMU2 systems it

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imported from Russia earlier.[7] Israel has developed its Iron Dome[8] system to counter very short range ballistic missiles, the "David's Sling" system[9] for longer ranges and the Arrow-1/2/3[10] systems for even longer range interceptions.

Indian Progress in BMD Development

India's Defence Research and Development Organisation embarked upon an endeavour to develop a two layer BMD system. This comprised a 'Swordfish' Long Range Tracking Radar (LRTR) and Multi-function Fire Control Radar (MFCR) which is a suitably modified Israeli origin 'Green Pine' radar.[11] There is an indigenous Missile Control Center (MCC) and Launch Control Centres (LCCs).[12] The development was planned to proceed in two stages. The first stage was aimed at development of a two layer system able to defend against ballistic missiles of ranges up to 2000 km. In the second phase, the capability is to be extended to engage threats with ranges of over 2000 km also.[13] The first interceptor to be developed and tested was the Prithvi Air Defence (PAD) missile to tackle threats in the exo-atmospheric region. The Advanced Air Defence (AAD) missile interceptor was developed to carry out endo-atmospheric interceptions. The PAD was succeeded by the Prithvi Defence Vehicle (PDV) in 2009. The PDV was reported to field higher performance characteristics than the PAD.[14] The DRDO has plans in its second phase of BMD development to progressively increase flight performance of its interceptor missiles based on the under development AD-1 and AD-2 missiles to deliver faster acceleration and hypersonic speed capability.[15]

On 11 February 2017, DRDO tested its PDV missile against a live test target and achieved a hit to kill interception at an altitude of 100 km AMSL.[16] The hit to kill aspect of the test requires emphasis. Hit to kill gives the best assurance of destruction of the target as compared to proximity fuses. However, hit to kill requires very high accuracy in guidance at all stages of the intercept and is a real feather in India's R&D community's cap. On 1March 2017, DRDO conducted a test launch of the AAD missile for an endo-atmospheric test flight, achieving a hit to kill intercept at above 15 km AMSL.[17] The missile utilised its on board radio frequency (RF) seeker for terminal guidance after earlier radio command guidance from its supporting ground radars. Successful tests of both the exo-atmospheric and endo-atmospheric missiles in two consecutive months could indicate that the efforts of DRDO in developing its initial Stage-1 BMD system are nearing fructification. More tests by DRDO followed by possible tests by the probable end users could be expected in the coming months to prove the DRDO's Phase-1 BMD system for induction in an operational role. The milestones achieved so far by the DRDO in this project are praiseworthy. The recent two tests place the Indian R&D effort in this field just a shade below that already achieved by Russia, USA, and Israel.

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Given the progress till date it is likely that India could soon field a world class indigenous BMD system over the next few years. Especially in view of the nuclear as well as conventional ballistic missile threat India faces, this could enhance national security while giving the country greater chances of being able to counter enemy attacks more effectively by providing a shield to the infrastructure needed to execute its proclaimed strategy.

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Conclusion

India has worked towards development of military technology within the country ever since its independence in 1947. Many of these efforts have floundered. Despite setbacks R&D professionals have continued their efforts. The Indian missile program is one vivid example of successes achieved by India's R&D establishments. The ongoing development of the BMD system by DRDO provides another example of success of indigenous R&D efforts. The indigenous BMD system has undergone more than seven development tests as on date and more are expected to be carried out over the next few months. Once these development tests are concluded the system could be offered for user trials prior to induction into active service. After the system is ready in its initial configuration further development and enhancement of its capabilities are likely to take place.

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