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Proliferation Assessment of Ballistic Missiles in the Middle East

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Strategic Context

Recent developments in ballistic and cruise missile technology around the Gulf show an increasingly alarming rate of proliferation. These developments are the result of matured national programs whose continuation and developments were supported by their respective political leaderships as well as popular support. Many of the states involved in missile proliferation have also either already acquired a nuclear military capability or are suspected to be in the final stages of acquiring such. Consequently, the security impact on GCC states is serious and this environment of proliferation can threaten the progress made in achieving some of the highest levels of welfare and sustainable economic prosperity in the world by GCC states over the past three decades.

A proliferation race is ongoing in the wider region where Israel, India, Pakistan, and Iran are all participants. The lack of a seriousness to find a solution to the proliferation problem on the part of the international community is made worse by what are perceived to be double standards of Western policy in the region. Unfortunately, seemingly double standard to policies of Western powers seeking to prevent proliferation in the region is making the overall situation more difficult to resolve. There is a widely held perception that some countries are allowed to proliferate, while others are not. In other words there is no serious effort to effectively "reign in" proliferation trends, which are now spiraling upwards faster.

It is possible to find examples of contradiction in dealing with proliferators in the region. On the one hand, a serious embargo was enforced against Pakistan, especially in the 1980s, to curtail its programs, and more recently a physical invasion of Iraq whose effects the region is still to recover from, was also seen. On the other hand there is almost total indifference towards the Indian nuclear and missile programs and with Israel, the policy towards it is in fact complimentary and rewarding with the substantial political, technical and financial support for its programs. With regards to Iran, the underlying issues remain vague however unpredictable events could happen to stop the Iranian nuclear and ballistic missile programs – further complicating the security environment in the region and the impact on Gulf security.

When we look back at past experiences, whether they are found under the mandate of the United Nations, on the part of Western policies (such as sanctions and embargos), to prevent the proliferation of missile technology and nuclear and other weapons of mass destruction (WMD), it is possible to draw practical lessons from which policies have proved effective and which have not. The embargo enforced against South Africa did not prevent them from successfully developing their nuclear and ballistic missile program, and we also saw Pakistan and North Korea achieve the objectives of their programs in the face of international embargos.

In the period since these policies have failed, we are yet to see the engineering and application of an effective model for preventing proliferation, and the creation of worthwhile incentives for the countries like Libya who have abandoned their programs – Libya remains under the United Nations Charter but with the international embargo resolutions against it 'frozen' rather than canceled or eliminated. The same is true of Iraq where resolutions remain 'frozen' rather than cancelled even after a complete invasion and where any tangible evidence that a WMD program exists and is active remains to be found.

One of the most important questions in the regional security debate remains to be one that asks about which kind of proliferation policy is effective and should be implemented, and what sort of incentives can be provided to states in the region that are willing to abandon their programs? With the current regime against proliferation failing, the threat of regional proliferations trends not only remains heightened but is constantly growing. This paper seeks to assess and address current proliferation trends around GCC states and trace the developments that have been made in national ballistic and cruise missile programs in the region over the past twenty years (this paper will not however address the nuclear programs of these countries) in order to better understand the direction the region is heading and re-emphasize the need to create an effective model to prevent and reverse current proliferation trends.

An Introduction to Ballistic Missiles

Ballistic missiles are generally categorized into four classes: Short-range (SRBM), which have a range of up to 1000km; Medium-range (MRBM), with range of approximately 1000km-3000km; Intermediate-range (IRBM), which have operational ranges of approximately 3,000km-5500km, and; Intercontinental-range (ICBM), which can travel upwards of 5500km which we see today in the National Regional Program in our Gulf area that all these countries have reached an advanced maturity in their program and all of them are in IRBM or in ICBM range.

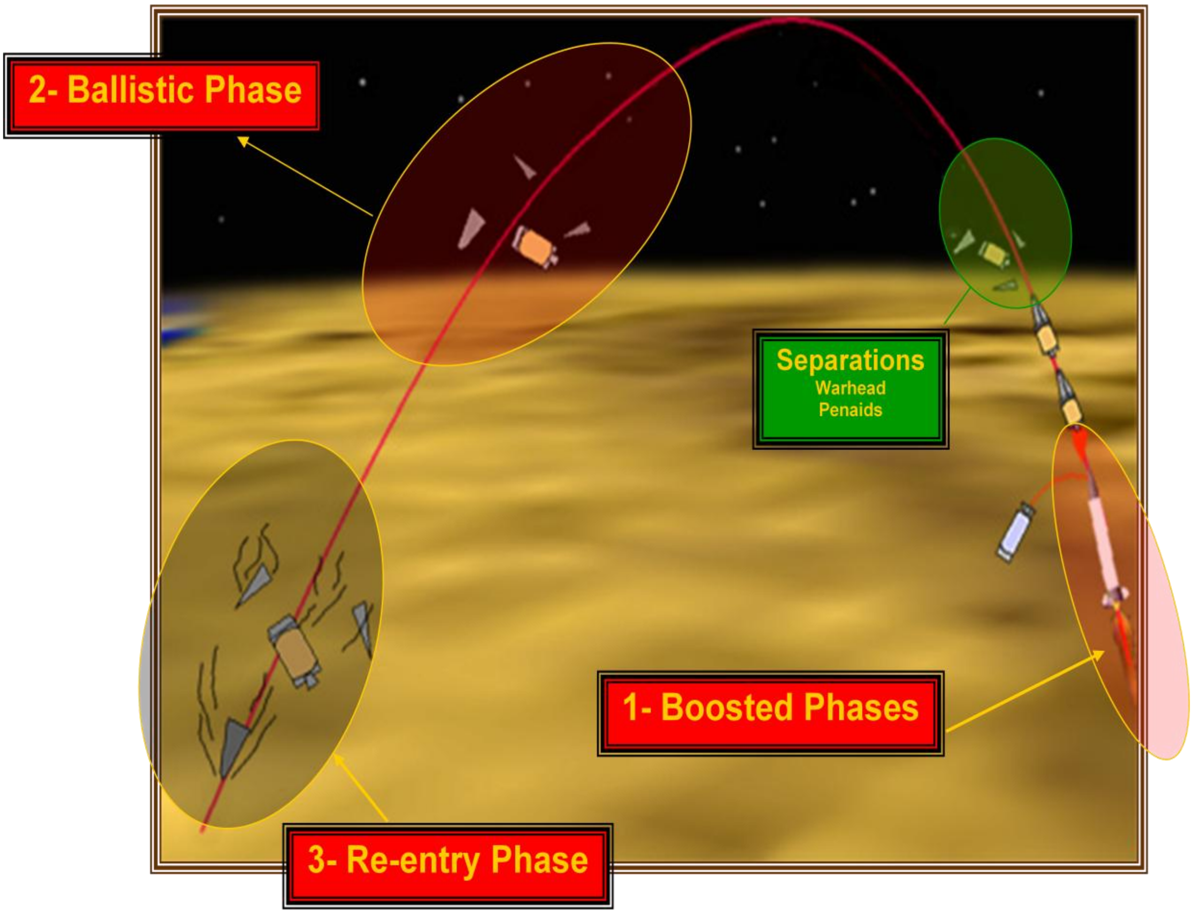
Ballistic missiles offer deep targeting and high effective penetration capabilities that can destroy military, political, and economic assets. They are also regarded as the best solution to carry WMD. Logistically, the ease of operations allowed by ballistic missiles compared to aircraft makes them indisputably useful weapons systems to have in the force arsenal. By acquiring such capabilities, you are making the entire opponent country into the battle field, transferring the battle from the battlefield front to the entire country where economic, political, military and civilian targets can be simultaneously targeted much more easily at any time, in large part regardless of how these targets are defended.

