BRAHMASTRA OF FUTURE WARS
"THE BRAHMOS"

R.S. NAGRA

The director of the movie "Titanic," James Cameron, would have been the happiest person after seeing the video clip of a derelict naval ship going down the deeps of the Arabian Sea, destroyed by a powerful BrahMos supersonic cruise missile fired from the deck of an Indian naval ship *Rajput* on January 15, 2005, as its drowning replicated perfectly the computer simulated sinking of the legendry ship *Titanic* in the cold waters of the Atlantic Ocean. It was the tenth successful hit by a BrahMos missile, scoring a perfect 100 per cent in its nascent development stage of merely four years. Ten successful launches of BrahMos missiles have catapulted India into the orbit of nations having cruise missile technology, and perhaps the only nation having supersonic cruise missile technology besides its joint venture partner, Russia. It also heralded the formal induction of BrahMos missiles into the Indian Navy.

The genesis of cruise missile technology can be traced back to the evolution of rocketry. Though many nations claim to have fired rockets or rocket-like weapons first in the history of warfare, India can claim to be the pioneer in the evolution of modern rocket systems wherein Haider Ali formed a rocketeer contingent of 1,200 men in 1788 and Tipu Sultan later built on this asset. Remarkably, two of the rockets fired by Indian troops under the leadership of Tipu Sultan in the Battle of Seringapatnam (1792), are on display at the Royal Artillery Museum in London. By 1804, Colonel (Later Sir) William Congreve had begun studying and refining captured Indian rockets at the Royal Laboratory,

Lt Gen **R.S. Nagra**, PVSM, VSM** (Retd.), DG and MD, BrahMos Aerospace Pvt. Ltd.

Woolwich Arsenal in Kent. A variety of rockets, which later came to be known as Congreve rockets after their designer, were introduced, paving the way for modern rocket systems.

With such a background it was inevitable that our country after Independence revived the traditional rocketery prowess. The mission was accomplished by our great scientists, Vikram Sarabhai, Prof. Dhawan, Dr. A.P.J. Abdul Kalam (now president of India) and their successors when they hurled spaceships, SLV3 (July 1980), ASLV (March 24, 1987), PSLV (October 22, 2001) and GSLV (September 20, 2004) into orbit. Along with space rockets, spinoff technologies assisted in the development of the ballistic missiles Prithvi and Agni; area air defence systems Akash and Trishul; and third generation anti-tank missile Nag. After space ships and missiles of varied configurations, what next was the dilemma facing the Indian scientists ?

The growth of ballistic missiles has received considerable attention in recent years. Less noticeable has been the spread of increasingly lethal and cost-effective cruise missiles, and equally less attention has been paid to the defence against these missiles.

Prior to and during World War II, German interest in the development of guided weapon (GW) systems has been well documented. Their interest in GW was not only confined to V rocket systems; research into small wire and radio guided missiles was also undertaken. The Germans launched XH-7 anti-tank missiles from the air just before the end of World War II and also fielded air-launched radio-guided HS 294 anti-ship missiles, which were used in attacks on Allied shipping. At the end of the War, much of the German technology was studied by the victorious Allies, most notably the USA and Soviet Union, and incorporated into their national missile development programmes. It was recognised that the GW exhibited three key attributes; precision, lethality and standoff, which made them effective weapon systems in most applications. This triad of characteristics also proved cost-effective, leading to the GW revolution.

The growth of ballistic missiles has received considerable attention in recent years. Less noticeable has been the spread of increasingly lethal and cost-effective cruise missiles, and equally less attention has been paid to the defence against these missiles. It was evident during the Iraq War in 2003 that while the United States has made rapid strides in protecting its forces against ballistic missiles, it has yet to address the threat posed by cruise missiles. In the Iraq War 2003, Patriot batteries intercepted and destroyed all nine of the ballistic missiles launched by Iraq, whereas they failed to detect or intercept any of the five HY-2 Seersucker cruise missiles launched against Kuwait.

In the Iraq War 2003, Patriot batteries intercepted and destroyed all nine of the ballistic missiles launched by Iraq, whereas they failed to detect or intercept any of the five HY-2 Seersucker cruise missiles launched against Kuwait.

