Agni I to VI – Not Just a Number Game

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Introduction

Often there is a tendency to perceive the journey of Agni ballistic missiles over the years as merely a function of range escalation, the fact, however, is that each successive missile type is related to a particular need and operational logic. This article tries to make sense of this logic by connecting each successive Agni missile to the felt need and technological challenge that prevailed at that point in time.

When the Integrated Guided Missile Development Programme (IGMDP) of the Ministry of Defence (MoD) for research and development of a comprehensive range of missiles, namely *Prithvi, Trishul, Akash* and *Nag,* was started by the Defence Research and Development Organisation (DRDO), Agni was conceived only as a Technology Demonstrator (TD), which by definition, is a prototype version of a conceivable product of a future system which is aimed to prove a concept or a new technology. This was exactly the status of the first version of Agni.

Need for Re-entry Technology

Well before the second nuclear tests in 1998, when the IGMDP got started in 1982-83, the stakeholders knew it well that for carrying our warheads (both conventional and nuclear), to longer ranges in the land of the potential adversaries, re-entry technology was an essential requirement. Re-entry in the context of ballistic missiles, relates to the end portion of a cycle which starts by missiles going out of the earth's atmosphere (exo-atmospheric) during accent flight (post boost phase), traversing most of their

flight paths (mid-course phase) in the exo-atmospheric region, flying on a sub orbital trajectory before finally making a “re-entry” into the earth’s atmosphere (100 km/53.9 nautical miles) for striking their intended targets (terminal phase). Since ballistic missiles are not powered all the way like, for example the cruise missiles, specific advantages are gained in pushing such missiles out of the earth’s atmosphere for most of their flight paths. Firstly, during their flights outside the earth’s atmosphere, longer ranges can be achieved since no energy is wasted in overcoming air resistance, and secondly, and as a consequence, comparatively very high velocities can be achieved using the same propellant (boost) charge. These velocities could be of the order of 5000 miles per second or thereabout. Such tremendous velocities enable the ballistic missiles to cover long distances in very short periods of time. This increases their lethality and effectiveness, as such missiles give minimal reaction time to the defenders to employ counter measures. For instance an intercontinental ballistic missile (ICBM) can cover a range of 10,000 km in a matter of 30-35 minutes.

The big challenge arrives at the moment of re-entry, when owing to the atmospheric drag due to air resistance impacting on the missiles, temperatures of the order of 3000^0 C/5432^0F are reached. These temperatures can totally disintegrate the re-entry vehicle. In addition, there are a host of other technological challenges at the time of re-entry related to gas flows, accuracies and more which have not been covered in this article.

Since longer ranges for delivery vehicles were operationally required as an essential component of our deterrence strategy, harnessing the re-entry technology was the starting aim of embarking on the Agni journey. It is also relevant to mention here, that Agni was the only ballistic missile out of the ones being developed under the IGMDP. Others were either surface-to-surface or surface-to-air or anti-tank missiles.

Range and Altitude Capabilities

The period 1982-83 to about 1988 saw Project Agni take its baby steps gradually maturing into its first success. The expertise

brought in by the IGMDP Project Director Dr APJ Abdul Kalam from the Satellite Launch Vehicle (SLV)-3 programme was the starting block. While the basic requirement to provide the delivery means for the carriage of conventional or nuclear warheads into the domain of our potential adversaries remained fundamental to the development of the Agni (and Prithvi) series, the question was to progressively achieve such range and altitude capabilities that made our strategic deterrent credible and effective in the perception of our adversaries.

Development of Agni II Missile

In the timeframe 1982 to 1988, the first of the Agni series (Agni II) was developed starting from the basic design developed in the TD version. The missile had a range capability of 2500-3500 km. The range consideration was obviously driven by the range to be effective in the gut of the adversary's vulnerabilities. Also pertinent to mention here is the fact, that around the same time, Pakistan successfully test fired its Ghauri Missile (Ghauri I range 1500 km, Ghauri II range 1800 km) capable of reaching India's rear areas. The first successful test of Agni II on 11 Apr 1999 achieved a range of 2000-2100 km.

First launch of Agni II Missile 11 Apr 1999

There were two specific target requirements in this very first development. First, the requirement to keep the missile rail and

road mobile so as to keep it quickly moveable/deployable (15 minutes) essentially as a measure of survivability against adversary's first strike. Secondly, the technological challenge to harness the re-entry technology. Both were successfully achieved.

It is to be noted that the approximate time frame of maturing of Agni II also coincided with the Indian nuclear tests of 1998, supposedly making the nuclear boosted fission weapon available.[1,2] The re-entry vehicle (RV) of Agni II was designed to carry this warhead. As time would roll, another 7-10 years (say around 1995) and lighter nuclear warheads (thermonuclear weapon payloads) would be made available, Agni II would see another technological escalation ushering a new Agni RV Mk II. Since the warhead would be lighter, there would be a room to pack liquid fuel into the pressurised vessels of the RV, making it manoeuvrable (MaRV), thus ushering the cutting edge manoeuvrable re-entry vehicles. Such RVs could be programmed to be manoeuvred to their target.

MaRV was a major milestone achievement. The conventional RV is a passive ballistic load whose accuracy is dependent on the accuracy of its parent missile's insertion into the exo-atmospheric sub-orbital trajectory. MaRV on the other hand, can be manoeuvred to its intended target with its own propellant steam, thus improving its accuracy manifold, and also, making it unpredictable.