Ballistic missiles with their relatively poor accuracy today are more a weapons of “terror” than an accurate military targeting weapon system. However, ballistic missiles are ideal weapon to deliver nuclear warhead because these do not depend on highly accurate targeting for effectiveness. That said, certain nuclear powers in the region like India and Israel have achieved sophisticated terminal guidance systems which deliver greater targeting accuracy in their ballistic missile programs, too.

First Generation Ballistic Missile Technology

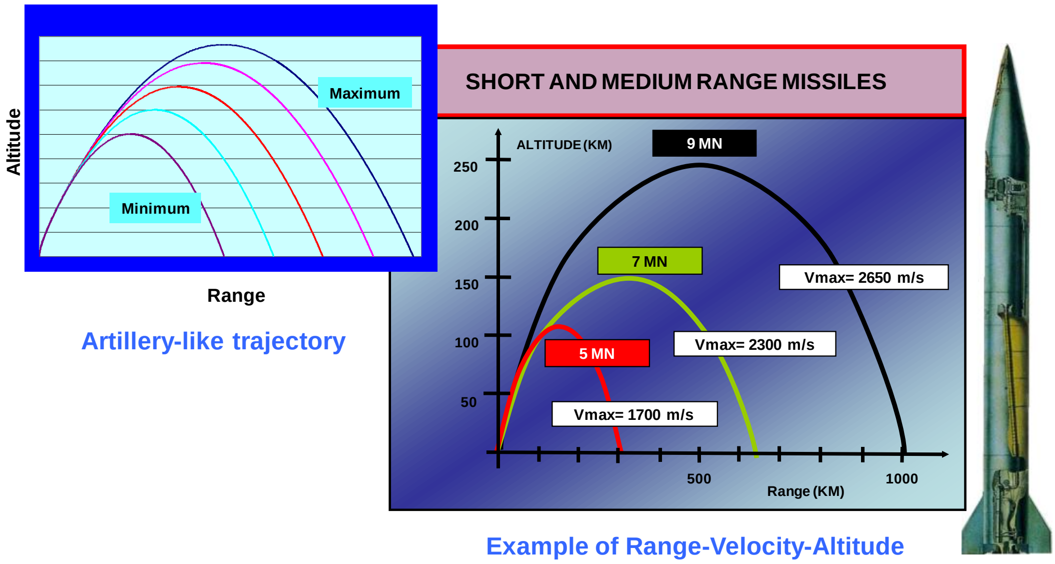
The first generation of ballistic missiles were made in mid-1940s by the Germans, and are sometimes referred to as the “scud type system.” These systems involved a fairly basic architecture involving a single warhead, single-stage liquid-based propulsion, and simple inertial guidance system. First generation missiles can have a separable warhead, which relatively improves accuracy and may reduce the chances of detection (although this is not always the case). The ballistic missile flight phase involves three basic flight phases: Immediately following the launch is the boost phase, the ballistic phase (warhead separation would take place before this phase), and finally, the re-entry phase. First generation ballistic missile trajectory types can be compared to artillery-like trajectories where firing higher into the air to achieve maximum altitude would in turn result in range maximization. The range-velocity-altitude metrics have a strongly correlative relationship where range maximization needs higher altitudes, and as a result the velocity is maximized on re-entry due to the missile's return from higher altitude by gravitational pull. Thus, the longer the range of the missile, the greater the altitude it will reach before the re-entry phase, and the greater will be the velocity and the angle upon re-entry.

Ballistic Missile Flight Phases



For a Short-range Ballistic Missile (SRBM) or Tactical Ballistic Missile (TBM), typically weapons with ranges of around 300km, the missile will typically reach an altitude of 80-100km before re-entry. Its velocity on return will hit around 1700 m/s (1.7 Km/s) and it will cover the distance of 300km in roughly five minutes. For a short-to-medium range missile that is launched at a target of, say, 650km away, the missile will reach an altitude of 130-150km before re-entry, travelling at a maximum speed of 2300 m/s to cover the distance in roughly seven minutes. For a Medium-range Ballistic Missile (MRBM) such as the Iranian Shehab-3, by reaching an altitude of 230-250km the missile can reach maximum speeds of 2650 m/s on its return to cover a distance of 1000km in roughly nine minutes. Controlling the range of flight of MRBMs can be achieved by cutting-off the missile engine at the velocity according to the program range or distance to be achieved.

Ballistic Missile Trajectory Types: First Generation



Artillery-like trajectory

Example of Range-Velocity-Altitude

Intermediate Range Obtained by Cutting-off The Engine

Trajectory Characteristics

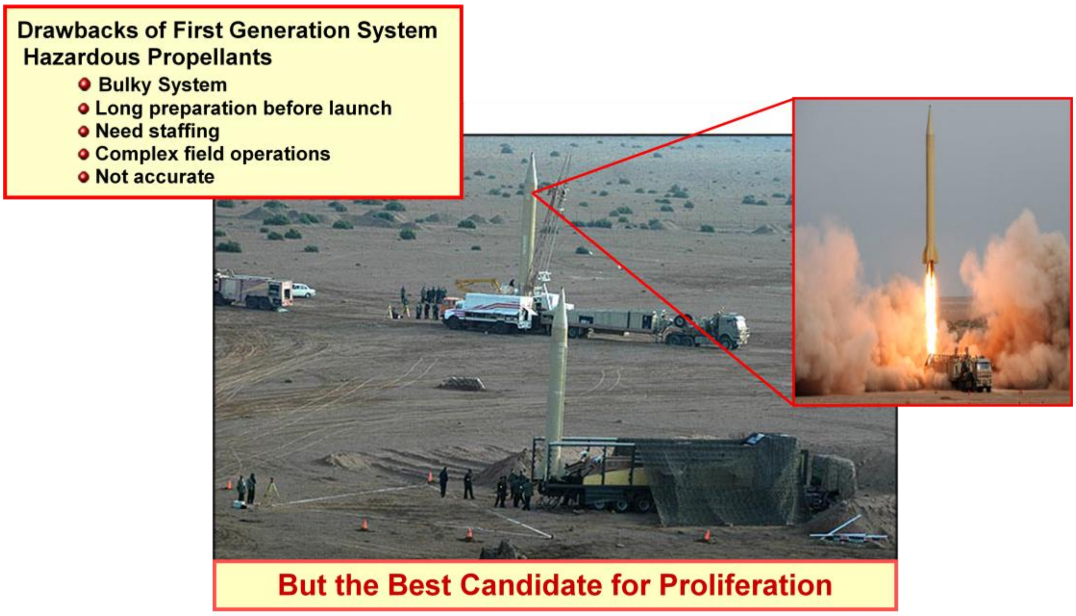
Minimum Energy trajectory

MISSILE RANGE km	MISSILE ALTITUDE (APOGEE) km	FLIGHT TIME sec	RE-ENTRY SPEED m / sec	RE-ENTRY DURATION from 120 to 0 km sec
300	80	303	1700	--
500	140	390	2250	116
1000	240	570	2650	95
3000	750	1000	4650	80
4500	1100	1500	5250	60

- **High Speed**
- **High Altitude**
- **Long Range**
- **Wide Range of Re-entry Path Angle from 30°-70° angle**

The operational preparation for a first generation missile can take more than six hours to launch due to heavy logistical support. Preparations for launch will begin with the TBM vector transloading from the transport truck to the Transport Erector Launcher (TEL). Next, the TBM vector tanks will be filled with oxidizer fuel on the TEL, brought in large fuel carrying tankers. The warhead mating is done after this fueling process is completed. Following the warhead mating, the TBM is ready for deployment on the launch zone. Once the electrical connection is made and the TBM flight and target parameters loading is complete, the missile is ready for launch. The preparation for launch can take around 30 minutes on the launch zone.

