Shourya/Sagarika Missile

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Introduction

Shourya[1] and Sagarika is a new common missile that can be launched from multiple platforms viz. ground, submarine and mobile launcher. Naval version is called Sagarika while the land based version is called Shourya. Indian doctrine of Minimum Credible Nuclear Deterrence envisages "No First Use" (NFU) policy and a triad of nuclear counterstrike capability. The land based Agni-2 missile range is limited to about 3,300 Km, and the longer range Agni-3 will enter service soon. The sea leg of the triad based on blue water naval assets dispersed across the world's oceans is most survivable thus a critical part of the triad. The ability to reach all corners of a potential challenger requires a range of 5,000 to 8,000 km. DRDO is developing sub surface launched long range Agni-3SL with heavy MIRV payload and ABM countermeasures. Indian nuclear powered ATV due for sea trial in 2009 will reportedly carry 12 launch tubes[2] of 2.4m diameter. Launch tubes can be flexibly configured to either carry a 2 meter diameter Agni-3SL or three wooden rounds[3] of 0.74m diameter K15-Sagarika missile. Shourya and Sagarika fills the short to medium range gap that is below Agni-III's minimum range. At operational level these missiles provide for range of warheads necessary for graduated nuclear escalation as enunciated by Indian staff and military warfare collages[4].

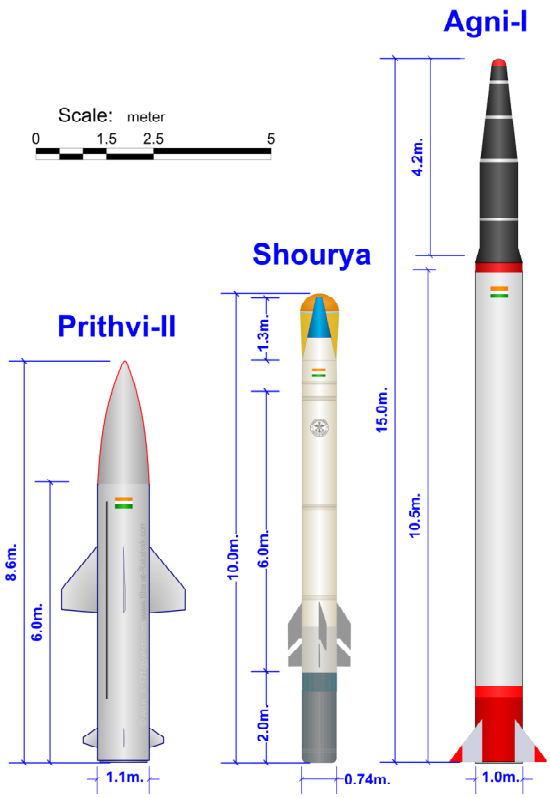

Figure 1: Shourya and its relative size

This multifunction missile made in large quantities would fulfill India's immediate requirements. The missile optimally matches latest types of strategic weapons tested at Pokhran-II in 1998. The missile will most likely take over the strategic weapons role of Prithvi and Agni-1 missiles, and make them unambiguously dedicated for conventional roles thus stabilizing nuclear deterrence. Shourya and its counterpart Sagarika has been tested 6 times[5] till date. The missile is expected to enter service in 2010. Sagarika will be deployed on submarines and very likely on '*Sukanya*' class naval vessels too.

Figure 2: Wooden round. Dense smoke from launch gas generator reduces Shourya's launch signature [Photo courtesy: DRDO via Shiv Aroor]

Description

Shourya is a compact, slender, two-stage, solid fuel missile designed as a wooden round. The missile development was initiated as project K15 and was first flight tested[6] on 27 October 2004 in the guise of solid fueled Prithvi-III[7]. It is stored, deployed and launched in a fiberglass composite canister, which is easy to handle, mobile and can be flexibly deployed on different types of surface and sub-surface platforms. Shourya and Sagarika share a common design. The missile is sealed and can be launched from a moving submarine at 50 meter depth. The 6.2 tonne Shourya is 10 meters long, and has two solid fuel stages of 0.74 meters diameter. The first stage booster is about two meters long and the second about six meters long.

