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that while overall the cruise is a sober success, discourse of the weapon has got relatively less attention in strategic studies. He believes that this has been more due to the ballistic missile being associated with nuclear weapons. But though the missile discourse is much older than the nuclear discourse, one needs to resort to a comparative study on the psycho-dynamic aspects of weapon systems. In pursuit of this, at the basic, one needs to identify the nuances in the politics and psyche involving 'atom-power' while comparing them with the nuances involving the lesser known, lesser publicised concept of 'air-power' and aerodynamism.

8. **TRANSFORMATION IN MILITARY LOGISTICS** 141

Advances in technology were bound to affect major transformation in all aspects of military sectors and, hence, transformation in military logistics is no exception. Group Captain **J. V. Singh** argues that there is a need for a revolutionary change in the way we support the armed forces. This revolution is about more than providing equipment and supplies better, cheaper and faster although these initiatives are crucial for readiness and modernisation today. It is also about rethinking logistics functions and processes that will enable decisive victories well into the future. This revolution spans the depth and breadth of military logistics. It includes integrating logistics functions, replacing volume with velocity, reducing demand and lightening the logistics load on the ultimate customer— the soldier.

EDITOR'S NOTE

Change is the only constant factor in human history. But aerospace power has been in the throes of change at a phenomenal pace. Much of this is due to two factors: that of an exponential advancement of technology, and second, the changes taking place in the nature of warfare. This has also created new paradoxes in the sense that while military power has become much more effective on the strength of its aerospace capabilities, it has also become less usable in traditional roles and missions. Israel, for example, began to base its counter-terrorism strategy almost exclusively on air power, while the US/ North Atlantic Treaty Organisation (NATO) relied very heavily on aerospace power in their wars since the end of the Cold War.

But before we start to draw analogies and lessons from their experiences we must note that they have been fighting these wars in foreign territories and without a hostile air environment. This is not to say that they would not have won the wars if there was hostile air power to face, but to emphasises that these two conditions for us simply would not exist as long as the armed forces are operating for homeland defence, whether in traditional wars or in counter-terrorism. And to go beyond this paradigm would require quite different politico-military dynamics and strategies than we have been used to in the past if for no reason than the existence of weapons of mass destruction (WMD). Application of aerospace power, therefore, in our environment would have significantly different dimensions where three parallel armed conflicts would have to be taken into serious consideration and each and all of them would be contested.

It is in this context that we need to emphasise that while transformation in technological and operational domains would remain crucial, the transformation of the mind would assume far greater importance if the first two have to serve their intended purposes. This transformation has to be based on rational, objective, pragmatic and accurate assessments of the threats and capabilities and the best ways of force employment, with the full knowledge that there would not only be an adversary that seeks similar capabilities, but that it would seek ways and means of its own transformation, knowledge of which would remain ambiguous at best. Success in armed conflict would depend heavily on aerospace power in the future; and this success would be conditioned by the ability to conceptualise the options and strategies of force employment that allow for flexibility to deal with fast changing situations.

NATIONAL DEFENCE AND AEROSPACE POWER

FALI HOMI MAJOR

INTRODUCTION

Marshal of the Air Force Arjan Singh, General Shankar Roychowdhury, Lieutenant Gen Nambiar, Air Commodore Jasjit Singh, eminent scholars, guests, colleagues, ladies and gentlemen. It is indeed an honour to be amidst such a learned audience, to present some of my views, at the inauguration of the 5th Subroto Mukherjee Seminar on "**National Defence and Aerospace Power"**.

Air Marshal Subroto Mukherjee, besides being the first Indian commander-in-chief and Chief of the Air Staff of the Indian Air Force, was a man with immense foresight and vision. His experiences during World War II, and during the early years of the Royal Indian Air Force (RIAF), had given him privileged insights into long-term planning and strategic decision-making. Not only did he lay down firm foundations for a balanced force, he also encouraged the development of strategic thought and future doctrines. I think that he was very conscious of the role that the Indian Air Force (IAF) would play in the future of independent India.

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* Air Chief Marshal **Fali Homi Major** PVSM, AVSM, SC, VM ADC, Chief of the Air Staff, IAF. This is his Inaugural Address at the "5th Subroto Mukherjee Seminar on Aerospace Power at the Centre for Air Power Studies, New Delhi, on December 3, 2008.

NATIONAL DEFENCE

National defence is an all encompassing concept. It lies in the fundamental character of the nation-state itself. Today, we live in a world where traditional concepts and beliefs are under threat of being turned on their head, giving way to radical and new arrangements. The concept of Westphalian national sovereignty itself stands under threat of becoming irrelevant, with the emergence of conglomerations like the European Union and other such alliances. Mutually symbiotic relationships, pragmatism and convenience dictate the form of the new world order. In such an uncertain environment, it would be worthwhile to critically examine our specific context and unique requirements. An analysis and understanding of these imperatives is essential, before we determine the role that aerospace power will play in national defence.

INDIAN IMPERATIVES

Our traditional environment has remained largely unaltered over the past decades. It is also very different from the environments of other countries; say, for example, New Zealand or Luxemburg. For us, the protection of territory and its geographical borders, you will agree, will continue to retain primacy. The present resurgence, economic prowess and increasing zone of influence has made us revisit our appreciation of national defence. It will obviously have to include the protection of our exclusive economic zones, our lines of communication and our assets, which may be located beyond our geographical boundaries.

I also place before you the proposition that the ambit of national defence must also include the protection of elements of soft power, which I daresay, include the intangible elements of reputation, credibility and honour. Within this enlarged purview lie our collective responsibilities.

It is essential that we, as a nation, must have a comprehensive strategy, which is coordinated at the highest level, encompassing all elements of national power. Our military capability must be able to influence events to our advantage when required. We need to demonstrate credible capability and international presence, so that we are able to exert widespread influence, and smoothen our way to permanent membership of the UN Security Council.

INFLUENCE OF AEROSPACE POWER

To this learned audience, I need not emphasise the profound influence that aerospace power has had in shaping the modern world. Aerospace power today, perhaps, holds the key to the practical demonstration of national military capability and will continue to remain the centerpiece of national force.

I say this with confidence because the effect of aerospace power is inherently strategic in nature. Every action or even inaction, presence or posture, has strategic implication.

Take for example, the strategic airlift of Berlin at the end of World War II, which is a classic case of achievement of an objective, without firing a shot! The use of air power in Kargil, though in our own territory, immediately altered the nature of the conflict and international perception. Consider the excitement created in the media and in strategic circles, by the simple activation of two of our advanced landing grounds (ALGs) at DBO and Fukche, recently. These are Our ALGs, in Our territory and we have activated them in accordance with Our requirements, to develop alternative logistic and supply routes. But that action by itself initiated a flurry of diplomatic activity. And I would like you to note that these are not even offensive combat assets!

It is **this** nature of aerospace power that needs understanding. Simple presence, backed by professional credibility, can sometimes achieve national objectives. It must be used in this manner, and why not? Military power does not always imply destruction and delivery of firepower alone. When at the bargaining table, the presence of power and capability in the background, adds great value to one's position.

A force in being demonstrates purpose and intent, and accordingly has to be considered with due gravity. The IAF carries out a number of operational-level exercises. These exercises, both national and international, besides the obvious reasons of learning lessons of tactical value, are very important indicators of own capability. Performance during these exercises is monitored very carefully and demonstrates the potential of the air force, and ultimately the nation, creating credibility. This, coupled with posture, can sometimes broadcast intent, and often that alone is sufficient to achieve the desired objectives.

FUTURE APPLICATIONS OF AIR POWER

The years to come will perhaps see the use of aerospace power in many unconventional models. The possibility of conventional conflict, with one nation declaring war on another legally, seems remote today. The primary focus, I feel, will be towards domination of the battlespace. This control will remain an essential prerequisite for the success of any kind of operation, be it land, sea or air.

Besides the existing conventional roles and capability, the Indian Air Force will have to prepare for new roles and imaginative methods of application. I anticipate that aerospace power will take on a more intrusive role in the future. Surveillance and persistence may be the new requirements, with increasing relevance of space-based and unmanned platforms. Routine tasks are set to become more automated with elements of artificial intelligence looking after basic analysis.

As recent events indicate, threats from non-state actors would possibly increase, in the form of irregular warfare with diffused forces in urban terrains. Such a scenario redefines the envelope within which operations would have to take place, with the associated issues of restrictive rules of engagement and collateral damage. In such a context, it seems inevitable that the kind of weapons to be used may see a revolutionary change. The induction and use of non-lethal and non-kinetic weapons may soon become inevitable.

CONCLUSION

Our region is unlikely to achieve a degree of stability in the near future. Practically speaking, there will always be social, political and economic turmoil, at least for some time to come. Such a situation remains conducive to all forms of unrest and violence. The natural implication is that there would always be unforeseen emergent situations. I think that aerospace power is the only instrument that possesses the required speed and flexibility, when military intervention would be required.

The fact that aerospace power is the prime element of national defence, is not in question. The question is, how well do we truly understand the capabilities and principles of application of air power? The nature of future conflict will be far from the conventional, and will require flexibility of response. Aerospace power, by its inherently strategic nature, is a very powerful expression of national capability and intent, and must be used as such. National defence is a function of national capability and will. We will have to learn to combine them.

JAI HIND!

BUILDING AIR DOMINANCE

T.M. ASTHANA

We have travelled the "full circle". There was a time when the emphasis of all air forces was on gaining 'air superiority' over the adversary, in order to permit friendly air power to operate at will, while ensuring that the adversary's air power does not, or cannot, interfere with the operations of the surface forces. When air superiority was not achievable because the adversary's air power was non-cooperative, air forces sought to achieve a 'favourable air situation' (FAS), and in case FAS was not achievable, air forces sought to achieve an FAS for specific periods. However, this emphasis of the air forces was contested by the surface forces, and, they insisted on support from the air in their operations from Day 1 of the campaign assuming non-interference of enemy air as granted. It has dawned that this non-interference cannot be taken for granted – **it has to be earned.** The transformation of mindset of the surface forces has taken a long time, and, finally, they have accepted that the state of air superiority is a virtue that air power has to earn. We have travelled from air superiority to FAS, to FAS for specific time-frames, and now, air forces consider air dominance as their prime objective. Hence, we have travelled the "full circle". (Air Superiority = Command/Control of the Air = Air Dominance).

Winston Churchill once said, *"There is nothing wrong with change, if it is in the right direction. To improve is to change, so to be perfect is to change often."*

* Air Marshal **T.M. Asthana**, PVSM, AVSM, VM (Retd), former Commander-in-Chief of Strategic Forces Command, is a Distinguished Fellow at the Centre for Air Power Studies, New Delhi.

Transformation is a reality; however, transformation is not just change for change's sake; it is change in the right direction.

Transformation is a reality; however, transformation is not just change for change's sake; it is change in the right direction. Reality usually prompts ideas and innovation. Today's reality is that there are unique challenges facing our war-fighters – some obvious, some not so obvious. If we look at where airmen fight, and their contributions, perhaps we can uncover some challenges that need to be addressed. Airmen are providing air dominance over Afghanistan and Iraq, allowing the North Atlantic Treaty Organisation (NATO) forces to operate in any capacity as an effective joint and coalition force with zero risk of enemy aggression from the skies. This air dominance is enabled by network-centric operations. We fly combat air patrols in a different way than we did 20 years ago. Fighters and bombers have become multi-role strike platforms with deadly precision. They carry versatile weapon loads in orbits over critical ground engagements and allow a level of precision never before achieved. Who would have imagined a few years ago that a B-1 crew would be flying a close air support mission? This is a great example of how air power has changed. The soldiers under fire gave their coordinates, bearing and range for the enemy fire. The B-1 crew found the target with synthetic aperture radar (SAR), received clearance to engage, and the crew released two joint direct attack munitions (JDAMs). The first JDAM destroyed the target. You can see how air power has transformed.

Air dominance today is not only about air power but encompasses the entire gambit of aerospace power.

Air dominance today is not only about air power but encompasses the entire gambit of aerospace power: a large number of technological assets operating efficiently from the air and space to merge into a composite 'air picture', which provides the much required 'situational awareness'. This statement is only one half of the spectrum. Information seeking technological assets available on the surface also contribute towards 'situational awareness'. All these inputs need to be digested to ensure that 'total situational awareness' is achieved. Total situational awareness is a prerequisite for air dominance. While air dominance enables the aerospace forces to operate at will, it also provides freedom and unhindered operations to surface forces, i.e. air dominance possesses the ability to dictate non-usage of enemy air to counter our army and navy.

The objective in this state is the denial of enemy air power *effectiveness* to the extent possible.

AIR DOMINANCE — OFFENSIVE OR DEFENSIVE?

> *In Desert Storm, we had air dominance. That air dominance allowed our strike aircraft to devastate the enemy air forces and, at the same time, allowed our ground forces to operate without any enemy air interdiction. Desert Storm taught us something about air dominance.* ***We had it, we liked it and we're going to keep it.***
>
> — Secretary of Defence William Perry

For this paper, it is presumed that every usage of the term air dominance amounts to aerospace dominance. First of all, we must clarify the nature of air dominance. Is air dominance offensive in nature, or is it defensive? In the attempt to answer this question, let us consider all the categories or states of air effectiveness of own vs enemy air.

Air Denial : Friendly air forces may initially operate in a state of air denial at the start of the operations when the enemy has air dominance. Air denial is the lowest air power state where friendly aircraft can conduct air operations sufficient enough to oppose the enemy air dominance while conducting those air power activities necessary to halt an initial enemy advance. The objective in this state is the denial of enemy air power *effectiveness* to the extent possible. The friendly ability, through air defences or airborne threats, to provide protection to friendly ground and air forces, decreases the *effectiveness* of enemy air power. Enemy flak during the Korean War did not prevent air operations but it did make them more expensive. Despite air superiority at medium and high altitudes during the Vietnam War, the United States lost to North Vietnam in part due to the condition of air denial in the low altitude

Air superiority "rarely is an end in itself but is a means to the end of attaining military objectives."

environment with its surface-to-air missiles (SAMs) and anti-aircraft artillery. The SA-2 SAM did force the US to devote considerable numbers of aircraft to defeat it. And, in many cases, the SA-2 forced aircraft to jettison ordnance in order to evade it, which in effect negated the aircraft's mission – thus, *effectiveness.* The bottom line consideration is that it does not matter for what reason an aircraft cannot drop its bombs – what matters is that the target is not attacked – or that the mission was *not effective.*

Air Superiority : The next air power state is air superiority. Air superiority "rarely is an end in itself but is a means to the end of attaining military objectives." Air superiority is the degree "in the battle of one force over another which permits the conduct of operations by the former and its related land, sea and air forces at a given time and place without prohibitive interference by the opposing force." This state is not enough to ensure the *effectiveness* of air power.

Air Supremacy : The next state is air supremacy which is "that degree of air superiority wherein the opposing air force is incapable of effective interference." Most theorists add that air supremacy is achieved when superiority is ensured just about everywhere, thus, allowing friendly aircraft the ability to fly anywhere within the theatre of operations. However, this air power state also does not adequately address the issue of air power's *effectiveness* at dropping bombs on enemy targets at will.

Air Dominance : The final air power state is the attainment of *effectiveness* in the conduct of offensive air operations. Air dominance is the highest air power state when the requisite *effectiveness* of air power is achieved, so that 100 per cent of friendly bombs will hit enemy targets while no enemy bombs hit friendly targets, and that wars are won quickly (such as during the Six-Day War of 1967 and Operation Desert Storm of 1991), and fewer friendly casualties are suffered. The lack of air dominance, on the other hand, may give the enemy time to use the "kill as many military personnel as they can" tactic. The low attrition of the friendly military in Desert Storm seems to have established optimistic expectations about war, which may constrain some future commanders. The lack of air dominance will also make it significantly more costly for the military instrument of power to support "The National Security Strategy." The lack of air dominance will also make it more difficult and costly for the military instrument of power to conduct its growing role in deterrence and military operations other than war (MOOTW). Air intervention plays a key role in the military's expanded role in MOOTW. Air dominance contributes to the safe accomplishment of these missions. The successful application of military power is dependent on uninhibited access to the air and sea. Our forces will seek to gain superiority in, and dominance of, these media to allow our forces freedom to conduct operations and to protect both military and commercial assets. These demands require a capability to rapidly defeat initial enemy advances in order to seize the initiative and minimise the losses of territory and/or life. One is relatively well informed when it comes to defending assets and infrastructure through the use of air power, but protecting and ensuring that space capabilities continue to deliver in all, or, near all, conditions, demands greater planning and money. Air dominance, therefore, delivers the following:

Our forces will seek to gain superiority in, and dominance of, these media to allow our forces freedom to conduct operations and to protect both military and commercial assets.

- Enables fullest range of operations.
- Secures commanders' initiative and fulfills the "what-where—when."
- Provides operational freedom to permit "execute 'as you wish' not 'as you have to' operations."
- Provides opportunities for dominant manoeuvre and shields friendly mobility while denying enemy mobility.
- Simultaneous "Offensive Sword" and "Defensive Shield."

AIR DOMINANCE – PLATFORMS

Air dominance goes beyond air superiority and supremacy, in that, it not only ensures that friendly aircraft can fly anywhere in enemy territory, but they can also be *effective* in performing their mission. Suppression of ground-to-air attacks,

Modernisation of the air force is not only a strategic necessity, but is also a fiscally sensible course of action.

prevention of attacks on our air bases and forces, and overcoming domestic attacks on military and industrial infrastructure are all important in ensuring the effectiveness, or dominance of air power.

Combat Aircraft—Fighters and Bombers: Nearly four and a half decades ago, each aircraft of this category had a dedicated role allotted like air defence, ground attack, close air support and electronic counter-measures (ECM) (Wild Weasel). In addition, there were aircraft dedicated to the counter-insurgency role known as COIN aircraft. Gradually, but surely, aircraft were produced that were effectively used in more than one role, and the concept as well as the terminology "multi-role aircraft" began to take shape. Today, with the harnessing of a large number of technologies, lighter and more durable materials and miniaturisation, combat aircraft have the capacity to carry a variety of weapons, sophisticated avionics suites, concurrently demonstrating increasing agility and endurance. For the public, the wars and subsequent stabilisation efforts in Iraq and Afghanistan have accentuated the actions of ground forces, but air power has been a key behind-the-scenes factor all along. Air warfare will, if anything, grow even more critical to military operations in the years to come.

Modernisation of the air force is not only a strategic necessity, but is also a fiscally sensible course of action. Significant new capabilities becoming available in the form of upgrades and munitions will help the air force bridge the gap from its existing fleet of ageing fighters and bombers to a force mostly of stealthy aircraft in the coming decade. The aircraft mentioned here are combat ready aircraft and not test or evaluation systems. Basically, the aircraft will be optimised for air superiority missions, but they will also be capable of strike missions with weapons like the JDAMs. These aircraft should have the ability to pick up and go for 90 days to a deployed location and operate a dozen aircraft round the clock. The biggest conditional factor will be having sufficient spare parts for the war readiness kit that must accompany the unit to a deployment.

It is assessed in a US Air Force (USAF) study that the USAF needs 381 F/A-22s to be able to guarantee air dominance in any conflict, from terrorist hunt to all-out war. There is a strong lobby in the US that believes 381 F/A-22s in exchange for 880 fighters of earlier types such as the F-15, F-117 and F-16 "is a good investment trade to make." The F/A-22 fighter, despite just emerging from its development phase, is delivering a 78 per cent mission capable rate and has proved unbeatable even when outnumbered 2-to-1 by today's fighters. With the advanced radar, a new F-15 would have greater detection range but lack the survivability of the stealthy F/A-22 Raptor. Raptors are more cost-effective because more of them will survive combat, and each can destroy more enemies. It takes two to three aircraft to replace the killing capability of the F/A-22. An F/A-22 at $113 million a copy is a better deal than buying at least two $75 million F-15s to accomplish the same effects. The F/A-22 requires fewer personnel, fewer air-to-air refuelling tankers and can operate more frequently than earlier types, and so will save considerable money in the long run. It is claimed that the USAF analysis and maths supporting the 381 figure has been validated over more than a dozen independent reviews. There was a view that "if we can't afford it, we can't afford it, but the threat does not get any smaller just because you can't afford to meet it." It must be noted here that the numbers quoted are of aircraft available for fighting, after deducting a certain number devoted to training, test, maintenance and attrition reserve.

The same study also quotes a similar figure for the F-35. While the F-35 is stealthy, it lacks the speed and altitude capability that allows the F/A-22 to so dominate air combat. It has been indicated that the larger percentage of F-35s acquired should be of the short take-off and landing variety to cater for some objectives. The air force does not have a vertical landing requirement. The main conclusion of the study was that "**air dominance continues to be a key enabler"** for the entire military, regardless of the kind of campaign under way. Another conclusion was that the in-service aircraft such as the F-15, F-16, and F/A-18 are at parity with threat aircraft or at a disadvantage because the overseas designs are increasingly stealthy and fitted with advanced avionics.

The IAF can also claim strategic reach now with aerial refuelling becoming a reality. However, we need to remind ourselves that modernisation of the fleet in an ongoing process and one has to continuously plan to remain ahead.

While we accept that the USAF is the leading air force of the world in terms of capability and its overpowering ability to acquire the state-of-air dominance, I personally, cannot reconcile to the logic of reducing the numbers of combat aircraft just because a more capable aircraft has appeared on the horizon. Any air force will always require the numbers of combat aircraft that it has been accustomed to. There should be no compromise on this issue.

The Indian Air Force (IAF) can today boast of a comparable or better fleet of fighters in the neighbourhood. Nearly all the fighters have proven their capabilities in national and international exercises. The IAF can also claim strategic reach now with aerial refuelling becoming a reality. However, we need to remind ourselves that modernisation of the fleet in an ongoing process and one has to continuously plan to remain ahead. Along with the modernisation process, it is mandatory to upgrade and modify the existing platforms and integrate better and more accurate munitions with extended ranges. The absence of a dedicated bomber aircraft has often been adversely commented upon. In all fairness, it must be stated that no serious shortfall in the force's capability has been felt in the recent past, or, indeed, will be felt in the near future. Not for a moment am I suggesting that the IAF need not acquire a fleet of dedicated bomber aircraft, because as we have seen, today's bomber aircraft have also been pressed into service for close air support missions, provided the state of air dominance exists. In other words, the bombers of today and tomorrow will also be multi-role aircraft.

SENSORS

Air dominance allows more deliberate, persistent and penetrating intelligence, surveillance and reconnaissance (ISR). We need to develop the capacity to place ISR assets where and when the joint force needs them.

Airmen provide persistent, dynamic and non-traditional ISR that benefits the entire military. ISR is everyone's job. This means even fighters, strike aircraft and ground units are involved in building the battlespace picture using onboard sensors connected to command and control nodes through networks. Today's ISR is unbelievably effective and timely. Developments in this field are providing and upgrading better data processing and storage technologies by the day. The progress is indeed rapid. The process of miniaturisation is well under way and in the near future, sensors will be available off-the-shelf as COTS. Till now, there was either a space or weight crunch when it came to how many sensors one could put on an aircraft/unmanned aerial vehicle (UAV) or any other aerial platform. With miniaturisation, nearly all the desired technologies would be easily accommodated on the platforms. In respect of ISR, one can be sure to include electro-optical, infrared and SAR imagery on a single platform, all thanks to miniaturisation. This will ensure that the limitations of one sensor will, to a large extent, be adequately covered by the other sensors on board. In all likelihood, the same platform could also collect data for the required signals intelligence (SIGINT) and electronic intelligence (ELINT). However, it must be mentioned here that all these sensors only provide information. This information needs to be collated, analysed, and compared with available intelligence to convert this information to actionable intelligence.

The mobility and flexibility of air power permit it to ensure that all operations desired to support the combat of the surface forces as well the air force are conducted swiftly and in the desired time-frames.

Combat Support Operations: The mobility and flexibility of air power permit it to ensure that all operations desired to support the combat of the surface forces as well the air force are conducted swiftly and in the desired time-frames. Time is at a premium and when operations are assisted and/or precipitated at unbelievable time-frames, it may even take the enemy totally by surprise. The platforms for this part of operations are the transport and helicopters of air power. Significant and unprecedented movements of the surface forces to regroup, reinforce or augment the friendly forces at planned and random intervals provide the much-desired fillip to the operations of the surface forces. These operations too can only be executed with impunity when the state of air dominance is achieved.

Unmanned Aerial Vehicles (UAVs): UAVs are here to stay**.** A mere glance at the interest generated by a number of countries to acquire UAVs reflects the international opinion in favour of the UAV. The suitability of the UAVs for the 'dull', 'dirty', and 'dangerous' missions cannot be disputed. However, for a long time from now, the manned aircraft and UAVs will coexist and operate in a complementary manner to each other. We are aware of the tremendous contributions of UAVs in recent wars and names like Global Hawk and Predator are much too familiar to demand a repetition. I intend to cover some of the trends in the platforms of UAVs. These are:

(a) Next Generation Sky Warrior's Maiden Flight a Success. On June 18, 2007, resurrecting a great name from the 1950s, General Atomics completed the maiden flight of their Sky Warrior UAV. The new Sky Warrior will operate as an unmanned long-range surveillance, communications and weapon delivery drone. The Sky Warrior will be able to run on diesel or jet fuel due to its heavy fuel engine and will form part of the US Army's extended range/multi purpose UAV.
(b) On June 28, 2007, Boeing successfully demonstrated the simultaneous command and control of multiple UAVs by a single operator. These UAVs will be able to operate through a central control point while having the ability to self-organise and make independent decisions.
(c) Reaper UAV. On August 31, 2007, the USAF announced the deployment of a new squadron of UAVs into the combat zones of Afghanistan and Iraq. Capable of carrying a payload of 3,759 pounds, the jet fighter sized Reaper can fly at 300 mph, reach 50,000 ft and stay airborne for 14 hours at a time. This 'hunter-killer' UAV also incorporates infrared, laser and radar targeting and is capable of deploying precision-guided weapons.
(d) Fast Jet-Pilots Direct Multiple UAVs. On April 4, 2007, a new system was demonstrated which provides a single pilot with the ability to fly his own

military fast jet while simultaneously directing up to four UAVs. The system gives the UAV an advanced level of autonomously independent decision-making, including self-organisation, communication, sensing the environment, identifying possible enemies, and targeting of weapons with the final decision to shoot retained by the pilot. The project trials initially will take place exploring the use of UAVs for non-military operations. The flight trials were flown using a Tornado as the command and control aircraft and a BAC 1-11 trial aircraft acting as the 'surrogate' UAV. The Tornado pilot also had the responsibility of commanding a further three simulated UAVs. Working in combination, the Tornado and four UAVs carried out a simulated ground attack on a moving target. The sophisticated computer on the UAVs allowed them to target their weapons after an analysis of the environment, including possible enemies. However, the final decision to fire any (simulated) weapons was retained by the Tornado pilot. The system has been designed to provide the UAVs with a significant degree of independent intelligence in order to substantially reduce the workload of the pilot and also ensure that the most important decisions are retained by the human operator, viz, the Tornado pilot (in this case). Consolidation trials and development of expertise will take place in search and rescue, disaster relief and environment monitoring operations before full-fledged induction in military operations.

SPACE

The harnessing of space capabilities for military operations in recent wars has amply demonstrated the advantages that accrue. The benefits of space capabilities are evident in our daily lives also with satellite-based TV and commercial communications. This has led to ensuring that most of the required equipment is of the COTS category. Better data processing and storage techniques, on the one hand, and miniaturisation, on the other, will permit the use of smaller, lighter and more sensitive sensors for the full range of surveillance and reconnaissance needs for electro-optical, infrared, hyperspectral and SAR imagery catering for all weather conditions round

With miniaturisation maturing, we will witness a far greater capability on each satellite since weight will no longer be a restriction.

the clock. With miniaturisation maturing, we will witness a far greater capability on each satellite since weight will no longer be a restriction. Such attractive contributions cannot be ignored, nor can we permit any agency to interfere or deny us these lucrative benefits. Therefore, space control will remain our major objective wherein it will be ensured that our space platforms continue to provide us with the desired inputs. Aerospace domination implies aerospace control and requires build-up of considerable aerospace capability. Miniaturisation will also give us the opportunity to launch smaller satellites, as well as provide the redundancies that are so desperately planned for in every military operation.

NEAR SPACE

The contributions of space are much too expansive indeed. However, there are a few limitations that mainly pertain to persistence of observation and surveillance. It has been realised that launching satellites is an expensive proposition, and that very soon, we will witness saturation of space itself. It is with this background that we are travelling the "full circle" again by thinking of, and trying to launch, lighter than air vehicles, namely balloons, at altitudes from 50 to 70,000 ft. These balloons will have adequate space available and they could be charged with various sensors which will deliver all the information required on a permanent schedule, and that too, continuously. One may argue that with high altitude long range endurance (upto one week) UAVs, we do not need balloons, but the UAVs will not grant persistence of observation of an area as well as a balloon will. Once again, it may be argued that the balloon will be very vulnerable, but that is where the ingenuity of application of air power and ground-based defences would come into play to ensure their safety and survivability. These balloons could also be powered by relatively small motors, which could slowly, but surely, move them to locations as desired. Hence, near space platforms will also be major contributors in future wars.

In addition, they will be inexpensive platforms, and launching alternates may be a suitable plan for redundancies. While accepting the elapsed time gap for the alternate to become operational, one may satisfy oneself by optimum utilisation of the information available through the other platforms as a stop-gap measure.

Offensive and defensive cyber warfare must, hence, also be a major consideration for all military operations.

FORCE MULTIPLIERS

At the very mention of this terminology, terms like airborne warning and control system (AWACs), airborne warning and control (AEW&C) and air-to-air refuelling tankers ring a bell. In my logic, the days have arrived when cyber warfare (both offensive and defensive) should also form a part of this category. The reliance on goods delivered by avionics suites, communications (both line and satellite-based), data transferring capacity and a host of other facilities have made command and control a relatively easy proposition. Any interference with this achieved comfort level would be most disturbing and cause serious discomfort to both plans and execution. Offensive and defensive cyber warfare must, hence, also be a major consideration for all military operations.

NETWORK-CENTRIC WARFARE (NCW)

Converting the host of information collected into actionable intelligence is only half the work done. The other half, and the more important half, is to ensure that the required intelligence data is transmitted to the correct agency/ unit that would put this intelligence to use by converting it into well planned execution with the optimum weapon at the most opportune moment. Time is at stake and real-time intelligence makes it relatively simpler to plan and execute with the perfection and lethality that we desire, with the elements of surprise and shock effects thrown in as confirmed destroyers of the will to fight. The demands on avoiding collateral damage have increasingly become a trend in warfare. This would only be possible when all the participating forces

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and agencies are linked in a network which is capable of transmitting the required data and creating total situational awareness. This is achieved by NCW. We must also not forget that both the task of collecting the information undisturbed, and nil interference during execution by enemy air, can only be achieved when air dominance has been secured.

AIR DOMINANCE INFRASTRUCTURE

Immaculate and intensive planning needs to be undertaken for erecting the air dominance infrastructure, be it in the form of airfields, command and control nodes and installations, NCW infrastructure and all the associated hardware required for building air dominance to optimum levels. The air dominance infrastructure must be robust, survivable and capable of ensuring enough redundancies to cater for a determined enemy.

CONCLUSION

> *If you want to overcome your enemy, you must match your effort against his power of resistance, which can be expressed as the product of two inseparable factors, viz, the total means at his disposal and the strength of his will.*
>
> — Carl von Clausewitz, *On War*

The contest for air dominance is the most important contest of all, for no other operation can be sustained if this battle is lost. To win it, we must have the best equipment, the best tactics, the freedom to use them, and the best pilots. A potential enemy will also observe the history of air dominance and reach similar conclusions, but air dominance/supremacy/superiority (in that order) will be an absolute necessity in future conflicts whether they are big or small. The debate on how, and with what weapons air dominance can be achieved, is never likely to end. As a nation, however, as so aptly pointed out by Clausewitz, we must never forget that the enemy has a vote. Technological superiority alone does not, and will not, guarantee victory. Stealth has opened a window of opportunity, a window of hope, which offers air superiority with minimal risk to the pilots asked to gain it. It seems likely, therefore, that despite the cost, stealth is here to stay. Stealth, however, has not fundamentally changed how an air campaign is fought. It is unlikely that any stealth platform will fly into a high threat environment without airborne suppression of air defence (SEAD). We must continue to pursue additional technologies to fill the gap between stealth capabilities and limits in current SEAD inventories. One cannot win by fighting head to head.