Effect of Technology Denial Regime

Getting back to 1998-99, a major setback happened. Soon after the nuclear tests of 1998, the Missile Technology Control Regime (MTCR), then alliance of Group of Seven (G7) nations established in 1987 (Canada, France, Germany, Italy, Japan, UK and USA, now 35 member strong), imposed a technology denial regime on India preventing it to import missile related technologies.[3] This actually proved to be a blessing in disguise since all systems and sub-systems were then to be home grown; an uphill task but a sure route to developing indigenous capability (read pride).

As the events unfolded within a year or so, India got engulfed in the Kargil War. Besides everything else that happened in the said war, an operational need was felt to have a warhead carrying capability that could cover a huge gap between Prithvi II (250 km) and Agni II (2500 Km) missiles both of which stood developed by then.

Such a capability in the form of a single stage, solid fuel, road and rail mobile SRBM was ready as early as 1989 itself. In fact, the first test firing of this missile in the TD mode was carried out in 1989 itself. The capability, pursuant to the felt need was operationalised post Kargil with its first launch taking place on 25 Jan 2002. Several successful launches have happened after this, including one on 06 Feb 2018 conducted by the Strategic Forces Command (SFC).

launch of Agni 1 missile 06 Feb 2018

Agni III Missile

The graduation from Agni II to III was firstly to conform to the fundamental requirement of range and reach increment as explained earlier, and secondly, to incorporate newer technological features as were available at that point in time. As to range, Agni III with a capability of 3500-5000 km actually ushered the nation into the select group of nations who possess an

Intermediate Range Ballistic Missile (IRBM) capability. Besides, it made us capable to strike much deeper across our northern borders.

In addition to the above, the miniaturisation of components and their smart placement allowed this missile to be more compact yet have a much larger range (Agni II - 21 m, Agni III - 17 m). Another milestone achieved by this missile was its accuracy. In that, it is no small credit to say that Agni III is the most accurate IRBM in its class in the whole world today having a Circular Error of Probability (CEP) of 40 m in range.[4] CEP is the measure of a weapon system's precision. It is defined as the radius of the circle, centred on the mean where 50 per cent of all the missiles fired are likely to land.

Agni III more compact, yet longer range than Agni II

Agni IV Missile

The escalation from Agni III to Agni IV was not range-driven but technology driven. In that, while Agni IV retained the range bracket of 3000-4000 km only, it included many a cutting edge features as the flight of missile technology had made available by that point in time. Most importantly, since the era of composite materials had kicked in by then, the same was adopted for missile construction bringing in a huge weight reduction. In that, while Agni III weighed 48000 kg, Agni IV weighed only 17000 kg.

In a bid to carry out continuous improvement in the RV technologies and moving ahead to include multiple independently targetable re-entry vehicles (MIRVs) as warheads, the missile featured the inclusion of a new heat shield (to ward off the temperature challenge at re-entry, as explained earlier). In addition, new and enabling technologies like the ring laser gyros for precise measurement of angular rotation of the missile, accelerometers for accurate measurements of vibrations in the rotating missile, micro navigation system based on accurate inertial navigation, high performance on board computers, distributed avionics architecture and more, made this missile really a cutting-edge system. Agni IV like its predecessors, was road mobile with a very low radar cross-section signatures (RCS) making it difficult for detection by adversary's sensor systems. A successful firing of this missile was conducted on 02 Jan 2017.

Agni IV - lighter sleek and technology driven

Agni V Missile

The nation knocked at the threshold of having the intercontinental ballistic missile (ICBM) when Agni V successfully soared the skies on 03 Jun 2018. The most notable feature in this missile is the fact that despite its huge range of 5500-8000 km, the missile is canister launched which means that it does not need any pre-built launch site but can be quickly launched from any pre-surveyed location. A huge plus on the survivability providing much higher operational flexibility keeping the No First Use in mind. Maraging steel has been used in the construction of this missile which provides superior strength, superior toughness without losing on malleability.

Of course the design of the canister is very critical as the same has to withstand huge stresses up to 200-300 tons besides keeping the missile hermetically sealed. Technically, this capability can also be further developed into an anti-satellite (ASAT) capability.[5]

India enters the ICBM club...

Conclusion

The country now looks forward to Agni VI ICBM which, as per open source, is under development. Thus goes the saga of Agni missiles where each successive stage is not just a number game in achieving higher range and reach, but is driven by operational need and technological advancements as these unfolded with the march of time.

Another aspect which also becomes clear is the fact that in ultimate analysis, our range and reach requirements are finite and driven by cold opertaional logic and security challenges. This will ensure that our number escalation in Agni (1, 2, 3...6) will also be finite. In fact each new version will be driven by specific operational need and security challenge that will present itself as we progress into the future. Such has been the precedent all along.

Endnotes

[1] https//www.drdo.gov.in>agni-ii-missile, Accessed on 15 Jul 18

[2] https//www.e..wikipedia.org>wiki>agni-ii. Accessed on 15 Jul 18

[3] https//www. yaleglobal.yale.edu>once-excluded-from-the-club-india-pursues-global-status-as-nuclear-power. Accessed on 15 Jul 18

[4] https//www.firstpost.com>india-test-fires-nuclear-capable-agni-iii-ballistic-missile, Accessed on 15 Jul 18

[5] https//www.en.m.wikipedia.org>agni-v> accessed on 15Jul 18

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Disclaimer: The author has had the opportunity to be associated first hand with the *Prithvi* and *Agni* programmes. The assessments made in this article are the personal views of the author. These have no official endorsement or authority.

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