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The missile supports a range of unitary warhead configurations, weighing 180 to 1,000 kg. High missile accuracy and ability to fly in a highly depressed trajectory well within atmosphere indicates it is a weapon of choice to interdict Command & Control (C&C) and preemptive tactics.

The sixth test flight on November 12th, 2008 was a depressed trajectory flight (at Mach 6 and 50km altitude) with continuous rolling to dissipate heat over a larger surface demonstrated mastery of difficult aspects of rocketry involving sustained hypersonic flight.

The wooden round design sealed in a fiber glass canister with the aero fins folded inside in a clean & controlled environment makes it maintenance free and tamper proof. The missile is launched by a hot gas generator developing 15-200 bar pressure using high burn rate HTBP based composite propellant. The thick dark gas cloud greatly reduces the thermal signature of the missile.

Figure 3: Shourya on Mobile launcher. [Photo: DRDO]

Figure 4: Inside view of the ATV missile launch tube that hosts 3 Sagarika missile canisters. [Photo: DRDO]

Once out of the launch tube the first stage booster motor ignites taking the missile to 5Km altitude when the main second stage motor takes over. The booster debris reaches a maximum altitude of 6 km, well below the horizon of radars beyond 330 km. The clean and small diameter missile presents a tiny RCS (radar cross-section). The second stage air fins provide necessary in-flight trajectory control. The main motor is typically expended at 33 km altitude well within the atmosphere; however the air fins remain effective beyond post boost phase. The air fins also allow the missile to fly in a depressed trajectory as well as cruise and glide in sustained hypersonic regime at 50 km altitude. The payload separation can be done much later after exploiting aerodynamics for trajectory modification during ascent or descent. The missile is resistant to ABM defense[8].

Re-entry Vehicle

Shourya Re-entry Vehicle (RV) supports wide range of weapons, with total payload mass ranging from 180 to 1,000 Kg. The missile range is a function of payload mass (see graph in Figure 7 below).

The November 2008 test unveiled the new generation RV that is designed and optimized for newer boosted fission and thermonuclear weapon (including those awaiting confirmatory test). The sharp nose high 'βeta' (Ballistic coefficient[9]) RV design employs 16 cm diameter blunt nose and half angle of 12° that is mounted on a payload adapter to interface with the 0.74m diameter mission control module atop the upper stage. The high 'βeta' RV in combination with an all carbon composite body enables higher re-entry speed even with a light weight payload[10].

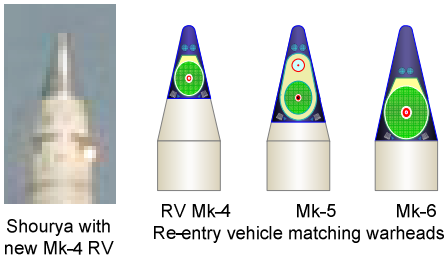

Figure 5: Re-entry vehicle options.

- Mk-4: For light weight 17Kt Fusion Boosted Fission (FBF) warhead[11]. Mass[12]: ~180 Kg[13].
- Mk-5: For 50Kt FBF or 200Kt Thermo Nuclear (TN) warhead[14]. Mass: ~340 Kg
- Mk-6: For 150Kt FBF warhead[15]. Mass: ~550 Kg.

Table 1: Comparative destruction area

Warhead Yield	*Destruction w.r.t 17Kt*
50 Kt	2.0
150 Kt	4.2
200 Kt	4.9

The all carbon composite re-entry heat shield with multi-directional ablative carbon-carbon re-entry nose tip make it very light and tough[16]. This very light RV mass enables scalable payload and range tradeoff especially for lightweight warhead.

Propulsion

The Shourya has two solid fueled stages of 0.74m diameter. This diameter is compatible with a recently tested Indian sub-surface launch system that has a 2.4 meter diameter launch tube[17].

First Stage: The first stage solid fuel booster is approximately 2 meter long and weighs about 1,300 kg including 1,000 Kg high density fuel. The booster lifts the missile to an altitude of 5 km so that the second stage can operate more efficiently at low atmospheric pressure. It uses hot gas reaction control for initial control of yaw, pitch and roll before the air fins unfold and missile gains sufficient velocity for aerodynamic control surfaces.