We are not looking for a fair fight. Each weapon of war must be capable of achieving greater things in war than the weapon it replaces. Options such as the unmanned high altitude Global Hawk with high loiter times and the ability to attack enemy radars and sensors should be explored and fielded. In short, a wide range of technologies must be fielded out of the thinning defence budgets. *"War is, thus, an act of force to compel our enemy to do our will."* The advantage we hold must be so complete and so overwhelming that **air dominance is the only answer.**

FUTURE SHAPE, SIZE AND ROLE OF INDIAN AIR FORCE

P.K. MEHRA

Determining and suggesting the future shape and size of a large air force is a very complex process and requires a multi-disciplined team to go through the multi-faceted deliberations. Even after a systematic, and perhaps, a scientific study, the result has to have built-in flexibility to meet many unforeseen situations. Even though some people may call this process 'crystal gazing', this activity is undertaken not only in the Indian Air Force (IAF), but world-wide, both officially and in the open literature. The study involves a number of imponderables like the numbers, weight categories, quality, technology/ generation levels, time-frames, replacement / upgrade plans of aircraft and other combat support equipment, besides politics, which do not permit finalisation and unanimity. Most of the time, the discussion centres on fighter aircraft but the other combat support equipment, which sharpens the teeth, is glossed over. If we look at the recent inductions, it is evident that the IAF is certainly focussed on the two most important factors i.e. strategic reach and joint operations in our scenario, keeping in mind the greater role expected to be played by India in the future. It is our government that needs to be convinced of our requirement of aircraft and other combat support equipment during peace-time in order to be prepared for war. Are we sure that a 55-

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There are a number of variables which impinge upon the security situation and, consequently, the kind of tasks the military is likely to be called upon to perform.

squadron force will be enough and what will be the requirement of support aircraft and other equipment to win the future wars?

There are a number of variables which impinge upon the security situation and, consequently, the kind of tasks the military is likely to be called upon to perform. Who could have visualised the end of the Cold War, Gulf and Iraq War, and the unification/ break-ups in Eastern Europe when outwardly the conditions were stable? In our neighbourhood, the geo-political situation has been in a state of flux for over 50 years, with nations alternating between democracy and autocracy, and externally having to deal with the leftover problems of partition and boundary disputes. In the past, there has been instability, strife and conflict, and a number of wars have been fought between the neighbours but the present security situation is changing with relative peace at the Line of Control/ Line of Actual Control (LOC/LAC) and, therefore, the kind of future war in our region may also undergo change. The Indian defence forces have to jointly plan for all contingencies, including conventional war under a nuclear overhang and based on the tasks, individual fighting forces should acquire capabilities. Credible air power has to keep pace with the march of technology and should have the backing of the desired level of self-reliance through own indigenous defence industrial base.

After stating the variables, it would be prudent to mention the factors which have remained constant. The interplay of these variables and non-variables introduces a high level of difficulty in formulating and following an acquisition plan, and allocating resources. These factors are given below.

These factors are being stated to highlight their impact on decision-making and defence preparedness. The Indian armed forces have remained apolitical and under civilian control in a democracy. There is a hot and cold relationship with our neighbours and some of the problems with them have been left over from history, requiring a political solution. The budget allocation for the year is mostly an increment from the previous years, based on the rate of inflation to provide for very limited increase in real terms. At times, sharp spikes in the defence budget have been made after an event connected with national security. An enabling environment for the all round growth of the defence industry has largely remained on paper, with defence public sector undertakings (PSUs) being the clear favourites. Inadequate efforts in research and development (R&D) have directly related to the technology requirements of the defence forces. At times, lack of self-reliance and the strategic international relations with a few countries have led to acquisitions based on availability and not qualitative requirements (QRs). It is difficult and very expensive to diversify purchases once hooked to defence diplomacy with a country.

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HISTORY OF INDIAN AIR FORCE DEVELOPMENT

The growth of the Indian Air Force has seen ups and downs ever since its inception. Acquisition of aircraft and equipment was initially from the UK and France, and after the Sixties, there was a clear tilt towards the then Soviet Union. The reasons for this shift are well known and the dependence on Soviet equipment grew to such an extent that presently nearly 70 per cent of the aircraft and equipment are from the present Russian state. The IAF had an approved strength of 15 squadrons up to the Sixties and an expansion was ordered after the Sino-Indian War of 1962. The Indo-Pak War of 1965 took place when the IAF was still inducting new aircraft and equipment and it was only in the 1971 War, that the IAF was fully prepared in terms of equipment and training since sufficient time was given to prepare for the war. The Indian Air Force has largely developed its aircraft fleet for border wars, with limited focus on acquiring combat support systems in the past. Even the air defence systems acquired in the past could provide only point defence and they too are on the verge of obsolescence. The deterrence value of these air defence

The air force doctrine will guide the future force structure, its organisation, training, equipping and fighting.

systems is not adequate to provide credibility. Barring the Su-30MKI, the aircraft of the Soviet era and other systems are verging on obsolescence. Efforts are on to upgrade the aircraft and equipment to improve their effectiveness for the next decade or so. Fortunately, the emphasis on acquisition by the IAF has undergone some change with the induction of air-to-air refuellers, aerostats, airborne warning and control system (AWACS), unmanned aerial vehicles (UAVS) and other air defence systems, which will permit the IAF to play its assigned role as a major regional player.

DOCTRINE AND FORCE STRUCTURE DEVELOPMENT

Joint military doctrine determines the manner in which the defence forces should be used to achieve national objectives, and the Indian Air Force doctrine should guide the employment of air power. The air force doctrine will guide the future force structure, its organisation, training, equipping and fighting. It helps the air force to plan acquisition of combat systems to support the future missions. Although doctrine can undergo changes, one must remember that building up a capable force will take even longer. Some of the doctrines introduced may have a major effect on the systems to be inducted, and, consequently, on the budgeting. It is important that the enunciated doctrine and policy is converted into force plans and acquisition plans, and appropriate funding is made. One of the doctrines based on the political vision introduced in recent years was "strategic reach" and the other was the emphasis on intelligence, surveillance, reconnaissance (ISR) utilising unmanned vehicles. Greater utilisation of space-based assets and induction of ballistic missiles in the future will bring about a sea-change in the force pattern, with attendant costs, integration with existing assets, etc. It is important that a review of doctrines and policy must lead

Greater utilisation of space-based assets and induction of ballistic missiles in the future will bring about a sea-change in the force pattern.

to credible intentions supported by workable plans, acquisition plans, budget allocations and measures of effectiveness.

The Gulf War showed that space can play a crucial role in the efficient execution of wars and it would remain the crucial combat enabler in the 21st century.

DOCTRINE AND TECHNOLOGY

The relationship between doctrine and technology will vary for different forces but its true benefit is what it suggests about the future. Will the air force develop its doctrine based on the likely technology available or will it drive the technological development? If the Indian defence forces are to play their expected role in sync with the country's aspirations, there has to be an enabling environment to develop technologies to meet the laid down doctrine. The doctrinal process should influence the direction of new and developing technologies, especially those connected with military space applications and ballistic missiles.

EMERGENCE OF SPACE FOR MILITARY APPLICATIONS

Civil and military establishments the world over depend heavily on satellites for secure communications, meteorological information, navigation aids, ocean surveillance, integrated early warning, and search and rescue. The Gulf War showed that space can play a crucial role in the efficient execution of wars and it would remain the crucial combat enabler in the 21st century. Although no dedicated military satellite has been launched so far, the Indian Air Force has in the past made use of Indian Space Research Organisation (ISRO) satellites for ISR, communication, meteorology, search and rescue, and imagery. It is understood that a military satellite is likely to be launched soon for utilisation by the armed forces. Increased militarisation of space may lead adversaries to develop systems to knock out these assets. China has already proven its capability in January 2007 and our ongoing research into space-based systems for anti-ballistic missiles (ABM) and anti-satellite (ASAT) is essential for securing our future. The Indian Air Force needs to gear up to use, and protect, space-based assets.

Hypersonic vehicles could be the combat vehicles of tomorrow, which can permit launch of attacks on time sensitive targets from home bases. Recent interest in developing reusable hypersonic vehicles and the increased proliferation of ballistic missiles require air and space to be seamlessly linked for purposes of air defence against trans-atmospheric threats. The need for space-based early warning for effective air defence against ballistic missiles cannot be overemphasised. Only the seamless integration of air and space defence with unity of command, can tackle the trans-atmospheric threats effectively.

RELATIVE STRENGTH OF THE VARIOUS AIR FORCES IN THE REGION

Wars in the last two decades have shown the primacy of air power in winning wars. Both China and Pakistan have embarked on joint development and acquisitions to beef up their air forces with current generation aircraft and systems. Although the total strength of the Chinese Air Force aircraft may be depleting due to phase-out of older aircraft, the total effectiveness has gone up with the induction of the J-10, Su-27, J-11, Su-30MKK and JF-17. Considering the acquisition of more advanced aircraft from Russia and their own development programmes, the People's Liberation Army Air Force (PLAAF) [not counting the PLA-Navy (PLAN) aircraft] should be able to field over 1,000 aircraft of fourth generation and better by 2025 against India. If we calculate even one sortie per aircraft per day, the throwweight against our targets can be overwhelming. In addition, China has, and will continue to deploy an array of ballistic missiles, cruise missiles and anti-radiation missiles (ARMs) to inflict substantial damage.

The Pakistan Air Force (PAF) has 22 squadrons of fighter aircraft with only F-16 aircraft of medium capability and the rest are F-7 versions, A-5, Mirage III and V. Their build-up is expected to maintain the present strength through continued induction of additional F-16s, upgrade of the existing F-16, JF-17 and possibly J-10 aircraft, thus, increasing the number of fourth generation aircraft. The PAF has also ordered six airborne early warning (AEW) aircraft from Sweden and two Il-78 aerial refeuelling tankers. In case the PAF is able to deploy about 250 aircraft with utilisation rate of two sorties per day using precision guided munitions (PGMs) and beyond visual range (BVR), then the IAF may face limitations in numbers because of deployment in both the west and north.

The problem is that we are unable to link China's capabilities with its intentions. The dragon is rising peacefully but will not hesitate to show its fangs when the time comes.

NATURE OF CONFLICT EXPECTED IN FUTURE

> *Observe calmly; secure our position; cope with affairs calmly; hide our capacities and bide our time; be good at maintaining a low profile; and never claim leadership.*
>
> **– Deng Xiaoping**

International relations have undergone a sea-change thanks to globalisation but it does not mean that wars will not take place. It is only the nature of wars which will change but as long as there is a state which is weaker than the other, the issue of dominance will come up, and in case the nations are equal in stature, then the competition to corner resources between them may lead to conflict. The possibility of a World War III on the same scale as the earlier two World Wars is remote but the reasons for conflict will continue to exist. Economic interdependence, competition for natural resources, globalisation, food, water, energy security and the role of non-state actors will determine the kind of conflict in the future. The proliferation of weapons of mass destruction (WMD), and more and more countries acquiring strategic strike surface-to-surface missiles, and weaker nations preparing for asymmetric warfare will require different *inter-se* priority amongst a number of procurement decisions. If there is a likelihood of sub-conventional war or irregular warfare, then there will be a trade-off between aircraft purchase and ISR related equipment and platforms. Our region is expected to face more civil wars and insurgencies because of the existing asymmetry between various players. China has embarked on the path to become a great power and is building up its military might to become a superpower in the years to come. The problem

War/conflict in our region will have to be fought differently since the opponents are expected to have a credible air force.

is that we are unable to link China's capabilities with its intentions. The dragon is rising peacefully but will not hesitate to show its fangs when the time comes. Our boundary dispute does not have an immediate solution and China may attempt to bargain from a position of strength. The two large countries in Asia, with growing economies and a huge appetite for natural resources, energy, water, food, etc may have to compete in the world market but the probability of war is low.

Pakistan and Bangladesh are facing the pangs of developing democracy with rampant poverty and economic slowdown. Without an economic upturn, there can never be peace in South Asia and the regional initiatives will remain just on paper. The spread of terrorist activity based on religious fundamentalism will keep the region on the boil. India will be faced with irregular warfare and the air force will have to be prepared to fight this kind of war under a nuclear overhang. Both China and Pakistan are nuclear powers and are focussed on developing their strategic strike capability and as long as India does not possess capability to thwart ballistic missiles attack, this will be their principal weapon of choice.

LIKELY TASKS OF THE INDIAN AIR FORCE

The wars fought in the last two decades in the Middle East and East Europe did not see air power being used by both sides. War/conflict in our region will have to be fought differently since the opponents are expected to have a credible air force. The terrain is so typical in the west and north that air power, including ballistic missiles, will be the preferred option. In our region, there will be a tussle for command of the air, hence, air defence, both offensive and defensive, will be of primary importance. In case the conflict is limited to irregular or low intensity, then the task of the air force will be mostly supportive of the other Services and will depend upon the area of operations. There is little likelihood of a war against China in the next two decades but that cannot be said about Pakistan. Considering the situation in Pakistan and its economic conditions, it can only resort to low intensity conflict (LIC) or support terrorism in India. In LIC, the ground forces will be the primary instrument and air power can increase their effectiveness. The tasks will normally be to provide mobility, aerial surveillance and agility to focus greater firepower in time and space, keeping the collateral damage to the minimum.

Another important task for the IAF is directly related to India's role as a regional power and a budding superpower. The IAF may be called upon to protect Indian nationals and other national interests, which may involve disaster relief, rescue of stranded Indians, support to neighbouring countries whenever asked for like in Maldives and the Indian peace-keeping force (IPKF) in Sri Lanka.

The economic growth in India means greater trade and especially the increase in energy consumption implies larger import of oil and gas. The increased investments abroad, especially into natural resources, and their protection, may require our defence forces to be geared up for the expeditionary role. Taking into account India's growing economic strength and transformation of its international stature, it is essential that the IAF acquires appropriate capabilities. A number of scenarios, from full-fledged war on two fronts to limited conflict in a small region can be painted and even use of expeditionary force can be visualised in the next quarter century with a degree of probability attached to each one of them. Operations under the UN flag with forces of other countries are also a distinct possibility in the coming decades. These operations are expected to be tri-Service, with the air force providing airlift capability, logistics support and, perhaps, protection from the air.

WHAT CONSTITUTES A CREDIBLE AIR FORCE?

Simplistically, it should have fighters, transport and helicopters but for this force to be credible, it should have a suitable mix of multi-roles, weight categories and technologies/generations. Transport aircraft are also required in a suitable mix of different weight categories for intra/inter-theatre operations

The air defence environment has to be shaped in order to ensure command of the air.

and to provide strategic reach. Adequate numbers of aircraft for special tasks and special forces like AWACS, tankers, joint surveillance target attack radar system (JSTARS), joint tactical information distribution system (JTIDS), combat search and rescue (CSAR), gunship, paradrop, electronic warfare (EW) aircraft, etc provide the force multiplier effect. Helicopters are part of the special task force, especially for destruction of enemy air defence (DEAD), combat assault, CSAR, paradrop, air maintenance in hostile/ mountainous terrain, etc. A mix of utility, medium lift, heavy lift, armed helicopter, combat helicopter, etc. is essential, especially with high altitude capability in our scenario, for credibility.

The air defence environment has to be shaped in order to ensure command of the air. AWACS, AEW, aerostats, chain of networked radars, SAMs, UAVs and space-based early warning systems are the major constituents of a credible air defence force, both offensive and defensive. These airborne air defence systems and other high value force multipliers need to be defended constantly by dedicated air defence fighters but this price is minimal once air dominance is gained.

SUGGESTED SIZE AND SHAPE OF INDIAN AIR FORCE

Having discussed the likely tasks and what makes a credible air force, we now need to suggest the future size and shape of the Indian Air Force. I do not wish to suggest the numbers because it has too many pitfalls and even the very advanced air forces have not been able to defend their original acquisition plan for aircraft and systems. Even the debate on manned versus unmanned has been raging with no clear-cut decision on the time-frame and numbers.

The most important factor is credible deterrence and that can be projected through numbers, technological level and combat support systems. When talking about numbers, it is essential that the ratio of aircraft holding between us and the two likely adversaries is maintained, especially in our context with responsibility to defend two borders. The technological level, throwweight capability and force multipliers will, of course, enhance the effectiveness of the IAF several fold. The size of the IAF has reduced to about 32 squadrons and is likely to go down further from the authorised strength of 39.5 squadrons. The present fleet is a mix of the obsolete aircraft like the MiG-21 variants, with upgraded Bison, Jaguar, MiG-27, MiG-29, Mirage 2000 and Su-30 MKI. Jaguar, MiG-27, MiG-29 and Mirage 2000 aircraft are in the process of being upgraded with improved avionics and systems in order to improve their effectiveness. Integration of PGMs and BVR on these aircraft will increase the kill potential through better accuracy and standoff ranges. These aircraft, along with the Su-30 MKI, can provide the strategic reach in conjunction with Il-78 aerial refuellers and the soon to be inducted AWACS aircraft. The planned induction of 230 Su-30 MKI, 126 medium multi-role combat aircraft (MMRCA) and some light combat aircraft (LCA) will at best arrest the decline in numbers but will substantially improve the combat potential by the end of next decade.

The most important factor is credible deterrence and that can be projected through numbers, technological level and combat support systems.

What should be the number of squadrons and what should be the mix between different technology levels and different weight categories of aircraft? Broadly, the IAF aircraft holding can be divided into three categories viz, low, medium and heavy, and, similarly, the level of technologies can be sub-divided into three levels, namely, low, medium and high. The size and shape of the IAF aircraft inventory has to be a combination of these two factors. The IAF is fortunately heading in that direction except that the aircraft belong to various vintage, types and original equipment manufacturers (OEMs). Ideally, there should be three categories and they should preferably be from the same design house and manufacturer. What I imply is that there is a challenge for the Indian defence aviation R&D and manufacturers to come up with a family of aircraft. We must have a mix of three weight categories of aircraft, with a judicious mix of the levels of technologies. What I suggest is a larger proportion of aircraft in the medium

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weight category, with medium technology through frequent upgrades. This statement is true for transport and helicopters as well and is the only way which can lead to self-reliance and sufficiency. The R&D and manufacture of transport and helicopters has a lot of commonality between civil and military, hence, these programmes will derive huge benefits from synergy.

Determination of number of aircraft, technology level and other force multipliers for a credible air force in different scenarios is a very complex process. It is suggested that the force level be treated as a system and the force mix be arrived at through a process. The interplay of various weightages, relative strengths, technologies, contribution to war-fighting and effectiveness in joint operations in different geo-political situations needs to be systematically studied for purposes of acceptance through consensus. Since there is reduced chance of a full-fledged war in the near future, it will be appropriate to determine priorities, allocate resources and commence programmes to develop technologies and systems now with a fruition deadline of a decade and no more. Participation and guidance as the owner at all levels will be the key. Moreover, the IAF has to maintain the asymmetry in both numbers and technological capability and must apply appropriate fighting strategy during operations. Besides aircraft development, there is a dire need to focus on infrastructure, force multipliers and key technology development in a time-bound manner.

India, being a nuclear power with the doctrine of 'no first use', has to ensure a very credible second strike capability. Presently, the triad is incomplete and there is a heavy dependence on the medium and heavy aircraft of medium or high technology as a delivery platform. The aircraft need to be maintained and made available for the task by the IAF. Survivability of the aircraft and weapons has to be ensured through dispersion, adequate number of trained crew, fail safe communication systems, clearly defined hierarchy for command and control and, finally, a display of strong will.

With the present aircraft fleet and that foreseen, it would be prudent to base them in the interior so that area defence is effective and more so the aircraft can be used for action in the west, north and over the sea.

INFRASTRUCTURE DEVELOPMENT

The IAF fleet has undergone changes and so have the fighting techniques. Acquisition of short range and mainly air defence aircraft in the Sixties required forward bases near the border to be effective. These bases required standing combat and patrol (CAP) and surface-to-air missiles (SAMs) for their defence and, in fact, faced the brunt during the 1965 and 1971 Wars. With the present aircraft fleet and that foreseen, it would be prudent to base them in the interior so that area defence is effective and more so the aircraft can be used for action in the west, north and over the sea without much wastage of flying hours. An exclusive base for strategic and special forces aircraft may be established in central India. The IAF needs to focus on upgrading our airfields for all weather operations and must automate its logistics management. The additional cost vis-à-vis the effort required to protect the forward bases during war may be determined through modelling and simulation.

WAR IN CYBER SPACE

In the recent past, a number of computer networks worldwide have reported intrusions that appeared to have originated within the People's Republic of China. It is claimed that the techniques used for intrusion were identical, thus, pointing to a single source. The intruders are not reported to have caused damage to the data or the network but it is clear that the intruders can easily cause serious damage if they are able to intrude. We are embarking on a networking of our systems and, hence, will become vulnerable in case adequate care is not taken to protect our networks. Purchase of hardware and development of software by external agencies is fraught with danger

The IAF has laid adequate emphasis on acquiring some of the force multipliers and the results are already visible but the numbers are totally inadequate to meet the commitments.

and, hence, in-house development of some critical modules with adequate safety measures should be resorted to. The futuristic concept of "no contact war" demands foolproof security of our networks and capability to disrupt that of the adversary. Capability to conduct cyber warfare would make us capable of protecting our own assets as well.

AIR POWER AND FORCE MULTIPLIERS

Budgetary allocation is never enough for the military planners. The proverbial saying "to get the bigger bang out of the buck" is primarily related to acquisition of force multipliers or combat support force to get greater effectiveness. Even timely upgrades bring about a multiplier effect which is generally stated in terms of increase in combat effectiveness. Some of the crucial force multipliers are:

- Airborne warning and control aircraft.
- Aerial refuelling aircraft.
- Electronic warfare systems, including electronic intelligence (ELINT) and commercial intelligence (COMINT) equipment.
- Precision weapons like stand-off guided weapons, BVR and directed energy weapons.
- Stealth.
- Network-centric environment.
- Unmanned aerial vehicles/unmanned combat aerial vehicles (UAVs/ UCAVs) with sensors for intelligence gathering and targeting cyber warfare.
- Aircraft and systems upgrade is a force multiplier.

The IAF has laid adequate emphasis on acquiring some of the force multipliers and the results are already visible but the numbers are totally inadequate to meet the commitments. Three AWACS, two aerostats and six tanker aircraft are not enough; similarly, unless we are able to develop our own PGMs, we will be dependent on imports and short of teeth. It is well known that we have lagged behind in developing airborne precision weapons but we must understand that the cost of acquisition escalates exponentially when weapons and systems are included as part of the package for fighter aircraft acquisition. Purchase of weapons for initial capability should not push their development programme onto the back-burner. Networking of sensors through a very secure medium providing situational awareness to the command and control (C2) centres and all the way up to the National Command post will definitely change the way the next war will be fought. The ability to conduct cyber warfare will ensure safety of our own networks and ability to cause disruption or disinformation in the adversary networks.

The Indian Air Force should influence the direction of new and developing technologies, especially those connected with military space applications.

INDIGENOUS DEVELOPMENT OF TECHNOLOGY

If the Indian defence forces are to play their expected role in sync with the country's aspirations, there has to be an enabling environment to develop technologies to meet the laid down doctrine. A missionary approach is required to develop the required technologies as is being done in the case of space by ISRO. The defence forces must be the stakeholders in terms of both funding and manning. Mere lip-service to self-reliance will not do, and active participation in actual technology development is needed. Greater integration of the scientific community and the user is essential. The Indian Air Force should influence the direction of new and developing technologies, especially those connected with military space applications, aero-engines, UCAVs, stealth, radar, electronic warfare systems, PGMs, and ABM/ASAT.

Taking up the development of a family of aircraft first, I feel that both the Defence Research and Development Organisation (DRDO) and Hindustan Aeronautics Limited (HAL) along with other academic institutions should work on the improved versions of the LCA and commence design and development

The astounding rate at which the technology is being developed means that the rate of obsolescence will also be very high.

of medium and heavy versions. One may say that it is in conflict with our induction of the MMRCA and Su-30 MKI but I feel that this indigenous effort will help in future upgrades of these bought out aircraft in the subsequent decades and will make them part of the family. Another question arises concerning the future of fifth generation aircraft development along with Russia; I feel that the proposed indigenous technology development will bring to the table a greater amount of our own technology, thus, strengthening our position.

The astounding rate at which the technology is being developed means that the rate of obsolescence will also be very high. Since the operational life of the fleet is likely to be 30 to 40 years, only frequent upgrades would be able to keep the fleet current. Since induction itself takes as much as a decade at the minimum, upgrades and even generational changes need to be planned even during the induction phase. The lessons learnt during the exploitation of the new aircraft point to the deficiencies and the fixes required.

The next focus of our technological development has to do with the debate on manned versus unmanned aircraft systems. UAVs and especially UCAVs have established a niche place wherein the manned aircraft cannot compete. The unmanned vehicles score over the manned with their much greater persistence and capability in attacking time sensitive targets. It is entirely possible in future to have a pilot controller on the ground or in the rear seat of a controlling mother aircraft to direct and guide a number of UCAVs and accomplish the mission. A combination of AWACS, aerostats and UAVs is formidable for ELINT and electronic support measures (ESM) purposes. Satellite imagery and that received from UAVs in real-time can provide the intelligence required for turning the tide against the adversary. Efforts to integrate UAV operations with other civil traffic will pay huge dividends and aerial refuelling will give it trans-continental reach. Development of sensors, data links and information technology (IT) will provide net-centricity, thus, changing the way the next war will be fought.

There are just about five or six countries in the world that have the technology to develop jet aero-engines. The history of aircraft development in India is well known and one of the major reasons for failures or short closing of programmes is the lack of a suitable engine. The DRDO has been working on this niche technology for over three decades but has not developed an engine which has got airborne so far. India must join this select group and the DRDO should take all steps to develop a jet engine and lay the foundation for developing scramjet engines in the future.

The manned flight is expected to take a leap through the hypersonic plane. The limitation of human endurance is sought to be overcome through speed.

The manned flight is expected to take a leap through the hypersonic plane. The limitation of human endurance is sought to be overcome through speed. R&D into this development will place India in the big league but I feel that it is the engine development which is likely to affect the development. The Kaveri development has not been successful so far and developing a scramjet will be a tall order.

BALLISTIC MISSILE DEFENCE (BMD)

The potential adversaries are developing their nuclear arsenal and delivery systems using ballistic missiles. The IAF will have to develop a potent air defence system against this threat. Some effort to develop the ABM system against these ballistic missiles is going on but unless space-based systems for early warning are in place, the success will be limited. There is a need to develop and network a combination of early warning satellites, ground-based radars and suitable surface-based or, if required, space-launched weapons.

MANNING REQUIREMENTS OF THE FUTURE

The IAF has already undertaken transformation in the manning, especially with respect to training and is considering the improvements in the teeth to tail ratio. The manning will depend on the number of squadrons, combat support systems and other infrastructure support but I feel that the IAF

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needs to be active in developing systems and technologies in-house for direct application in the field. These systems could also be developed through outsourcing but the decision to do so will depend on the level of technology and investment. There may be a need to induct suitable technical officers in a different cadre who can be either deputed or tasked with application technology development in-house. There is also a need to look at inducting civilian officers for tasks which require continuity like training, administration, etc.

ORGANISATIONAL STRUCTURE

The present organisational structure is suitable for the kind of border war expected in the future till the time when either the borders become irrelevant or the problem is resolved amicably. The IAF may consider change from geographical commands to functional commands in case the basing policy, as suggested earlier, is implemented and the likelihood of border wars has receded. There is an urgent need to form an Aerospace Command and Air Defence Command with the induction of space-based systems and increased responsibility for air defence against ballistic missile threats and cruise missiles.

AFFORDABILITY

Defence budget allocation reached a low of less than 2 percent of the gross domestic product (GDP) in 2007-08. This is definitely not enough and a correction is essential. The suggestions made in the paper are long-term directions and mainly concern developing indigenous technologies. During this period of economic slowdown, investment into design and development of technology will draw huge benefits later on. This is the time to set upon a path to become an exporter of high technology and arms rather than depend on import which indirectly supports the foreign defence industry. The ownership of technological innovations, whether through DRDO, PSUs, public-private partnership should be with the defence forces and the return on investment should be directly linked with the amount invested by the individual organisations. What is important is not the amount expended but the accountability of each one of us to get the most out of the buck. Some small steps have been taken in the past towards expenditure control through base level data gathering and bringing in transparency but the scope needs to be expanded through improved connectivity and computerisation.

The IAF may consider change from geographical commands to functional commands in case the basing policy, as suggested earlier, is implemented and the likelihood of border wars has receded.

CONCLUSION

Countries in the South Asian region are undergoing major changes in their polity and India is definitely affected by it. We may not see a conventional war in our region but sub-conventional or LIC cannot be ruled out. It is essential that we calculate the requirement of a combat force, including the support elements, rather than merely the number of aircraft. But the one thing that is certain is that the IAF has to maintain the asymmetry in both numbers and technological capability and must apply the appropriate fighting strategy during operations. Major acquisitions are in the pipeline and, hence, the IAF inventory will look very different in the future. More emphasis is being laid on acquisition of combat support systems as force multipliers but we must develop the technology which we need to fight the next war and not have to fight it with whatever is made available to us. The IAF needs to guide development of technology as a stakeholder, and interoperability with the other Services has to be built in. The IAF can make do with small aircraft with limited capability for border wars but has to have larger swing role aircraft, with greater reach and varied payload for meeting the regional and global commitments in the future. Development of space-based assets and capability to thwart ballistics missile attacks will be essential in the future, considering the direction taken by our potential adversaries.

ANALYSIS AND ASSESSMENT OF MILITARY-OPERATIONAL REQUIREMENT FOR AWACS IN IAF

A.B.S. CHAUDHRY

The ability to detect an enemy target, identify, intercept and destroy it, before the enemy does the same to you, has been a conundrum that has challenged military commanders for centuries. Whilst, within the air environment, airborne early warning (AEW) and airborne warning and control system (AWACS) aircraft are now simplifying this problem, it must be emphasised that the use of the third dimension for surveillance and control is nothing new.

The use of balloons for military operations goes back to the earliest days of flight; and airships and aerostats have, historically, also been used for military surveillance purposes. The use of radar by the Royal Air Force during the Battle of Britain was a vital component that led to the eventual defeat of the Luftwaffe, and subsequently, it was not long before man was designing radars that could be operated in an aircraft, thereby increasing the detection ranges. With the advent of ever improving technologies,

AWACS aircraft are now able to gather and present real-time information to numerous air and ground assets within the battlespace, and provide autonomous control over a wide gambit of missions.

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this airborne radar concept has so evolved over recent decades that AWACS aircraft are now able to gather and present real-time information to numerous air and ground assets within the battlespace, and provide autonomous control over a wide gambit of missions being undertaken within their area of responsibility.

The AEW systems have been employed in a variety of roles over the entire spectrum of the national security paradigm. The main areas of employment could broadly be categorised as:

- Political power projection, coercive/AWACS diplomacy and in support of allies and friendly nations.
- Strategic use of AWACS for implementation of pacts, accords and sanctions. For example, peace enforcement, implementation of no fly zones, sanitisation, regulation or monitoring the air space in support of national security requirements and friendly forces.
- Conduct of direct military operations as command and control and battlefield management platforms to perform the functions of air defence and air combat support platforms for offensive air operations and in support of maritime operations.
- In support of civil administration and armed / paramilitary forces in times of natural calamities and disaster management, anti-terrorism and anti-drug operations.

Starting from an elementary early warning platform for naval forces, the operational needs of AEW systems have continued to grow with the passage of time and their employment in wide ranging roles have engendered capabilities ranging from tactical control of combat aircraft to electronic intelligence, electronic warfare, air traffic management and battlefield management. The current generations of AEW systems are being further upgraded to improve the quality of radars, communications, computing speeds and data management to improve their efficiency as command and control platforms. At this juncture, it would be of relevance to broadly compare the development of these systems and their capabilities.

COMPARISON BETWEEN AEW/AEW&C/AWACS

AEW and AEW&C

Having been convinced of the huge potential of the radar system during World War II, there was a desire to look deeper to detect the incoming enemy. To overcome the limitations of ground-based radars and under the threat of *kamikaze* attacks, the US Navy embarked on a programme to expand the radar horizon by carrying it aloft in an aircraft. Under Project Cadillac in 1944, a TBM Avenger bomber was modified with the AN/APS-20 radar which proved successful in detecting targets over 150 km away. This was the beginning of the AEW. The Avenger was purely an AEW radar aircraft, as the aircraft had a crew of only a one pilot and one radar operator. All control functions were conducted on surface ships, with radar data transmitted via a data link which gave the video image and radar antenna angle, to enable a tactical picture to be developed in the Combat Information Centre (CIC)[1].

The early AEW systems were developed for localised requirements of individual Services. These were smaller systems, with limited range, and did not have any onboard control capability. The data was relayed to a ground/ship-based control station which further controlled the situation. These AEW systems consisted of naval systems like the Oko Eye on Kamov and Searchwater radars on Sea King helicopters.

Buoyed by the success, ambitions grew and Project Cadillac-II was started under which a B-17 bomber was converted to a naval version PB-1W flying command centre, having a number of operators. This can be assumed to be the beginning of airborne early warning and control (AEW&C) systems. Continuous improvements through the 1950s and 1960s saw numerous platforms performing the role of 'eyes and ears' in the air, prominent amongst these being the EC-121 which made history in 1967 by guiding the first successful airborne interception over North Vietnam.

The E-2 Hawkeye was the first carrier-based aircraft designed from the outset for the AEW&C function. Since replacing the E-1 Tracer in 1964, the

1. http://www.globalsecurity.org/military/systems/aircraft/aew.htm

Hawkeye underwent a number of upgrades to emerge as the most widely used AEW&C aircraft in the world today.