First Generation System Limitations



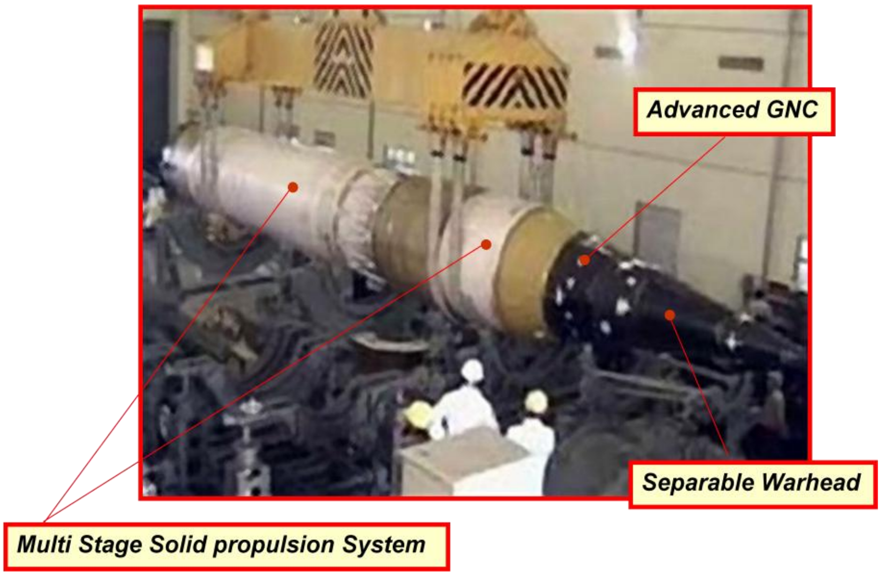
The drawbacks of the first generation system are various, including a bulky system (requiring heavy logistical support), the long preparation time required before launch, high staffing requirements, and the unavoidable complex field operations. Importantly, first generation ballistic missiles are not highly accurate. Nevertheless, first generation ballistic missiles remain the best candidate for proliferation because of the relatively less sophisticated technology they use which is either readily available or relatively easy to get hold of in the international market.

Today's Missile Technology

More advance generation ballistic missile architectures involve separable warheads, multi-stage solid propulsion systems, and advanced Guidance, Navigation, and Control (GNC) systems. These modern generation of missiles have an accuracy down to 10m and can carry nuclear warheads. The multi-stage solid propellant technology is responsible for many improvements in advanced generation TBMs such as: range enhancements, easing of field operations (including reduced staffing requirements), capability to launch at short notice, and long durations of storage they can endure.

With their GPS/GLONASS navigation aided and guidance control and their terminal guidance systems, this generation of ballistic missiles is largely immune to Electronic Warfare (EW) and jamming measures, and possess the maneuverability during re-entry phase to defeat most anti-missile defense systems in theory. Advanced generation ballistic missiles due to their

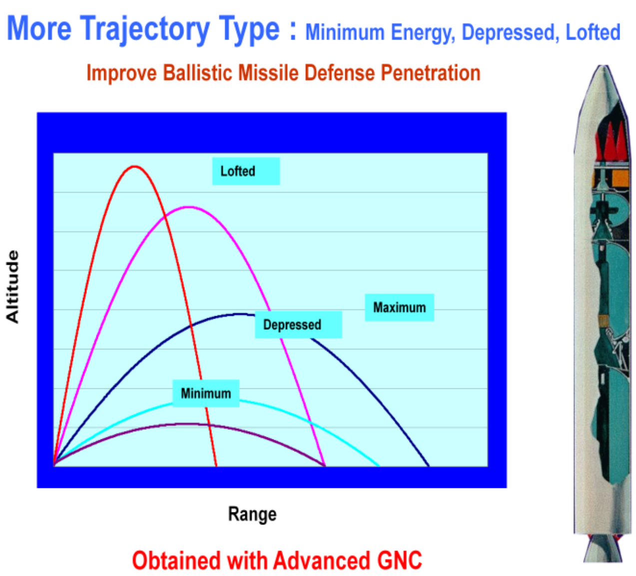
Ballistic Missile Architecture: Advanced Generation



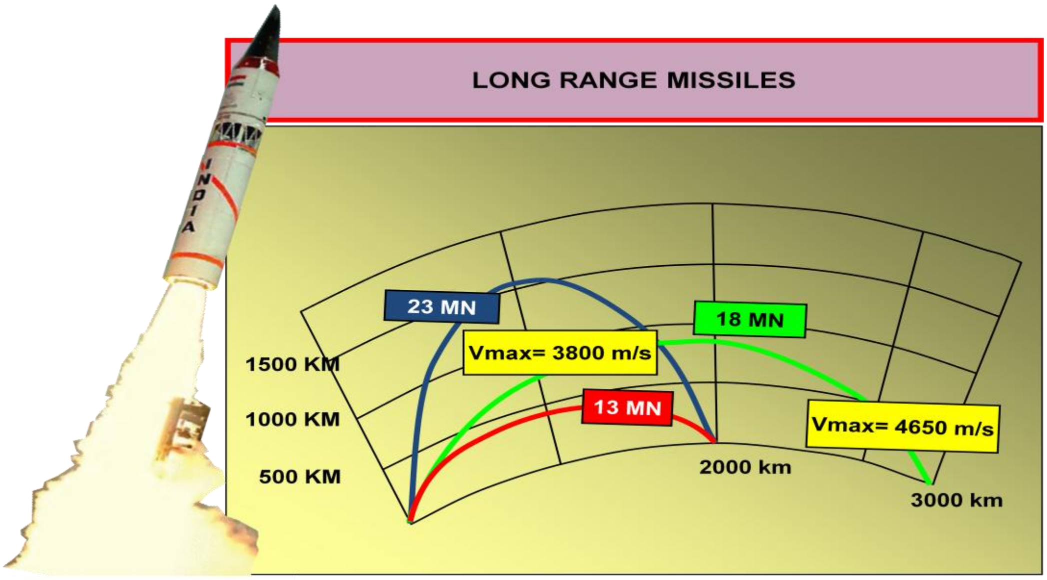
maneuverability have a greater range of trajectory types which improves their penetration capabilities against anti-missile defense systems. Trajectory types such as minimum energy, depressed, and lofted are relatively more effective in beating anti-missile shields. What these trajectory types do is essentially breakthrough the range-velocity-altitude metrics that held correlative relationships in first generation of TBMs. With the more advanced generation of ballistic missiles, the relationship that exists between altitude and range factors in the artillery-like trajectories of first generation TBM no longer stand.

Long-range Ballistic Missiles (LRBMs) of the advanced type are able to travel and cover large distances in short time spans by achieving fast speeds, although they need not be constrained by altitude factors. For example, an advanced generation LRBM can cover 2000km at approximately thirteen minutes and hitting altitudes of around 400km and maximum speeds of 3800 m/s. The same distance can also be covered by hitting altitudes of 1500km, at the same speed, but the time increases to twenty three minutes. In an another example, an LRBM can cover 3000km in just eighteen minutes by travelling at a speed of 4650 m/s and hitting an altitude of some 800km. What these typical trajectory examples highlight is the critical need for quick analysis by anti-missile defense systems in the event of a ballistic missile attack in order to have an effective and timely response.