Figure 6: Second stage motor [Photo: DRDO]

Second Stage: This 6 meter long stage weighs about 3.6 tonne and generates 16 tonne thrust. Case-bonded HTPB-based composite propellant with low burn rate is ignited by a small pyrogen ignition motor. The case is made of 250 grade maraging steel to maximize fuel mass fraction that is critical for scalable payload versus range flexibility. Its nozzle is made of composite material with metallic backup and carbon phenolic liners. The interstage coupling uses a soft-stage separation mechanism and retro rockets for reliable and safe stage separation.

	Stage-1	Stage-2	RV
Gross Mass [18] Fuel Mass[19] Empty Mass Stage Fuel-Mass-Ratio	1,300 kg 1,010kg 290 kg 0.78	3,600 kg 2,950 kg 650kg 0.82	70 kg - - -
Thrust @ Vacuum [20] Thrust @ Sea Level (Burn Time)	26,000 Kgf 23,000 Kgf (10 seconds)	21,000 Kgf - (~40 seconds)	Not Applicable
Specific-Impulse ISP @ Vacuum[21] ISP @ Sea Level	265 seconds 230 seconds	275 seconds 250 seconds	Not Applicable
Length [22] Diameter	2.0 meters 0.74 meters	6.0 meters 0.74 meters	1.1 meters 0.74 meters
Propellant Chemical Case Material	Solid HTPB/AP/Al Maraging	Solid HTPB/AP/Al Maraging	Not Applicable Not Applicable Carbon Composite

Note: Some parameters are estimated based on available news reports, trade practice and known Indian capability.

Navigation & Accuracy

Shourya largely carries the proven avionics set of Agni-III however for more extensive aerodynamic maneuvering, it is augmented by new sensors and flight control system. Shourya will also benefit form Indian Regional Navigation Satellite System (IRNSS)[23] expected to be ready by 2012, to ensure guaranteed national access to precision navigation. These systems enable high accuracy required for precision strike.

Range versus Payload

Missile range & payload mass are inversely related. It is interesting to note that press reports Shourya's range for 1,000 kg and 500 kg payload. The former corresponding to 1980 vintage 200Kt FBF warhead and the latter corresponding to 150Kt FBF that is yet to be field validated. The official reporting obfuscates missile's much higher range corresponding to field tested 17Kt FBF warhead that is mainstay of Indian deterrence.

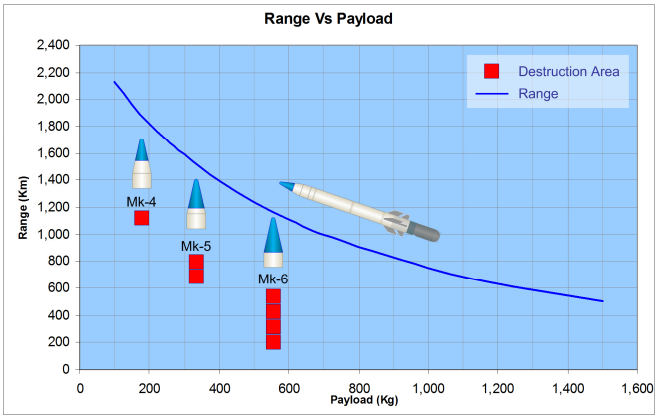

Figure 7: Range versus RV payload

Conclusion

Shourya class of missile is truly a multi-services missile that has desirable attributes of small size, mobility, stealth, rich set of warhead options, robustness and cost that could make it the most mass produced Indian missile. It complements the long range Agni class missiles to provide Indian military commanders global range necessary to secure Indian interests.

About the author:

Arun S Vishwakarma graduated with distinction from Madan Mohan Malviya Engineering College, Gorakhpur, UP and earned his M.Tech from IIT-Delhi. He is an aero-space and geo-politics analyst, as well as webmaster of space & missiles sections of www.Bharat-Rakshak.com. He has travelled extensively and lived in India, Singapore and USA. He can be reached at Arun.s1971@gmail.com.