Limitations

- Despite the advantages, there are some inherent disadvantages in these aircraft. There is a certain amount of space limitation, which, in turn, limits the number of control stations onboard the aircraft, as also the number of aircrew and operational crew. There are also some limitations on data handling capacity in terms of number of tracks and number of simultaneous interceptions/recoveries.
- The aircraft may not have aerial refuelling which limits their endurance to between four to six hours.
- Examples include the Hawkeye, ERJ-145, SAAB-2000, etc.

AWACS

Realising the immense potential of the AEW&C concept, efforts were directed towards performance and role enhancement by the US Air Force which wanted a system with a completely independent onboard battle management capability with a large footprint. The need emerged from a desire to provide effective air defence (AD) against anticipated low level bomber raids and to have effective command and control (C2) in a tactical environment. This was the beginning of the AWACS programme demanding longer endurance, enhanced radar range and, importantly, the ability to track a greater number of targets.

The US AWACS programme began on December 22, 1965, with the establishment of an AWACS System Programme Office by the Air Force Systems Command. The Boeing Company was selected as the prime contractor, after beating McDonnell-Douglas and Lockheed, pitting its 707 against the Lockheed EC-121 and the McDonnell-Douglas DC-8. The company flew the first test airframe in February 1972, and in early 1973, the US Air Force authorised full-scale development of the E-3 Sentry[2]. Some of the other

2. http://www.globalsecurity.org/military/systems/aircraft/e-3.htm

AEW&C & AWACS developed over the years are the Russian TU-126 Moss and A-50 Mainstay, the British Nimrod, the Israeli Phalcon and the Swedish SAAB 340 with the Erieye system.

An AWACS is capable of providing all-weather surveillance, command, control and communications.

Capabilities

An AWACS is capable of providing all-weather surveillance, command, control and communications. A typical AWACS radar has a range of 320 km for low flying targets which goes up to 450 km at higher altitudes. Combined with an IFF sub-system, it is capable of identifying and tracking a large number of threats while simultaneously controlling friendly aircraft. The AWACS contains a secure and jam-proof communication suite with a message priority system, thereby, reducing information overload. The electronic support measures (ESM) capability covers a wide band of frequencies which can be classified and compared with the available threat library. A contingent of up to 20 console operators performs surveillance, communication, identification, airborne control and battle management functions[3].

An AWACS has an endurance of approximately eight hours in mission profile which translates into an on station time of six to seven hours at a distance of about 1,000 km from the launching base. This can be further enhanced with air-to-air refuelling (AAR).

Advantages

A true force multiplier, an AWACS presents numerous advantages. It is a larger platform and has adequate space for the payload and the crew. It has higher endurance with aerial refuelling capability, which further increases its flying time.

The AWACS has a 360 degrees radar scan and a choice to select more than one mode of operation in sectors during a scan. It has an increased radar horizon and capacity to detect over 600 targets while directing up to 30 interceptors simultaneously. This makes an AWACS crucial in the campaign for

3. http://www.fas.org/man/dod-101/sys/ac/e-3.htm

control of air. It has an extensive communication network of HF, VHF, UHF and data links through LOS and SATCOM. The efficient data handling systems provide larger track handling capacity (1,000 or more tracks), and 15-16 simultaneous interceptions / recoveries.

Though becoming increasingly indispensable in any air battle, cost and vulnerability remain two of the main limitations of an AWACS.

It also has an adequate electronic warfare suite: electronic counter-measures (ECM) and electronic counter-counter-measures (ECCM) circuits, signals intelligence (SIGINT) systems, onboard detection, collation, analysis and dissemination or real-time relay to ground stations.

It is a flexible and versatile platform with a potential to project combat support and surveillance functions into a theatre worldwide within 24 hours. In conjunction with other AWACS or singularly, it can be employed in strategic, operational or tactical roles. By anticipating the threat in advance, it can retrograde inside own territory only to reemerge once the threat has subsided. In effect, it is able to channelise the enemy's effort into a theatre of own choosing.

Limitations

Though becoming increasingly indispensable in any air battle, cost and vulnerability remain two of the main limitations of an AWACS. With each unit costing up to $ 500 million and considering the number of units required for effective utilisation, its cost remains prohibitive for many countries.

A strategic asset, an AWACS is also one of the most lucrative targets whether on the ground or in the air, and needs to be protected adequately at all times. While the communication systems of an AWACS are true over the horizon or satellite capable, the radar, IFF and ESM sensors are limited by radar horizon affecting their range, especially in the case of intervening high terrain. Additionally, there is a cone of blind zone below and above the platform which can be exploited.

OPERATIONAL ROLES FOR AWACS

The flexibility of role and employment of AWACS has blurred the line between the strategic role and operational utilisation. An AWACS not only addresses the line of sight constraints of ground-based radars, it extends an airborne command and control station with long range communication facility in support of national air power. "Radar had the effect of forcing air operations down to lower levels to stay below the radar horizon and, thus, evade detection… an airborne platform, thereby, nullifying the benefits of a low-level approach has been perhaps, the single, greatest force-multiplier in air operations."[4] The impact of AWACS on air operations is explained in the subsequent paragraphs.

- **Radar Cover and Tactical Control of Offensive Missions:** Radar cover of ground-based radars is restricted by line of sight and consequently the ability to pickup low-level targets flying at 100 metres (300 ft) is restricted to 45-50 km, whereas a single AWACS provides a seamless low and medium level cover up to 400 km or more. Flying at 30,000 ft, and approximately 100-150 km inside own territory, an AWACS will provide 250 km of early warning and control capability in enemy territory for six to eight hours. This assumes greater significance in the case of a non-conventional strike, where an AWACS would provide positive cover and control, to ensure that such a mission goes through unhindered.
- **Strike Control:** One of the biggest advantage of the airborne radar platform is the ability to provide extended tail cover; warn and control own strike missions in the adversary's territory, which hitherto was not possible owing to line of sight constraints of ground-based radars. Under positive radar cover, friendly strike missions can fly at medium levels, thus, avoiding the

The flexibility of role and employment of AWACS has blurred the line between the strategic role and operational utilisation.

4. Squadron Leader Ajai Singh, "The Air War with AWACS Symmetry," *The Indian Defence Review*, © 1995 by Lancer Publishers & Distributors, downloaded www.bharat-rakshak.com/LANCER/index.html

three tier low-level radar cover of mobile pulse doppler radars (MPDR) which are restricted to 4.5 km (15,000 ft) in elevation coverage, and also be safe from en-route short range air defence systems (SHORADS) deployed in the tactical battle area (TBA) which have a slant range of 2.5 to 3 km (8,000 to 10,000 ft).

- **Air Battle Management and Target Designation:** AWACS execute the air battle management in real-time in coordination with ground-based/ship-borne air defence systems, multi-role air superiority fighters (MRASFs), a combination of electronic warfare and strike aircraft, and other combat air support operations like aerial refuelling. This provides it the capability to do real-time allocation and reallocation of weapon systems against enemy assets. In April 1996, rebel Chechen President Dudayev was assassinated with the help of a Russian A-50 AWACS operating over Chechnya. Capable of monitoring communication frequencies, an A-50 located the president's cellular phone frequency and the target data was relayed to a Su-25 ground attack aircraft armed with laser and TV guided bombs, which attacked the precise location to complete the mission.[5] The incident is a classic example of exploiting the system capability for real-time target allocation and shrinking the sensor to shooter loop to achieve the objectives with minimal force and time.
- **Low Level Ingress:** Low level ingress by strike aircraft is aimed at avoiding detection and giving minimal reaction time to the adversary. The gap free low level radar cover extending 250 km or more inside the adversary's territory would afford instant detection, greater reaction time and swift offensive action by fighter sweep, free escorts or tied escorts. Pakistan's lack of geographical depth would place all her main and satellite airfields within the detection ranges of Indian AWACS.
- **Defence in Depth:** AWACS would assist in early detection and interception, maintain continuity in application of firepower and afford opportunity for multiple interceptions, thus, imposing greater attrition

5. Timothy L. Thomas, "Air Operations in Low Intensity Conflict: A Case of Chechnya," *Airpower Journal*, Winter 1997, p.54.

and providing the classical defence in depth. Enhanced early warning and gap free radar cover would facilitate the area defence concept which affords optimal exploitation of speed, mobility, flexibility and firepower of fighter aircraft and greater freedom of action for terminal weapons deployed at vital areas/vital points (VA/VPs).

- **Air Space Management over TBA:** The problem of air space management emanates from delayed/no detection and identification of tracks, very little reaction time and unreliable chain of communication. AWACS with onboard long range HF/VHF/UHF RT and large detection ranges could perform the function of battlefield management. Detection ranges beyond horizon, early radio contact, medium level approach and timely communication give options of exercising positive control over AD weapons in the TBA, maximising their freedom of action and reducing the chances of fratricide.
- **Electronic Intelligence:** The SIGINT system on board AWACS can receive, analyse and locate radar and communication frequencies at ranges much greater than the radar range of 400 km. This would supplement the existing intelligence infrastructure. The enemy's electronic order of battle (ORBAT) can be updated for planning of air operations.
- **Air Intelligence:** Monitoring and analysing the adversary's air activity is an ongoing process during peace and during operations. Information on the adversary's capabilities and analysis of such information during flying training and known periods of air exercises would give a good insight into the enemy's tactics and capabilities. An AWACS can monitor air activity deep inside enemy territory and help in forming definite patterns of tactics and manoeuvres practised by the adversary.

INTEGRATION WITH EXISTING AD NETWORK

For any gainful exploitation of the AWACS, AEW&C or other such systems, it is extremely important that they are integrated into the existing AD infrastructure. The surface-based air defence radars which rely on short wavelengths for detection are limited to radar horizon and, therefore,

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oblivious to aircraft beyond the horizon. Even with careful deployment of the radars on mountaintops, the time between fast enemy aircraft/missiles being sighted and weapons being released is too little for effective engagement. These radars are ground-based, and, therefore, vulnerable to enemy attack. Also, the present ground-based system has a very poor low altitude capability.

These problems of vulnerability and lack of adequate low altitude detection can be addressed by the integration of AWACS, AEW&C and aerostats into the existing AD infrastructure. The net result of such integration will be a flexible and highly survivable air defence command and control system with long-range radar coverage at all altitudes over all terrain.

For effective integration of these high value air assets, the first and foremost requirement is that of networking. At the most fundamental level, networking aims to provide a mechanism to rapidly gather and distribute targeting information. A high speed network permits error free transmission in a fraction of the time required for voice transmission, and it also permits data transfer of a wide range of formats. AD involves an interactive decision-making process throughout the battlespace. Therefore, networking of ground-based sensors with the airborne sensors and the processing of data from these sources in order to generate a comprehensive air picture is a vital aspect.

A modern, well-integrated AD system requires a central AD organisation connected to regional and sub-regional control nodes which, in turn, are linked to air bases, missile command posts, autonomous AD zones, and ground-based sensors. This ground network, in turn, has to be dynamically linked to the AEW assets. Such a network will improve the operational tempo by accelerating the observe-orient phases of the observe, orient, decide, act (OODA) loop.

In parallel, data linking between the AEW assets and the combat aircraft is equally important. The Russian A-50 AWACS, for example, has a two-way data link communication with MiG-31 fighters which enables the A-50 to take radar information from the fighters and add it to its own picture, thus, making it possible to cover a much greater area.

For optimum utilisation of the AEW assets, they must also be integrated with the air defence elements of the army and navy.

The second prerequisite for effective integration is to ensure the availability of a reliable, robust and secure communications network. The AWACS would require a very large bandwidth to cater to the huge volume of information and imagery being exchanged. Narrow-band, dedicated point-to-point links need to give way to secure broadband data-links capable of handling large volumes of voice, data and video signals.

The third requirement for successful integration is that of automation. The quality of decisions that emanate at various levels of a networked system depend directly upon the quality of the air picture, and while a comprehensive air picture remains the most essential tool for making decisions, automation remarkably enhances the decision-making process by providing a host of decision support tools for mission planning, threat prioritisation, weapon selection and threat engagement.

For optimum utilisation of the AEW assets, they must also be integrated with the air defence elements of the army and navy. Integrating with the other Services would require automatic data transfer links among the army, navy and air force which will necessitate the development of an integrated command and control system like the integrated air command control system (IACCS). The IACCS integrates with ground-based/aerostat radars, unmanned aerial vehicles (UAVs), communication links (HF, V/UHF, and SATCOM); and the entire gamut could provide a fused data link to fighters on operational data link (ODL). With the implementation of such a system, the integrated real-time air situation picture of the associated area will be available on the joint network.

EMPLOYMENT IN INDIAN CONTEXT

It is now time to consider the employment of these platforms in the Indian subcontinent. The wars of future on the subcontinent are likely to be different. India has been fighting a limited war for the past 25 years, that too under the nuclear overhang. With the northern and western boundaries occupied by nuclear powers, as well as forces which have near parity in numbers, it can be surmised that long drawn, conventional wars are unlikely. Also, there would be near parity and symmetry in technology. Our future conflicts, in all probability, would be of short duration because of a possible third party or international intervention. The territorial wars would be fought not with the aim of occupying territory, but as a tool for strategic coercion. The conflicts would be spread over a limited area in which permanent territorial occupation or shifting of borders would not be the major objective, except when the Line of Control (LoC) or the Line of Actual Control (LAC) is contested.

With a landmass of subcontinental proportions, India occupies a predominant strategic position in Southern Asia and dominates the northern Indian Ocean with a coastline of 7,516 km and a total of 1,197 island territories in the Bay of Bengal and the Arabian Sea. India has an exclusive economic zone (EEZ) of 2.01 million sq km; 90 per cent by volume and 77 per cent of total value of India's trade comes from the seas. The resource rich EEZ provides 68 per cent of its oil production and fish production of 2.82 million tonnes. In addition, the entire import of oil and gas comes by the sea. India's economy, and, therefore, its development, is crucially dependent on the sea on account of the critical role of maritime trade as well as oil and gas, fisheries and other mineral resources[6]. India's land borders exceed 15,000 km which it shares with seven countries, including a small segment with Afghanistan (106 km) in northern Jammu and Kashmir[7] (J&K).

The AWACS would need to be employed over specific sectors and specified time-frames for conduct of operations in that area.

6. http://india.gov.in/sectors/defence/indian_navy.php
7. Brig Gurmeet Kanwal, "India's Borders," accessed through http://www.indiandefencereview.com/?p=379

Due to the close proximity of both the eastern and western borders, the AWACS over the hilly terrain in the J&K region would be under threat from enemy aircraft.

The topography along these borders dictates that the Indian Air Force (IAF) deploys its early warning sensors in coordination with those of the Indian Army and ship-based sensors and aircraft of the Indian Navy. The extended territorial borders in the west, north and the northeast and a very limited availability of aerostats and AWACS mean that obtaining a gap free radar cover would still be the responsibility of our ground-based radars. The AWACS would need to be employed over specific sectors and specified time-frames for conduct of operations in that area. This would mean that full utilisation of the offensive capabilities with the help of these platforms would be restricted to some extent in time and space, unless India procures copious assets.

Here, it would be worthwhile to see the peculiarities of terrain in our country. The terrain along the northern border and in the northeast is primarily mountainous, with prevalence of strong winds at mid and high altitudes. An enemy attack on the airfields or any other vital installation would face the constraints of terrain and altitude of the launching bases. However, the aircraft in the Tibetan region have the capability to reach the targets deep inside our territory. Also, a hostile presence near Coco Islands in the northern Bay of Bengal can create an effective air threat in the eastern theatre. Though the performance of ground-based radars would be limited in this mountainous terrain, the need for medium and high level coverage is being met by these sensors. Due to strong winds, tethered aerostats may be difficult to deploy in this region. Once again, here the AWACS would have to be used to enhance the coverage over a specific sector for limited duration.

The terrain along the western border comprises desert in Rajasthan, fertile plains in Punjab and mountains in J&K. The performance of the ground-based radars in these areas is good and achieving a gap-free radar cover is considered a reality.

The AWACS will be the ideal platform for providing cover and support to an Indian force involved in operations beyond our geographical borders.

Due to the close proximity of both the eastern and western borders, the AWACS over the hilly terrain in the J&K region would be under threat from enemy aircraft. This would entail ensuring an adequate degree of control of air for its safe employment over this region.

In the south, India's maritime interests lie right from Persian Gulf to Malacca Strait. There is a rising western interest in this sea line of communication (SLOC)and increased Chinese presence in the Bay of Bengal. The IAF would have to share the responsibility of defending the coastal and offshore resources and island territories along with the Indian Navy. The navy's proposed induction of the AEW&C aircraft, along with the IAF's AWACS, would play a significant role in the joint effort.

We would employ AWACS effectively to provide early warning for protection of our VAs and VPs on the coasts, such as the nuclear reactors or Bombay High. As and when the air force or the navy acquires more of them, these systems can be deployed to provide early warning to the island territories, to protect our assets deployed on them, to safeguard our SLOCs, such as the Malacca Strait.

The AWACS will be the ideal platform for providing cover and support to an Indian force involved in operations beyond our geographical borders. A naval effort to achieve control of the sea can be very well complemented by the Su-30s of the air force and MiG-29s of the navy, if coordinated by an AWACS platform. The sinking of a pirate mother ship by the INS *Tabar* off the Gulf of Aden in mid-November 2008 is a case in point. For similar operations in the future, an AWACS, along with a couple of fighters, would be able to respond faster to such a contingency. Naval ships may also not need to escort merchant ships in pirate infested waters – the AWACS could provide radar cover and monitor the area and direct the fighters as and when a contingency developed. The Indian Air Force must coordinate its AWACS effort with the AEW&C platform of the Indian Navy, when it is inducted, for an optimum time-sharing solution.

PRIORITISATION ON THE BASIS OF SECTORAL APPROACH

Threat Perceptions

The security challenges facing India are varied and complex. The country faces a series of low intensity conflicts characterised by tribal, ethnic and left wing movements and ideologies as also the proxy war conducted by Pakistan and various radical *jehadi* outfits through the instrumentality of terrorism. India is also affected by the trafficking in drugs and proliferation of small arms and the fact that it is surrounded by two neighbours with nuclear weapons and missiles and a history of past aggressions and war[8].

External security threats come from neighbouring countries and insurgents using foreign border areas as havens for activities in India. Countries such as Bangladesh, Bhutan, and Sri Lanka present no conventional military threat to India, but their inability to police and control areas bordering India has provided Indian insurgents with havens. Indian government and military officials have publicly expressed concern about the political instability in Nepal posed by the Maoist insurgents.

As far as external threats posed by other countries are concerned, popular opinion tends to regard Pakistan as the principal enemy, largely because of the Kashmir conflict and Pakistan's suspected links to numerous South Asian militant groups. Training camps for anti-India terrorists are mushrooming in Pakistan Occupied Kashmir (PoK) where they enjoy a safe sanctuary. The Pakistani government has not done anything to destroy these camps, and has at times even denied the existence of such infrastructure on its soil.

Besides Pakistan on our western border, the next decade and after, the increasing bonhomie between Pakistan and China may also bring in new areas of conflict between India and China. The border dispute between the two countries has its origin in the Chinese claim that the boundary drawn in Indian maps cuts deep into Chinese territory. This includes about 14,500 sq miles occupied in the western sector in 1962—Aksai Chin, some areas of Himachal Pradesh and Uttar Pradesh and the whole of Arunachal Pradesh.

8. http://mod.nic.in/aforces, accessed on November 18, 2008.

Based on the employment philosophy and the threat perceptions, it becomes imperative to draw out a prioritisation for the deployment and use of AWACS.

India is fast coming up as a nuclear and economic power. Financial power is a precursor to political power and global clout. As has happened throughout history, political posturing will be followed by military tension. Thus, any long-term planning for our AD should tackle China as a very probable adversary. This is all the more likely considering that country's close ties with Pakistan. China has been developing its infrastructure in Tibet and has, besides developing the roads, major operational airfields capable of undertaking all types of aircraft operations. The nuclearisation, militarisation and modernisation of Tibet by China, with missiles aimed at India, is certainly not for friendship. Aksai-Chin also gets China in contact with Pakistan. The Karakoram Highway, passing through parts of PoK, links China with Pakistan. It has been giving active support to Pakistan's nuclear programme, besides helping it with missile technology. Chinese arms have been found in Punjab, Kashmir Valley and the Northeast region—making it almost clear that part of the help to militants in these regions comes from China, directly or indirectly. Besides this, there are reports that China is developing the Coco Islands, a Myanmar territory very close to Andaman and Nicobar Islands in the Indian Ocean, as a naval base[9]. Myanmar remains an area of security interest for India not only on account of the activities of the northeastern insurgent groups that have set up camps across the Indian border, but also because of the activities of countries working against India's legitimate security concerns and the repercussions of the tussle between the forces of democracy and military government on these interests[10]. It will be relevant to mention that Myanmar is rather anti-India, owing to India's stance on the pro-democracy movement in that country.

The whole scenario needs many possibilities to work out, and many of the suppositions, even if they work out to a lesser degree, can result in grave

9. http://en.wikipedia.org/wiki/Coco_Islands
10. http://mod.nic.in/aforces, accessed on November 18, 2008.

implications for India. The wise always plan for the future keeping in mind the past. And the past track record of the players involved in this game is not very positive. India, therefore, must take steps to lay out the basics of what it requires to counter such contingencies. With the acquisition of AWACS and aerostats, a step is being taken in the right direction. By planning for China, the AD network will become truly proactive.

Based on the employment philosophy and the threat perceptions, it becomes imperative to draw out a prioritisation for the deployment and use of AWACS. The prioritisation on the basis of the sectoral approach to the total geographical area of coverage and depth of coverage, both within and outside the Indian territorial region, will not remain static and this prioritisation would have to be reviewed periodically. In the prevailing geo-strategic conditions, which may continue for another decade or more, the sectoral priorities would remain as follows:

Priority One

- In the west, J&K and Punjab with peripheral Rajasthan would remain as high priority.
- The entire area would need overlapping radar cover from low to high altitude.
- Considering the length and depth of the area and the past experiences of wars, there would be a requirement to use AWACS in this region.

Priority Two

- The northeastern region, especially Arunachal and Assam, and the Indian territorial region adjacent to Tibet Autonomous Region (TAR) and Ladakh would come at the second priority. This area also includes peripheral coverage of Bangladesh.
- The region's growing importance in India's security precepts may also put it at priority one in the coming years.
- AWACS may not be very effective in mountainous terrain, but still, will give better radar cover and early warning as compared to ground-based systems and aerostats. AWACS effectiveness could be increased if it is complemented by UAV-borne AEW systems and ground-based systems.

Priority Three

Growth in trade and economy, the importance of securing the SLOCs in view of the growing energy crisis, the importance of maintaining friendly relations with neighbouring countries in the Indian Ocean region, the growing influence of China's naval power and modernisation of Pakistan's navy—together these factors make the Indian Ocean very vulnerable to hostile activities. It, thus, emerges as a third front which needs continuous surveillance and enhanced security coverage in the 21st century. This would ensure security of our SLOCs, EEZ, offshore drilling and mining assets and our island territories.

VULNERABILITY OF AWACS

AWACS being a force multiplier would tilt the balance in the favour of the country operating this aerial platform. Hence, AWACS busting would be the primary aim of any adversary, particularly so when both countries have AWACS in their forces. This would lead to asymmetry, which, in turn, will be decisive for a war.

- The main vulnerability of an AWACS is that the platform is required to fly at medium/high level, thus, increasing its chances of detection by enemy medium/high looking radars.
- The AWACS platform, because of it being a high value target, and the associated infrastructure would be highly vulnerable to action by enemy strikes, saboteurs and infiltrators.
- The increasing number of long range surface-to-air missiles (SAMs), like the S-300 variants with 150 to 200 km range, S-400 with a range of 400 km[11], beyond visual range (BVR) air-to-air missiles (AAMs) like the Russian Novotor KS-172 AAM with a range of 400 km[12] and the advent of the long range surface-to-air, Chinese anti-radiation missile FT-2000 has further bolstered the case for engagement of AWACS. The possibility of AWACS engagement by these systems cannot be totally ignored.

11. http://www.deagel.com/Surface-to-Air-Missiles/S-400-anti-AWACS-missile_a000990001.aspx, accessed on November 26, 2008.
12. http://en.wikipedia.org/wiki/Novator_KS-172_AAM-L, accessed on November 26, 2008.

AWACS being a force multiplier would tilt the balance in the favour of the country operating this aerial platform. Hence, AWACS busting would be the primary aim of any adversary.

These vulnerability issues are a matter of discussion but do not seem to be a cause for worry for the time being. An air strike on AWACS is a difficult proposition, as the strike would be picked up well in time to enable evasion by AWACS or for timely reaction by the AD weapon systems. Moreover, the AWACS aircraft which are deployed at 150 km or more from the border, while flying away from the strike, would remain out of the reach of these airborne threats.

Also, one has to keep in mind that systems like the E-3C, Phalcon and A-50 have ESM platforms which can detect radar and radio transmissions from ranges larger than that of radar. Such radar and radio transmissions could be analysed to identify an emanating threat and this warning of 250 km is adequate to scramble or divert airborne fighters to engage the threat. As the threat closes in, AWACS would continue to retreat while guiding own fighters or it may hand over the interception to the aerostat or ground-based system in the case of the medium level approach.

Positioning the aircraft deep inside our territory and physical security in terms of hardened aircraft shelters, camouflage and concealment would provide some protection against saboteurs and ground infiltrators.

The possibility of AWACS engagement by missile systems cannot be totally ignored, however, the probability needs to be analysed against the following factors:

- S-300 / S-400 SAMs are mobile and heavy missile systems that are likely to be deployed in depth for defending strategic assets against aircraft and missile attacks and their launch against AWACS flying 130 km or more inside own territory is a possibility with low probability.
- BVR AAMs are the most potent weapons that could be used against AWACS, therefore, protection by air defence fighters equipped with BVR missiles at least 100 km ahead of AWACS becomes vital. The AWACS itself will provide early warning and combat support.
- The FT-2000 has a range of 100-120 km which means that the AWACS should

be flying within that range for it to successfully engage it, whereas the AWACS will operate at a distance of 150 km or more from the missile deployment location. It is a passive radar homing missile, therefore, what would be the impact of switching off the radar or activation of ECM after the missile has been launched is not known. The system has not been tested for its efficacy.

CONCLUSION

In modern air warfare, AWACS emerges as a most potent force multiplier which could easily tilt the balance in favour of an AWACS operator. Strategically and operationally, AWACS provides a decisive edge to air operations and air defence operations in particular. It provides the quantum jump in detection and control capability. The most outstanding feature of this platform is the reach and flexibility that it provides. As an air surveillance, command and control platform, it may be operated anywhere in the area of interest.

So vast is the asymmetry provided by AWACS in war-fighting that no air battle has been lost till now by the side that employed AWACS. With AWACS available only to one side in a conflict, a situation of asymmetry will prevail, leaving little or no chance for the have-nots to stake a claim for air space control. With the capability existing on both sides, although the system's usefulness would not diminish, its potential to shape the air battle by itself may reduce when faced with another AWACS across the border. In such a situation, the methodology of fighting an air war could see a change wherein air-to-air warfare would be the prime instrument of gaining air superiority while air battles could tend to be conducted at medium altitudes. The air battle with both sides having AWACS capability would be highly intense and crucial to the overall outcome for the struggle for air space control. It is in this context that it must be understood that to exploit the AWACS fully, we should aim to create a situation of asymmetry at the earliest by neutralising or destroying the enemy AWACS. The side that can achieve this would be better placed to gain air superiority and ultimately affect battles in the other dimensions as well.

So vast is the asymmetry provided by AWACS in war-fighting that no air battle has been lost till now by the side that employed AWACS.

CHINA'S SPACE POWER

SRIKANTH KONDAPALLI

How can we be counted a power? We cannot even deliver a potato into space.

– Mao Zedong responding on the news of
Yuri Gagarin's first space flight in 1961.

Along with the unfolding of the space arms race, world and regional big powers cannot help but select options that are in their own self-interest when faced squarely with harsh situations. This will inevitably give rise to new mistrust and scepticism. Before the old problems are resolved, new ones will crop up. This will inevitably add new, unsafe, and uncertain factors to regional relations and state-to-state relations. With the passing of time, such negative influences will become more salient.[1]

One of the motives behind the development in China's space programme, albeit generally not mentioned explicitly, is for military usage.

"Shenzhou IV" spacecraft [launch] is bound to boost our nation's aspirations, our country's prestige, and our armed forces' might. Our entire nation is

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1. "Call for International Treaty 'Banning' Space Weapons," *Liberation Army Daily*, June 13, 2001, at FBIS-CHI-2001-0613, June 15, 2001.

> proud of, and elated by, it…. The launch also indicates that China's manned space flight technology has matured day in and day out, while China's comprehensive national strength, scientific and technological strength included, has grown by a large margin.
>
> — Chinese leader Li Peng, summing up the spacecraft launch on December 30, 2002.[2]

Several events in the recent past have indicated towards a growth in China's aerospace power. Apart from significant achievements in launching satellites, manned spacecraft and lunar probe missions, China conducted the space walk recently. The 7th Zhuhai Air show, an aviation and aerospace exhibition held in early November 2008, that is conducted on alternate years, displayed China's prowess in this field as well as providing for business deals in these wares. While several of these appeared to be for scientific and civilian use, the following highlights the military dimension of China's aerospace efforts.

Indeed, one of the motives behind the development in China's space programme, albeit generally not mentioned explicitly, is for military usage.[3] China views its space programme, as do many countries, for civil-military dual-use purposes and, hence, in an organic whole to serve its national interests. The three main aspects of the Chinese space programme –satellites, spacecraft and moon probe – all have varying degrees of military usage. [4] In fact, in all these programmes, military applications like information and combat support are significant, although the Chinese tend to keep this aspect

2. Li, cited by Cao Zhi, Tian Zhaoyun, and Xu Zhuangzhi, "Our Country Successfully Launches 'Shenzhou IV' Spacecraft on 30 December, 2002; Li Peng, Wu Bangguo, Jia Qinglin Present at Launch Site in Jiuquan," Xinhua Domestic Service, December 29, 2002, FBIS-CHI-2002-1230, December 31, 2002.
3. For an excellent study, see James H. Hughes, "The Current Status of China's Military Space Program," *The Journal of Social, Political, and Economic Studies* (Washington), vol. 27, issue 4, Winter 2002, and Mathew Mowthorpe, *The Militarisation and Weaponisation of Space* (Lanham: Lexington Books, 2004), chapter 4, "China's Military Space Program," pp. 83-108.
4. Si Liang, "Craze for Developing and Launching Small Satellites is Arising in China," Zhongguo Tongxun She, September 6, 2001, FBIS-CHI-2001-0906, September 7, 2001.

under utmost secrecy.[5] Part of the reason is located in China's urge for protecting its national interests, or probably a contest, in the face of challenges from the advanced Western countries like the US and the European Union (EU).[6]

This factor is also related to countering the proposed ballistic missile programme (BMD) of the US and its allies in East Asia. For instance, China criticised the US for its "one-sided search for absolute advantages" in the civilian and military space programme, and the US development of missile interception in space by 2008.[7] The reported US move for space troops by the middle of the next decade is cited as a Chinese concern in this area. According to Hu Xiaodi, the Chinese envoy on disarmament at Geneva, China needs to "prevent" outer space weaponisation by other countries.[8]

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Another factor is the concern on dual-use technologies. In 1985, China started launching satellites for clients by its Long March series launch vehicles. The US imposed sanctions on China on four occasions on these launch services

5. You Ji, *The Armed Forces of China* (New York: IB Tauris, 1999), p. 84.

6. Indeed, a recent Chinese critique traces China's military efforts in space to its reaction to the US initiatives. Thus, at the organisational level, China established the China National Space Administration and Space Research Institute for enhancing coordination in these fields. Secondly, an astronaut brigade was established in the air force, and military educational institutions to enhance theoretical and practical studies on space-based operations. Thirdly, efforts were made to speed up development of laser weapons. Fourthly, experiments were carried out for the development of space planes and space stations. See "*Meiguo yichui xiangxing qiu dazhan haojiao Zhongguo hangtian shanyu yulai feng manlou*" [United States has sounded the clarion call for China's space star wars- The rising wind forbades the coming storm] November 25, 2008 at < http://www.glo123.com/?action-viewthread-tid-167658>

7. Li Heng, "China, Russia Calling for Space Arms Prohibition," *People's Daily,* December 12, 2003, in FBIS-CHI-2003-1212, December 15, 2003.