Ballistic Missiles trajectory types: Advanced Generation



Ballistic Missiles Trajectory Types: Advanced Generation



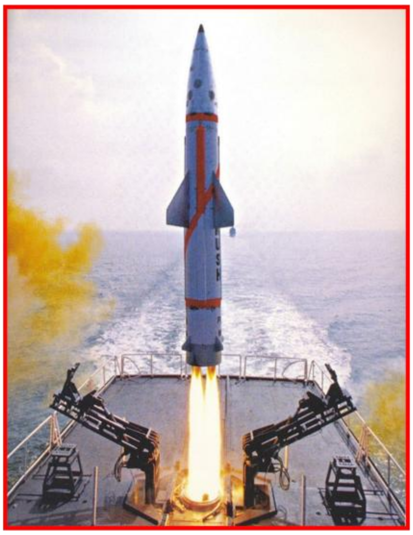
Example of Range-Velocity-Altitude

Operations: Advanced Generation

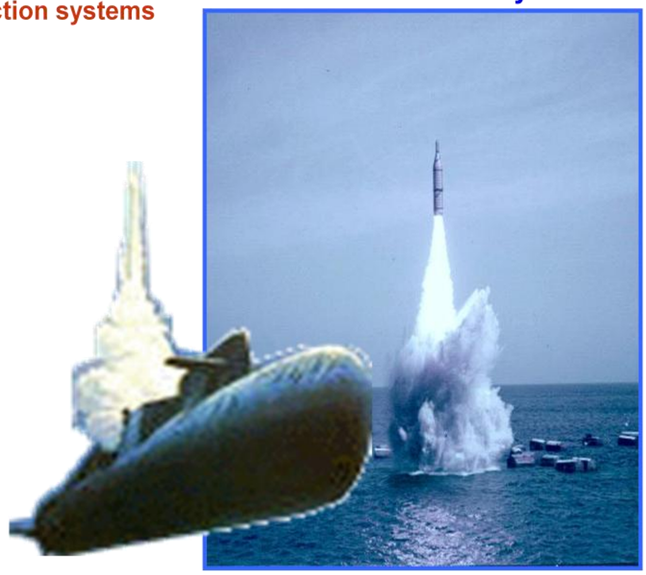
Sea-to-Ground Ballistic Missile

- First integration on ship platform
- Vulnerable. Need effective ship protection systems
- Fully autonomous System
- Require a reliable C2 Chain

Sub-marine based System



Ship- based System



- Lowest vulnerability to Counter-forces
- Long endurance System
- Fully autonomous System
- Require a reliable C2 Chain

Operations for advanced generation TBM can be done from mobile or silo-based systems for ground-to-ground attack, or from ship- or submarine-based systems for sea-to-ground attack. The mobile system has a low vulnerability to counterforce measures (because of its mobility and autonomy), and comes as a fully autonomous system – although it requires a reliable C2 chain. The silo-based system is more available: It can be implanted at a missile base and allows a

Operations: Advanced Generation

reliable C2 chain – however, a silo-based system is vulnerable due to its fixed position and needs to be protected by a reliable air defense system or with a hardened body.

The ship-based system is a fully autonomous system but requires integration with the ship platform and an effective ship protection system as well as a reliable C2 chain. Finally, the submarine-based system, which requires a reliable C2 system, has the lowest vulnerability to counterforce, has long endurance, and is also fully autonomous as a system.

The Warhead Factor and Technological Advancements

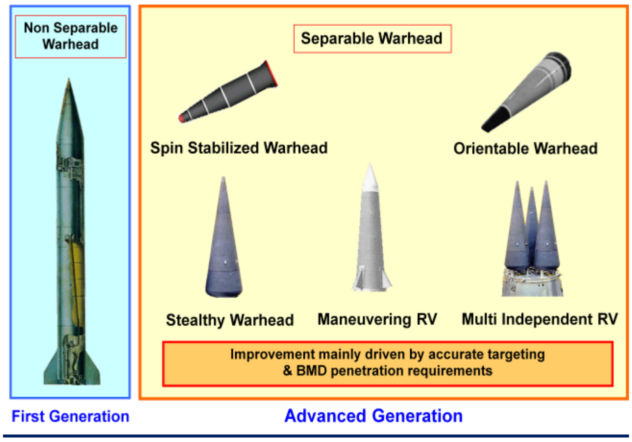
Ballistic missile warheads can carry nuclear, chemical or biological payloads in addition to conventional (bulk warhead or submunition warhead) ones. In fact, TBMs are regarded to be the best solution for delivering nuclear payloads. While basic types of first generation TBM do not have a separable warhead, more advanced TBM can carry one of various types of separable warhead such as a spin stabilized warhead, orientable warhead, stealthy warhead, maneuvering re-entry vehicle (RV), or multi-independent RVs. These improvements have been driven by accurate targeting and ballistic missile defense penetration requirements.

The re-entry phase of the ballistic missile happens after the warhead has accelerated to its maximum speed in the ballistic phase of its flight, reaching high velocity speeds of 1500 m/s to

5000+ m/s before its re-entry into the earth's atmosphere (roughly an altitude of 120km). The tip of the missile can reach temperatures of up to 3000ºC during flight in the re-entry atmospheric air (below 120km) due to air friction – this can give a spectacular warhead pattern at terminal re-entry phase. Upon re-entry, the warhead orients itself and high deceleration begins at 5g to 40+ g units. The re-entry of a ballistic object is very specific because its movements result from weight and aerodynamic effects such as lift and drag. Hypersonic aerodynamic models are needed to compute the re-entry movements.

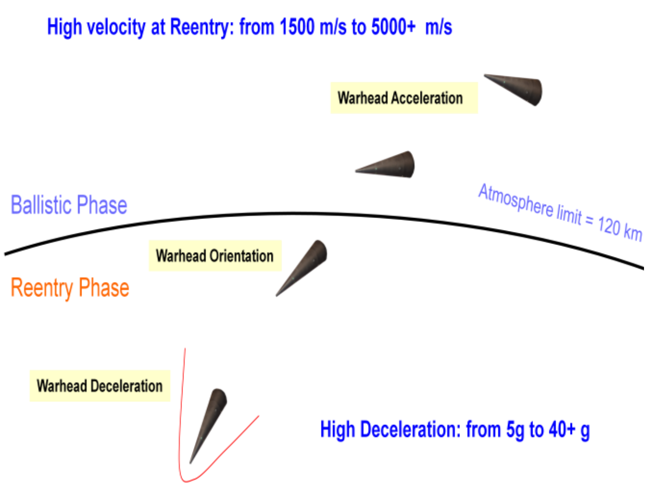
An important phenomenon in observing ballistic objects and reducing the detection of the early warning ballistic missile defense (BMD) radar is the important variations of the level of their Radar Cross Section (RCS) along the flight (more RCS area shown to the radar makes it susceptible to detection at longer ranges). RCS usually vary with the observation angle. Because ballistic objects rotate during their ballistic phase and during their re-entry, their aspect angle and RCS vary within the same period. With first generation ballistic missiles carrying a non-separable warhead, the RCS has a minimum signature at the tip of its nose – where the typically conical and non-stealthy warhead is located – and maximum RCS signature about half way down the body where small wing-like structures for aerodynamic stabilization may be found.

Warhead Technology



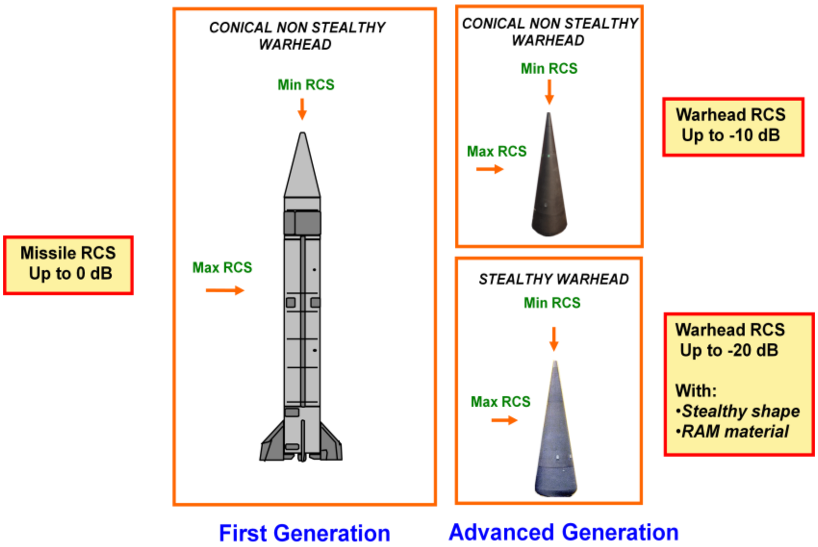
The missile RCS for first generation types is typically up to 0 dB. For advanced generation ballistic missiles, the separated conical non-stealthy warhead can give a RCS of up to -10 dB with its tip giving minimal RCS and the wider end of the conical warhead giving maximum RCS. For more capable missiles that utilize stealth technology, the warhead RCS is up to -20 dB. However, reducing RCS to the minimum (stealth technology) is not only a factor of object orientation but also much more sophisticated design and Radar Absorbance Material (RAM) technology.