Cruise missiles have a number of desirable characteristics which make them attractive arsenals for nations to acquire, viz,

- Radar absorbent material (RAM) allows developers to reduce visual, infra-red, and radar signatures of these missiles and, thus, makes them stealthier.
- Their small size enables them to hide easily and provides them better mobility compared to ballistic missiles.
- They can be deployed at a substantially lower cost.
- They have greater accuracy than ballistic missiles. This is achieved by hi-tech seekers based on inertial navigation systems with universal compatibility, radar scan, infra-red scan, DSMAC / TERCOM and multi-spectral seeking capability. High resolution imaging and geo-spatial information allows development of highly accurate and three-dimensional maps for targeting and mission planning.
- They are better at avoiding the enemy's air defence due to their unpredictable trajectory; and have reduced radar cross-section. Cruise missiles can also fly close to the terrain, thus, are capable of avoiding detection by air defence radars due to ground clutter. Moreover, their exhaust plumes are not generally

detected by launch warning systems. In comparison, at least to a limited extent, defences against ballistic missiles are available. Examples are the US improved Patriot designs and the Russian S-300 dual mode (air and missile) defensive systems. In case the of cruise missiles, no such defence has been contrived as yet, as already mentioned earlier, although development plans are already on board.

The best defence for a developing country, incapable of head-to-head confrontation with a strong adversary's air force and his ballistic missile defence, will be to resort to the use of low cost cruise missiles.

- Cruise missiles are placed in canisters, which makes them easy to maintain and operate in a harsh environment. Their relative compact size offers more flexible launch options, more mobility for ground-launched versions, and a smaller logistic burden, which reduces their battlefield vulnerability to detection—and, thus, improves their pre-launch survivability.
- Cruise missiles can be launched from multiple platforms, with multiple trajectories and on multi-targets.
- Cruise missiles are better suited to deliver chemical and biological weapons than ballistic missiles. A cruise missile's steady horizontal flight path allows it to release chemical or biological agents at right angles to the wind direction and upwind of target area, greatly increasing its efficiency. Disseminating either chemical or biological agents from a rapidly descending ballistic missile is both less efficient and technologically more challenging.
- Unlike the huge training, operation and maintenance costs associated with acquiring or developing air, ground or naval manned systems, cruise missiles, can be operated at considerably lower costs. With Rs 250 crore in our kitty, we can buy 100 plus cruise missiles (of the low-tech variety), whereas with the same amount of money we can merely buy 15 tactical ballistic missiles or 10 utility helicopters or 4 attack helicopters or 1-2 fixed wing fighters.
- In contemporary warfare cruise missile can be considered a poor man's air force, alongwith unmanned aerial vehicles (UAVs). The best defence for a developing country, incapable of head-to-head confrontation with a strong

adversary's air force and his ballistic missile defence, will be to resort to the use of low cost cruise missiles. A dozen cruise missiles equipped with sub-munition warheads can severely damage or destroy almost an entire fighter wing parked in the open or tank/ gun concentration in some hide or assembly area. Anti-ship cruise missiles similarly threaten the adversary's ships passing through chokepoints and littoral waters.

There are 76 nations which have between them approximately 130 or so cruise missiles of varied types which can be divided into two major categories: anti-ship cruise missiles (ASCMs) and land attack cruise missiles (LACMs). Around 19 countries produce cruise missiles and out of them about 12 produce LACMs. Over 70 countries have deployed approximately 80,000 cruise missiles of varied types, which can be classified as ;

There are 76 nations which have between them approximately 130 or so cruise missiles of varied types which can be divided into two major categories: anti-ship cruise missiles (ASCMs) and land attack cruise missiles (LACMs).

(a) Subsonic:

- Air breathing and multiple missions (e.g. Tomahawk).
- Sea-skimming and anti-ship (e.g. Harpoon, Exocet, Uran).
- Most of the flight subsonic with supersonic attack (e.g. Club).

(b) Supersonic:

- All through supersonic, (e.g. BrahMos and Moskit).

During the Gulf War of 1991 and Iraq War of 2003, cruise missiles were deployed on the first day of the war itself from multiple platforms, inflicting massive destruction on strategic targets and installations. During Operation Iraqi Freedom (OIF), on March 19, 2003, a barrage of 40 Tomahawk cruise missiles was launched at regime targets in and around Baghdad. During the first twelve days of the war, about 700 Tomahawk cruise missiles were fired, representing 25 per cent of all the Tomahawk cruise missiles in the arsenal of the US forces.