8. Hu suggested at the 58th Session of the UN General Assembly on October 21, 2003, three "cannot waits", viz., "We cannot wait until outer space weapons become a reality and cause real harm; we cannot wait until one country takes the lead in introducing weapons to outer space and spurs other countries to emulate; we cannot wait until outer space weapons proliferate before we take measures." See Chen Jian, "Chinese Representative Speaks at the United Nations: Save a Piece of Peaceful and Quiet Sky for the Future Generations," *Zhongguo Xinwen She,* October 22, 2003, in FBIS-CHI-2003-1022, October 27, 2003.

in which either these satellites or their components were made in the US.[9]

More specifically, China views space as an integrated whole, and recently, with several successes, has given importance to the "fourth combat front" [*disi zhanzheng*]. It refers to the battlefield, in addition to the traditional combat fronts on land, sea, and low-level air space, and to the outer space combat front covering the area extending from 100 km to 50,000 km above the earth's surface.[10] China has carefully studied US space war efforts in the recent period. The US positioning of satellites for the war effort has been the subject of Chinese interest. The US deployed nearly 90 military satellites in the 2003 Iraq War (as against 33 in 1991, 50 in 1999 and about 50 in the 2001 War) for uninterrupted intelligence supply.[11] This has been the subject of a critical discussion in Beijing. A "Forum on Satellites and Their Applications in the Iraq War" was convened by several Chinese aerospace organisations in which two military experts, Ai Changchun and Zhao Shaokui, discussed the value of remote sensing satellites. Another expert, Chen Shupeng, emphasised data analysis as the key feature of future work. [12] China also deployed the Beidou series of satellites to watch the US war preparations at this time.

The Chinese military utilises several satellites launched by the country. Several of the meteorological, remote-sensing, earth-observation and communications satellites have dual-use purposes. Satellite imageries received from these satellites are also meant to monitor military movements, deployments, installations across the Taiwan Strait, Japan, South China Sea, India, Central Asian Republics and other areas. China deploys satellite communication systems during most of the military exercises it conducts across the country and its periphery, specifically in the Dongshan Island

9. Zhang Qingwei, "China Explores Path for Diversified Space Development," *Liaowang*, June 2, 2003, in FBIS-CHI-2003-0616, July 31, 2003.

10. See the Editorial Committee of Inside Mainland China, *A Lexicon of Chinese Communist Terminology*, 2 vols (Taipei: Institute of Current China Studies, 1997) (Bilingual edition) [hereafter *The Lexicon*] vol.2, p. 378, for the definition.

11. Xiong Guangkai, "On Revolution in Military Affairs," in his *International Strategy and Revolution in Military Affairs* (Beijing: Qinghua University Press, 2003), pp. 167-185.

12. See "Military Satellite Application Increasingly Important," *Wen Wei Po*, April 12, 2003, FBIS-CHI-2003-0412, April 14, 2003.

exercises. China's military reconnaissance satellites keep about 350 nautical miles (nm) of territory generally under effective surveillance. For this purpose, China prefers to launch small satellites for the benefits of transforming aspects of reconnaissance, telecommunications, command, decision-making, logistics, and weapon systems in modern warfare.[13] A related factor here is Taiwan. In 2002, for instance, the Chinese Sinosat 1 satellite broadcasts were jammed, reportedly by the Falun Gong activists in Taiwan.[14] According to an unnamed person at the China Space Science and Technology Group, if Taiwan attacks Hong Kong (in the event of a war in the Taiwan Strait), China's air defence is well prepared to counter such strikes.[15]

China prefers to launch small satellites for the benefits of transforming aspects of reconnaissance, telecommunications, command, decision-making, logistics, and weapons systems in modern warfare.

One of the most explicit aspects of Chinese military issues in space is the anti-satellite (ASAT) programme.[16] Despite criticising the weaponisation of outer space, China is on the path of developing ASAT weapons to destroy the adversary's optical sensors through laser weapons.[17] The China Space Technology Research Academy, for instance, is reportedly developing an advanced ASAT weapon dubbed as a "piggy-back satellite" that attacks by attaching itself to the enemy satellite and either jams or destroys the latter.[18] Specific aspects in the ASAT programme include directed energy weapons, particle beam weapons that can engage missiles in flight and nano-satellites

13. Si Liang, "Craze for Developing and Launching Small Satellites is Arising in China," *Zhongguo Tongxun She*, September 6, 2001 FBIS-CHI-2001-0906, September 7, 2001.

14. Peter J. Brown, "Olympic-Sized Satellite Headaches," *Washington Times*, January 23, 2007, at <http://washingtontimes.com/commentary/20070122-093345-8426r.htm>

15. It is not clear which space equipment will be used by China in such an event. See "Have Hong Kong and Shanghai Become Taiwan Military's Targets of Attack?" *Zhongguo Tongxun She*, August 3, 2005, FBIS Translated Text CPP20050729000202.

16. Mowthorpe, n.3, pp. 101-102.

17. See "China Blasts Off," *Jane's Foreign Report*, October 30, 2003. According to this report, China plans to deploy such systems in 2005-2010.

18. "China is Developing Anti-Satellite Weapon as Counter-Measure," *Ming Pao*, January 30, 2001, in FBIS-CHI-2001-0130, May 2, 2001.

China is also in the process of developing micro-satellites to be placed in orbit by 2005 for disrupting the global positioning system (GPS).

for use as kinetic energy weapons for ASAT operations, etc.[19] The China Space Aviation Industrial Group, formed in 1999 as an export enterprise with Yuan 10 billion in assets, has developed the "Space Qinghua No. 1" mini-satellite and solid propellant carrier rockets. This company was named the "number one among the ten biggest military group companies for two years. Its rank in China's 100 power enterprises has risen from the 67th to 38th position."[20] According to Desmond Ball, the Shenzhou series of spaceflights, with their Yagi antennae, and other accessories, provided "substantial [and]… sustained coverage of electronic transmissions within their purview for about two-thirds of the time over the last three years." In addition, Chinese efforts in acquiring Hughes & Space Communications HS-702 satellites that provide satellite-based mobile phone facilities could be utilised for eavesdropping on about 20 Asian countries.[21]

China is also in the process of developing micro-satellites to be placed in orbit by 2005 for disrupting the global positioning system (GPS),[22] and has a programme of Changhong (CH-1), ASN-206, ASN-207 unmanned aerial vehicles (UAVs). These programmes are expected to further enhance Chinese reconnaissance and surveillance capabilities crucial for the revolution in military affairs (RMA) warfare. With such projects, China is in the process of integrating satellite GPS technologies with ground, air and sea-based military equipment for precision long-range strikes.[23]

19. See Larry M. Wortzel, "China and the Battlefield in Space," October 15, 2003, at <http://www.heritage.org/Research/AsiaandthePacific/wm346.cfm?renderforprint=1>.

20. "China Space Aviation Industrial Group Company Beefs Up Development of New Arms," *Zhongguo Xinwen She*, July 1, 2002, FBIS-CHI-2002-0701, July 16, 2002.

21. See Desmond Ball, "China Pursues Space-Based Intelligence Gathering Capabilities," *Jane's Intelligence Review*, December 1, 2003.

22. *The Strategic Balance in Northeast Asia 2002* (Seoul: Korea Research Institute for Strategy, 2002), p. 183.

23. For an excellent article on this subject, see Jacques Isnard, "Civilian and Military Rockets: China Combines Its Goals," *Le Monde* (Paris), October 16, 2003, in FBIS-CHI-2003-1016, October 21, 2003.

ASAT PROGRAMME AND TESTING

China's approach towards ASAT programmes is dualistic in nature. While critiquing other nations' efforts at such programmes as not conducive to the "peace-loving" countries' interests, China has its own ASAT programme, although nascent in nature. However, with the January 11, 2007, technology-demonstrator test, China has indicated that it is willing to engage other advanced countries in this area as well. At the beginning, when the Chinese space programme itself was involved in solving technological problems, China displayed concerns on the US and Soviet Union/Russian efforts in weaponisation of space. At this juncture, China argued that there should be a ban on outer space weaponisation. On June 6, 2001, for instance, the Chinese representative to the 44th Session of the UN Committee on the Peaceful Use of Outer Space sought an international agreement for prevention of outer space weaponisation.[24] In June 2006, at a conference on space issues at Vienna, Chinese official Tang Guoqiang repeated the plea for banning weaponisation of space.[25] At another level, China had displayed plans for several ASAT programmes. In about late 2000, it was reported that the China Space Technology Research Academy has embarked on an ASAT programme, with the ground-testing stage of a piggy-back satellite completed.[26] As noted above, other programmes include lasers, micro-satellites, electro-magnetic weapon systems and, using ground-based missile systems to destroy satellites in space. Prior to the January 2007 test, it was reported that China had fired high-power lasers at the US spy satellites in August 2006.

24. "Call for International Treaty 'Banning' Space Weapons," *Liberation Army Daily,* June 13, 2001, at FBIS-CHI-2001-0613, June 15, 2001.

25. Tang, cited by Joseph Kahn, "China Shows Assertiveness in Weapons Test," <http://www.nytimes.com/2007/01/20/world/asia/20china.html?ex=1169960400&en=abceb86fe881f10c&ei=5070&emc=eta1>, accessed on January 20, 2007.

26 "China Is Developing Anti-Satellite Weapon as a Counter-Measure," *Ming Pao* January 30, 2001, at FBIS-CHI-2001-0130, February 5, 2001. This unattributed report suggested that "once a space station or a space laser gun is locked on by the piggyback satellite, they will be immediately paralysed or destroyed." This report also suggested that the trigger for the Chinese programme is to deny the US advantage in the Taiwan Strait and "achieve a strategic balance by breaking the superpower's space monopoly and weaken the opponent's star wars capability."

The January 2007 test was the highlight of the Chinese space programme's military dimension.

The January 2007 test was the highlight of the Chinese space programme's military dimension. After twelve days of silence on the test, China officially acknowledged conducting the ASAT operation when one of its missiles destroyed an ageing 750 kg Fengyun 1C weather-forecasting satellite launched in 1999. Reportedly launched from the Xichang range in Shanxi province, an intermediate range ballistic missile (IRBM), with a kinetic interceptor destroyed the satellite at about 850 km above the earth's surface.

This test has evoked concerns among China's neighbours. It has sent shock waves in the world today because of several reasons. Nearly 200 satellites of commercial and military nature are positioned in the lower orbit. These are considered to be crucial for global navigation, communications and other purposes. The immediate impact of the Chinese test would be that of the debris on other satellites in orbit.[27] An estimated 300,000 pieces of debris of different sizes may have fallen into space as a result of the destruction of the Chinese satellite. Some large pieces have the potential of destroying other satellites. Moreover, the debris could persist in space for a long time – perhaps even for decades – as the US efforts indicated in the 1980s. If, indeed, the debris released by the recent Chinese act destroys other satellites, then the insurance rates in this sector and related fields are expected to increase phenomenally in the coming years.

Although China did not violate any international law related to outer space (such as that of 1959 or 1967 or 1979), the international outcry of concerned states such as the United States, United Kingdom, Russia, Japan, Australia and others, led it to issue a statement calling for opposing "the arming of space and military competition in space." The Chinese Foreign Ministry spokesman suggested that China had "consistently advocated the peaceful development of outer space." Further, the Foreign Ministry spokeswoman, on January 30, 2007, argued that the best way of dealing with outer space weaponisation

27. See J. Sri Raman, "Debris of Superpower Pride Endangers Peace in Space," *Truthout*, January 29, 2007.

issues is to conclude an international agreement in this regard.[28] Chinese Premier Wen Jiabao stated that the ASAT test neither threatens any country nor has it violated any international treaty; he called for an international treaty to ensure outer space peace.[29] Maj Gen Luo Yuan argued that this test is "normal" and that the US has been "over-reacting" to retain its "monopoly" in space.[30] Professor Meng Xiangqing of the Strategic Research Institute of the National Defence University suggested that the Chinese ASAT test is not aimed at the US and criticised the US Strategic Command's James Cartwright's assertion that the US should plan a nuclear counter-attack.[31] While official or military responses were muted, others have further explored the uses of the ASAT. For instance, according to Qi Faren, an expert at the Chinese Academy of Engineering and a pioneer on space technology, the Chinese ASAT technology could be directed against aircraft carriers as well.[32]

While the responses from China, Hong Kong and Singapore were relatively positive for Beijing, other quarters expressed concern. A commentary in the Singapore Press indicated that the ASAT test is a "historic event" although it has the potential to initiate an arms race between the US and China and affect Asian stability in the years to come.[33] However, the South Korean Foreign Ministry expressed concerns over the Chinese ASAT test and demanded an explanation from China.[34]

28. See Hao Yalin and Ma Wenbo, "China's Foreign Ministry Spokesman: Concluding Relevant International Legal Document is the Best Way to Prevent Arms Race in Space," *Xinhua,* January 30, 2007 at BBC.

29. "China Targets No Other Country in Outer Space Test: Premier," *Xinhua,* March 16, 2007.

30. Luo, cited by Chung Hsueh-ping, "The United States Overreacts," *Wen Wei Po,* January 24, 2007, at BBC.

31. Meng, cited by Ke Chung, "US Exaggerated China Space Threat Ridiculous," *Wen Wei Po,* April 6, 2007 at BBC.

32. "Qi Faren: Anti-Satellite Technology Can Be Used To Attack Aircraft Carrier," *Ming Pao,* March 5, 2007 at BBC. Qi reportedly made these comments while attending the Chinese People's Political Consultative Conference at Beijing.

33. "Singapore Daily Questions Asia's Stability as China Takes Arms Race into Space," *The Straits Times,* January 22, 2007 at BBC.

34. "S. Korea Concerned Over China's Anti-Satellite Weapons Test," *Yonhap* News Agency, January 21, 2007 at BBC.

One of the immediate targets of the Chinese ASAT test is Taiwan.[35] Taiwan has launched Republic of China Satellites (ROCSAT) with US help. It has also reportedly leased capability on an Israeli reconnaissance satellite. Taiwan is also dependent on the command, control, computers, communications, intelligence, surveillance, reconnaissance (C4ISR) networks in waging a future war against China if the latter were to invade the island.[36] The war could as well spill over into space. The likely Chinese target, given the importance of communications, could be the ROCSAT. It was reported that in addition to the current test with a missile, China is planning to deploy piggy-back satellites nearly 0.5 metres below the ROCSAT. These could destroy the Taiwanese satellites at a time of China's choice.[37] In addition, the cross-strait region offers one of the dense electromagnetic spectrums in the world, perhaps only after the Israeli battlefield environment. With nearly 900 aircraft deployed by both sides on each other, in addition to coastal batteries, surface and sub-surface platforms and an estimated 700 missiles, the Taiwan Strait provides for several vulnerabilities, specifically in the electro-magnetic fields. China's efforts in this regard are reportedly in the development of electro-magnetic pulse (EMP) weapons to paralyse the enemy's systems. For this, China is reportedly planning to drop a nuclear device about 40 km above the earth to paralyse the electro-magnetic spectrum.

This is the context for a drastic response from Taiwan. The Taiwan Cabinet spokesman questioned China's inconsistency between peaceful ascendancy and the ASAT test.[38] Interestingly, the Taiwanese Deputy Defence Minister, Ko Cheng-en, argued that the Chinese test came in the wake of the "two plus two meeting" between the US defence secretary and his Japanese counterpart and a meeting between the US secretary

35. "China's Satellite Killer Worries US Experts," *AFP*, January 24, 2007, at <http://www.taipeitimes.com/News/front/archives/2007/01/24/2003346080>, accessed on January 31, 2007.

36. See "A New Way to Censor CNN?," at <http://www.pekingduck.org/archives/004481.php>, accessed on, January 31, 2007.

37. Personal communication.

38. "Taiwan Cabinet Says Anti-Satellite Test Destroys China's Credibility," *Taipei Times*, January 20, 2007, at BBC.

of state and her Japanese counterpart and its import on cross-strait security issues.[39]

The United States is expected to be the country most concerned about the recent Chinese test,[40] as it is heavily dependent on the space-based communications for civil as well as military purposes. It is also involved in several experiments in militarising space. It had launched a missile from an airborne platform for the ASAT mission in 1985 and has developed lasers to block satellites in space. It has reportedly launched nearly 40-50 satellites to observe the Chinese military and other activities of concern. These satellites provide real-time reconnaissance, as indicated in the 1991 Gulf and 2003 Iraq Wars or the 1999 Kosovo and 2002 Afghan Wars. Its early warning satellites are necessary to track missile launches by an adversary and a key input in the BMD system. The GPS-guided munitions provide the US forces unprecedented accuracy in targeting the adversary. For these reasons, any paralysis of these systems through destroying its satellites would pose enormous problems to the US forces on the high seas, on land or in the air.[41] And the Chinese regard this as a crucial weakness of the US. The US National Security Council spokesman said that this test "is inconsistent with the spirit of cooperation that both countries aspire to in the civil space area."[42] Paradoxically, several US firms – like Loral

The United States is expected to be the country most concerned about the recent Chinese test, as it is heavily dependent on the space-based communications for civil as well as military purposes.

39. Mandy Wong and Deborah Kuo, "Taipei Minister Says China's Satellite Destruction Warning Over Taiwan," *Central News Agency*, February 1, 2007, at BBC.

40. See Marc Kaufman and Dafna Linzer's article on the subject in *Washington Post*, January 19, 2007; Ewen MacAskill, Michael White and Brian Whitaker, "Western Protests Flood in Over Chinese Satellite Killer," *The Guardian*, January 20, 2007, at <http://www.guardian.co.uk/china/story/0,,1994817,00.html >, accessed on January 31, 2007; Dharam Shourie, "Big Questions China's 'Killer' Missile Poses," January 22, 2007, at <http://www.rediff.com/news/2007/jan/22china.htm?zcc=rl >

41. On the naval dimension of the Chinese ASAT test, see George Friedman, "Chinese Move for Space and Sea Lane Control," *Stratfor.com*, accessed on January 31, 2007.

42. Cited at "Countdown to Space Arms Race, or a Ballistic Bargaining Chip?," January 20, 2007, at <http://www.theage.com.au/articles/2007/01/19/1169095979206.html>, accessed on January 31, 2007.

Although Russia is considered to be a "strategic partner" of China from 2001 and has launched several cooperative mechanisms with China, including in the military field, it has expressed concern over the Chinese tests.

& Hughes Inc. – have reportedly transferred satellite guidance systems, super computers and other sophisticated technologies to China in the last decade. The United States, which has an overwhelming presence in the global space industry, has expressed concern.[43]

Japan is also a concerned about the Chinese ASAT test. The RMA of Japanese forces is considered to be high, with its heavy dependence on C4ISR networks. Japan has launched four spy satellites to observe the North Korean strategic weapons programme, but possibly also include China. A month before the Chinese test, Japan reportedly launched an experimental Kiku-8 satellite. The Japanese chief Cabinet secretary said, "Regarding the use of a ballistic missile to destroy a satellite, the Japanese government is very concerned from the viewpoints of national security and peaceful use of outer space."[44]

Although Russia is considered to be a "strategic partner" of China from 2001 and has launched several cooperative mechanisms with China, including in the military field, it has expressed concern over the Chinese tests.[45] While Russian Defence Minister Sergei Ivanov brushed aside the Chinese test as a rumour, the visiting Russian President Putin said in New Delhi that the "genie" should not be let out of the bottle. Russia's main concerns are related to the possible fallout on its vast and easily not accessible Far East region to which the Chinese are reportedly immigrating in large numbers. Another concern is that several Russian satellites are in the lower orbits and

43. "The United States Will be Anxious if China is Able to put out the 'Eyes in Space,'" *Zhongguo Tongxun She,* January 20, 2007, at BBC.

44. "Japan PM Urges China to Stand by Policy of Peaceful Use of Space," *Kyodo,* January 19, 2007, at BBC.

45. See "Russia Wary of China's Anti-Satellite Capabilities," accessed from < http://www.pinr.com> on January 22, 2007; Andrei Kislyakov, "The Chinese Satellite Killer," *RIA Novosti,* January 29, 2007, at <http://www.spacedaily.com/reports/The_Chinese_Satellite_Killer_999.html >

could be intercepted, as the test indicated, relatively easily. Paradoxically, as in the case of the US, Russian scientists reportedly helped China in acquiring several military capabilities. China reportedly offered employment to several Russian scientists in the on-going intercontinental ballistic missile (ICBM) projects in the 1990s. In addition, Russia provided GLONASS facilities for China.

China's test indicated that it can destroy the one and only military satellite that India possesses at the moment – thus, putting at risk India's military networks.

China's test indicated that it can destroy the one and only military satellite that India possesses at the moment – thus, putting at risk India's military networks. The Defence Research and Development Organisation (DRDO) chief has said that the test is a "matter of concern" but India is unlikely to test its own ASAT for the moment. However, an arms race in space is likely between the two countries in the longer run. The announcement by the Indian Air Force chief on establishing an Aerospace Command can be seen as a move in this direction. M. Natarajan, scientific advisor to the Indian defence minister, has stated that the Chinese ASAT test is a matter of concern for India, specifically in areas of GPS, navigation and military applications.[46] The Indian Space Research Organisation chief Madhavan Nair was more forthright in condemning the Chinese tests. He said: "They [China] should not have done this as it goes against international convention. In any case, no one is supposed to weaponise outer space. India should exert pressure on Beijing not to undertake such tests."[47]

CHINA AND THE INDIAN SPACE PROGRAMME

Although China has shown interest in cooperation with India in the space programme with an early 2002 signing of a memorandum of understanding (MoU) on cooperation in peaceful uses of outer space, and visits such as

46. "India to Assess Chinese Anti-Satellite Test – Official," *Press Trust of India,* January 20, 2007, at BBC.

47. "Nair Criticises China Arms Test," *Asian Age,* February 6, 2007.

that of Premier Wen Jiabao to the Indian Space Research Organisation in Bangalore in 2005 and mutual delegations' visits, such cooperation appears to be preliminary in nature and difficult to categorise as substantial. We have outlined briefly above the Indian concerns on the Chinese ASAT test conducted on January 11, 2007, as India has only one military satellite that could be vulnerable in the event of a conflict between the two countries. As RMA aspects have become crucial in the Indian military operations, such concerns are an obvious reflection of the objective reality. Nevertheless, both cooperation and competition are exhibited in the India-China equation in the space programme, with the latter possibly becoming dominant in the long-term future.[48] With similar trajectories in the space programmes, India and China are likely to compete for commercial space launches in the future.

Much like their views on Japan, Chinese mainstream views on the Indian space programme are reflective of this competitive trend. In 1995, China opposed the United Nations and Western European nations' efforts to set up space-based organisations at Bangalore. The Chinese scholars or military observers' assessments on the Indian space programme have been relatively in negative images. For instance, Dai Wenming mentioned that India is on the verge of acquiring strategic intelligence through satellite imageries in the South Asian region and beyond to serve its security interests in the changed conditions after both India and Pakistan acquired missile capabilities. Specifically tracing such programmes to 2001, Dai stated that India has a plan to launch a series of satellites that can observe the region more accurately, with picture resolutions reduced from 2.5 metres to 1 metre to 500 millimetres. With the help of Israel in January 2004, India is now in a position to acquire "absolute advantage" over Pakistan in information collection. This can be used for the proposed missile defence system's early warning.[49] Yi Fan has summarised the Indian space programme and argued that it has ambitions to

48. See K.K. Nair, *Space: The Frontiers of Modern Defence* (New Delhi: Knowledge World, 2006), p. 131.

49. Dai Wenming, "*Yindu jiasu fazhan zhencha weixing yongyu huoqu zhanlue qingbao*" [India accelerates development of reconnaissance satellites to obtain strategic intelligence] *PLA Daily,* May 17, 2005, at <http://www.chinamil.com.cn\site1\jsslpdjs\2005-05\26\content_213827.htm> India launched a high resolution satellite in April 2005 and planned to launch one more later in the year. See also <http://www.chinamil.com.cn\site1\jsslpdjs\2005-05\13\content_202992.htm>

become one of the great countries in the world in the 21st century; he estimated that by 2020, India would be a space power in the fields of military surveillance, telecommunications and meteorological aspects and acquire the ability to launch mini-satellites for military purposes.[50] A People's Liberation Army (PLA) writer, after tracing the Indian space programme from the 1980s (implying that these have dual-use applications), argued that "the development trend of India's missile technology has been vigorous, and that India is constantly accelerating the steps to realize its intention to dominate South Asian affairs and to enter into competition with the world's great powers." More intriguing is the comment that the defensive and offensive space and missile programmes "might upset the existing strategic balance in the South Asia region. What influence this series of changes will have on the Kashmir region in South Asia, people will just have to wait and see.[!]"[51] Another recent assessment of the Indian aerospace power contended that it is aimed at securing for itself an influential position in international affairs.[52]

Beijing invited India's immediate neighbours like Pakistan and Bangladesh to be part of its space-based groupings like APSCO in October 2005.

In this backdrop, Beijing invited India's immediate neighbours like Pakistan and Bangladesh to be part of its space-based groupings like Asia-Pacific Space Cooperation Organisation (APSCO) in October 2005. Specifically, cooperation with Pakistan in the space programme can be traced to more than a decade. In July 1990, a demonstration launch was made by China for Pakistan's 50-kg Badr 1 satellite at a charge of US$ 300,000.[53] Pakistan has been admitted as a

50. Yi Fan, "*Yindu hangtian fazhan zongshu,*" *Hangkong Zhishi,* Issue 387, July 2003, pp. 41 and 22.

51. "India's Missile System Gradually Takes Shape," *Liberation Army Daily,* February 6, 2002, in FBIS-CHI-2002-0206, February 11, 2002.

52. "*Youjin wutui de dubo – Yindu hangtian liliang fazhan jiemi*" [Point of no return gamble - Unveiling the mystery of Indian aerospace power] March 30, 2008, at <http://js360.bolaa.com/forum/blogtopic_5635752.html> According to this critique, the Indian space programme is "beyond the law of scientific development and the objective conditions"; has only fringe benefits to the economy; with higher accident rates, etc.

53. See Jane's Space Directory, *China's Launch Vehicles (Orbital & Sub-orbital),* November 25, 2003, accessed from http://www.janes.com

China has reportedly tasked SUPARCO to form a working group to work out details of purchase of satellites from China.

member of the APSCO. Pakistan Foreign Minister Khurshid Kasuri reportedly visited certain space installations in 2007 in China with the view to seeking space technology transfer. According to Salim Mahmud, former head of the Pakistan Space and Upper Atmosphere Research Commission (SUPARCO), China is the only country which could transfer rocket and space technology to Pakistan. In this context, he viewed the Chinese ASAT test in positive terms.[54] China has reportedly tasked SUPARCO to form a working group to work out details of purchase of satellites from China. It has committed to launch three earth resources satellites for Pakistan in the next five years. Possible areas of cooperation between the two include climate science, clean energy technologies, clean water technologies, cyber-security, basic space, atmospheric and earth sciences, and marine sciences.[55]

54. Hanif Khalid, "Pakistan Seeks Chinese Help to Boost Space Programme," *The News* (Islamabad), March 26, 2007, at BBC.

55. This is based on "Pakistan, China Boost Space Cooperation," *Associate Press of Pakistan,* April 24, 2007, at BBC.

MISSILE DEFENCE: CONCEPTS AND TECHNOLOGIES

ANAND SHARMA

During the 1950s, counter-force attack was the only effective solution against ballistic missiles, i.e. by destroying them while they were still in silos or on launchers. However, efforts were progressing to develop some sort of anti-missile shield to counter the ballistic missiles that were launched. As the research and development (R&D) of anti-ballistic missile systems continued gaining effectiveness and advance capabilities, counter-measures to missile defence also matured and were outflanking the efforts. This offence–defence play-off brought ballistic missile defence into prominence in security planning. Many technologies have come to the fore to provide defence against annihilating ballistic missile attacks.

A great deal of political, technical and public debate is persistently focussed on the extreme issue of efficacy of missile defence. The answer in the extreme is 'no'; however, it is appreciated that though the phenomenal technological growth and advancement may not provide foolproof security, missile defence still has its importance in mitigating the effects of a preemptive strike and deterring the adversary from believing that a ballistic missile attack can provide him a clear military or political advantage.

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Defending against ballistic missile attacks is a challenging technical task. The defensive system needs to hit a warhead smaller than an oil drum that is travelling in space at speeds greater than 18,000 km/hr.

The scope of this paper is to study the concepts and various technologies which have evolved to provide a useful defence against ever improving, sophisticated offensive threats. The paper reviews the characteristics of the relevant technologies and outlines the key uncertainties concerning those technologies' potentials. It researches the imperatives of defences in various phases of missile flight and against numerous counter-measures.

INITIAL ENDEAVOURS

From the late 1950s till 1970, both the superpowers developed the anti-ballistic missile systems using nuclear tipped missiles as interceptors. US efforts included the Nike, Spartan, Sprint and Sentinel missiles. When using nuclear tipped interceptors, difficulties could spring up from collateral damage or blinding of the defence's own radar tracking system and communications.

The Soviet Union's missile defence programme also progressed through their ABM-1 to ABM-4 systems, namely, the Griffon Galosh, Gazelle, and Gorgon. The USSR missile defence capabilities were successful and remained operational with nuclear warheads till the late 1980s.

Given the concerns about using nuclear tipped interceptors, in the 1980s, the US Army began studies about the feasibility of hit-to-kill vehicles, where an interceptor missile would destroy an incoming ballistic missile just by colliding with it head-on. The first successful programme, which actually tested a hit-to-kill missile interceptor was the army's homing overlay experiment [1] (HOE), which used a kinetic kill vehicle (KKV)[2] on June 10, 1984, intercepting

1. A.Fenner Milton,M.Scot Davis, John Parmentola, *Making Space Defense Work: Must the Superpowers Cooperate*? (UK: Pergamon-Brassey's International Defense Publishers Inc., 1989), Ch.1, p. 8.
2. The KKV was equipped with an infrared seeker, guidance electronics and a propulsion system. Once in space, the KKV could extend a folded structure similar to an umbrella skeleton of 4 m (13 ft) diameter to enhance its effective cross-section. This device would destroy the ICBM reentry vehicle on collision.<www.nationmaster.com/encyclopedia/National-missile-defense#Homing_Overlay_Experiment>

the Minuteman RV (reentry vehicle) with a closing speed of about 6.1 km/s at an altitude of more than 160 km. The feasibility of kinetic energy intercept technology as demonstrated subsequently became the most matured basis of ground-based defence system concepts.

Ideally, it is preferable to intercept ballistic missiles as far away from their intended target and as early in their flight trajectory as possible while offering the opportunity for multiple shots.

The beginning of the second era coincided with the origins of the Strategic Defence Initiative (SDI) programme, which had, as its goal, the development of non-nuclear missile defences. Much of the technologies that Reagan proposed for the system were at the very edge of technology. They included space and ground-based lasers, rail-gun kinetic energy interceptors, space sensors, particle beam weapons, etc. The concepts of ballistic missile defence have been evolving with each of these technologies.

CONCEPTS OF BALLISTIC MISSILE DEFENCE

Defending against ballistic missile attacks is a challenging technical task. The defensive system needs to hit a warhead smaller than an oil drum that is travelling in space at speeds greater than 18,000 km/hr. Counter-measures such as decoy warheads further complicate the problem of intercepting targets. It is essential to exploit the particular vulnerabilities that a ballistic missile presents during the phases of its flight: boost phase, mid-course phase, and terminal phase. The characteristics of different phases of the ballistic missile trajectory are as shown in Table 1 below:

Table1: Phases of Ballistic Missile Trajectory

Phase	Duration	Description
Boost Phase	1-3 minutes for tactical short range missiles. 3-5 minutes for long range missiles.	Powered flight of the rocket boosters lifting the missile payload into a ballistic trajectory.

Post-Boost Phase	10s of second to 10s of minutes.	Most intercontinental ballistic missiles (ICBMs) now have a "post-boost vehicle" (PBV), an upper guided stage that ejects multiple, independently targetable reentry vehicles (MIRVs) into routes to their targets. If these RVs are to be accompanied by decoys to deceive ballistic missile defence (BMD) systems, the PBV will dispense them as well.
Mid-Course Phase	About 20 minutes (less for sea-launched ballistic missiles (SLBMs).	RVs and decoys continue along a ballistic trajectory, several hundred to 1,000 km up in space.
Reentry Phase	30-100 seconds.	RVs and decoys reenter the earth's atmosphere, decoys first slow down in upper atmosphere, then burn up because of friction with the air and RVs are protected from burning up in friction by means of an ablative coating, At a preset altitude, their nuclear warheads explode.

Ideally, it is preferable to intercept ballistic missiles as far away from their intended target and as early in their flight trajectory as possible, while offering the opportunity for multiple shots. To interdict a missile and its warhead in any phase of its flight i.e. boost, mid-course or terminal, requires an ability to detect and intercept the attack within a very few minutes or to track and destroy the attacking missiles and their warheads during their longer mid-course journey through space before their reentry into the atmosphere so that the debris will burn up on reentry. Finally, the last ditch attempt would be to destroy the attacking missiles as they reenter and pass through the atmosphere to the target in their terminal phase.

Each of these phases furnishes intercept opportunities, but also has inherent limitations that must be taken into account in the design and deployment of the missile defence architecture, as shown in Table 2.