Warhead Re-entry Profile



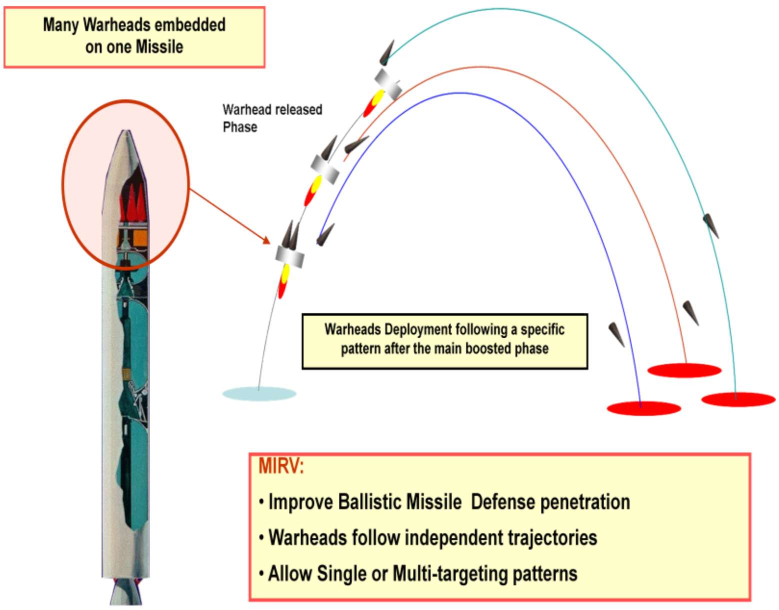
Multiple Independent Re-entry Vehicles (MIRVs) are a collection of warheads that are embedded into one missile. Missiles carrying MIRVs must choose between a trade-off between warhead sizes and the number of warheads. Each vehicle can follow independent trajectories. Today, most modern missile can carry 3 to 5 warheads. MIRVs improve chances of BMD penetration and allow single- or multi-targeting patterns to be realized. MIRV technology would be used extensively in efforts to deliver nuclear warheads for obvious reasons. This technology so far exists in the region only with the Israelis, and is believed to have been acquired by them as long ago as 2002.

Warhead Observability

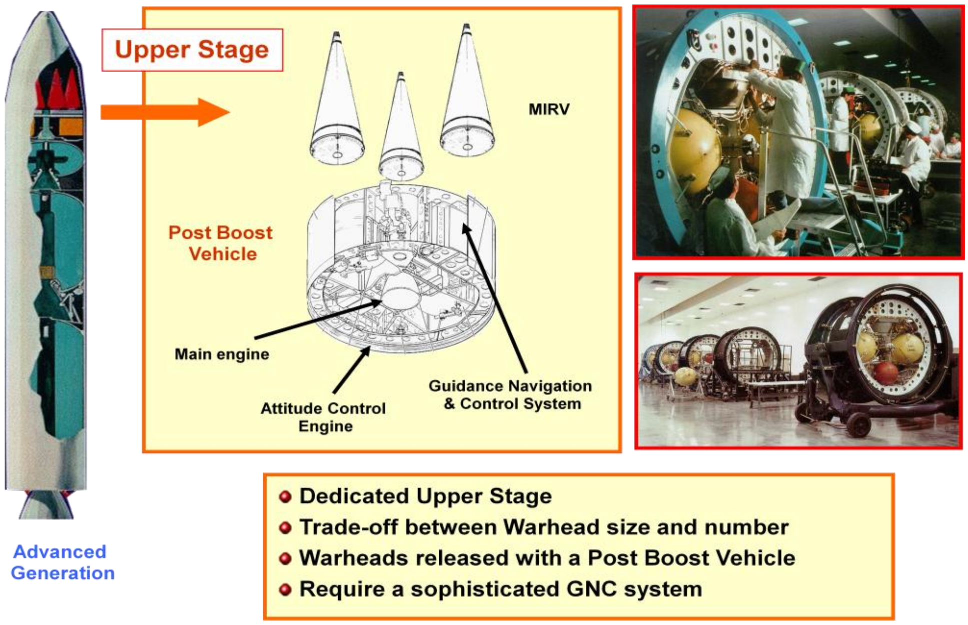


Warheads with independent re-entry vehicles have a dedicated upper stage where the post-boost vehicle is located – this is where the warheads are released from. The post-boost vehicle is comprised of a main engine, an attitude control engine, and a sophisticated GNS system.