According to US defence officials, fewer than 10 of these missiles failed to strike their intended targets. What emerged during these wars was that :

(a) with precise and coordinated attacks of cruise missiles on critical enemy installations, enemy forces can be crippled, leaving no scope for a counter-offensive, thereby, ensuring minimal losses to own forces; and

(b) cruise missiles came to be regarded as the 'first strike weapons' that play a decisive role in the war.

What prompted our scientists to decide about the type of cruise missile and technology for its development—whether it should be subsonic or supersonic; whether we should achieve propulsion in flight by the use of ramjet, scramjet or turbojet; whether we should use liquid hydrogen, liquid oxygen or kerosene as fuel; whether we should adopt a graduated development strategy i.e. subsonic cruise missile first and then supersonic cruise missile? The answers to all these questions were evolved after deliberate research, and decisions were based on pragmatic analysis.

It is seen that the supersonic cruise missiles have a competitive edge over subsonic cruise missiles which is clearly evident from the table shown below. Supersonic cruise missiles have long flight range with shorter flight time, minimum reaction time and higher destruction capability.

Table 1. Comparison - Supersonic Vs Subsonic Cruise Missile

Parameters	**Subsonic**	**Supersonic (e.g. BrahMos)**
Speed	0.8 Mach	2.8 Mach
Time to Hit	1 Unit	1/3 rd
Target Dispersion	1 Unit	1/3rd
Reaction Time	1 Unit	1/3rd

In order to cut down time over-run and, thus, development costs, the search for a partner country for co-development started. As a result of thorough deliberations, India decided to pursue a supersonic cruise missile development programme in cooperation with Russia, with special emphasis on the adoption of higher technologies like inertial guidance system (INS), liquid ramjet engine, onboard computer and special algorithms, active multi-modal seekers, universal launch system for multiple platforms and advanced fire control systems.

To achieve the desired objective, a joint venture company BrahMos Aerospace Private Limited, was established in 1998 by signing an inter-governmental agreement between the Russian Federation and the Republic of India. The tripartite agreement was signed by Dr. A.P.J. Abdul Kalam, the then director general (DG) of the Defence Research and Development Organisation (DRDO), Dr. Herbert Yefremov, DG of NPOM and Dr.A Sivathanu Pillai, DRDO's chief controller as chief executive officer and managing director of the joint venture.

The BrahMos missile has a flight range of upto 290km with supersonic speed all through the flight, leading to shorter flight time, consequently ensuring lower dispersion at target, quicker engagement time and non-interception by any known weapon system in the world.

The BrahMos is a two-stage missile with solid propelled booster engine as its first stage which brings it to supersonic speed and then gets separated. The liquid ramjet of the second stage then takes the missile closer to Mach 3 speed in the cruise phase. Stealth technology and guidance system with advanced embedded software provide the missile with special features. The BrahMos missile has a flight range of up to 290 km with supersonic speed all through the flight, leading to shorter flight time, consequently ensuring lower dispersion at target, quicker engagement time and non-interception by any known weapon system in the world. It operates on the 'fire and forget principle,' adopting varieties of flights on its way to the target. Its destructive power is enhanced due to large kinetic energy on impact. Its cruising altitude could be up to 15 km and terminal altitude is as low as 10 metres. It carries a conventional warhead weighing 200 to 300 kg. The missile is launched from a canister, which also acts as a storage-cum-transportation container. Due to its low drag and low radar cross-section, it is difficult to detect the missile during flight.

The missile has identical configuration for land, sea and sub-sea platforms.

Land and sea versions of the BrahMos have already been developed with the sea version of the missile already inducted in the Indian Navy, starting with their installation on the Rajput class of frigates and with plans to fit them on other types of warships. The land version is likely to be inducted shortly in the Indian Army.

Land and sea versions of the BrahMos have already been developed with the sea version of the missile already inducted in the Indian Navy, starting with their installation on Rajput class of frigates.