Table 2: Implications of Intercepting Ballistic Missiles During Different Phases

Phase	Advantages	Disadvantages
Boost	Missile's thermal signature is large. Easy detection and tracking. Booster is large physical target and missile is vulnerable due to slower speed, large cross-section. Decoys are difficult to deploy. Multiple engagement opportunity.	Time available for intercept is short (about three to five minutes). Interceptor must be positioned close to country from which missile is launched. Rocket plume can obscure the missile's body Missile's acceleration complicates the tracking solution. Hitting the booster can leave a live warhead that falls short of its target.
Ascent/Early Ascent (Post-Boost)	Missile is still large and hot. Extends the time available for intercept. Missile mostly would be flying a predictable ballistic trajectory.	Warhead separation on the missile being targeted may be very rapid. Interceptor must be positioned close to country from which missile is launched. Interceptor must destroy warhead because warhead has enough speed to reach its target.
Mid-Course	Longest time is available for intercept. Missile is probably flying a predictable ballistic trajectory. Defences can be positioned in the oceans.	Missile's thermal signature is small, making it difficult to detect and track. Warhead is small physical target. Decoys can dilute defences

Terminal	Most decoys are stripped away during atmospheric reentry. Forward deployment is unnecessary.	Time available for intercept is very short. Debris from the intercept may fall on defended territory.

Layered Defence

As anti-missile capabilities emerge from R&D programmes and progress made to date in missile defence development efforts, it can be reasoned out that the best way to counter even a limited number of missiles attacks is through *defence in depth*[3]. Multiple defensive layers, with system elements working together synergistically are central to the approach.[4] Promising technologies and approaches include space-based detection sensors, ground-based and seaborne early warning and tracking sensors and also include kinetic energy (hit-to-kill) and directed-energy interception systems with various land, sea, air and space basing.

To achieve a high probability of ballistic missiles' destruction in flight, a layered defensive approach is imperative.

To achieve a high probability of ballistic missiles' destruction in flight, a layered defensive approach is imperative. Layered defences are built on the premise that although technological limitations might keep any one layer from having an adequate chance of successfully intercepting its target, multiple layers could together provide an effective defence. The layered approach provides multiple opportunities to engage the warheads from detection in the boost phase till the reentry phase, thus, reducing the burden on any single layer of defence. Further, layered defences complicate the design of the adversary's offensive systems as the offensive systems have to cater to multiple layers of defences, demanding complex counter-measures, thus, reducing the payload capacity or compromising in attributes such as range and speed.

3. Defence in depth means there will be a number of opportunities to destroy missiles as they are launched and transit through the various stages of their flight paths or trajectories.
4. Milton, et. al, n.1, Ch 2, pp 24-32.

Sensor and data processing technologies are crucial to an advanced ballistic missile defence system.

However, there are drawbacks as well to layered defences. The most obvious problem is that more layers will cost more—especially if the layers are completely independent.

Second, the degree to which the layers can combine to produce high effectiveness will depend on how independent the layers are. To take an extreme example, if all the layers depend on the same sensor system and that sensor system fails, all the layers will fail. The layers must be able to take advantage of the other layers without being overly dependent on them.

Third, the robustness of the system against the loss (or severe degradation) of one layer will depend on how much capacity is built into the system to compensate for that loss. For example, if boost and post-boost defences permit twice the expected number of objects to reach mid-course, and if that in turn substantially degrades the mid-course defence's ability to sort objects, the mid-course may let through not only the additional RVs but also many of the ones it would otherwise have intercepted.[5]

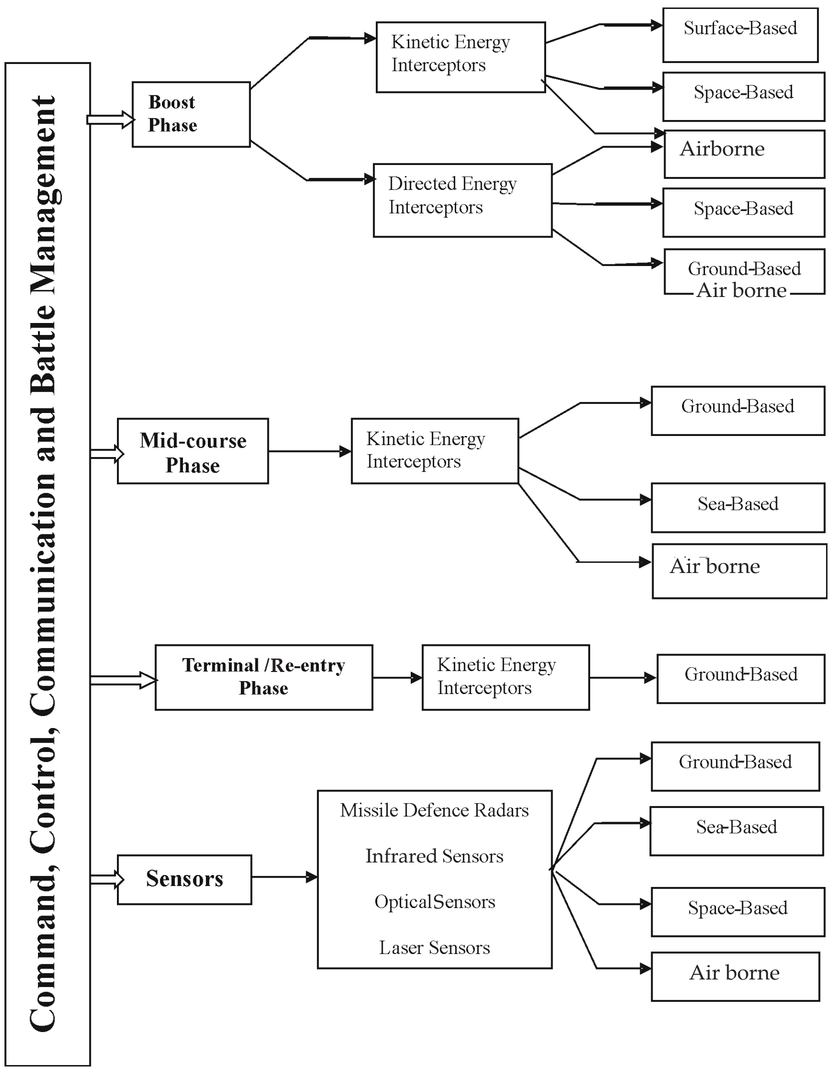
There is a wide variety of technologies which could, in principle be integrated to form a comprehensive ballistic missile defence (BMD) system. Each technology, however, is limited by physical laws. These limitations complicate, but do not eliminate, the possibility of a working system based on that technology. For example, the limitation on the distance travelled in the time available, due to finite velocities (kinetic energy weapons); inability of the energy-delivery device to penetrate the atmosphere effectively (particle beams, X-rays, possibly kinetic energy); the curvature of the earth (pop-up systems). The relevant criteria used to determine the usefulness of the different technologies mostly concern their ability to neutralise targets in a shortest possible time (seconds, at the most).

Sensor and data processing technologies are crucial to an advanced ballistic missile defence system. The chain of operations which each layer must perform as individual tasks are *surveillance* and *acquisition, discrimination*

5. Richard L.Garwin, "Enforcing BMD Against a Determined Adversary?" in Bhupendra Jasani, ed., *Space Weapons and International Security* (SIPRI, Oxford University Press , 1987), pp.73-74.

of actual missiles and warheads from decoys and other debris, *pointing* and *tracking* with precision as required by the weapon designated to destroy that target, *target destruction* and *kill assessment*. In addition, if it can be determined why a targeted warhead was not destroyed (for example, incorrect pointing), the analysis can be used for a subsequent attack.

Fig. 1 Layered Integrated Ballistic Missile Defence Architecture



Kinetic Energy Interception

As early as 1962, the concept of ballistic missile intercept through interceptor rockets was developed which would catch up the attacking missiles and get close enough to kill them by exploding nuclear warheads. By the mid-1980s, small, light, accurate guidance systems made it possible to do away with warheads altogether[6], and to create actual collisions between interceptor rockets and missiles.

Kinetic weapons for targeting objects in space flight i.e. anti-satellite or anti-ballistic missiles, need to attain a high velocity so that they can destroy their target with their released kinetic energy alone.[7] The force of the impact destroys the attacking missile or warhead, renders it inoperable, or diverts it from its intended target without the potential collateral effects of nuclear warhead explosions inherent in earlier BMD systems. Absence of a warhead saves weight and there is no detonation which is required to be precisely timed. This method, however, requires direct contact with the target, which requires a more accurate trajectory because a near-miss has the same effect as a large miss. This places greater demand on the homing guidance system, the amount of fuel required for homing and the required peak acceleration to transfer maximum kinetic energy at the point of impact.

Kinetic weapons for targeting objects in space flight i.e. anti-satellite or anti-ballistic missiles, need to attain a high velocity so that they can destroy their target.

The 'eyes' of a kill vehicle typically include seekers (basically, one or more sensors) that 'acquire' the target and help guide the interceptor to the final impact point. Initially, the KKV must home in on the rocket plume, and then switch to home in on the missile body near the impact point. Seekers may be active or passive. There are passive seekers for a broad portion of the

6. Eric Croddy, James J. Wirtz, *Weapons of Mass Destruction: An Encyclopedia of Worldwide Policy, Technology, and History* (Oxford, UK: ABC-CLIO, 2005), p. 216.
7. Compare the energy of TNT, 4.6 MJ/kg, to the energy of a kinetic kill vehicle with a closing speed of 10 km/s, which is 50 MJ/kg and, hence, explosives are not necessary. i.e. it has about 12 times the energy of a high explosive such as TNT. Anything that gets in the way of the attacking missile—even a plain rock—is likely to destroy it.

Designers could compensate for a system that took longer to commit by producing faster interceptors, or they could make up for slower interceptors by speeding up a system's commit time.

electromagnetic spectrum, including short, medium, and long-wave infrared as well as ultraviolet and visible wavelengths. Active seekers may include conventional radar or laser imagers or rangers.

Exo-atmospheric and endo-atmospheric kill vehicles design and requirements are quite different because the aerodynamic drag and lift forces on an endo-atmospheric kill vehicle will substantially affect its performance. An endo-atmospheric kill vehicle requires a shroud to reduce the aerodynamic drag and a window to protect the infrared sensors from overheating. However, endo-atmospheric kill vehicles have an advantage that they can manoeuvre with aerodynamic lift forces, thus, requiring less fuel for divert manoeuvre.

Boost Phase Interception

The missile boosters are accelerating targets. The time available for intercept, coupled with the distance that an interceptor must travel to reach its target, which results from the geography of a particular scenario, determines the response time and interceptor speed needed for a boost phase interceptor.

A boost phase interceptor engagement can be conceptually divided into two stages. The first is the commit stage, which lasts from when the threat missile is launched until the interceptor is fired. During the commit stage, the system must detect its target, track it, and decide to commit an interceptor to an engagement. The second stage is the fly out stage, which lasts from when the interceptor is launched until it reaches and destroys its target.

Designers could compensate for a system that took longer to commit by producing faster interceptors, or they could make up for slower interceptors by speeding up a system's commit time. Alternatively, the total time available for an intercept might be extended by incorporating the capability to hit a missile in its early-ascent phase.

Ballistic missiles can manoeuvre during their boost phase, thus, introducing errors in the predicted intercept point.

During the boost phase, however, a ballistic missile's signature comprises both the missile body itself and the large rocket plume. At high altitudes, the plume 'blooms' around the missile—in effect, creating a smokescreen of hot exhaust gas that, depending on the kill vehicle's angle of approach, can obscure the body of the rocket. A kill vehicle must be able to detect and hit the missile within the plume. Light detection and ranging (LIDAR) systems that use a laser to penetrate the plume and locate the missile body have been developed for that application. However, a LIDAR system's potential to improve the probability of hitting the target must be weighed against its disadvantages, which include increased complexity, weight, and costs relative to other alternatives.

More importantly, ballistic missiles can manoeuvre during their boost phase, thus, introducing errors in the predicted intercept point. The divert and altitude control system (DACS) is the propulsion package that not only gives the kill vehicle, manoeuvring capability for the intercept but also keeps it balanced and pointing in the right direction.

The characteristics of ballistic missiles against which the defences have to be developed influence the performance of the defensive systems. For example, the type of booster used in an intercontinental ballistic missile (ICBM) is particularly important to designers of boost-phase intercept systems. Solid-fuel ICBMs usually have shorter boost phases than liquid-fuel ICBMs. Thus, a boost phase interception (BPI) system designed to counter solid-fuel ICBMs will need higher performance because its interceptors will have a short time window for intercept. The effectiveness of interceptor rockets would require that interceptors be based in near vicinity of the possible boost-phase flight paths of attacking missiles. In general, because less time is available to reach the target, more BPI sites are needed so that interceptors can have a shorter fly out distance. The size and location of potential threat countries play a role in determining the effectiveness of a BPI system by determining the distance that an interceptor must fly to reach its target.

Similarly, because of the short engagement time, engagement should include two interceptor shots (salvo) to increase the probability of a successful intercept. Some surface-based boost phase interceptors could be based at sea on the navy's surface combat ships, thus, extending the reach of interceptors in the boost phase.

It is widely believed that the best basing mode available is a submarine as it offers a lot of flexibility. It enables positioning of the interceptor missile closer to the enemy's launch site, thus, offering a huge advantage in the boost phase intercept. With submarine basing, one has the advantage of ambiguous presence because the enemy is always uncertain about their location.

The performance of space-based interceptors is less sensitive to geographic factors; however, geography is an important factor in determining the number of space-based interceptors needed in the defensive system. Orbital dynamics requires that the higher the latitude of the country to be covered, the more the interceptors that must be deployed. Space basing provides an advantage of access to any point on earth, including the interiors of very large countries that could never be reached with a surface-based interceptor launched from an adjacent country.

The space-based kinetic energy experiment (KEE) has its origins in the Brilliant Pebbles of the Reagan era. While geostationary orbit is an attractive location for continuous observation and defence, it is too far away from earth (about 35,000 km) to be useful for any practical weapon system. Thus, a space-based system would be a constellation of interceptor satellites located in low-earth orbit at an altitude of about 250 to 300 km. A kill vehicle near the missile launch site would then use its onboard propulsion and sensors to accelerate out of its orbit and home in on the target missile. Satellites in inclined low-earth orbits are not fixed over one spot and instead follow a sinusoidal ground track as they move over the earth. Thus, providing full coverage of a specific threat country requires a constellation of space-based interceptors (SBIs) with their orbits positioned such that at least one SBI is capable of reaching the threat at any given time. At lower orbits, however, satellites would have shorter life spans because of atmospheric drag. The number of space-based interceptors needed to cover a threat country depends on the performance of the system (which determines the coverage area, or footprint, of each satellite) and the latitude of the country. Further, the shorter burn time of solid-fuel ICBMs results in a smaller effective footprint for each space-based interceptor which means that the size of the constellation must increase.

The orbit of these space-based interceptors would be at low altitude and predictable, leaving them vulnerable to attack by inexpensive, short-range missiles.

A 2003 American Physical Society study showed that many hundreds or thousands of space-based interceptors would be required to provide limited global coverage against ballistic missiles and given the technology expected for the next decade, each SBI would weigh a ton or more. As a result, deploying such a system would be hugely expensive.[8]

On the negative side, the orbit of these space-based interceptors would be at low altitude and predictable, leaving them vulnerable to attack by inexpensive, short-range missiles. By eliminating only those few relevant interceptors, an attacker could create a hole in the defence. The defence could also be defeated by simultaneously launching multiple missiles from one location, overwhelming the system. In short, a defence based on deploying hundreds or thousands of space-based interceptors, at enormous cost, could be defeated by a handful of enemy missiles.

Mid-Course Interception

The mid-course phase provides a longer time-frame for interception of the missile or its payload. For an ICBM, this phase may account for as much as 80 percent of the missile's total flight time. Therefore, the mid-course phase allows the longest window of opportunity to intercept an incoming missile. Conversely, a longer intercept window also provides an opportunity to the

8. "The Missile Defence Space Test Bed"<www.ucsusa.org/global_security/space_weapons/space-test-bed.html>

A sea-based system might be more expensive to procure than an equivalent ground-based system.

attacker to deploy counter-measures against the defensive system.

The principal disadvantage of interception during the mid-course phase is that the RVs and decoys would have already been dispensed, increasing by a factor of up to 10 the real number of targets. Approximately, 10 to 100 mid-course decoys can be deployed at the expense of one RV. These decoys travel alongside the RVs and pose an enormous challenge of discrimination of decoys from RVs. Very good decoys travelling on the right trajectory with the right shape, radar signatures and thermal properties take up more space and consume valuable time in discriminating the decoys and also make the other task of battle management (surveillance, tracking and kill assessment) perplexing.

Countries capable of fielding an ICBM would be capable of developing counter-measures and these counter-measures would have a significant impact on the effectiveness of ground-based mid-course defence (GMD). Rather than focussing on making decoys resemble a warhead, they configured the warhead to make it look like a decoy, which would be a simpler prospect. Also, the warhead can be covered in a liquid nitrogen-cooled metal shroud, which will make it more difficult for the interceptor kill vehicle to detect in time to manoeuvre into its path.

A multiple kill vehicle (MKV) [9] launched from interceptor missiles will counter complex ballistic missile threats during their mid-course phase. MKV payloads do not require the BMD system to pinpoint a single lethal object within a threat cluster. Instead of pairing one kill vehicle with one interceptor missile, the MKV payload allows a single interceptor missile to deliver several kill vehicles that can attack multiple threat objects within the threat cluster. This arrangement of MKV dramatically increases the probability of destroying the lethal object within a threat cluster.[10]

9. Missile Defence Agency Factsheet <www.mda.mil/mda.info@mda.mil>
10. "Multiple Kill Vehicle" < www.mda.mil >

Sea-based mid-course interceptor platforms will be intrinsically mobile and highly dispersed, and would offer the opportunity to engage the threat early in its trajectory, possibly as early as in its ascent phase of mid-course cruise, thereby, reducing the susceptibility to counter-measures. Sea-based systems also can be operated in forward (i.e. overseas) locations in international waters, without the need for negotiating basing access and without restrictions from foreign governments on how they might be used.

At reentry, the defence can discriminate the warhead unambiguously and launch interceptors with greater confidence.

Conversely, a sea-based system might be more expensive to procure than an equivalent ground-based system due to the potential need to engineer the sea-based system or fit it into a limited space aboard a ship. Also a sea-based BMD system operating in a forward location might be more vulnerable to enemy attack than a ground-based system, particularly a ground-based system sited in a rear location. Defending a sea-based system against a potential attack would increase the cost of defence by means of additional ships.

An integrated (combined land and sea) architecture could provide more operational flexibility and robustness than architecture that relies solely on sea-based interceptors or on a single land-based interceptor site. This would provide an additional defence layer that can engage the threat ahead of the land-based interceptors, and, thus, provide a multi-tiered defence architecture that has the potential for more robust and more confident protection.

Terminal Phase Interception

The terminal phase provides missile defence systems with a last shot opportunity. During this phase, the warhead, along with decoys or chaff, reenters the atmosphere at an altitude of about 100 km, creating a bright infrared signature. Atmospheric drag then produces dramatically differing behaviour for lighter as compared to heavy objects. Decoys decelerate significantly and burn up, but the warhead does neither. Thus, at reentry, the defence can discriminate the warhead unambiguously and launch interceptors with greater confidence. The terminal phase has many advantages compared to other phases such as the reaction time provided by the early warning is long. Second, both sensors and interceptors can be based within a geographic area, thus, reducing the cost. Third, ranges are short, thus, small, high frequency, hardened or mobile radars can be used for tracking instead of larger radars which are expensive and vulnerable. Finally, the penetration aid problem (counter-measures) is manageable.[11]

However, terminal defence presents severe challenges resulting from the very high speed of the offensive warhead and the very short time in which terminal defence operates. The terminal phase is the last one or two minutes of a ballistic missile's flight. Several counter-measures are available to combat a terminal-phase defence:

- **Speed**: Early reentry vehicle designs used blunt shapes which caused them to decelerate significantly during reentry. Modern reentry vehicles are cone shaped to minimise aerodynamic drag, providing high-speed re-entry. It carries the collateral benefit of reducing the duration of exposure to terminal missile defences.
- **Trajectory and Manoeuvres**: A ballistic missile can follow a lofted trajectory or a depressed trajectory. A lofted trajectory gives less time for engagement, thus, complicating the terminal phase defence. Further, it is possible to design a reentry vehicle that will perform simple but unpredictable and intense manoeuvres upon reentry. This can be done by using a slightly bent nose, a small fin at the rear, or an internal weight that is moved laterally during reentry. In the 1970s, the US developed a manoeuvring reentry vehicle, the Mark 500, for the Trident 1 submarine-launched ballistic missiles (SLBM). Its tests were successful and included 200G manoeuvres that would severely challenge any defence. Manoeuvring reentry vehicles of this type sacrifices some accuracy and payload; however, these are not significant.
- **Ladder Down**: A nuclear warhead exploding in the upper atmosphere would create a cloud of ionised gas that would be opaque to a radar for

11. Milton, et al., n.1, Ch.2, p. 43.

several minutes. One tactic available to the offence would be to use such a precursor explosion to mask a following reentry vehicle. The reentry vehicle would become visible after passing through the cloud, but the time remaining for the defence would be significantly reduced.

DIRECTED ENERGY WEAPONs (DEWs)

The advanced technology has raised the possibility of countering an ICBM attack through the directed-energy weapons, which possess profound lethality and unmatchable key features. Their ability to fire shots at or near the speed of light (186,000 miles a second), which would seem like relatively freezing even high-speed targets in their motion; their ability to engage multiple targets very rapidly; and their very long range (thousands of kilometres in space) are the key features. There are three principal forms of directed-energy weapons: the particle-beam weapons, high power microwave (HPM) weapons and the high-energy laser.

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By virtue of their cost and unique capability, development of DEWs may provide truly transformational war-fighting capabilities, which may signal a revolution in military hardware; perhaps more so than the ballistic missiles. Some unique characteristics which mark them as potentially revolutionary are:

- First, the speciating facets are speed and distance. There is a clear advantage to propagating lethal energy over militarily significant distances within a blink of an eye. That means many of the problems associated with aiming and firing existing weapons are effectively eliminated, because virtually no time elapses between firing a directed-energy weapon and its impact on the target.
- Second, the cost of discharging such weapons is typically a small fraction of what it costs to fire a missile, because the method of destruction is pure energy. Although directed-energy devices may require a major investment

in weapons technology development and support infrastructure, the price of intercepting a missile or aircraft may be only one or two percent of what conventional munitions would cost. A DEW provides an efficient alternative wherein it costs only a few thousand dollars per shot to achieve equivalent or superior probability of kill. For comparison, procurement costs of the join direct attack munition (JDAM) are US $ 21,000 (tail kit only); for the joint stand-off weapon (JSOW) $ 660,000; for the joint air-to-surface stand-off missile (JASSM) $ 300,000; and for the advanced medium range air-to-air missile (AMRAAM) $ 386,000. Even the basic Maverick can cost $ 152,000. By contrast, the fuel required per shot of the large laser in the airborne laser (ABL), costs approximately $ 10,000. For a 100 kilowatt (KW) solid state laser, the cost of the fuel required to generate electricity for each shot is less than a dollar.[12]

- Third, directed-energy weapons provide war-fighters with surgically precise and discriminate firepower. While indiscriminate damage is certainly within their capability, it is possible to employ directed-energy weapons in ways that generate no collateral damage at all. A related feature of DEW technology is the ability to customise the weapon by adjusting the amount of energy incident upon targets. This allows for a wide range of results: lethal or non-lethal, destructive or disruptive.
- Fourth, directed-energy devices potentially enable war-fighters to rapidly engage many different targets, because of their instantaneous effects and the relative ease of reaiming them.
- Energy beams are essentially immune to gravity which also frees them from the kinematics and aerodynamic constraints that limit more traditional weapons. Hence, the complex calculations required to determine ballistic trajectories and other flight characteristics of conventional munitions are irrelevant to directed-energy devices
- Finally, another feature contributing to their multi-target capability is the

12. Richard J. Dunn, " Operational Implications of Laser Weapons", (Analysis Centre Papers, Northrop Grumman, September, 2005), <http://www.analysiscenter.northropgrumman.com/files/Operational_Implications_of_Laser_Weapons.pdf>

compactness and low cost of the fuel that drives them. Directed-energy weapons could be based on a variety of platforms, and they come in a wide range of power levels.

While DEWs are technologically revolutionary, their associated requirements will have to develop in a similar fashion. Such weapons also have unique disabilities. The lethal power of their beams may quickly degrade on interaction with the surrounding medium, such as when a laser beam passes through water vapour or dust. In the absence of reflectors, they are strictly line-of-sight weapons. But their weaknesses, like their strengths, contribute that directed-energy weapons are fundamentally different from past technologies of war, and are potentially transformational.

Particle beam weapons work by accelerating a stream of atoms or sub-atomic particles near to the velocity of light and projecting them in a beam. Particle beam weapons can be divided into neutral particle beam weapons and charged particle beam weapons. Both electrons and protons can be used to form this beam, and would be the choice for a weapon to be used within the atmosphere. Hydrogen atoms are the preferred choice for an extra-atmospheric weapon—they have a neutral charge, and, thus, the beam wouldn't be deflected by the earth's magnetic field, or scattered by the mutual repulsion of similar charged particles.

Particle beam weapons increase the kinetic energy of a large number of individual atomic or sub-atomic particles which are propagated at essentially the speed of light and then direct them collectively against a target. Every particle in the beam that strikes the target will transfer a fraction of its kinetic energy to the target material. If enough particles hit the target in a short time, the deposited energy would be sufficient to burn a hole in the skin of the device, detonate the chemical explosives, disrupt the electronics inside or result in damage from the swift temperature increase and possibly an explosion; for example, the effects of a lightning bolt—which is essentially a charged particle beam—and this gives an idea of how destructive such a weapon could be.

However, particle beam weapons are yet to be practical because of the huge power requirement i.e. of millions or even billions of watts, in a very short time as a powerful burst, necessary to create destructive pulses.[13] The technology to create such a power source already exists; the problem is in making it small and light enough to be portable. Since the beam is strongly affected by passage through the atmosphere and also due to the earth's magnetic field, precision is questionable in practicality.

High-power microwave (HPM) weapons are also known as radio frequency weapons and ultra-wideband weapons. HPM weapons have been in development in the United States, Russia, and China for decades. An HPM device employs electromagnetic radiation as its weapon effect. Not as powerful as nuclear electromagnetic pulse (EMP) weapons, HPM weapons create a narrower level of microwave electromagnetic radiation as the atmosphere is generally transparent to these frequencies. As a rough point of comparison, HPM systems produce 100-1,000 times the output power of modern electronic warfare (EW) systems[14]. For example, a high-power microwave device can be aimed at an aircraft, immediately upsetting its onboard electronics and sending it into a fatal dive without firing a projectile or even leaving evidence of its use. Such a weapon was successfully field tested by the US in April 2001, and reported to have been deployed during Operation Iraqi Freedom.[15]

The laser is perhaps the most important optical invention in the last several decades. Since its invention in the early 1960s, the laser has proved to be an extremely useful device not only for the scientific and commercial

Since its invention in the early 1960s, the laser has proved to be an extremely useful device not only for the scientific and commercial communities, but also for the military.

13. "Neutral Particle Beam" <http://www.fas.org/spp/starwars/program/npb.htm>

14. "Space Operations: Through The Looking Glass," A Research Paper presented to "Air Force 2025
"<http://csat.au.af.mil/2025/volume3/vol3ch14.pdf>

15. Stuart Millar, article published in the *Guardian* on March 19, 2003 < www.guardian.co.uk/profile/stuartmillar>

communities, but also for the military. [16] At first, it was considered to be "a solution without a problem," and today, the laser is at the heart of an extensive array of military applications: range finders, satellite communications systems, remote sensing, target designation, and laser radar-based navigational aids.

The employment of laser-guided munitions in Operation Desert Storm brought new meaning to the idea of "precision engagement," and represents just one example of how the laser has shifted to become "a solution." In fact, numerous countries are now developing their own laser technologies for weapons applications. Since the early 1990s, lasers have demonstrated the capability to produce sufficient energy to merit serious consideration, even by the most ardent sceptics, as potential weapons against the ballistic missile threat. There are four fundamental approaches to high—and medium—power laser energy: chemical lasers, solid-state lasers, fibre lasers, and free electron lasers.[17]

In the case of lasers, intense beams of monochromatic light can be precisely aimed across hundreds or thousands of kilometres to disable a

16. Lasers are extremely flexible weapons, producing effects that cover the full "spectrum of force." At low power, laser beams can be used as battlefield illumination devices, to designate targets from space, blind sensors in the laser's optical band, ignite exposed flammable objects, raise the temperature in localised regions, perform as an emergency high-bandwidth laser communication system, and serve as a laser probe for active remote-sensing systems. At slightly higher powers, the enhanced heating produced by the laser can be used to upset sensitive electronics (temporarily or permanently), damage sensor and antenna arrays, ignite some containerised flammable and explosive materials, and sever exposed power and communications lines. The full power beam can melt or vaporise virtually any target, given enough exposure time. With precise targeting information (accuracy of inches), a full-power beam can successfully attack ground or airborne targets by melting or cracking cockpit canopies, burning through control cables, exploding fuel tanks, melting or burning sensor assemblies and antenna arrays, exploding or melting munitions pods, destroying ground communications and power grids, and melting or burning a large variety of strategic targets (e.g., dams, industrial and defence facilities, and munitions factories)—all in a fraction of a second. <http://csat.au.af.mil/2025/volume3/vol3ch14.pdf>

17. Chemical lasers can achieve continuous wave output with power reaching multi-megawatt levels. Examples of chemical lasers include the chemical oxygen iodine laser (COIL), the hydrogen fluoride (HF) laser, and the deuterium fluoride (DF) laser. Diode-pumped solid-state (DPSS) lasers operate by pumping a solid grain medium (for example, a ruby or a neodymium-doped YAG crystal) with a laser diode. Combining the outputs of many fibre lasers (100 to 10,000) is a possible way to achieve a highly efficient HEL. Free-electron lasers (FELs) use a relativistic electron beam (e-beam) as the lasing medium. Generating the e-beam energy requires the creation of an e-beam (typically in a vacuum) and an e-beam accelerator. This accelerated e-beam is then injected into a periodic, transverse magnetic field (undulator). By synchronising the e-beam/electromagnetic field wavelengths, an amplified electromagnetic output wave is created.

Multi-megawatt class lasers (much larger than any system under development today) would be required to defeat the faster and much harder targets.

wide range of targets, from missiles to satellites to aircraft to ground vehicles and even people. They can also be reflected off mirrors in space to hit targets not visible from their source while retaining much of their initial fluence. These special features make it possible to focus the laser energy with mirrors into narrow beams characterised by small divergence angles. Thus, a laser with 1 micrometre (=1 micron) wavelength projected with a 1 metre mirror could have at best a 1.2 micro radian divergence angle, making a spot 1.2 metres wide at a range of 1,000 km. A 10 metre mirror with a hydrogen fluoride (HF) laser beam would yield a 0.32 micro radian divergence angle and create a laser spot 1.3 metres in diameter at a range of 4,000 metres. The distribution of 20 megwatts (MW) over the laser spot would create an energy flux of 1.5 kilowatts per square centimetre (KW/cm^2). The laser spot would need to dwell on the target for 6.6 seconds to create the nominal lethal energy of 10 kilojoules per square centimetre (kJ/cm^2). At a range of 2,000 metres, the destruction of the booster would require 1.7 seconds of illumination. This perfect performance is called the diffraction limit[18].

Laser light can damage boosters in two distinct ways. With moderate intensities and relatively long dwell times, the laser simply burns through the missile skin and is called thermal kill. The second mechanism requires very high intensities but only one short pulse, the high intensity causes an explosion on and near the missile skin, and the shock from the explosion injures the booster. This mechanism, called impulse kill, is more complex than thermal kill.[19]

DEW systems can be land-based, sea-based, or space-based. Since lasers can theoretically defeat artillery and missile attacks, any group fielding an effective laser system will gain decisive advantages in ground, air and

18. Matthew Mowthorpe, "The Revolution in Military Affairs and Directed Energy Weapons," *Air & Space Power Chronicles*, March 8,2002 < www.iwar.org.uk>
19. Stephen D. Rockwood, "Technical Issues for Strategic Defence Research," in Jasani, ed., n.5, pp.63-65.

space combat. Under radar control, lasers have shot artillery shells in flight, including mortar rounds. [20]

Ground-Based Directed Energy Weapon

Ground-based lasers are well suited to terminal point defence of critical targets. These lasers can fire tens of shots against offensive missiles very quickly, making them difficult to overwhelm. The chemicals consumed per shot cost much less than the millions of dollars for defensive missiles. Thus, even taking into account the initial cost of the laser weapons, laser-based BMD may prove to be a highly effective and more affordable means of adding an additional layer of defence against theatre ballistic missile (TBM) attack.

They can complement missile defence against longer range missiles. Megawatt-class chemical lasers could defeat a TMB. Multi-megawatt class lasers (much larger than any system under development today) would be required to defeat the faster and much harder targets. In both cases, the effectiveness of a laser defence would depend on developing systems concepts that overcome the potential effects of clouds, fog or dust storms. For example, aircraft basing would allow the laser weapon to operate above these weather effects.