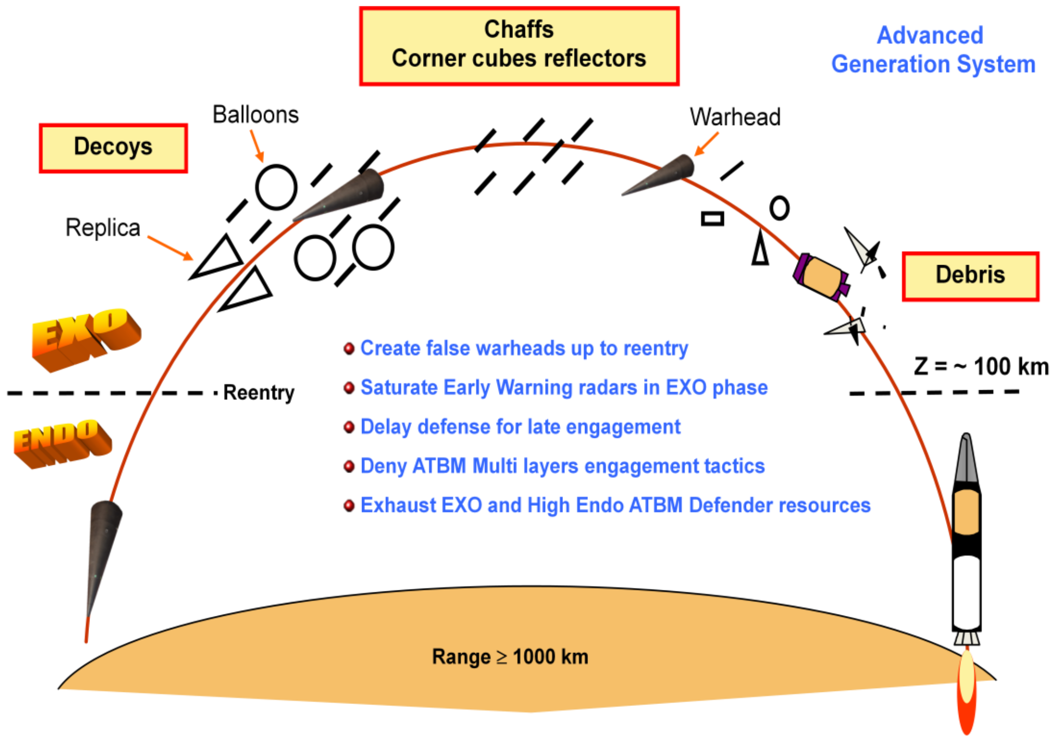
Multiple Independent Re-entry Vehicles



Multiple Independent Re-entry Vehicles

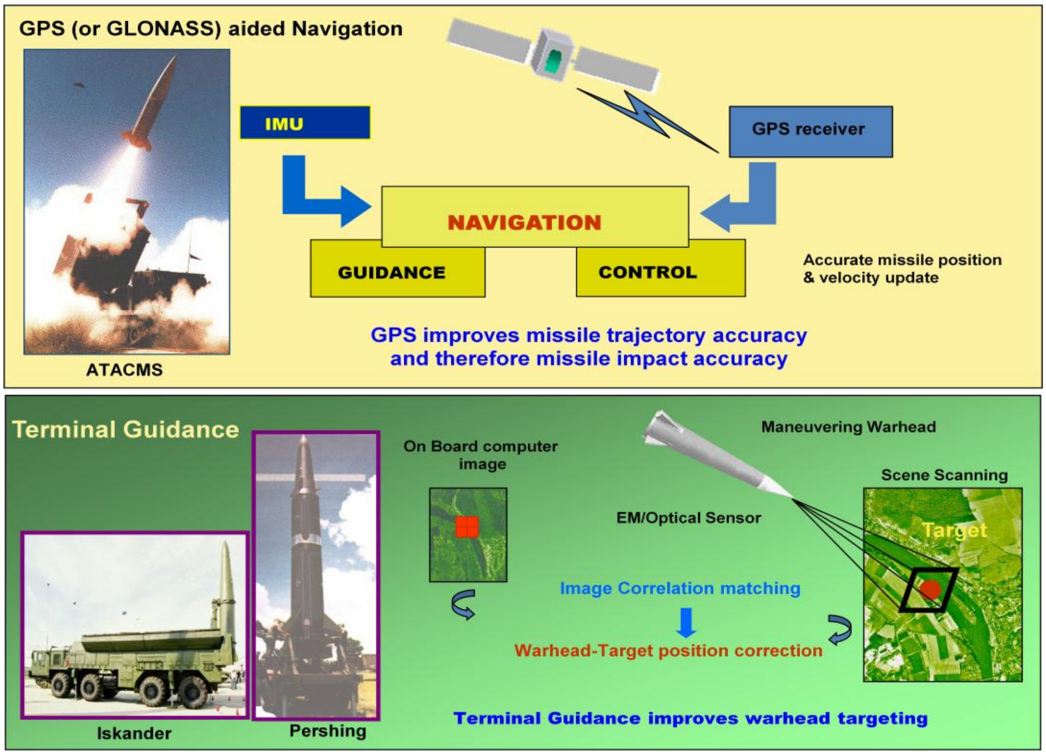


Penetration Aids (Penaids)



Penetration aids (also known as "penaids") is a tool of deception. These objects fly alongside real warheads and are decoys designed to confuse the ground early warning radar up to the point of re-entry by creating false warheads. The purpose is to delay the classification of the real warhead from the deception and thereby critically reduce the reaction time for the air defense system, or makes the air defense system engage more targets than is necessary or it is able to handle. Chaffs or corner cubes reflectors, balloons, and replica warheads can all act as decoys and may saturate early warning radars in 'EXO' phase, delaying defenses for late engagement, denying multiple layers of BMD systems their engagement tactics, and exhausting EXO and high ENDO anti-ballistic missile defender resources.

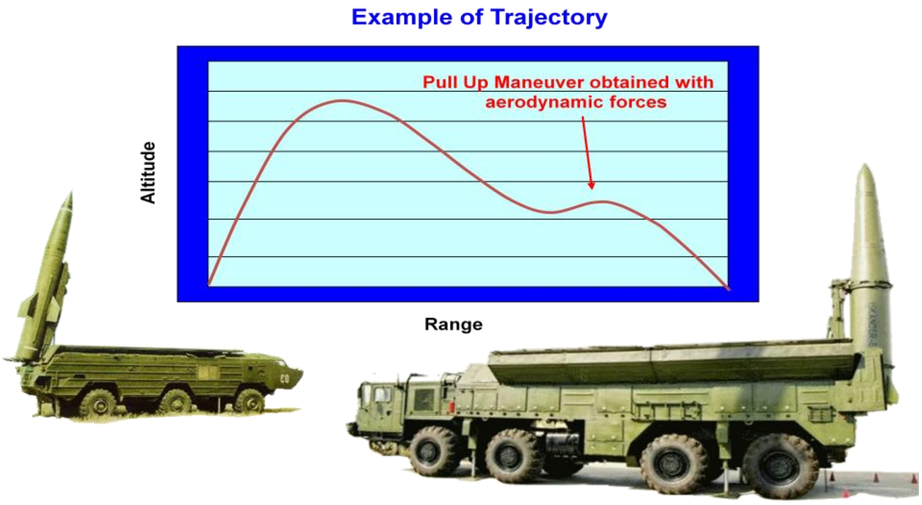
New Generation of TBM: Accuracy



New generation TBMs have also achieved improved accuracy by removing errors of navigation through the use of high performance Internal Measurement Units (IMUs), or by using external references such as GPS during flight. In addition to providing accurate missile position and velocity updates, GPS can improve the missile trajectory accuracy and therefore missile's accuracy on impact. Terminal guidance systems on the other hand have improved warhead targeting by providing scene scanning and on-board computer images to enable image correlation techniques which allow warhead target position corrections.

New generation TBMs have also made advances in the trajectory domains and are able to dodge BMD systems. For example, the pull up maneuver (which literally pulls the missile back to a higher altitude temporarily), can be achieved through methods that play on aerodynamic forces. The attitude of the missile is generally ensured by thrust control however aerodynamic control is also possible in the atmosphere with fins or paddles.