BrahMos Aerospace is now all set to make the air version with developmental efforts directed towards producing a combination of the BrahMos and Sukhoi-30. The initial plan is to fit one missile under the Sukhoi's belly and if the wings can be strengthened, two more missiles can be fitted on the flanks. The air variant is likely to be lighter as the designers plan to reduce the size of the booster and replace the nose thrusters with a small configuration at the tip of the nose. The seeker will be the same as that fitted on the land version.

Imaginative employment of the weapon system will pay rich dividends in war. Its surgical strike capability with a conventional warhead makes it a weapon of choice for delivering a stunning blow to the adversary’s war-making and war-fighting potential. The types of targets that can be engaged with the missile are individual ships, groups of ships, off-shore platforms and land-based targets like ammunition dumps, ammunition factories, oil refineries, oil depots, command and control centres, communication centres, atomic reactors, thermal power plants, operation rooms, bridges, airports, and so on; in short, wherever we need ‘precision attack’ and least collateral damage, use this missile system. A preemptive strike by a group of missiles launched from multiple platforms in a theatre of operation for destruction of critical strategic/tactical targets will prepare

Surgical strike capability with a conventional warhead makes it a weapon of choice for delivering a stunning blow to the adversary's war-making and war-fighting potential.

the battlefield for surgical, shallow/deep strikes by own strike formations and air force. Perhaps, it may prove to be the most effective option for preemptive strikes on the adversary's air defence systems, to pave the way for our air force to strike deep into the enemy's territory with minimal interference from his ground / air-based air defence systems. During such operations, the BrahMos, mounted on varied types of platforms, can supplement air operations.

Command and control of the weapon system will depend on the type of conventional warhead that we intend using, the type of target that is to be destroyed, and the stage of the war that is being waged.

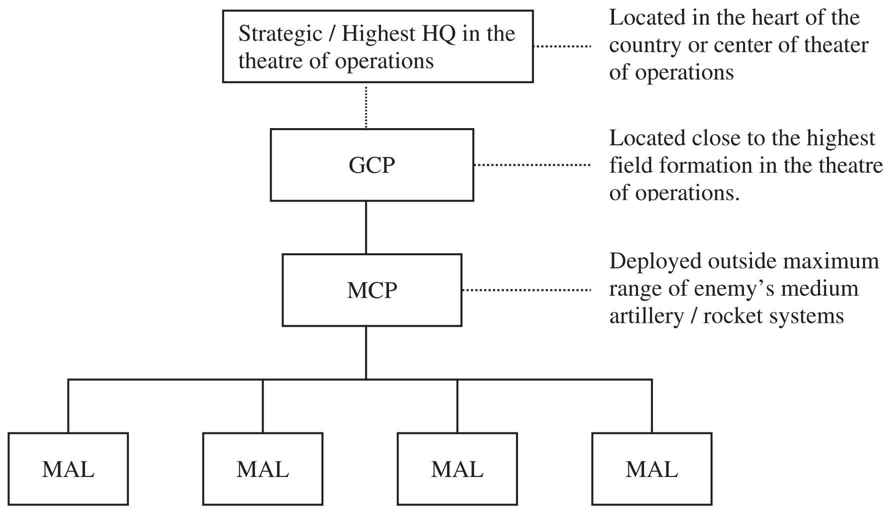
Command and control of the weapon system will depend on the type of conventional warhead that we intend using, the type of target that is to be destroyed, and the stage of the war that is being waged. Destruction of strategic targets will be controlled at the highest level, and for tactical targets, the control will be delegated to lower formations, depending on the stage of the war. A suggested hierarchical structure for the command and control of a typical land-based battery with four launchers, called mobile autonomous launcher (MAL), controlled by one mobile command post (MCP), which in turn is fed target data by group command post (GCP), is shown in Fig. 1.

ROAD AHEAD

The cruise missile technology is likely to spread rapidly. India has achieved a unique position in supersonic cruise missile technology and every effort should be made to retain this hard earned advantage. This will also require reorientation of our road map regarding further development of ballistic missiles, especially the Agni series of missiles, keeping in view the latest trend in missile technology development in the

The cruise missile technology is likely to spread rapidly. India has achieved a unique position in supersonic cruise missile technology and every effort should be made to retain this hard earned advantage.

Fig 1



world wherein ballistic missiles appear to have lost their importance due to the competitive edge of cruise missiles and the vulnerability of ballistic missiles to fast developing ballistic missile defences.