The ground-based laser architecture may consist of multiple ground stations with high-energy lasers placed in different regions of the country. Lasers are not all-weather systems. Clouds absorb and scatter laser light, removing power from the beam and distorting the beam's 'footprint'. Thus, the ground-based lasers systems must be located in regions that have good weather all year round.

Each of the ground systems would include a high-energy laser, beam director, adaptive optics[21], acquisition and tracking systems, and related

20. India Daily, "The Race for Developing Deadly Solid-State Laser Weapons that can Change the Future battlefield," March 10, 2005, < http://www.indiadaily.com/editorial>

21. Adaptive optics techniques such as the Guide Star System have been developed to correct atmospheric distortions to low-power laser beams projected from earth to space and back again. Adaptive optics systems developed to date depend primarily on deformable mirrors—mirrors with small actuators that change the mirror's shape to pre-compensate the beam and correct anticipated or pre-measured distortions. Further advances will be required in this technology, both in terms of bandwidth and number/size of actuators, to make this technology work for weapons class lasers. < "Space Operations: Through The Looking Glass",http://csat.au.af.mil/2025/volume3/vol3ch14.pdf>

support systems. The laser beam is transmitted through the atmosphere to a constellation of mirrors in space. Changes in the altitude of the space mirrors will affect the diameter required for the beam director's primary mirror, relay mirrors, and mission mirrors, and as well as the number of space mirrors. A total of four relay mirrors in geosynchronous orbit would provide the necessary worldwide coverage. One of these mirrors would be positioned as close as possible to the zenith of the ground lasers to minimise atmospheric effects.[22]

Space-Based Directed Energy Weapon

For the boost phase intercept, the Strategic Defence Initiative Organisation (SDIO) proposed several hundred satellites armed with powerful (>100MW) lasers. Microwave and particle beams were also considered but lasers remain the more developed technology. Space-based lasers (SBLs) can be located on satellites placed in low-earth orbit. The satellite needs to be at an altitude sufficient to enable it to intercept the farthest boosting missile it can see.[23]

In the late 1990s, SBL planning was based on a 20-satellite constellation, operating at a 40° inclination, intended to provide the optimum tactical missile defence (TMD) threat negation capability. At this degree of deployment, kill times per missile will range from 1 to 10 seconds, depending on the range from the missile. Retargeting times are calculated at as low as 0.5 seconds for new targets requiring small angle changes. It was estimated that a constellation consisting of only 12 satellites can negate 94 percent of all missile threats in most theatre threat scenarios. Thus, a system consisting of 20 satellites is expected to provide nearly full threat negation.[24]

22. Lt Col William H. Possel, USAF, "Lasers and Missile Defence: New Concepts for Space-based and Ground-based Laser Weapons," *Occasional Paper*, No. 5 Centre for Strategy and Technology Air War College, July 1998.< http://www.fas.org/spp/starwars/program/docs/occppr05.htm>

23. Matthew Mowthorpe, "The Revolution in Military Affairs and Directed Energy Weapons," *Air & Space Power Chronicles*, March 8,2002 < www.iwar.org.uk>

24. "Space-Based Laser" [SBL] < http://www.globalsecurity.org/space/systems/sbl.htm>

AIR-BASED MISSILE DEFENCE

Ballistic missile defence components can also be mounted in or on aircraft. Sensors can be interconnected into the missile defence network and aircraft can carry the means of intercepting ballistic missiles, particularly early in their flight, while their rockets are still burning. The means of intercept can employ either directed energy (lasers) or kinetic energy.

The airborne laser (ABL) is the avant-garde of a revolution. While the phrase "revolution in military affairs" is overused, the emergence of systems utilising directed energy for tangible war-fighting applications is worth noting. Efforts during the 1970s provided that it was possible for an airborne laser to intercept aerial targets and confirmed that lasers had weapon potential. Iraq's use of the Scud missile as a terror weapon during the Gulf War exposed a potential mission. This led the United States Air Force (USAF) to propose an ABL weapon system that would be capable of locating, tracking, and destroying such missiles in their boost phase. A 747 aircraft, an advanced detection and tracking system, adaptive optics, and a revolutionary high-energy laser, are all being integrated into a single weapon system for the first time.

The ABL is among the first generation of deployable directed energy weapons with potential to present the US not only a new capability to destroy ballistic missiles, but, more importantly, a foundation of an entirely new defence architecture. The ABL is also being evaluated for its suitability to perform other adjunct missions. These include cruise missile defence (CMD), intelligence, surveillance and reconnaissance (ISR) and protection of high value airborne assets (PHVAA).

Under cloud-free line-of-sight conditions the ABL's infrared surveillance system can detect both aircraft and TBM, and acceleration and altitude will permit discrimination among target types. However, identifying them as positive hostile targets will require off-board confirmation such as airborne warning and control system (AWACS) warning. The ABL can destroy aircraft before they penetrate close enough to fire their air-to-air missiles. Cruise missiles, though similar to aircraft, are more difficult targets, particularly those flying low-level profiles. Detecting and identifying cruise missiles as hostile will be the ABL's most challenging target and probably require off-board help. Flying low to avoid the ABL's high energy laser (HEL) will shorten the ABL's effective range. Obviously, this capability has gaps that can only be filled by the traditional weapon, the fighter, and its long-range eyes, the AWACS.

BALLISTIC MISSILE DEFENCE SENSORS (BMDS)

BMD sensors detect, identify, track and assess the missile launch and generate accurate targeting coordinates and stimulate a target shootdown. New and innovative approaches to these requirements are being developed which include not only detecting and tracking of targets but also discriminating targets from decoys and debris.

For a layered BMDS, multiple sensors, with the different characteristics, are essential. This would provide information using network-centric ability by gathering data from various land-based, airborne, sea-based and space-based sensors. Multiple sensors will not only provide redundancy but also utilise important characteristics of various sensor systems like radar, infrared sensors, optical sensors or laser detection sensors. For example, the boost phase detection is ideal for an infrared seeker whereas during the mid-course phase, RVs emit little energy and detection would be difficult by infrared sensor but would be a better target for a radar sensor system.

The resolution and accuracy of the sensor system are also worked out as per the weapon system being used for interception. For a DEW system, the resolution required is of a few centimetres so as to keep the laser focussed on one spot. The KEI system would require less accurate information from a remote sensor because a homing sensor onboard an interceptor would give the fine resolution needed in the last few seconds to approach and collide with the target.

For a layered BMDS, multiple sensors, with the different characteristics are essential.

Resolution improves with reduction in distance to the target. Therefore, a sensor satellite placed in geostationary orbit at 36,000 km surveys the entire earth but the resolution will not be of practical value. Even a constellation of satellites at altitudes around of 4,000 km would not be adequate for DEWs. Further, the vibration and jitters would preclude the transmission of target position to the weapon platform with 10 cm accuracy. Therefore, each DEW would need its own sensor to provide final pointing accuracy.

Kill assessment is an important factor for sensors. Missed targets have to be retargeted and disabled targets should be ignored.

Kill assessment is an important factor for sensors. Missed targets have to be retargeted and disabled targets should be ignored. Though KEI weapons' kill assessment is mostly simple and straightforward, in the case of partial damage of a booster, leaving the missile intact, it will be a precarious situation as the kill assessment would be affirmative.

In the case of DEW, assessment of damage of the target is a difficult process. A laser or a neutral particle beam might burn through the critical component without detectable damage and divert the missile from its intended course.

For surface-based radars, BMDS relies on fixed and transportable radar. These radars include X-band radars in the form of the sea-based X-band (SBX) radar. An X-band (wavelength 2.5-4 cm; frequency 8-12 GHz) radar can search, detect, and track missiles, and distinguish between warheads and counter-measures. The SBX radar is built upon a movable sea platform that will improve the ability to acquire, track, and discriminate counter-measures during the mid-course phase of flight. The ground-based mid-course defence system also includes the upgraded early warning radar (UEWR) and the L-Band (Cobra Dane) radar. These radars provide long-range missile surveillance, acquisition and tracking, and object classifications, as well as update information for the BMDS exo-atmospheric kill vehicles.

Space sensors fulfill five functions in supporting the BMDS. First, 'situational awareness;' second, sensors send a wake-up call—'the early warning'; third, 'sensor-to-sensor cueing,' which allows a sensor with a threat missile in track to pass pertinent information on that missile to another sensor; the fourth and fifth functions are 'launch' and 'engage'. Sensor accuracy, timing, information latency, coverage, and availability are all system attributes that determine if a possible sensor system is capable of supporting these five functions. For example, highly accurate information that is too late or timely information that is inaccurate can negatively affect the execution of the BMDS mission. This balancing act between accuracy and timeliness is one of the major design traits that dominates the sensor capability analysis. The space sensor assets that can most readily be incorporated into BMDS are overhead non-imaging infrared assets. Future systems with advanced radar technologies to improve system robustness, reduce cost, and enhance radar performance parameters for all-weather missile tracking are under development.

The enemy can try to degrade the BMDS performance in several ways. Reduction of observables of RV i.e. stealth, by the shape of the RVs such that it gives minimum radar signatures, using either super lofted or super depressed trajectories so as to avoid the search volume, etc. However, such tactics are relatively easily countered by expanding the sensor search volume. Infrared sensors can be degraded either by reducing the signal originating from the target (cooling the target) or by increasing the competing signal coming from the background.[25]

COMMAND, CONTROL, BATTLE MANAGEMENT AND COMMUNICATIONS (C2BMC)

The C2BMC programme is a key enabler for implementation of the missile defence system in all three phases of flight. Responding to ballistic missile threats presents an unprecedented challenge of speed, precision, and coordination among numerous weapon systems, sensors, and war-fighters. Decision cycles are reduced to minutes, and, in some cases, seconds, during which air, ground, sea, and space sensor-interceptor-communications elements must be orchestrated into engagement scenarios that seamlessly detect, track, target, and engage incoming missiles. Unlike the other elements, this is not primarily a hardware issue, but rather a software development challenge. The C2BMC element is the critical tool that links the various individual sensor-interceptor-communications elements into one coordinated system utilising

25. Stephen Weiner, “System and Technology,” in Ashton B. Carter, David N. Schwartz, ed., *Ballistic Missile Defense* (Washington, DC: 1984), Ch.3. pp.49-59.

the best offensive/defensive attributes of each element, ensuring the highest BMDS capability for protection against all types of ballistic missile threats in any phase of flight. C2BMC can be thought of as 'middleware' linking decision-makers, weapons, and sensors together in a networked environment.

C2BMC is an evolutionary concept that integrates modelling and simulation, deliberate planning and analysis algorithms together in a time constrained manner to 'propose' solutions and engagement sequences to the decision-makers. It is a method of data processing and comprehensive algorithms that describes, organises and provides prioritisation to a multitude of variables—most of which change rapidly in an operational situation.

C2BMC ***Functional Attributes***

C2BMC must be able to see, understand, analyse and prioritise the threats and it must do so in compressed timelines commensurate with the nature of the threat. Once C2BMC validates the threat, it begins to formulate the BMDS response.C2BMC has the following functions:[26]

- Planning capability to optimally locate sensors and weapon systems to counter identified threats.
- Situational awareness of the evolving battle and status of defensive assets at all leadership levels. Situation awareness tools and intelligence updates will provide indications and warning to allow decision-makers to move the BMDS to higher states of alert when necessary.
- Networking and integration of sensors, weapon systems, and war-fighters.
- Provision of automated, real-time, multi-source information to project a single, near real-time command and control (C2) picture to allow commanders to quickly assess missile threats and execute coordinated, immediate responses.
- Missile detection and battle management to optimally pair sensors and shooters for effective and efficient BMDS asset utilisation and engagement of multiple threats for the highest probability of kill.

26. <http://www.lockheedmartin.com/products/c2bmc/index.html>

One of the problems is that there are numerous ways that offence can attack, thus, making it impossible to achieve the desired confidence in the defensive system.

- Efficiently manage and distribute essential data in support of advanced strategic planning and supporting military echelons 24x7. Additionally, C2BMC must perform the above activities for each threat and continuously iterate them when new information is received and assessments made

Peace-time activities include the day-to-day operations of the system, including planning updates, training, maintenance, asset management, logistics and data base updates, including intelligence. These updates, to the greatest extent possible, should be automated.

Engagement control (EC) incorporates the traditional capabilities of command, control and battle management, and recognises the evolutionary and transformational capabilities that are different from traditional C2BM but are required for successful C2BMC. Engagement control will use and support two distinct C2 paradigms: traditional C2 requiring approval before continuance, and management by exception (MBE). Traditional C2 is the accepted human-in-control paradigm where the human makes the key decisions regarding execution plans, weapons engagements and re-tasking. MBE, on the other hand, represents the C2BMC computers, prosecuting the engagement by proposing and executing all necessary products and decisions automatically. In MBE, the human operator will review the proposed plans and engagement sequences and has to manually stop the C2BMC process to make changes.

Additionally, the C2BMC capability must have the adaptability to take inputs from the combat commander regarding changes to defended assets and changes to priorities, and automatically cascade these changes through the situational awareness and planning tools.

The communications capability required for C2BMC must necessarily be robust, interoperable, collaborative, and provide connectivity to the entire community of interest. It will be net-centric and allow for common access to

BMDS data sets and databases. It will provide connectivity across operational echelons and geographic locations. C2BMC communications are a foundational element and key enabler for all the other C2BMC key capabilities.

The attributes of an effective communication system would include:

- Adequate band width and range.
- Reliability.
- Tolerance of component damage.
- Security from interception or take-over.
- Tolerance of nuclear effects.
- Jamming or spoof resistance.

OPERATIONAL IMPERATIVES

With the ever progressing technologies, many innovative systems and approaches to missile defence will evolve. So is the case with the offensive missile technologies which are improving consistently in range, accuracy and lethality. This offence-defence challenge is the key factor to analyse the requirement of a comprehensive missile defence system. For a country to appropriate a missile defence system, the decision has to rest on serious assessment in terms of its effectiveness against offensive missiles capabilities and counter-measures, its survivability, its affordability not only for acquisition but also for operation as well as maintenance and also its completeness to provide a comprehensive defence with known and trusted limitations.

Testing of missile defence systems is especially difficult. The basic reliability of individual components can be ascertained but for the system as a whole, is a challenging task. One of the problems is that there are numerous ways that offence can attack, thus, making it impossible to achieve the desired confidence in the defensive system. Simulation may provide a near realistic picture but estimation of leakage is the challenge. Similarly, simulation of counter-measures may not be realistic and, thus, correct assessment of defensive effectiveness may

Preemptive attack against the components of the defence is most likely and one of the most deadly counter-offensive actions.

A well integrated, layered, defensive system using different technologies and basing methods depending on geography, threat perception, envisaged capability and cost analysis is the only answer.

not be valid in the actual scenario.

The survivability of a defensive system can be challenged through many means. For example, the defensive system can fall apart if its sensors have been nullified or destroyed. Preemptive attack against the components of the defence is most likely and one of the most deadly counter-offensive actions. Blinding the satellite sensors can be achieved with a laser based on a high altitude aircraft. The simplest form of counter-defence attack can come from an anti-satellite (ASAT) interceptor launched from the ground. Measures like hardening, manoeuvrability, self-defence and redundancy could be used to protect the defensive system against ASAT systems.

Completeness of a missile defence system can be said to be achieved if it can address the vulnerability to attacks not only from ballistic missiles but also from other weapons such as cruise missiles, bombers or unmanned aerial vehicles (UAVs). For this, BMD must also support the conventional air defences while integrating each other's assets.

Notwithstanding the limitations and vulnerabilities, ballistic missile defence, even with imperfect defence, can drastically alter the calculus of military planning of the adversary by introducing an extra element of uncertainty and raising the cost of destroying important military targets. A partial defence may also be able to reduce casualties, particularly in the event of limited attacks. Thus, even partially effective defence would strengthen deterrence by reducing the confidence of the adversary that the attacks would not achieve their objectives.

SUMMARY

As discussed in the preceding paragraphs, missile defence is a 'system-of-systems' comprising various technologies and concepts. The distributed nature of the system-of-systems described above can be its greatest strength or its greatest weakness. The system-of-systems must be designed carefully to minimise or eliminate all critical nodes. Critical nodes that cannot be eliminated must be protected by deception, added defences (hardening, placement within a secure environment), or redundancy.

Such capability acquisition by a country must be based on various important attributes such as timeliness, responsiveness, precision, survivability, reliability, selective lethality and cost. Various methods of basing of weapon systems, i.e. ground-based, sea-based or space-based systems, all have their inherent unique advantages and limitations. (For example, space strike weapons are currently not possible without reliable and affordable access to space.)

As we carefully study the characteristics and capabilities of various candidate weapon systems, it becomes evident that there is no 'super weapon system' that can provide complete defence. A well integrated, layered, defensive system using different technologies and basing methods depending on geography, threat perception, envisaged capability and cost analysis is the only answer.

The overall architecture should have the desired flexibility and adaptability of integrating future advance technologies, [for example, airborne weapon system, transatmospheric reusable aerial vehicle (TAV), etc.], new offence tactics and new offensive weapon counter-capabilities.

EVOLUTION OF THE CRUISE MISSILE DISCOURSE: A CONCEPTUAL CONSTRUCT

SITAKANTA MISHRA

By all reckoning, the cruise missile has arrived on the world stage. It no longer seems a mere supplement to the global inventory of weapons; rather, it has acquired a taxonomy of its own by gradually coming up to the demands of modern warfare. Many nations have already mastered it and many more are striving for it. Surprisingly, the missile has been used more frequently than any other weapon system. While the major powers have used the "Big Stick" conveniently in increasing numbers, the Third World countries find in them the "poor man's arsenal". In the process, the system has been enriched with more lethality and sophistication but its evolutionary trend vindicates that it may revolutionise the discourse of modern warfare in many ways. When the world is grappling with the issue of weapons of mass destruction (WMD) proliferation and no way out of this menace is on the horizon, would the cruise missile further complicate the WMD imbroglio?

There exist considerable ambiguity and assessment challenges in regard to the global inventory of cruise missiles. One estimate shows that as many as 130 types of cruise missiles exist today, with 75 countries possessing them.[1] A

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1. Andrew Feickert, "Cruise Missile Proliferation", http://www.fas.org/sgp/crs/nuke/RS21252.pdf#search=%22Feickert%20cruise%20missiles%2

Approximately 70,000 cruise missiles are operational worldwide. Seventy-five different types of systems are currently in service and over 40 additional cruise missiles are reportedly under development.

Congressional Research Service estimate reveals that 81 countries today appear to have cruise missiles of some kind. In 1992, 63 countries had cruise missiles. Approximately 70,000 cruise missiles are operational worldwide. Seventy-five different types of systems are currently in service and over 40 additional cruise missiles are reportedly under development.[2] Moreover, overall trends since the end of Cold War show a significant net decrease in worldwide ballistic missile arsenals. Even though the range of ballistic missiles has slowly increased, their horizontal spread has been largely kept under check. By the start of the 21st century, one can observe that while the spread and use of ballistic missiles had dominated the policy-maker's attention, during the last decade of the 20th century, the land attack cruise missiles (LACMs) had become more prominent instruments of warfare than ballistic missiles. Witness America's use of LACMs in seven different contingencies. Cruise missile use, beginning in 1944 to the present (19,645), greatly exceeds that of ballistic missiles (5,880) by over 3 to 1.[3] More than 2000 cruise missiles have been fired since Desert Storm, including 802 Tomahawks in Operation Iraqi Freedom alone. Does the trend suggest that cruise missiles have reached their mature stage or that the process of evolution is in full swing?

Available literature on cruise missiles mostly concentrates only on the extent of their spread and the threat they are assumed to pose. This is partly owing to the fact that the discourse has "evolved without a well-defined conception"[4], of *why and how they have evolved*. However, assessments have

2. Statement of Christopher Bolkcom, analyst in national defence, Congressional Research Service, before the Senate Governmental Affairs Committee Subcommittee on International Security, Proliferation, and Federal Services. Hearing on Cruise Missile Proliferation, June 11, 2002, p. 14.
3. Dennis M. Gormley, *Missile Contagion: Cruise Missile Proliferation and the Threat to International Security* (London: Praeger Security International, 2008), p. 47.
4. Richard K. Betts, ed., *Cruise Missiles: Technology, Strategy, Politics* (Washington D.C.: The Brookings Institution, 1981), p. 1.

been undertaken lately on why they are needed and their full implications. With the nuclear weapons and ballistic missile discourse all pervasive in the strategic domain, the emergence of the cruise missile as a viable weapon system seems to have been given meagre attention. However, its emergence to the stage that it has reached today is not haphazard. Rectification of the limitations at each stage of its evolution over the years has gradually endowed it with the intended capability, cleverly evading all non-proliferation norms. The cruise missile today is a reality; it is no longer a potential weapon that can still be shelved. But, is it merely another weapon in the familiar class of aerial munitions or does it represent a potentially revolutionary class of weapons in its own right? This necessitates an intensive survey into the history of the missile development, national policies and strategies, as well as the strategic environment in which it has been designated.

SURVEY OF LITERATURE

Though the history of use of modern cruise missiles can be traced back to World War II and their use in a rudimentary way during World War I, scholarly study on their development, spread and consequences has started to be undertaken only recently. This does not mean that development of cruise missile technology has been unnoticed, but a concerted effort to monitor and analyse the phenomenon started only in the late 1980s and more vigorously post-Gulf War.

The first study to notice the cruise phenomenon was perhaps the edited volume *Cruise Missiles: Technology, Strategy, Politics* by Richard K. Betts published in 1981, where he says that "cruise missiles have evolved without a well-defined conception of why they are needed and without an assessment of their full implications".[5] Though the study is focussed on the US, Soviet Union and the Cold War rivalry, it brings a perspective on the question of what transformed the neglected cruise missile into an important part of US defence programmes. The study says that the evolution of cruise missile was an "uncoordinated, integrative, and synthetic technological innovation,

5. Betts, Ibid.

Before World War I was over, the cruise missile, or the "aerial torpedo", as it was then called, was touted as "the gun of the future" and compared in importance with the invention of gunpowder. Former Assistant Chief of the US Air Service Billy Mitchell saw it as "a weapon of tremendous value and terrific force to air power."

rather than a deliberate effort or an epochal breakthrough." In the volume *Evolution of the Cruise Missile,* Kenneth P. Werrell describes that "the cruise missile, as an operational concept and system, has been around for some time; and very early on inspired rather far-reaching claims".[6] Before World War I was over, the cruise missile, or the "aerial torpedo", as it was then called, was touted as "the gun of the future"[7] and compared in importance with the invention of gunpowder[8]. Former Assistant Chief of the US Air Service Billy Mitchell saw it as "a weapon of tremendous value and terrific force to air power".[9]

Dennis M. Gormley, in an article entitled "The Neglected Dimension: Controlling Cruise Missile Proliferation" in *The Nonproliferation Review* (Summer 2002) observes that we have undergone an era where cruise missile and unmanned aerial vehicles (UAVs) were considered merely "lesser-included cases". However, Gormley hopes that this era is coming to a close.[10] Particularly, the events of September 11, 2001, appear to have changed such treatment of missile threats. In his view, there now emerging "complicating predictions about the evolution of the cruise missile threat" owing to "a

6. Kenneth P. Werrell, *The Evolution of the Cruise Missile*, Maxwell Air Force Base, Alabama (Air University (AU), Air University Press), September 1985.
7. Elmer Sperry to Admiral Earle, October 25, 1918, quoted in Delmar S. Faluney, "The History of Pilotless Aircraft and Guided Missiles," manuscript, Naval Historical Center, c. 1958, pp.112, 113.
8. George O. Squier to Chief of Staff, October 5, 1918, Subject: "An Automatic Carrier for the Signal Corps (Liberty Eagle)"; Bion J. Arnold to the Secretary of War, "Secret Report on Automatic Carriers, Flying Bombs (FB), Aerial Torpedoes (AT)" January 31, 1919, Exhibit F, Air University Library Film 623 .451 W253B.
9. William Mitchell, "Lawrence Sperry and the Aerial Torpedo," *US Air Services*, January 1926, p. 16.
10. Dennis M. Gormley, "The Neglected Dimension: Controlling Cruise Missile Proliferation", *The Nonproliferation Review*, Summer 2002, pp. 21-29.

diverse set of crosscutting motivations and constraints facing proliferating states".[11] Gormley, in an earlier writing, had suggested that "understanding the differences between cruise and ballistic missiles helps to explain why cruise missile proliferation could become at least as severe a threat".[12] Ron Huisken, the research consultant, United Nations Centre for Disarmament, is of the view that "the debate has centred on the weapon's military value and on its implications for strategic arms control but in consequence, the question of where and how the concept of a strategic cruise missile originated, insofar as it has been addressed at all, has been addressed in a peripheral way".[13] He traces the origin of the strategic cruise missile to the development of the US submarine-launched Regulus-I which became operational in 1955.[14] This was followed four years later by the ground-launched Snark, the first and so far the only cruise missile with intercontinental range. By 1960, military interest in strategic cruise missiles in the US had waned. A little more than a decade later, a period in which first the US and then the Soviet Union deployed huge forces of land and sea-based strategic ballistic missiles, the strategic cruise missile staged an abrupt and unheralded comeback.

Lt Col David J. Nicholls of the US Air Force (USAF) in an Occasional Paper of the Centre for Strategy and Technology, Air War College, says that by the late 20th century, significant technological advances that accrued over the past thirty years have transformed cruise missiles into reliable weapons, which have militarily significant ranges and sophisticated defences.[15] Further, he asserts that proliferation of technologies has remedied the historical shortcomings of cruise missiles to produce a weapon that has significant military capabilities and this will transform cruise missiles into important and perhaps decisive

11. Gormley, Ibid., p. 23.
12. Dennis M. Gormley, "Hedging Against the Cruise-Missile Threat", *Survival*, vol. 40, no. I, Spring 1998, p. 93.
13. Ron Huisken, "The Origins of Strategic Cruise Missile: Perceptions and the Strategic Balance", *Australian Journal of International Affairs*, vol. 34, Issue 1, April 1980, pp. 30-40.
14. Huisken, Ibid.
15. David J. Nicholls, "Cruise Missiles and Modern War: Strategic and Technological Implications", Occasional Paper No. 13, Centre for Strategy and Technology Air War College, Air University, Maxwell Air Force Base, May 2000.

Also, the *Review* asserts that proliferation of cruise missiles will be driven primarily by the attraction of regional powers to the weapon.

weapons in the 21st century. In future, this will also be the cost-effective weapon for developing states in comparison with manned aircraft and ballistic missiles. Published on December 1, 1987, the *Adelphi Papers 28: 226* opines that the cruise missile is increasingly become a competitor of the ballistic missile for strategic missions, such as hard-target kill that require great accuracy.[16] The *Jane's Intelligence Review* (April 2000) concludes that while considerable effort has been made in the development of weapon systems for ballistic missile defence at the tactical, theatre and national levels, cruise missile defence has remained of marginal concern. These efforts have been undermined by the ambiguity of the threat posed by cruise missiles.[17]

Also, the *Review* asserts that proliferation of cruise missiles will be driven primarily by the attraction of regional powers to the weapon. Other drivers include the increasing number of cruise missiles that are out in the market, the deflation in the military effectiveness of ballistic missiles as anti-missile systems are deployed, and the relaxation of acquisition rules. However, if at any point the spread of cruise missiles is expected to slow down, it may be so only owing to the lack of innovative tactics by regional armed forces. But recent trends show that all innovative technologies and equipment are easily available in the market and indigenous research and developments (R&D) in several countries is rampant.

Considering the pace and gravity of the spread of cruise missile technology and their use, several issues merit attention. Have these threats been exaggerated or has the threat been announced prematurely, with the prospect for cruise missile proliferation only now beginning to emerge? During Operation Iraqi Freedom, Iraq fired five modified HY-2 missiles at US forces and Hezbollah used them during the conflict with Israel in

16. "II. Modern Cruise Missile Programmes", http://www.informaworld.com/smpp/title~content=t713662270, December 01, 1987, p. 5.

17. "The Cruise Missile Threat: Exaggerated or Premature?" *Jane's Intelligence Review*, April 2000, pp. 47-51.

Lebanon. These events in the post-9/11 period have highlighted the potential threat to the international community. From the other angle, a major power like the US is using cruise missiles more frequently than any other weapon. In August 1998, the US Navy fired 79 Tomahawks against Afghanistan and Sudan, destroying a pharmaceutical plant in Sudan. During the "Global War on Terror" the Allied forces used this in greater numbers. Therefore, defence analyst Steven Zaloga rightly says that the Tomahawk "has proven the ideal weapon of the New World Disorder, a 'Big Stick' when diplomacy fails."[18]

Cruise missiles are not destined to supplant ballistic missiles but when both are employed together, they could severely test even the best missile defences.

From the above comments, it seems that the passing of years has not dimmed enthusiasm for the device. A newspaperman in 1977 claimed that "except for gunpowder and atomic bomb, no weapon has threatened a greater effect on war and peace than the cruise missile".[19] In a recent study, Dennis M. Gormley finds that rapid and unexpected developments facilitate the proliferation of missiles capable of delivering WMD and highly accurate conventional payloads, and this trend is approaching a critical threshold.[20] In his view, cruise missiles are not destined to supplant ballistic missiles but when both are employed together, they could severely test even the best missile defences. He further sayss that several LACM development programmes probably commenced in the mid-1990s, but only now, roughly a decade later, has a series of seemingly small events nudged LACM growth toward a dangerous "tipping point" in missile proliferation. The question he repeatedly raises is: *what might be shaping the sudden outbreak of cruise missile proliferation?*

Therefore, an intensive review of the cruise missile's long historical record is warranted and can illuminate not only where it has been, but suggest where

18. Zaloga, Ibid.
19. Howard Silber, *Omaha World-Herald*, April 17, 1977, p. 11.
20. Dennis M. Gormley, *Missile Contagion: Cruise Missile Proliferation and the Threat to International Security* (London: Praeger Security International, 2008), p. 5.

it may be going. For instance, what has changed and what has remained constant between the earlier and current versions of cruise missiles? What are the advantages of, and disadvantages inherent in, cruise missiles as a class of weapon? Why were cruise missiles not introduced on a large scale into military inventories earlier? What obstacles, if any, has the weapon system encountered? Overall, what lessons can be gleaned from the historical record of the cruise missile? Is there any useful parallel? Moreover, how important is the cruise missile? Is it just another weapon like so many others, or does it represent a revolutionary class of weapon? The answers to these questions may well have far-reaching implications, for the current version of the cruise missile represents not just an evolutionary development but a quantum leap forward in weaponry. However, before attempting to answer these intriguing questions, it is pertinent to first understand the cruise phenomenon – the concept of cruise missile – and its operational principles. The basic aspects in this regard that need careful introspection are: how did the idea come about? Where did it take place? What were the chief motives that encouraged its emergence? Surprisingly, existing literature provides hardly any perspective on the cruise missile as a concept.

THE CONCEPT OF THE CRUISE MISSILE

Weapons come and go. Sometimes, some classes of weapons cast both dramatic and lasting impact upon the conduct of warfare. This is because they are not only revolutionary but also clearly superior to equipment already inducted. In the course of their use, loopholes in the system get exposed. At the same time, new challenges of warfare demand more efficiency in the system. In the process of meeting these challenges, the system acquires sophistication and lethality. Such a case is the cruise missile. It has come a long way and seems set to dominate the strategic thinking for many decades to come. In this study, an endeavour is made to find out conceptually what cruise missiles are all about and the causes of their spread.

According to the Intermediate Range Nuclear Forces (INF) Treaty, a cruise missile is an "unmanned, self-propelled vehicle that sustains flight through the use of aerodynamic lift over most of its flight." The treaty considers the missile a "weapon-delivery vehicle". In contrast to a ballistic missile which is powered during launch and flies to a high altitude, a cruise missile relies on aerodynamic lift to keep it in the air, is powered during most or all of its flight, and has flight controls that allow it to manoeuvre.[21] Starting from the pre-World War I till the recent days, there have been many variants of cruise missiles and, therefore, defining them too strictly can be problematic. For example, there is no consensus on categorising a missile by its range. Cruise missiles can be built with ranges as short as 20 km and as long as 3,000 km. The INF Treaty covers missiles with a range of 500 km or more, irrespective of size or character of the payload. Similarly, the Missile Technology Control Regime (MTCR) is concerned only with missiles capable of a range of 300 km or more while carrying at least a 500 kg warhead. Weapons with a range of 40 km or less can be strategic in many parts of the Third World, given the small size and their proximity.

A cruise missile is an "unmanned, self-propelled vehicle that sustains flight through the use of aerodynamic lift over most of its flight."