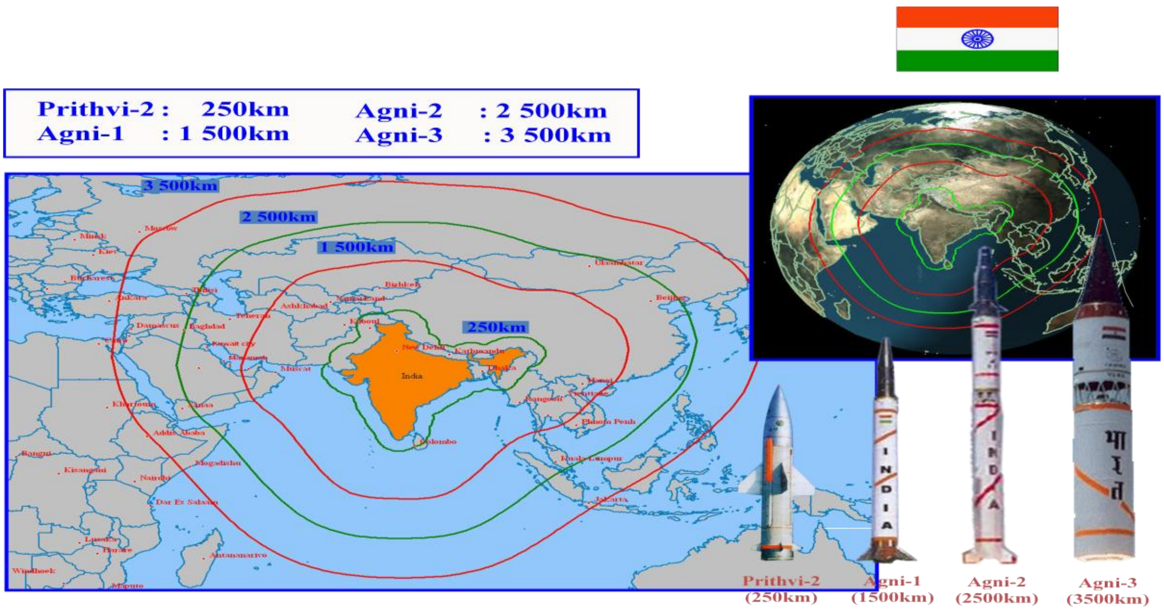
New Generation of TBM: Trajectory



Regional Ballistic Missile Inventory

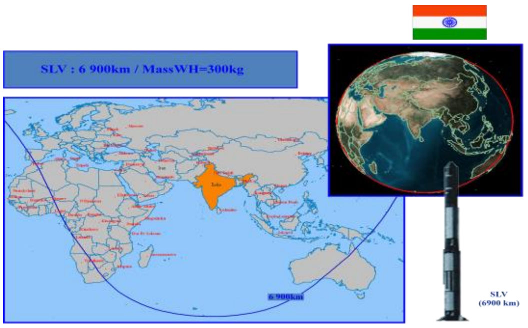
Regional ballistic missile inventories are made up mainly by India, Pakistan, Iran, and Israel. These countries have invested heavily over the last 20-25 years in missile technology programs – programs which are notable for the broadest political support and national prestige they have received in their countries. These states have devoted considerable amounts of human capital, sophisticated technical infrastructure, vast resources, and billions of dollars to create a national missile capability. Their achievements have also however created a more threatening environment for their neighbors and laid the basis for serious proliferation challenges in the region. Double standards in region-specific policies to the prevent proliferation of such technologies have weakened the chances of success in efforts to create an environment where states could meet their security needs without necessarily proliferating missile and related technologies.

Indian Ballistic Missile Inventory



India possesses: Prithvi-2, a 250km SRBM; Various versions of the Agni series such as Agni-1, a MRBM with a range of 1500km and payload of up to 1000kg capable of delivering nuclear warheads, the Agni-2, a MRBM with a enhanced range of 2500km, and the Agni-3, a IRBM which has a range of 3500km. India also possess an ICBM capability, achievable by converting its current Space Launch Vehicle (SLV) civil missile launcher into a military version, able to carry a warhead of 300kg to ranges of up to 3900km.

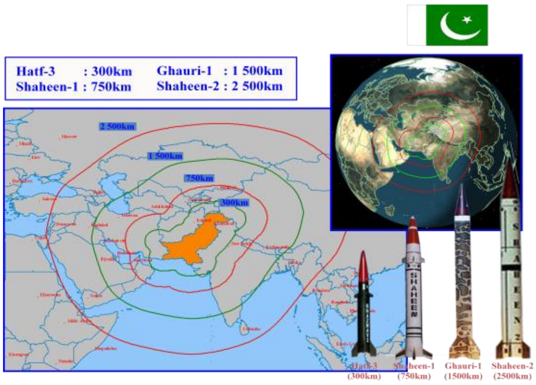
Indian Long Range Ballistic Missiles



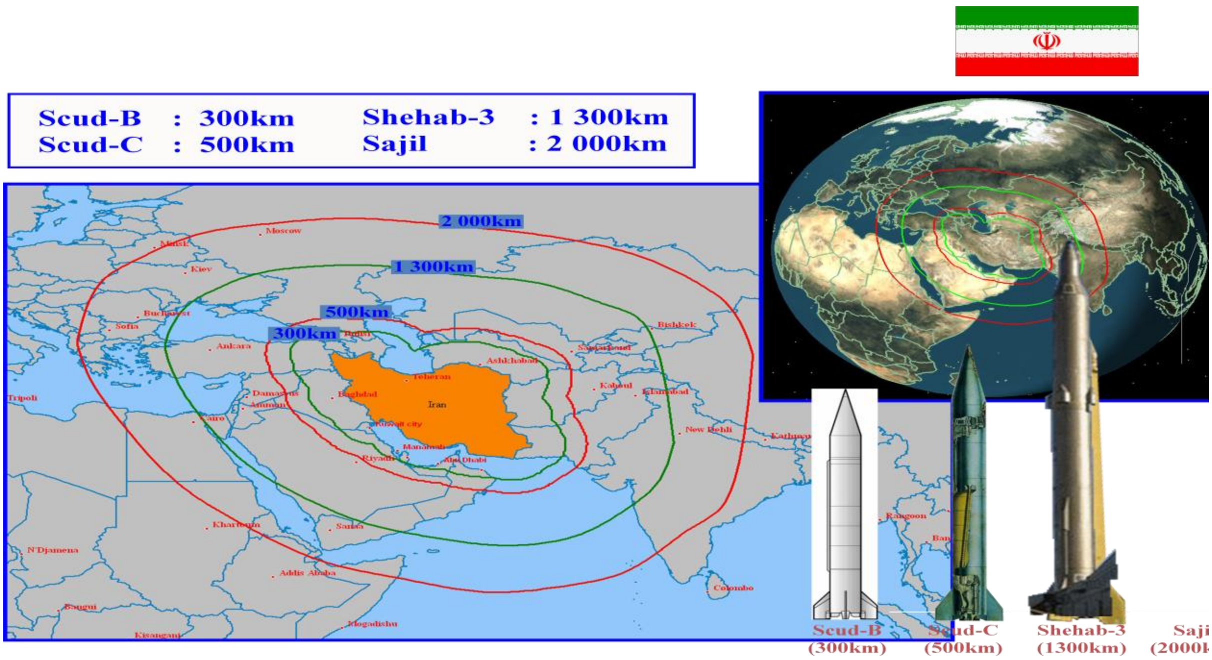
Pakistan's arsenal includes the Hatf-3 SRBM, with a range of 300km, the Shaheen-1, a SRBM with a range of 750km, the Ghauri-1, a MRBM with a range of 1300km (payload of up to 1000kg the payload can be conventional or nuclear warhead), and the Shaheen-2, a MRBM with a range of 2500km.

Iran possess the Scud-B SRBM and Scud-C SRBM with ranges of 300km and 500km respectively, the Shehab-3, a MRBM with a range of 1300km (payload of up to 1000kg the payload can be conventional or nuclear warhead), the Sejeel, a MRBM with a range of 2000km, and the Shehab-4 IRBM and Shehab-5 ICBM with ranges of 3500km (payload of up to 1000kg) and 5300km (payload of up to 500kg) respectively which have been finally launched as a civilian SLV program to launch satellite.