Advanced cruise missiles designed with stealth capabilities to evade detection need effective cruise missile defence, well coordinated with other air defence efforts. Ballistic missile defence and cruise missile defence should be mutually supportive with inter-Service synergy to make them cost-effective Cruise missile defence will require rapid and accurate performance by various hi-tech devices, such as surveillance radars to detect aerial intruders (manned and unmanned aircraft, including cruise missiles); surveillance systems for continuous tracking of the intruder along its flight path; identification systems to determine whether the intruder is a cruise missile, or a friendly or neutral aircraft; network-centric battle management system to decide how to engage the intruder and which defence asset—naval, ground or airborne platform—is to be used. For interception and neutralisation of the cruise missile, missiles and guns are presently available and other technologies such as directed energy weapons, need to be studied.

Cruise missile defence is simple in concept but difficult and costly in execution. With so many impediments in designing a foolproof defence against cruise missiles, there is another school of thought, according to which it will be preferable to destroy them on the ground before they are launched. In this context, it may be mentioned that it is easier to attack mobile targets as experienced in OIF compared to 'scud hunting' conducted during the Persian Gulf War. However, destroying mobile ground launched cruise missiles and other 'time-critical - targets' remains a major challenge and requires to be handled on priority.

Cruise missile defence will also require improvement in our military capabilities, primarily:

(a) Detection of threat through better sensors, especially airborne sensors.
(b) Better integration of air and missile defence systems and improvement of existing air defence radars, battle management cyber network and communication links.
(c) Improved combat identification systems.
(d) Extensive and imaginative use of aerostats and UAVs / UCAVs.
(e) High bandwith communication and 'network-centric' targeting to improve counter-force targeting capabilities.
(f) Inexpensive but proven 'jamming technology' (e.g. high power microwaves) that can disrupt cruise missile guidance systems.
(g) Efficient point air defence weapon systems with radar-guided missiles and guns to destroy less sophisticated cruise missiles. To be reinforced later with directed energy weapons.

The BrahMos is totally designed to carry only conventional weapons, keeping in view the national policy on this issue. However, its precision kinetic energy on impact and lethality of high explosive, without the danger of collateral damage, will prove cost-effective in the theatre of operations. In order to further improve the terminal effect of the BrahMos, it will be prudent to have varieties of conventional warheads with greater damage potential, e.g. warheads with terminally guided submunition.

India must retain its advantage in supersonic cruise missile technology besides concurrently improving military capabilities and participate in proactive counter-proliferation and strengthened non-proliferation efforts along with other nations that are likely to be threatened by rogue states and terrorist organisations. Due to recent developments in missile technology, our existing roadmap for design and development of ballistic and cruise missiles needs to be updated at priority.

The genesis of modern rocketry can be traced back to the days of Haider Ali and Tipu Sultan; and rightly, our scientists, perhaps by genetics or inclination, undertook the task of developing spacecraft, ballistic missiles and cruise missiles after Independence. Their hard work and perseverance has today propelled our nation into the orbit where we, alongwith the Russians, are the only two nations having expertise in producing supersonic cruise missiles, a technology likely to be acquired by the developed countries in the world in the not too distant future and, therefore, it is imperative that our scientists continue to upgrade this technology and maintain the competitive edge.

Cruise missiles, due to their triad of superb characteristics of lethality, accuracy and range can be regarded as *brahmastras* of the future battlefield and, therefore, their employment philosophy needs to be deliberated upon seriously. However, their proliferation due to the low cost war-waging option for a developing country, not forgetting terrorist organisations, is a matter of great concern and must be tackled by the comity of nations by strict implementation of control regimes, and evolution of counter-measures—a topic requiring separate treatment.

SUMMARY

This article traces the genesis of cruise missile technology in India, discovering the roots of modern rocket systems from the rocket arsenals of Hyder Ali and Tipu Sultan in the 18th century and how our scientists decided to embark on designing, development and production of spacecraft and ballistic missiles; leading onto the weapon of the future, the “BrahMos.” In brief, the author has outlined the evolution of the BrahMos supersonic cruise missile in a joint venture with the Russian scientists, its employment philosophy, a typical command and control set-up, and has suggested some actions for the future in order to maintain the existing supremacy in supersonic cruise missile technology and defence against such missiles.