In the first instance, a missile is a piece of war technology, basically air power. It is the *culmination of the principles of war strategy and tactics* imbibing an efficient *coordination of distance, time and force*. Originally, strategy was understood to govern the prelude to a battle, while tactics controlled its execution. It is often said that the art of strategy defines the goal to be achieved in a military campaign, while tactics define the methods to achieve these goals. But during the conduct of warfare, there always exists "'time-induced tension' between political and military imperatives". And it is the application of air power that resolves the time-induced tension as air power works through a time-based strategy. A time-based strategy is defined as one in which time is a paramount or extremely significant consideration. Such a strategy seeks to overcome time-induced tensions and achieve political-military congruence by employing forces and forms of military power. A time-based strategy also

21. W. S. Carus, *Cruise Missile Proliferation in the 1990s* (Washington: CSIS and Praeger, 1992), p. 8.

During the conduct of warfare, there always exists "'time-induced tension' between political and military imperatives." And it is the application of air power that resolves the time-induced tension as air power works through a time-based strategy.

weighs operational risks and benefits with the goal of balancing them to achieve the greatest time benefit at the lowest risk. The missile, as an instrument of air power which uses aerodynamic techniques, addresses the time-induced tension effectively by minimising chances of risk as it inflicts sufficient damage on the adversary from a larger distance, with speed and precision.

A corollary to the distance-time-force coordination is the *surface-to-air-space continuum*.[22] It denotes coordination among the triad of land, air and sea, instead of a classic separation among them. A classic separation among them is inimical to proper interaction between air and surface arms. This is why it has encouraged the historians of land campaigns to treat "the air" as another background topic along with the weather, logistics, etc.

Second, at the basic, a cruise missile is a projectile with a certain degree of *independence in its operation* or automatic action. Beside other things, war-fighting very often requires automated action to reduce or eliminate time-induced tension. The certainty of the weapon reaching the target depends upon the weapon system's capability to sustain manoeuvrability. To manoeuvre, the system needs to be equipped with a self-propellant and guidance mechanism.

Third, the key to success in a war is the *temporal dominance* of the adversary. Robert Leonhard's *Fighting by Minutes* identifies four temporal characteristics of warfare[23]. They are: duration – length of conflict; frequency – tempo or length of events; sequence – order of events; opportunity – time sensitive decision points, and synchronisation of all means at disposal. A cruise missile imbibes all the qualities to meet the difficulties that arise at each level of the four temporal characteristics. It is endowed with the capabilities to

22. Neville Brown, *The Future of Air Power* (London: Routledge, 1986).

23. Robert Leonhard, *Fighting by Minutes: Time and the Art of War* (Westport, CT: Praeger, 1994).

meet the temporal imperatives by achieving significant results quickly, ensuring freedom of action quickly, and inflicting a profoundly upsetting psychological blow quickly. Since the last two centuries at least, the nature of the land battle has drastically changed which Sir Basil Liddell Hart identified in 1960 as "the defence has been gaining a growing material ascendancy over the offence" – the thesis is popularly known as the "Liddell Hart Fallacy"[24]. In his opinion, this is a consequence of a steady fall in the number of troops needed to hold a mile of front in pitched battle, that in its turn was due largely to improvements in firepower though also to those in mobility and communications.

The endurance of any war technology lies in its wide application, in other words, *application across the spectrum* of military engagement: intercontinental, strategic, theatre, nuclear, and conventional.

Fourth, the endurance of any war technology lies in its wide application, in other words, *application across the spectrum* of military engagement: intercontinental, strategic, theatre, nuclear and conventional. Also armaments are always considered in the context of the quality-quantity trade-off. Military establishments usually prefer quantity to quality in weapons.[25] After World War II, the military Services became accustomed to the rapid pace of innovation, thus, concentrated on maximising the sophistication of weapons systems. But in recent years, the pendulum has swung toward concern about quantity. Unit costs of high-performance weapons have risen geometrically, and the technological sensitivity of complex systems has outstripped maintenance capacity. The cruise missile system is a potential combination of high quality and quantity, with emphasis on the latter. The simplicity and commonality that make the cruise missile versatile permit economies from very large purchases.

Fifth, *versatility* is another important feature of an enduring war technology. It fits the system for apparent wide application. To be versatile, a system

24. John Mearsheimer, *Liddell Hart and the Weight of History* (Ithaca: Cornell University Press, 1988)
25. I.B. Holley, Jr., *Ideas and Weapons: Exploitation of the Aerial Weapon by the United States During World War I* (Yale University Press, 1953), pp. 175-176.

***Selective engagement* is the concept upon which the application of cruise missiles is also based.**

needs to be open to innovation in the changing defensive threat environment. In this matter, a cruise missile can be modified more quickly than a manned aircraft and performance parameters can be attained which are not economically feasible for manned aircraft.[26]

Sixth, the most important conceptual issue is whether the system provides new *tactical options*. And a salient question is *cost-effectiveness*. Does the system offer more "bang for the buck" than other systems? In this respect, the cruise seems to have fulfilled the expectations in successive stages of its evolution.

Seventh, *stand-off-ness* is one of the important features of modern generation warfare where combat operations are conducted without direct participation by ground forces. The indirect method and form is used to inflict damage on the enemy, thereby reducing the chances of retaliation. The new generation wars are known as stand-off wars where there is absence of classic armed confrontation between states. This requires the use of stand-off precision offensive and defensive conventional weapons, weapons based on new physical principles, information and electronic warfare (EW) assets. Perhaps stand-off-ness is one of the major concepts upon which the missile system, especially the cruise missile, is based.

Eighth, *selective engagement* is the concept upon which the application of cruise missiles is also based. Analysis of development trends in high-precision weapons and their combat employment in recent conflicts shows that the required effectiveness of engagement of targets can be reached through selective strikes, and it is not necessary to engage the entire specified areas. Selectivity consists of the destruction of a strictly specified individual target or a combination of such targets (target selectivity), in determining the time of the strike (time selectivity), in the selection of a damage-producing element, and selective-action weapons. Depending on the prevailing conditions (available

26. John J. Kohout III, "Cruise Missile Carrier or Manned Penetrating Bomber: Must It Be Either Or?", *Air University Review*, cited in Betts, n.4, p. 6.

assets, specified destruction extent, resistance to the high-precision weapon systems), by automated identification of the target, it is possible to single out for destruction the elements vital to the enemy's functioning.

The concept of an artificial intelligence-based framework for planning missions is the core of cruise missile functioning.

Ninth, efficient and advanced *manoeuvrability* is an important attribute of *aerodynamic stability*. Aerodynamic stability connotes the property of a body in the air to maintain its altitude, or to resist displacement, and if displaced, to develop aerodynamic forces and movements tending to restore the original condition. The degree of manoeuvrability depends on the magnitude of aerodynamics the body is equipped with. The cruise missile is evolved around this concept. Advanced aerodynamism generates efficient manoeuvrability for the missile to determine its flight path to locate, and guide it towards, the target.

Tenth, precise guidance is the hallmark of targeting. The cruise missile, imbibing the attribute of *precision targeting*, manoeuvres effectively. While targeting, the explosive must arrive quite close to the target as the power of an explosive decreases radically with the distance from the detonation. Cruise missiles with the global positioning system (GPS) can be guided to their target with constant position updates.

Eleventh, *artificial intelligence* is a critical component of the missile that provides the input guidance to the aerodynamism for effective manoeuvring. The concept of an artificial intelligence-based framework for planning missions is one of the core aspects of cruise missile functioning.

Last, the core concept of *unmanned-ness* is probably the progenitor of the idea of a missile. Distance matters greatly in warfare. The main objective of a nation in a war situation is to inflict sufficient damage on the adversary while minimising the chances of getting damaged. Therefore, it is needed to be stationed at a distance while fighting a war until the situation of temporal dominance over the adversary emerges. When distance is involved between adversaries, air power comes into play. But

Although piston-powered flying bombs during World War II were comparable in cost to manned aircraft, they proved less reliable, less accurate and more vulnerable than conventional aircraft.

till the 20th century, the traditional way of overcoming distance in a war scenario was the use of manned aircraft. In such operations, the risk of losing the man and the aircraft is high. Therefore, to inflict sufficient damage from a distance without losing much is the core idea. Employment of technology in such places is the only way to minus the human factor from such tasks. But the technology that intends to replace the human being is not that simple. Such *technology is a package* combining many supporting structures. For example, consider the task of delivery of a warhead. Here, to deliver it exactly at the target, the delivery system leading towards the target must be equipped with an efficient guidance system. It must also be equipped with reconnaissance technology. Therefore, the endeavour to upgrade the system for one specific capability necessitates adding new technology to the system. Perhaps this is how the evolution of the cruise missile emerged: with every attempt, shortcomings in the process have been identified and overcome in the process, but in the long run, it has generated a new set of problems to address which vindicates a cyclical process of evolution.

By reviewing the success story of the cruise missile, one can easily figure out the series of failed attempts through its long history. The practical effort, on record, for an unmanned flying bomb was first attempted in April 1915 when Peter C. Hewitt, the inventor of the mercury vapour lamp, approached Elmer A. Sperry of Sperry Gyroscope Company with the idea of an automatically controlled "flying bomb" or "aerial torpedo". But the device was expensive, required complicated launching facilities and its "use in long range attacks against forts and cities is of doubtful military value on account of the difficulty of striking at any desired point rather than at random within the limits of the city or fortress." Among the Europeans, the British were the first to launch such a programme under the leadership of H.P. Folland but the Folland missile proved unsuccessful, failing to get airborne on three attempted launchings in July 1917 and, finally, that led to end the project. In April 1917, America's Naval Consulting Board recommended, and allotted funds for a "flying bomb" project. After the success of the manned N-9 tests, failure dominated the new phase with the unmanned vehicle. On the first attempt at an unmanned "flying bomb" on August 18, 1920, the machine crashed after 150 yards. The third "flying bomb" launched on April 25, 1921, flew for less than two minutes. The missile's lack of progress, coupled with declining funds, led the navy to cancel the effort in 1922. Meanwhile, the army had developed a somewhat more successful flying bomb with the interest of Glenn Curtiss and Maj Gen George O. Squier and under the leadership of Charles F. Kettering. But the Kettering missile experiments faced difficulties. Launch problems caused a number of crashes. Limited knowledge of aerodynamics, lack of testing, and haste in building the machine guaranteed problems. In particular, neither guidance systems nor engines performed as designed. Only one of the 12 Sperry-Navy tests functioned properly. By 1927, the British were developing three types of missiles: a mechanically-controlled "flying bomb", a radio-controlled missile, and an air defence missile to break up enemy aircraft formations. However, the Royal Air Force really did nothing with the flying bomb until its final cancellation. In September 1936, the Air Staff reviewed both the air defence and Larynx missiles and decided that neither merited further development. The British, however, did have a successful inter-War missile development programme. The Queen Bee first flew under radio control in 1934.

Subsequently, technical problems proved too great. The American flying bomb development shifted from pre-set guidance to radio-control from an accompanying aircraft. While radio-control efforts worked in theory and in tests, they did not work well in combat. Mechanical problems with the missile, explosive, and guidance systems precluded adequate testing of both the equipment and the concept. A realistic appraisal of these piston-powered flying bombs during World War II led to the conclusion that although they were comparable in cost to manned aircraft, they proved less reliable, less accurate and more vulnerable than conventional aircraft. The Germans, however, came up with a breakthrough to make the flying bomb a marginal, if not truly practical, weapon. Therefore, the path of cruise missile development was marked with failures but every attempt was made to overcome the difficulties with some innovation.

All the above concepts were not assimilated simultaneously when the cruise system was initially experimented with. In subsequent stages of its evolution, the imperatives of war experience and changing pattern of warfare necessitated sophisticated features to be added to the system through consequent R&D. Primarily, these are some of the important concepts upon which the evolution of the cruise missile system is based. Many more concepts and features would also be added to the cruise missile technology according to the demands of the time. So to define a cruise missile in definite terms is a difficult task as new features have been assimilated in subsequent stages and its evolution is still not complete. Therefore, there is no single definition for the cruise missile. According to one widely accepted definition, a cruise missile is an "unmanned, expandable, armed, aerodynamic, air-breathing autonomous vehicle".[27] "Expandable" signifies its wide application; "autonomous" means it carries out a "programmed mission" or guides itself after it is launched. This definition describes it as an offensive military weapon which is different from rocket powered and remotely controlled vehicles. Though many vehicles which have been experimented with, and used, since World War I can be termed as missiles, discussions of cruise missiles usually offer the German Buzz bomb (V-1) of World War II as the progenitor of the cruise missile.[28] Also, rocket powered anti-ship missiles were usually regarded as cruise missiles.

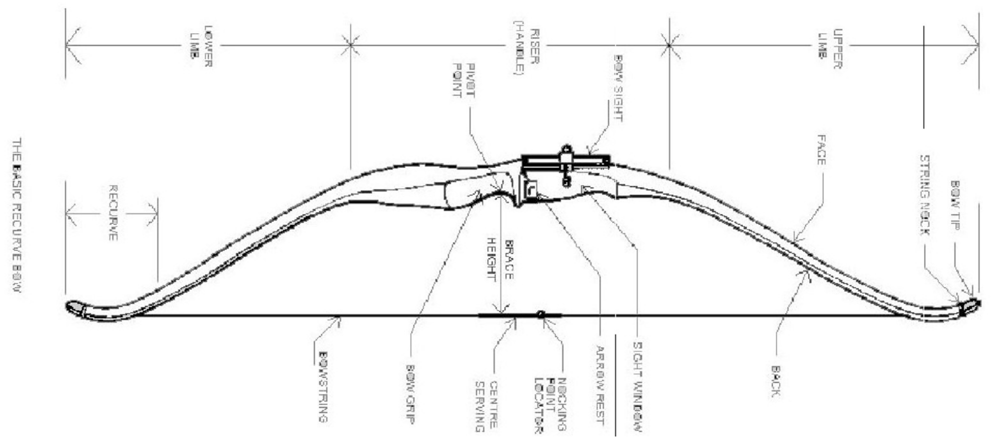
THE CRUISE TECHNIQUE IN ANTIQUITY

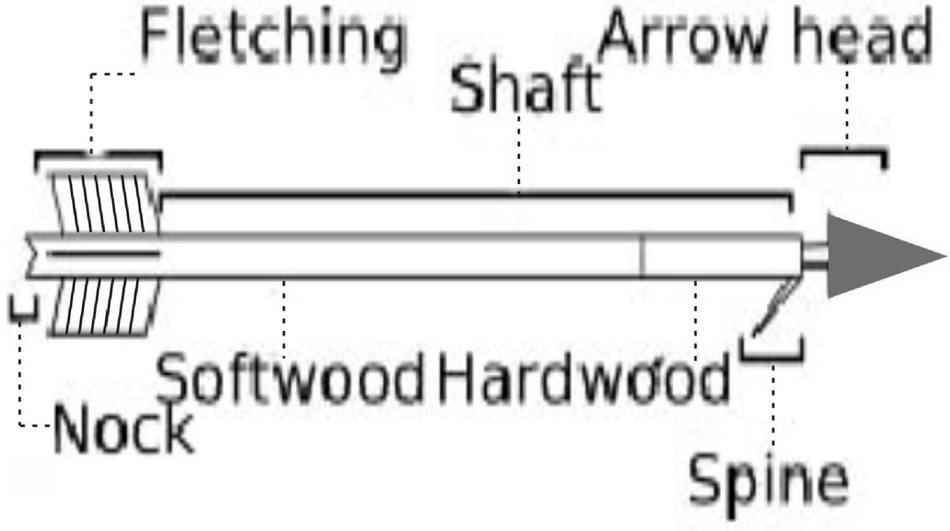
At the basic, the cruise, both as a concept and technology, is as old as human

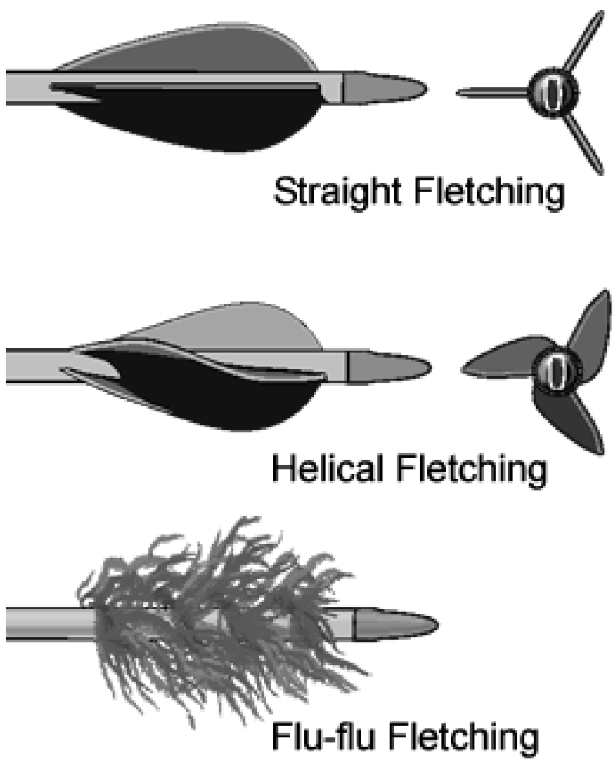
27. John C. Toomay, "Technical Characteristics", in Betts, n.4, p. 31.
28. Ralph Kenney Bennett, "The Missile the Russians Fear Most", *Reader's Digest*, February 1977, pp. 129-32; Juan Cameron, "The Cruise Missile Can Do It All—Almost", *Fortune*, May 8, 1978, pp. 174-184.

civilisation itself. If we analyse the objectives of a cruise missile, it is clear that even primitive man utilised this technology while hunting, though in a completely different fashion. For example, since time immemorial, the bow and arrow comprised one of the first ranged weapons which used mechanical principles.

The bow seems to have been invented in the late Paleolithic or early Mesolithic age. There are numerous instances in the epics regarding the uses and techniques of archery. It was a complete war-fighting system with considerable innovation. The bow functions by converting elastic potential energy stored in the limbs of the bow into kinetic energy of the arrow. In this process, some energy is dissipated through elastic hysteresis, reducing the overall amount released when the bow is shot. Of the energy remaining, some is damped both by the limbs of the bow and the bowstring. Depending on the elasticity of the arrow, some of the energy is also absorbed by compressing the arrow, causing it to bow out to one side. This results in an in-flight oscillation of the arrow in which its centre protrudes out to one side and then the other repeatedly. The flight of the arrow is dependent on its fletching which is a fundamental in an aerodynamic technique.




Fletching
Shaft
Arrow head
Softwood
Hardwood
Nock
Spine


Straight Fletching
Helical Fletching
Flu-flu Fletching

Perhaps the technique of fletching is the ancient art of aerodynamicity to stabilise the arrow through air resistance in flight. Fletches are the fins or vanes attached to an arrow, each of which is known as a fletch. Traditionally, fletching consists of three matched half-feathers attached near the back of the arrow or dart's shaft that are equally spaced around its circumference. Some fletches act to impart a spin on the projectile, but all are there to impart a drag on the tail of the projectile to ensure that it does not tumble during flight. They are usually angled to make the arrow spin as it flies, to give a more stable, straighter flight. The fletching can be arranged to cause the arrow to rotate along its axis if desired. This improves accuracy by evening out pressure build-ups that would otherwise cause the arrow to slowly tilt in a random direction after shooting. If the fletching is not arranged to induce rotation, it will still improve accuracy by causing a restoring torque any time the arrow tilts away from its vector of travel. Arrows themselves may be designed to spread or concentrate force, depending on their applications. Practice arrows, for instance, use a blunt tip that spreads the force over a wider area to reduce the risk of injury. Arrows designed to pierce armour would use a very narrow and sharp tip to concentrate the force. Arrows used for hunting would use a narrow tip that broadens further down the shaft to facilitate both penetration and a large wound.

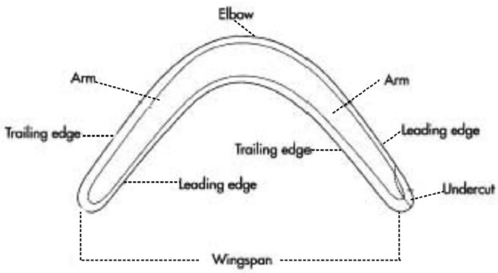
Various techniques of bows and arrows were practised in Egyptian culture since its predynastic origins. Classical civilisations, notably the Indians, Persians, Parthians, Koreans, Chinese, and Japanese fielded large numbers of archers in their armies. Archery was highly developed in Asia and in the Islamic world. In East Asia, the ancient Korean civilisations were well-known for their archery skills. Central Asian and American Plains tribesmen were extremely adept at archery on horseback. The Sanskrit term *Dhanurveda* (from *Dhanus* "bow" and *Veda* "knowledge" which came to refer to martial arts in general) is the term for the "science of archery" in Puranic literature.

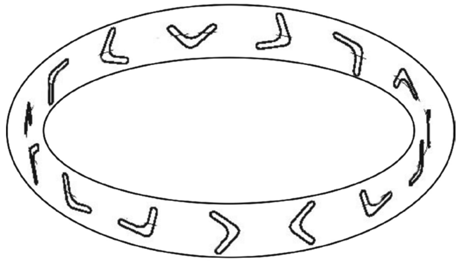
There are numerous references in the Hindu epics of the *Mahabharat* and *Ramayan* to the unprecedented techniques mastered by characters like King

Dasaratha of Ayodhya and Ekalavya, the young prince of the Nishadha tribe. King Dasaratha was capable of shooting arrows at distant objects only by listening to the sounds they produced. While Sravana Kumara was collecting water in his pitcher for his blind parents, Dasaratha, who was on a hunting expedition, mistook the sound for a deer drinking water, and shot an arrow in his direction, instantly pinning him to the ground. The same was the case of Ekalvya. While practising archery, Ekalavya heard a dog barking. Before the dog could shut up or get out of the way, Ekalavya fired seven arrows in rapid succession to stuff the dog's mouth, without injuring it. The technique of shooting arrows to kill only by listening to the sound from the target, without seeing it, is called *Shabdavedi Vidya* (the art of shooting by listening) in Sanskrit. If such skill and concept really existed, then ancient man was much advanced in matters of defence and warfare.

Beside archery, instruments like the boomerang are based on the aerodynamic principles and microgravity dynamics of flight. The boomerang is primarily associated with Australian Aborigines, but has been found amongst the peoples of Northeast Africa, Sardinia, Arizona, southern California, Native Americans, and in India. A boomerang is an airfoil. When it is thrown with high spin, the wings produce lift. Because of its rapid spinning, a boomerang flies in a curve rather than a straight line. When thrown correctly, a boomerang returns to its starting point.

Returning boomerangs consist of two or more arms or wings, connected at an angle. Each wing is shaped as an airfoil, so air travels faster over one side of the wing than the other. This difference in air speed creates suction or lift along what is roughly a plane which intersects the airfoil at a near right angle along the long axis of the wing. These wings are set so that the lift created by each wing opposes the lift of the other, but at an angle such that the flight pattern is constantly shifted as the forces of lift, drag, speed, rotational inertia etc. 'attempt' to reach equilibrium. Gyroscopic precession is what makes the boomerang return to the thrower when thrown correctly. Some boomerangs have turbulator bumps or pits on the top surface that act to make the flight more reliable.





In an unprecedented experiment, on March 18, 2008, Japanese astronaut Takao Doi "threw a boomerang and saw it come back" at the International Space Station (ISS).[29] In the pressurised environment of the ISS, microgravity has very little effect on the boomerang flight.[30] It was proved that the boomerang is versatile, with gyroscopic precession and angular momentum compensating for the lack of gravity.

From the above description, it is clear that missiles, in general, and cruise missiles, in particular, have their ancestors, though of completely different variety and quality. The stage that missile technology has reached today simply symbolises a *graduated process of evolution* through various ups and downs. According to Kranzberg's third law of technology, "Technology comes in packages, big and small"[31]. One innovation leads to another and very much according to the need of the time. Kranzberg's sixth law of technology also asserts that "technology is a very human activity and so is the history of technology". In that sense, the spread and sophistication of cruise missiles in the course of time is not surprising. But no human activity takes place in a vacuum. And again, while studying the evolution of technology, that too war technology, one needs to explore in detail the "period of ideological and social preparation".[32] Lewis Mumford argues that "mechanisation (of war)

29. "Boomerang Works in Space, Says Astronaut", http://www.news.com.au/couriermail/story/0,23739,23411383-952,00.html, March 21, 2008.
30. "Does a Boomerang Work in Space?", http://www.universetoday.com/2008/03/24/does-a-boomerang-work-in-space/
31. Melvin Kranzberg, "Technology and History: Kranzberg's Laws", *Technology and Culture*, vol. 27, no. 3, pp. 544-560.
32. Lewis Mumford, *Technics and Civilization* (London: Routledge & Kegan Paul Ltd., 1967), p. 4.

and regimentation are not new phenomena in history; what is new is the fact that these functions have been projected and embodied in organised forms". Further, "Techniques and civilisation as a whole are the result of human choices and aptitudes and strivings, deliberate as well as unconscious, often irrational when apparently they are most objective and scientific"[33].

Conceptually, the phenomenon of the spread of cruise missiles can be looked at in two ways: (1) the cruise missile as a piece of technology; and (2) the cruise missile as a piece of the war machine.

With this perspective in mind, we need to examine the evolution and spread of cruise missiles in the world: why they have spread; is there any discernible pattern in their spread; is their evolution purely the story of innovation of technology; what necessitated the cruise missiles to come up to this stage after a sustained and unrelenting endeavour? Is it only the sheer curiosity for technological innovation that motivated the innovators for their sustained effort? Or is it the non-technical factors that have taken precedence in such technology policy decisions? Kranzeberg's fourth law of technology amplifies the point that "although technology might be a prime element in many public issues, non-technical factors take precedence in technology-policy decisions". Therefore, the evolution of cruise missiles and the extent of their spread, need to be looked at both from the point of view of laws of technology and the politico-ideological context. The subsequent section investigates such aspects but at a very conceptual level.

SPREAD OF CRUISE MISSILES

Conceptually, the phenomenon of the spread of cruise missile can be looked at in two ways: (1) the cruise missile as a piece of technology; and (2) the cruise missile as a piece of the war machine. Though both perspectives are complementary and mutually reinforcing, such categorisation would serve the purpose of judging the trend and nature of their spread. Also, a term like 'proliferation' is deliberately avoided since the focus of this paper is purely on

33. Mumford, Ibid., p. 6.

the evolution of the cruise missile as a piece of technology. In both respects, various theories are applied to examine the path of its evolution.

(1) Spread of the Cruise Missile as a Piece of Technology: In the first instance, we need to consider the evolution of the cruise as an artifact and its spread thereof. According to Melvin Kranzberg's first law, "Technology is neither good nor bad; nor is it neutral".[34] It evolves "in a socio-cultural milieu and its interactions with both the social and cultural factors sometimes lead to developments that are far removed from the original goals of the technical elements themselves".[35] In other words, for Kranzberg, technology acquires value and meaning in a socio-cultural context and gets shaped in a never ending process, leading to further addition of value and modification of its structure and function. For that matter, if we apply his principle to the evolution of the cruise missile as a piece of technology, it is evident that the aerodynamic principle and rocket technology have been utilised in different societies for different purposes. Countries used them for launching satellite and space missions; and many countries have used them for military purposes. In the same line of argument, the *instrumental theory* of technology views technology as subservient to values like politics or culture. But it views technology as "neutral," without a valuative content of its own.

In the instrumentalist understanding of technology, *neutrality* means: (1) technology is indifferent to the variety of ends it can be employed to achieve; (2) it appears to be indifferent with respect to politics – it appears to be quite different from traditional legal or religious institutions which cannot be readily transferred to new social contexts. The transfer of technology, on the contrary, seems to be inhibited only by its cost; (3) the socio-political neutrality of technology is usually attributed to its rational character and the universality of the truth it embodies; (4) the universality of technology also means that the same standards of measurement can be applied in different settings. Then, if we apply the instrumentality approach to examine the phenomenon of

34. Melvin Kranzberg, "The Information Age: Evolution or Revolution?", *Information Technologies and Social Transformation*, National Academy of Engineering (NAE), 1985.

35. Kranzberg, Ibid.

At every stage of its evolution, only a technical solution was applied to any technical problem that occurred, as there was no alternative to it. And this kept it evolving.

the spread of cruise missile technology, it amplifies the fact that this technology tends to spread, firstly, as a tool standing ready to serve the purposes of the users. How its leaders use this technology depends on the national culture, whether for war-fighting or civilian application.

But the *substantive theory of technology* attributes an autonomous cultural force to technology, overriding all traditional or competing values like politics. Ellul and Martin Heidegger argue that technology constitutes a new type of cultural system that restructures the entire social world as an object of control. Ellul makes it clear that the technical phenomenon has become the defining characteristic of all modern societies, regardless of political ideology. *Technique* has become autonomous. It is not simply a means but has become an environment and a way of life. That is its "substantive" impact. Among many other human activities, *technology is progressive as it is rational*. [36] If this argument is applied to the spread of cruise missiles, it may emphasise the fact that the evolution of the cruise missile from its rudimentary stage in the past to today's sophistication stage is marked by the *technological fix* principle. At any stage of its evolution, only a technological solution was applied to any technical problem that occurred, as there was no alternative to it. And this kept it evolving.

However, the *critical theory of technology*, though it agrees with the instrumentalism, it rejects the neutrality aspect and argues instead that "technological rationality has become political rationality".[37] Meaning thereby that the values and interests of the ruling classes and elites are installed in the very design of rational procedures and machines even before these are assigned a goal. It further asserts that the dominant form

36. "The Technological Fix", http://www.clemson.edu/caah/history/FacultyPages/PamMack/lec122/techfix.htm

37. Andrew Feenberg, "Critical Theory of Technology", http://www.sfu.ca/~andrewf/CRITSAM2.HTM

of technological rationality is neither an ideology nor is it a neutral requirement determined by the nature of technique. Rather, it stands at the intersection between ideology and technique where the two come together to control human beings and resources in conformity with what Andrew Finberg calls "technical codes". Critical theory argues that technology is not a thing in the ordinary sense of the term, but an "ambivalent" process of development suspended between different possibilities. This "ambivalence" of technology is distinguished from neutrality by the role it *attributes to social values in the design, and not merely the use*, of technical systems. In this view, technology is not a destiny but a scene of struggle. If the evolution of the cruise missile is looked at from this perspective, national decision-making has a bearing on its march to the stage at which it stands now. The strategic culture, the ideological inclination of the decision-maker, the threat perception of the national leaders, and the security environment sufficiently impinge upon national security planning and, thereby, the defence planning and preparedness. Therefore, the plan to develop or acquire cruise missiles can be viewed as an offshoot of the national politico-security environment and, therefore, technology is not neutral, as argued by the critical theory. However, this leads to the other aspect of the discussion – the cruise missile as a piece of the war machine.

The dominant form of technological rationality is neither an ideology nor is it a neutral requirement determined by the nature of technique.

(2) Spread of the Cruise Missile as a Piece of the War Machine: The spread of cruise missile as a piece of technology, at the outset, needs to be viewed in the overall perspective of *diffusion of military technology*.[38] And the revolution of frequent change in military technology needs to be seen not as a thing apart but as an integrated element of a broader revolution in science, technology and the human condition as a whole. The advanced military technology has spread throughout the international system by transfer of weapons from the manufacturing countries to the non-manufacturing countries.

38. Barry Buzan, "The Diffusion of Military Technology: Looking Backward, Looking Forward", www.cia.gov/nic/pubs/research_supported_by_nic/conference_paper/chenghu.htm

States perpetually strive to address their perception of national security deficit by arming themselves with the latest military equipment. One adversary acquiring certain weapons tilts the balance that instigates the other side to enhance its capability, and this leads to an unending arms race.

And the well established arms trade, with a powerful constellation of vested interests has always supported the trend. But what is the motive that instigates a nation to acquire such weapons? Very often, a deteriorating national security situation is advanced by the concerned countries as the reason. Instead of achieving security by the help extended by other nations, countries always try to achieve an independent ability to defend, and wage war. One country in a given region acquiring any weapon leads to a chain reaction of an arms race among the adversaries of a given region, which Barry Buzan calls the *security complex*. It implies that the process of diffusion of military technology cannot be considered in isolation from the geo-politics of a given region.

Barry Buzan has formulated his security-complex thesis keeping only Asia in mind. If we look at any other part of the world, similar complexes can be identified, where states perpetually strive to address their perception of national security deficit by arming themselves with latest military equipment. One adversary acquiring certain weapons tilts the balance that instigates the other side to enhance its capability, and this lead to an unending arms race. All these security complexes are bipolar and suffer from a *security dilemma* which is the source of all conflict formation and armament race. And this regional bipolarity is characterised by an intense security dilemma: "A situation in which no community can provide for its own security without threatening the security of others".[39] None of the states involved want relations among them to deteriorate, but as each state acts militarily or diplomatically to make itself more secure, the other states interpret its actions as threatening. This

39. John H. Herz, "Idealist Internationalism and Security Dilemma", *World Politics*, Vol. 2, 1950, pp.157-180.

initiates the conflict formation process which channels external interventions along the line of internal rivalries. Also different regions are so interlinked that the issues of one region have sufficient implications on the other regions. Therefore, an arms race in one region instigates the same in the other regions as well. Such security complexes can be found mainly in Asia and Africa which constitute the Third Word. And most of the Third World countries either have their own missile programmes or have received them from their patrons.

The kind and variety of cruise missiles a country requires in one security complex may be completely different from the requirement of another country in another complex.