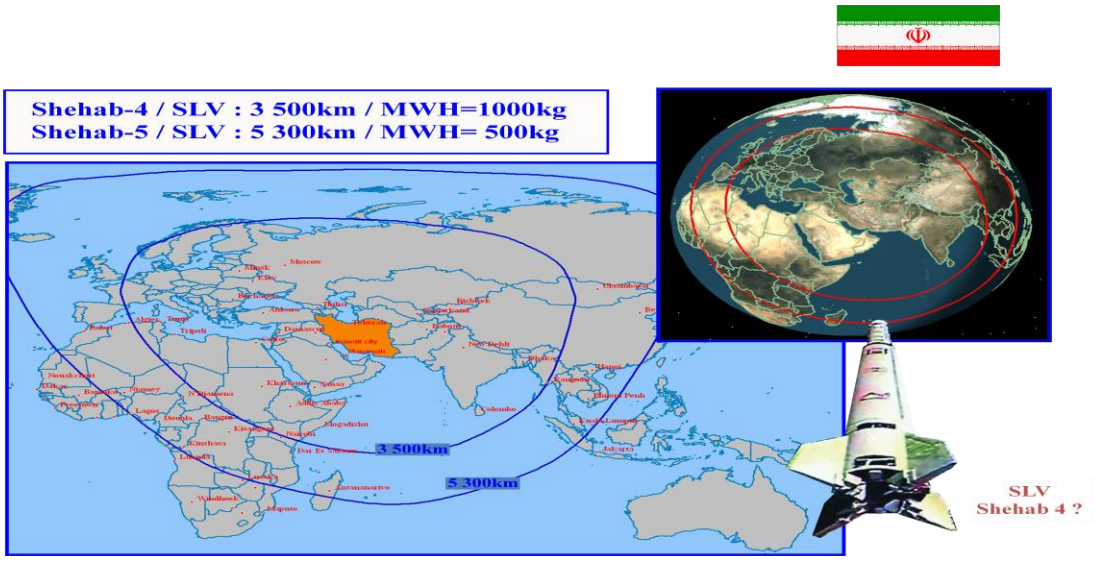
Pakistan Ballistic Missile Inventory



Iranian Ballistic Missile Inventory

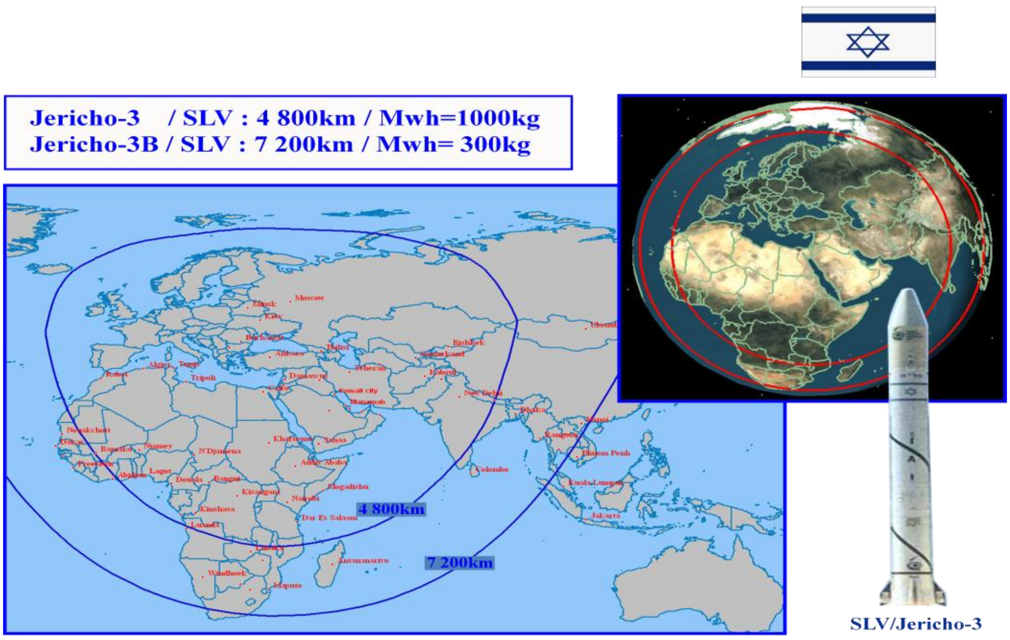


Iranian Long Range Ballistic Missiles

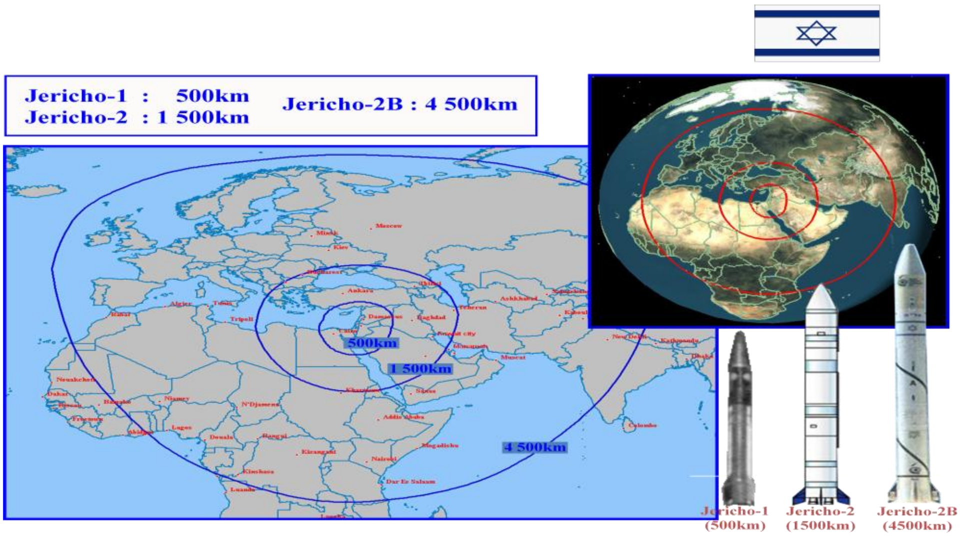


The Israeli ballistic missile inventory includes the Jericho-1, a SRBM with a range of 500km, the Jericho-2, a MRBM with a range of 1500km (payload of up to 1000kg the payload can be conventional or nuclear warhead), the Jericho-2B, a IRBM with a range of 4500km, and the Jericho-3/SLV and Jericho-3B/SLV ICBM with ranges of 4800km (carrying payloads of up 1000kg which is constituted of 3 nuclear warheads as a MIRV technology) and 7200km (carrying payloads of up 300kg nuclear warhead), respectively.

Israeli Long Range Ballistic Missiles



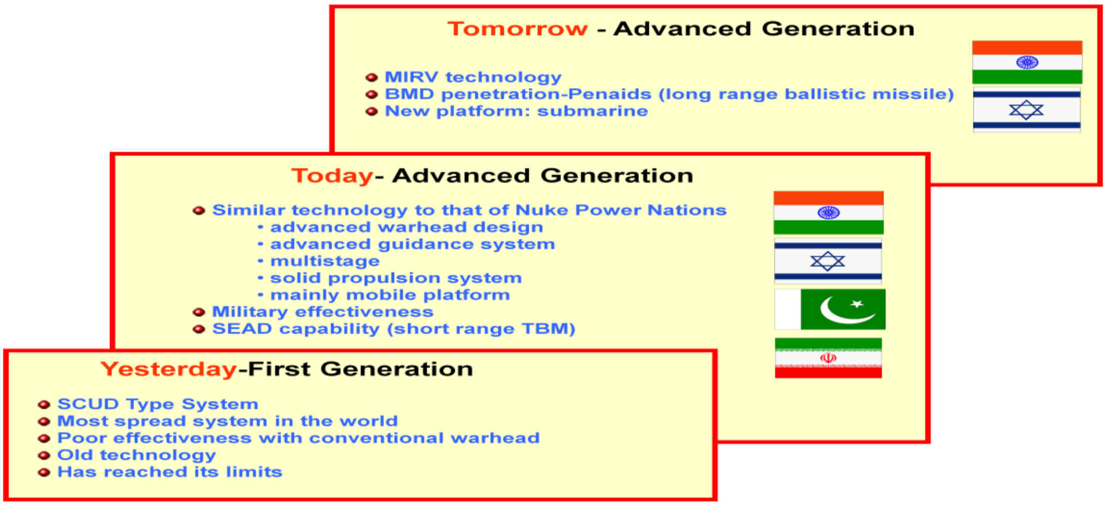
Israeli Ballistic Missile Inventory



Conclusion

The first generation of ballistic missile known as the Scud-type systems use old technology that is regarded to have reached its limit. While the most widespread type of ballistic missiles in the world, first generation TBMs have poor accuracy and are limited to delivering conventional warheads. Today, advanced generation TBMs use technology similar to that of nuclear power states by utilizing advanced warhead designs, advanced guidance systems, solid propulsion systems, and are designed for use increasingly from mobile platforms. Today's generation of advanced TBMs offer much improved effectiveness and SEAD (Suppression of Enemy Air Defenses) capabilities. Tomorrow's TBMs will move towards further improvements with the incorporation of MIRV technologies and BMD penetration penaids (for longer range TBMs). They will also extended operability with new platforms such as submarines, and we will see the introduction of new maneuver capabilities in flight trajectories as missile try and counter developments in BMD systems. The puzzle to find a security framework that is mutually acceptable to all regional states in the face of intensifying proliferations trends remains to be solved. The next paper will address the cruise missile proliferation in the region.

National Program Trends



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