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11. http://www.nbr.org/publications/analysis/pdf/vol13no3.pdf VOLUME 13, NUMBER 3, JUNE 2002. "Ballistic Missiles and Missile Defense in Asia"
12. Nuclear Weapon Archive, 'India's Nuclear Weapons Program: Present Capabilities' http://nuclearweaponarchive.org/India/IndiaArsenal.html

[1] Shourya is a Sanskrit word for Valor, and Sagarika is a Sanskrit word for "Oceanic".

[2] 'The secret undersea weapon', India Today, 01/17/ 2008,

http://indiatoday.digitaltoday.in/index.php?option=com_content&task=view&id=3659&Itemid=1&issueid=37&page=in&latn=2&limit=1&limitstart=1

[3] A "wooden round" missile is delivered to ships and submarines as an all-up-round (AUR), which includes the missile that flies the mission, the booster that starts its flight, and the container (canister for ships and capsule for submarines) that protects it during transportation, storage and stowage, and acts as a launch tube. Such ammunition has almost 100% reliability, very long shelf life, and requires no special storage, maintenance, or handling.

[4] War clouds, nuclear overhang, The Pioneer, December 27, 2008. Op-Ed by Brig.(rtd)Gurmeet Kanwal, Centre for Land Warfare Studies, , "The nuclear tipping point in a conventional conflict is a matter of fine military judgment. A rational Pakistani approach would be to opt for a graduated response in case push comes to shove. Lt Gen Sardar F S Lodhi (Retd) has written about a demonstration warning shot followed by a low-yield nuclear explosion over Indian forces advancing inside Pakistani territory. If that fails to stop Indian offensive operations, Pakistan may choose to target a small border town in India. In the end India's conventional superiority would prevail and a future conflict in the plains may be expected to end on terms favorable to India".

[5] 'Sagarika' missile test-fired successfully', The Hindu 27/02/2008 http://www.thehindu.com/2008/02/27/stories/2008022756120100.htm

[6] Prithvi-III test-fired for first time: T.S. Subramanian, The Hindu, 28 October 2004, (http://www.hindu.com/2004/10/28/stories/2004102807641300.htm).

[7] The author was the first to suggest Prithvi-III configuration as a 2 stage missile with 0.75meter diameter and 1000 km range, in the missile article hosted at http://www.bharat-rakshak.com/MISSILES/Prithvi.html

[8] "Shourya missile cannot be easily detected" The Hindu, 14/11/2008 http://www.hindu.com/2008/11/14/stories/2008111462151500.htm

[3] The ballistic coefficient β ('*Beta*') is a measurement of an object's ability to move through a fluid. It takes into account the effects of an object's density and its skin friction, and is expressed as: βeta = **m** * C_D / **A** where **m**: mass, C_D: coefficient of drag, **A**: area.

[4] This was an issue with the earlier RV Mk-2 design. The older Mk-2 with its blunt nose is an all range RV, however for lighter payload its β is relatively low, thus slowing down the RV at the tail end of its trajectory.

[11] The FBF primary stage of the 1998 Shakti-1 test.

[12] Total mass including mass of RV.

[13] DRDO scientists appreciated for successful launch of Agni-3, Indian Express, Friday April 13 2007 "Union Minister of State for Defence MM Pallam Raju has said "the strategic payload of the missile is between 100 kg to 250 kg, and it is a two-stage solid fuel combustion system type missile."http://www.newindpress.com/news.asp?ID=IEA20070413023541

[14] The 1998 Shakti series of nuclear test in 1998 at Pokhran unambiguously demonstrated Indian mastery of Fusion Boosted Fission weapons. The Thermonuclear experiment (Shakti-I) based credible warhead requires confirmatory/proof test or credible Laser Ignition Facilities. While awaiting proof test Indian posture will likely field the TN warhead in compliment with missiles with FBF warheads.

[15] Ibid

[16] Ibid

[17] Launching platforms for Project K-15. http://www.drdo.com/pub/techfocus/aug04/missile13.htm

[18] Trade estimate

[19] Ibid

[20] Estimated by using Ballistic Rocket Simulator (ROCKSIM)

[21] Trade estimate

[22] Geometric resolution from photo evidence

[23] Indian Regional Navigation Satellite System approved, 9/5/2006 http://www.india-defence.com/reports/1894

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