However, this regional complexity has actually helped the evolution process of cruise missiles in one way or the other. For example, the kind and variety of cruise missiles a country requires in one security complex may be completely different from the requirements of another country in another complex. So the nature of the regional security situation and geo-politics determine the features of the missiles of a nation. Therefore, if states start their own programmes, they design them according to their specific requirements, like the range, payload, speed, etc. If they receive the missiles from any other country, they redesign or modify them according to their strategic requirements, thereby the missiles go through a different phase of evolution.

Also the popularity and spread of a weapon depend upon the status it bestows upon the state, the objective it can accomplish, and how cost-effective it is. In this context, the nuclear weapon is viewed to bestow higher status and is considered so far the ultimate weapon. Though many countries have shown interest in it, only a few have achieved success only because it is not affordable for all and involves extremely difficult technology. Next to nuclear weapons, probably the missile is an instrument where status or prestige is involved. It is also comparatively affordable in both qualitative and quantitative terms, for a large number of countries. Therefore, many Third World countries have already acquired missiles.

Requirement generates new challenges which drive nations to work on the leading edge of technology[40]. If we consider the cruise missile purely as a piece of the war machine and part of the military industry, the principle of "requirement push and technology pull" has also significantly contributed to its evolution. This push-pull factor has definitely worked in the evolution of cruise missiles.

Overall, the cruise is a sober success. But to address why the cruise missile has got relatively less attention in strategic studies, even though the missile discourse is much older than the nuclear discourse, one needs to resort to a comparative study on the psycho-dynamic aspects of weapon systems. In pursuit of this, at the basic, one needs to identify the nuances in the politics and psyche involving 'atom-power' while comparing them with the nuances involving the lesser known, lesser publicised concept of 'air-power' and aerodynamism.

40. James R. Hansen, "Technology and the History of Aeronautics: An Essay", http://www.centennialofflight.gov/essay/Evolution_of_Technology/Tech-OV1.htm.

TRANSFORMATION IN MILITARY LOGISTICS

J.V. SINGH

Improvements of the weapons are due to the energy of one or two men, while changes in the tactics or the case of the entire process of transformation has to overcome the idea of a conservative class.

— A.T. Mahan

Battles are decided by the logisticians before they have even begun.

— Field Marshall Erwin Rommel

Military logistics has seen quite a few transformations since the technological revolution, specially in the field of communication and information technology. The main reason for this transformation has been the growing realisation that logistics is the key element of the war-fighting supply support and this has been amply demonstrated in almost all the wars that have been fought. What has, however, emerged in recent times is that with the revolution in military affairs (RMA), there has been a corresponding transformation in military logistics so as to keep pace with the RMA and provide commensurate logistics support to sustain the war-fighting effort in the changed geo-political power equilibrium. The evolution in logistics

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The pace of transformation in military logistics has, however, been rapid in the post-Cold War period. Also, the transformation has been influenced by corresponding changes in the logistics practices of the civil sector.

practices has been a continuous phenomenon and has been driving the logistics managers to ensure the required material support to sustain operations in both peace and war. The pace of transformation in military logistics has, however, been rapid in the post-Cold War period. Also, the transformation has been influenced by corresponding changes in the logistics practices of the civil sector.

The end of the Cold War has had a signalling effect on the overall geo-political equations the world over. New alliances have been emerging, resulting in something like a multipolar world order. That is not to deny the fact that as the sole superpower, the United States continues to dominate the power equilibrium and wields considerable influence in world affairs. Translated in military terms, this shift has affected the dynamics of recent conflicts and possibly the shape of future wars. Since logistics is intrinsic to any conflict, it is natural that there would be corresponding transformations in military logistics to meet the operational requirements. Some of the other factors that have influenced this transformation include the economic considerations whereby the armed forces have to ensure cost-effective measures to provide for the best value for money that a country spends on defence, albeit without compromising on the military preparedness.

A significant shift in military affairs has been due to the impact of information technology (IT). The advancements in computer science, communications and other IT sectors have resulted in RMA globally. Since military logistics is closely linked with warfare, this RMA has to be supported by a corresponding revolution in military logistics (RML).[1] The key to further operations would be to deploy a force that is defined less by size and more by mobility and swiftness. Such a force will be easier to deploy and sustain and

1. Mark J. O' Konski, "Revolution in Military Logistics: An Overview," *Army Logistician*, January-February 2000, pp. 23-30.

will rely heavily on advantages in stealth, precision weaponry and IT. Thus, the logistics pipeline must be shrunk, the load lightened and the closing time cut. The RML is not only central to preparing for future military operations; it is the fulcrum of efforts by military forces to balance readiness and modernisation. The RML has to focus on exploiting improvements in communications, business practices, reshaping command and control relationships to provide better utility of command and reduced logistics footprint. The RML is also about developing distribution technologies that facilitate rapid throughput and follow-on sustainment.

Tranformation of the US armed forces logistics began in 2001 with the RML concept which provided for a clear vision of the logistics changes required. Chief of Staff of the Army Gen Dennis J. Reimer, has clearly declared, "As I have said many times, there can be no Revolution in Military Affairs (RMA) without having a Revolution in Military Logistics (RML)." The RML included *six tenets* on how the armed forces will be supported in the future. These are, seamless logistics systems, distribution-based logistics, agile infrastructure, total asset visibility, rapid force projection and adequate logistics footprint.

Introduction of automation in various walks of life has made us conscious of the fact that for equipping and sustaining the forces, a very powerful tool has come into the existence. Modern technology has permitted the growing use of computers into logistics units. Latest communications have made it possible to pass the demands automatically through the whole chain of command and supply right down to the base depot. This enormously improves management capabilities and increases the speed of supply. Computerised stock control has made the handling of demands much faster than before and present the commanders with an immediate "read-out" of holdings and reserves at various levels. This information can be flashed into the computer monitors at all levels of commands. This will, in turn, help the operational commanders to correctly assess their requirements and supply positions in so far as their immediate needs are concerned. Thus, IT provides us with better tools and more reliable inputs for taking material related decisions in both peace and war. The impact of this important shift has been far reaching in the management of defence logistics across the board.

The aim of this paper is to examine the factors leading to the transformation in military logistics the world over, with a special emphasis on the model adopted by the US and other developed countries, look at the greater role of the private sector as a preferred route by the armed forces to shed excess baggage and discuss their impact on the Indian armed forces.

NEED FOR CHANGE IN MILITARY LOGISTICS

Change is the only constant in nature. Change, therefore, in the field of national security and defence is something that needs foremost attention so that the requisite adjustments and change in strategy to deal with the implications of the changes taking place are made. On the other hand, military organisations are historically noted for their conservatism, besides the inevitable human inertia and the unwillingness to change. Admiral William Owens who retired as the vice chairman, Joint Chiefs of Staff, and went on to head the SAIC, the largest employee owned company in the USA, admitted, "*Military organizations, especially successful ones, normally resist change.*" [2] This conservatism is understandable since few prudent people would like to take chances in such a key area of human enterprise as national security and defence. The risks of errors in dealing with change can be momentous. The internal dynamic of traditionalist versus radicals in military organisations can destroy or encourage dissent, discourse and innovation acceptance. Incremental changes are the preferred route.

Equally important is to understand that change is both evolutionary and revolutionary, the latter less often. No doubt, more than 95 per cent of organisational changes are evolutionary. The resistance to revolutionary changes are indeed strong. Most organisational change consists of improvements, incremental steps to fix a problem or change a part of the larger system. Such variations are ongoing; there is no beginning or end point in this change process. Revolutionary changes, on the other hand, by

2. Admiral William A. Owens, *High Seas* (Annapolis: Naval Institute Press, 1995).

definition, can be seen as a jolt to the system. As a result, nothing will ever be the same again. Organisations that change their missions exemplify revolutionary change.

Defence forces also require an internal consensus to change, as much if not more than the technology and socio-economic imperatives which necessitate change.

Defence forces also require an internal consensus to change, as much if not more than the technology and socio-economic imperatives which necessitate change. At the turn of the century, technology and threats have both changed dramatically. This is forcing defence organisations to examine the doctrinal and organisational assumptions on which they have operated so far. This global development is also impacting on India's armed forces. The burden of tradition and resistance to change rests heavy on Indian defence organisations. The manner and extent to which they are willing to change will determine their success in defending Indian military interests in the future. Change in military organisations does not come about easily. Gen Starry, a former head of the US Army Training and Doctrine Command, has listed seven conditions needed for changing a military organisation. First, a mechanism is needed to identify the need for change. Second, reformers should share "cultural commonality of intellectual endeavour" through shared educational and training background. Third, there must be an effective spokesman for change. Fourth, there is need for consensus building to get a wide audience for new ideas. Fifth, there should be continuity of service amongst the architects of change. Sixth, a champion of change must be found at the apex of the organisation. Seventh, changes must be through rigorous trials and their viability demonstrated.[3]

Before one looks at the transformation of military logistics, it is important to examine the issue of core and non-core logistics functions. Where the military *per se* is concerned, it is easy to identify war-fighting capabilities as the core competency. However, in the case of military logistics, the difficulty lies in identifying the logistics services that should

3. Donn A. Starry, "To Change an Army," *Military Review*, 63, no.3, March 1983.

be retained as core military competencies. Core activities are those that would be undertaken inside an area of operations. Non-operational activities are activities associated with training and support that do not require military skills, are generally commercial or administrative in nature, and are not directly related to operational activity. Drawing from these definitions, non-core logistics functions can be described as non-operational activities, which military personnel are not required to undertake. Gradually, the armed forces are moving out of non-core functions globally.

MILITARY LOGISTICS SYSTEMS OF OTHER COUNTRIES

Transformation of military logistics has been almost a universal phenomenon in all modern militaries in the world. However, the extent and specifics of such a transformation have obviously been varied and guided predominantly by the security and threat perceptions of each individual nation. What has, however, been common across the board is the impact of the information technology revolution on the way armed forces have begun to model their logistics management. Perhaps the most visible model in logistics transformation has been the US experience in this field. Though the US model need not necessarily serve as a role model tailor-made for other militaries to follow in a straightjacketed method, it, however, offers a fair idea of managing logistics in the modern day conflict scenario where rapid deployment and sustaining mission oriented logistics will need a relook at the way traditional logistics management has been done so far. Hence, the US model is discussed in greater detail.

TRANSFORMATION OF MILITARY LOGISTICS IN THE USA

Logistics is the lifeblood of the armed forces. Changing how we fight influences changes in how we support. The US Chief of Staff of the Army (CSA) has stated, "The transformation objective is to field a force that is strategically responsive and dominant at every point on the spectrum of operations. American military might must draw on new technologies and strategies in the 21st century. We must build forces based on revolutionary advances in the technology of war that will allow us to keep the peace by defining war on our terms.

"A future force that is defined less by size and more by mobility and swiftness, that force will be easier to deploy and sustain and will rely heavily on US advantages in stealth, precision weaponry and information technology."[4] The transformation challenges the armed forces to balance near-term readiness and force modernisation in an environment of increased missions and fewer resources. The logistics pipeline needs to be shrunk, the load tightened, and the closing time cut. At the joint level, change started with Joint Vision 2010 and focussed logistics. At the army level, change started with the RML. The RML is considered central to the preparation for future military operations and is the fulcrum of the army's effort to balance readiness and modernisation.[5] The transformation in the way the army is to be deployed in the future is the process of converting the army's focus and structure from a Cold War construct to a full spectrum combat force that is strategically responsive and dominant at every point of the spectrum of the conflict. It is more than technology, it is doctrine, training, leadership, organisations, material readiness, installations, and soldiers.[6] These changes are vital for an RML. The first wave of RML focusses on exploiting improvements in automation, communications, business practices, reshaping command and control relationship to provide better unity of command and reduced logistics footprint. The RML is also developing distribution technologies that facilitate rapid throughput and follow-on sustainment as the army builds up its future objective force.

4. Eric K.Shinseki, Congressional Statement on The Army Transformation, Statement presented to the 106th Congress, 2nd session, March 2000.
5. Charles S. Mahan Jr, "The Challenges of Fielding The Army's Objective Force," *Army Magazine*, October 2001, p. 128.
6. William Grisoly, "Army Tranformation," Department of the Army Transformation Office, Carlisle , US Army War College, February 1, 2002.

Automation

The RML requires more than just changes in technology. It teams technology with new support techniques and dynamic logistics doctrine. The precision delivery of combat service support (CSS) is anticipatory and provides significant efficiencies in both supply and distribution. To harness these economies, the armed forces must capture, process and manage the disparate data and communication systems that make CSS occur. At the heart of the CSS information system is the Global Support System –Army (GCSS-Army). This system is much more than a close combat coordination and CSS delivery information system. It integrates and fuses information from the factory to the actual theatre of operations, coordinating, expediting and managing the numerous activities in between. Performing these functions requires communications and interactions not only within and between command layers and theatres, but also between sister Services. Knowledge gives leaders the necessary awareness. Precise real-time knowledge of the disposition of their assets allows commanders to manoeuvre CSS assets as quickly as they manoeuvre combat elements, thereby shaping the battle. [7] The army continues to streamline its operations in both peace and in combat, and a passive approach to logistics is no longer acceptable. Waiting for support is not a strategy. GCSS-Army is an evolutionary logistics information system that builds on the functions and processes of existing systems to generate data, integrate databases, and fuse CSS information from external sources as necessary to execute the RML.

GCSS-Army software will be delivered in a number of modules, according to the particular function needed. Each module will have common components and share a common database. The maintenance module will facilitate maintenance management at all levels, from the organisation up, and provide maintenance management information to logistics staff elements. The property accountability module will capture accountable property data, build and track hand receipts, provide management data

7. Colonel Edward J. Shinko and Lieutenant Colonel Thet-Shay Nyunt, "GCSS- Army – Making the Revolution in Military Logistics Happen," *Army Logistician*, January- February 1999, pp. 85-91.

for cross-levelling, and eliminate excess. Ammunition and supply modules are designated for support organisations with supply support activities and ammunition supply units. The Integrated Material Management Centre (IMMC) module allows MMC-level users to 'see' and manage the stocks on the ground and in-transit in their support area. The management module will give commanders and staff officers visibility and management information for CSS assets in their areas of responsibility. Additionally, the management module will fuse information from non-GCSS-Army databases, such as the Standard Installation/Division Personnel System, Transportation Coordinator's Automated Information Management System II, and others as needed

A seamless logistics system that ties all parts of the logistics community into one network of shared situational awareness and unified action can be achieved only in an environment dominated by global, wireless, assured communications.

Communications

The revolution in military logistics will also require a dynamic new approach to logistics support. A seamless logistics system that ties all parts of the logistics community into one network of shared situational awareness and unified action can be achieved only in an environment dominated by global, wireless, assured communications. Many world-class commercial companies have reduced inventories significantly and now rely on real-time information, coupled with rapid transportation, to meet customers' demands. Substantial cost savings in acquisition, warehousing, packaging, and transportation have been achieved by reducing inventories. Much of their inventory is in motion in the logistics 'pipeline.' To manage their reduced inventories, these companies employ global, wireless communications systems that give them up-to-the-minute status on shipments and deliveries.[8]

8. Roger Houck and Williams Cousins, "Communications Technologies for the Revolution in Military Logistics," *Army Logistician*, January-February 2000, pp. 95-97.

In the future, by leveraging information technologies, logisticians will be empowered to provide the right support at the right time at the right place. They will no longer rely on 'historical' data. Rather, they will have real-time, predictive information to make intelligent decisions and optimise force readiness. Global wireless communications will provide soldiers the capability to reach and 'see' virtually anywhere on the battlefield or in the world. Today, some 700 communications satellites orbit the earth. It is predicted that there will be over 2,000 by the year 2010. The market for commercial use of global wireless communications, both voice and data, is growing exponentially. Therefore, providers are scrambling to increase total capacity by putting up more satellites, and to increase the speed of information flow by improving technology. Competition for market share is driving down the size and cost of mobile equipment, while battery life is increasing steadily.[9] These communication systems are being developed for a global commercial market, but have broad applications for military use at the strategic, operational, and tactical levels. These technologies can provide the capability to receive, transmit, store, and retrieve information in a single seamless logistics system supporting a modern force in tomorrow's army.

Best Business Practices

Methodologies and applications used in private industry that elevate a commercial enterprise above the competition are referred to as "commercial best practices." Best practices enable leading-edge organisations to deliver world-class standards of performance to their customers. These best practices and standards of performance have generated much interest within the army logistics community, which is constantly being asked to do more with less. The emergence of commercial best practices took place because of downsizing and a hunger for profitability, or doing more with less, so it stands to reason that there could be a great deal of benefit to army implementation of these best practices

Leveraging of commercial best business practices is a popular topic in the literature and presentations concerning the army of the future, the RML, and the Objective Force. The RML, as a precursor and roadmap to the Objective Force, could be accelerated greatly by investigating and embracing many commercial logistics best practices. Integrated supply chain management, the industry's changing view of logistics, electronic commerce, automated identification technology, direct vendor delivery, load optimisation, outsourcing, and smart simple design are all examples of commercial best practices that could be very useful in helping the army achieve the RML.[9] The Army Material Command (AMC) will transform into a more responsive Army Support Provider (ASP). This ASP will ensure: sustainability is designed into future systems with enormous improvements in reliability, availability, and maintainability; a single command, control, communication, computers/information and technology (C4/IT) architecture provides logistics information at all levels; centralised contracting information is always available; and, embedded. [10]The next few paragraphs will briefly discuss the emerging trends, capabilities, and best practices of commercial firms that perform the logistics function and move assets and information throughout the supply chain. The parallels with the RML and the army's modernisation of business practices and information technologies are striking.

The scope of supply chain management includes the supplier's supplier and the customer's customer. In recent years, supply chain management software providers and consultants have emerged as a multi-billion-dollar industry.

Integrated Supply Chain Management

The Massachusetts Institute of Technology defines integrated supply chain businesses management (ISCM) as a process-oriented, integrated approach to procuring, producing, and delivering products and services to customers. In

9. Robert D. Paulus, "Industry and Logistics Transformation," *Army Logistician*, July-August 2001, pp. 39-40.
10. Paulus, Ibid., p. 96.

this context, ISCM has a broad scope that includes suppliers, customers, and internal information funds flows. Thus, the scope of supply chain management includes the supplier's supplier and the customer's customer. In recent years, supply chain management software providers and consultants have emerged as a multi-billion-dollar industry. The information technology and software solutions offered by global vendors, many of whom have Fortune 500 client lists, offer the tools, visibility, and connectivity to facilitate supply chain management, integration, and optimisation. Supply chain management solutions have been most successful when a holistic, end-to-end approach is employed and when processes and information are integrated throughout the enterprise.

Implementation of software to manage the supply chain must integrate many different processes, including supply and demand planning, transportation and distribution management, and advanced planning and scheduling (for asset management or manufacturing operations). This approach can result in inventory reductions, increased on-time deliveries, reduced total product cycle (make-to-sell) time, increased revenues, and better customer service.[11] All of this adds up to significant savings and an important gain in competitive advantage. Applying tailored, integrated, enterprise-wide business process management software suites when implementing supply chain management techniques is creating a growing revolution in corporate-wide logistics management. This holistic approach is revolutionising corporate-wide logistics management. Many companies are promoting their logistics chiefs to executive vice presidents and senior vice presidents. Senior logisticians are being included as members of executive committees. This trend illustrates the institutionalisation of the value of logistics to the bottom line. Likewise, use of the logistics matrix in the corporate suite for planning and policy decision-making is also increasing.[12]

11. Helen Keeler, "Transformation Office Calls For Cultural Changes, Possible Acquisition Shifts," *Defense Daily International*, November 30, 2001, pp. 1-5.

12. Keeler, Ibid., p. 2.

Electronic technologies and applications have expanded to affect many aspects of logistics. US companies have used electronic commerce to increase productivity as they enhance business transactions, data and information exchanges, business process reengineering, organisational changes, and process automation.

With increased ability to handle tremendous volumes of transactions and the ability to amass, analyse, and control large quantities of specialised data, organisations have improved efficiency and accuracy and reduced costs, while providing faster, more reliable, more convenient services. These capabilities and the concomitant benefits will be further enabled by rapidly developing intelligent agent technologies that greatly enhance information filtering, search, retrieval, and off-line delivery. Electronic commerce and the sharing of information among entities and organisations facilitate vendor-managed inventories (VMI), paperless contracting, collaborative forecasting, and workflow management.[13] Through VMI, suppliers can control inventory and replenishment, as well as manage forecasting for improved customer service and increased inventory rotations. With VMI, suppliers can generate more accurate forecasts, which can lead to better production scheduling and reduced operational costs.

Electronic catalogues post product information on the internet. Many sites offer interactive capabilities such as on-line ordering. Internet purchasing and electronic catalogues are being used to streamline order cycle times, cut administrative costs, and speed up product delivery to the customer. The ability to order supplies over the internet can reduce cycle times drastically throughout the supply chain. This means that a low-cost, web-based, distributed procurement and resupply system can be delivered by standard web browsers.[14]

Automatic identification technology (AIT) includes bar codes, radio frequency (RF) tags, satellite tracking, 'smart' cards, and laser cards.

13. Larry Smith, "Commercial Logistics Best Practices for the Revolution in Military Logistics," *Army Logistician*, January-February 1999, pp. 137-141.

14. Smith, Ibid., p. 138.

Industry has found that to have successful implementation of these best practices, which would have system-wide impact and/or result in extensive change, it must also have the top leadership's commitment, support, and involvement.

Commercial-off-the-shelf (COTS) satellite tracking provides real-time monitoring of transportation assets and customer products. Bar codes, the most widely used form of AIT, and the visibility they provide, have enabled a great deal of the agility found in today's world-class manufacturers and retailers. The visibility of goods and assets in storage, in transit, and in process has resulted in reduced inventory levels and order and ship times, and improved overall responsiveness to customers.

Outsourcing non-core competencies is a recognised best practice. The reasons for outsourcing logistics functions include lower costs, a streamlined labour force, access to top personnel, and cutting-edge technologies. According to the Outsourcing Institute, 85 per cent of companies now outsource work they used to do in-house. The key reasons to outsource a function are cost and performance. Third-party logistics providers can leverage their core competencies to improve enterprise-wide performance. They provide significant economies of scale through their specialisation. By partnering with world-class providers of logistics services, companies dramatically improve service, profitability, and response times. The key to some of the best practices found in world-class organisations is an integrated information system with total, real-time asset and activity visibility. The technology and expertise currently exists to leverage best business practices into army operations and execute the RML. Industry has found that to have successful implementation of these best practices, which would have system-wide impact and/or result in extensive change, it must also have the top leadership's commitment, support, and involvement. The army Objective Force cannot be successfully supported with the resources and infrastructure that are currently projected. We need best-in-class logistics practices. The army must partner with world-class logistics providers when appropriate and become a world-class provider itself by leveraging the best industry has to offer. The challenge is to determine where and when to pursue each of these industry-proven strategies.

Infrastructure and Reduced Logistics Footprint

The RML requires increased agility in a number of dimensions. Army logistics will have to become more agile structurally, physically, and mentally in order to cope with the demands of dynamic RML support to the agile and mobile forces of the Objective Force, the goal of the current RMA.

Structural agility will be accomplished through total integration of all army components, as well as incorporation of support teams from other Services, allies, and the army's partners in industry to meet the demands of specific missions. Teaming and task-organising are key RMA skills that apply especially to RML support forces. Logistics task forces need to be able to scale up and down in size, as well as in technical expertise. Personnel, teams, and units from all components should be capable of deploying and moving independently to an in-theatre rendezvous location. Active and reserve component units must be ready to accept, employ, and, in some cases, support Department of the Army (DA) and Department of Defence (DoD) civilian augmentation, as well as contractor personnel and equipment. All must be prepared to integrate with allied and host nation support organisations.[15]

Physical agility enhances the ability to deploy and manoeuvre the operational infrastructure of the distribution-based logistics system. Distribution-based logistics depends on an integrated, inter-nodal network of information systems, distribution platforms, and automated materials-handling equipment. To keep pace with fast-moving Objective Forces and to stay one jump ahead of an opponent's long-range weapons, the logistics units and personnel operating this network must be able to manoeuvre the component systems and control the movement of the distribution platforms on the fly. And they must be able to do so without degrading the throughput of sustainment to the fighting forces.

15. O'Kinsky, n. 1.

Army logistics has risen to the challenge of the RML and responded with a viable concept, backed up by a plan that provides previously unheard-of levels of capability as well as previously unheard-of levels of efficiency and economy.

Mental agility refers to attitude. RML logistics is fast logistics. All logistics managers in the supply chain need to think several steps ahead, all of the time. Real-time, 24-hours-a-day, 7-days-a-week operations will be the norm. Organisations need to have staff for this tempo and train team members to work in such a fast-paced non-stop environment. Additionally, many of the initiatives in the revolution in business affairs that streamline and improve logistics, acquisition and financial processes, contribute to this new, heightened agility.

Acquisition agility is a key army goal in the RML. In order to keep pace with the fast changing demands of RMA warfare and RML support, the acquisition system must support rapid and flexible access to a wide range of commercial sources of supply. The agile acquisition system also will be crucial to designing, building, and fielding the advanced systems and modernisation packages that will make the Objective Force a reality. Reduced development cycles will provide state-of-the-art technology to our forces in the field at a price the nation will be willing to pay if we are agile enough to exploit it.[16]

Army logistics has risen to the challenge of the RML and responded with a viable concept, backed up by a plan that provides previously unheard-of levels of capability as well as previously unheard-of levels of efficiency and economy. But there always will be a limit to how small the logistics system can get without sacrificing support to the combat units and accepting too much risk.

Maintaining an adequate logistics footprint involves a number of things. First, is presence in the theatre of operations. In today's complex world, there is always a significant trade-off between capability and force protection. Commanders-in-chief (CINCs) are understandably reluctant to have any more soldiers and civilians placed in harm's way than is absolutely necessary.

16. Keeler, n. 2.

When the theatre force must be limited due to force caps, shortages in lift assets, or force protections requirements, cutting support forces is an attractive option. Unfortunately, these support forces are often the key to sustaining the dominant combat power of modern US fighting forces. Operational planners should be sensitive to the sustainable force level as well as to the total deployed force level. The readiness maintenance and enhancement capabilities of logistics support forces need to be considered when force packages are being designed. Future CSS units must enable aggressive reduction in the manoeuvre sustainment footprint with fewer vehicles and leverage reach-back capabilities. *Ideally, combat forces are empowered by logistics, not encumbered by logistics.*

Operational logistics infrastructure also assumes a new configuration in the RML. As envisioned in the Objective Force Operations Support Command (OPSCOM), the RML logistics support for an engaged CINC will be operationally, not geographically, focussed. This means that the CINC's logistician and the OPSCOM commander will command and direct forces, units, agency offices, and contractor operations on a global basis, all focussed on the CINC's operations. This will give the CINC and his OPSCOM commander great flexibility in moving work to workers and workers to work. However, care must be taken in sizing future logistics organisations so that when missions are moved to allow a reduction at one level of command, they are not given to organisations whose capabilities have been reduced under previous mission transfers.[17]

Maintaining a viable logistics infrastructure between operations is also vital. Today's logisticians throughout the army and DoD currently perform numerous essential tasks every day, efficiently, and with little fanfare. The ability to project a sustainable force at a few hours' notice is possible only through their constant effort. In the same way, institutions need to maintain and pass on a corporate memory and corporate culture to remain great. Army logistics does this well at all levels and in all components. However, the toll of

17. The Army Transformation Office, "Statement of Required Capabilities, Future Combat Systems," November 2, 2001.

the recent series of drawdowns has had its effect. In future sizing decisions, the viability of institutions to continue operations and develop leaders must be considered.

Creating an adequate logistics footprint involves more than structural change. It also involves the development and refinement of concepts, ideas, and material. The Army Training and Doctrine Command is using a series of war games to bring together senior defence policy-makers to participate in scenario-driven exercises and discuss critical strategic and operational issues that will shape the army. Product improvements and block material replacements will change the way the army develops, tests, acquires, and maintains equipment. There will be increased reliance on split-based operations to reduce the logistics footprint in the theatre of operations. The number and type of weapon systems needed by land forces in the battlespace to hold and dominate terrain will change, and so will the operational and tactical logistics requirements.

Resupply, maintenance, and other combat service support functions will be accomplished in completely different ways or in the relative safety of a rear-area or continental United States location. It is this relocation of functions that offers the greatest potential for reducing the logistics footprint in the theatre of operations.

Modularity and new commercial best practices will be leveraged to minimise the logistics footprint without sacrificing capability. Smart simple design, a commercial industry best practice, has reduced the costs, assembly, and manufacture cycle times. It has reduced the number of parts in commercial systems and increased the serviceability of these systems. Army acquisition programmes must emulate smart simple design or similar initiatives to improve manufacture, assembly, and serviceability. Weapon systems or major end items that have fewer parts and, thus, are easier to repair and maintain will require lower levels of inventory and fewer maintenance personnel to support them. Use of this methodology for army weapon systems could reduce logistics demands and contribute to an adequate logistics footprint.[18]

18. Roger Houck," Adequate Logistics Footprint," *Army Logistician*, May-June 2000, pp. 101-102.

Other potential contributors to a responsive and efficient logistics footprint include robotics, unmanned vehicles, intelligent agents, diagnostics and prognostics, smart/brilliant munitions, real-time communications, and fuel and energy efficiencies. Advanced robotics technologies will replace people in missions such as reconnaissance, material movement, and transport. The use of unmanned transporters may range from aerial vehicles to tanks.

Sensors, advanced information technology, diagnostics, and prognostics alone could have tremendous impacts throughout the army logistics system and are key components of the RML. The incorporation of prognostics in digitised weapon systems will drive the numbers of weapon systems, material, and maintainers required in the battlespace. The ability to predict system failures before they occur will improve repair lead-times and prevent failures during mission-critical operations. Parts that diagnose themselves and requisition their own replacements or needed components will reduce the number of soldiers involved in the supply process. Assured communications and tele-maintenance applications will allow the expertise, but not necessarily the expert, to travel. The increased speed of repair and the enhanced capabilities will reduce the number of weapon systems required for adequate lethality on the battlefield and in the inventory.

This lethality will be achieved through the use of smart munitions and lighter, ultra-reliable weapon systems, as opposed to the mountains of ammunition employed in the past. One-to-one or better kill ratios mean lower ammunition support requirements and fewer weapon systems needed to complete fire support missions. The incorporation of advanced materials, biomimetics (materials that mimic the properties of those found in nature), manufacturing technologies, and design methodologies will result in lighter, ultra-reliable systems. All of these will have an impact on the logistics footprint. Finally, fuel will most likely continue to be a significant part of the support burden faced by army logisticians. But with fewer, lighter weapon systems and advances in hybrid systems, this requirement will also decline significantly.

Adequate logistics footprint, as an RML tenet, is not just about reduction. It is about balancing the right size, the right amount, and the right knowledge to do the job in supporting 21st century operations. It is the result of a reduced logistics demand, more lethally efficient weapons, information technologies that focus directly on the war-fighter, a seamless logistics system that allows for streamlining redundant support functions and organisations, and a transformation from a supply-based to a distribution-based logistics system. The next section explores the concept of distribution-based logistics.

Distribution-Based Logistics

The operational concept of distribution-based logistics (DBL) relies on distribution velocity and precision, rather than redundant supply mass, to provide responsive support to war-fighters. It reduces the mass required to compensate for the lethal uncertainties of war by reducing uncertainty across the joint theatre. DBL rests on three pillars: visibility, capacity, and control.

Visibility: The acquisition of near real-time situational understanding, or visibility, has been a major objective of Force XXI. The army is continuing this effort, fielding the first digitised division in December 2000, to be followed by the digitised corps in 2004. The advent of the new Army Vision has only emphasised the need for improved visibility.[19]

Visibility can be grouped into three major categories. First, there is visibility of the supported war-fighting units, which includes the unit's prioritised requirements, the commander's priorities among units, and the current and projected commander's intent. Situational understanding of the supported unit is the most essential element of the visibility tenet, since the status of the war-fighting unit defines the logistic mission and establishes priorities.

The second category of visibility is logistic capabilities and constraints. The logistician must have real-time situational understanding of his own

19. Robert McKay and Kathy Flowers, "Transformation in Army Logistics," *Military Review*, September- October 2000, pp. 45-51.

capabilities and constraints. These include visibility of elements of capacity such as infrastructure, material systems, inventories, transportation resources, personnel skills and training, and the logistic implications of the situation.

Army personnel reductions, extremely slow acquisition processes, and limited budgets for research and development (R&D) and procurement are making it very difficult for the AMC to accomplish its currently assigned tasks and missions.

The third category of visibility includes logistic requirements and priorities to the supporting organisations at the theatre and strategic levels. Conveying situational understanding to supporting logistics organisations, such as from the corps support command to the theatre support command or the Defence Logistics Agency, becomes increasingly important, particularly as the army loses autonomy to strategic-level providers, even within the theatre of operations.[20]

Capacity: The logistics force must have the physical capacity to act on the knowledge provided by real-time visibility. This includes the array of material systems: the lean but adequate inventories; road, rail and facilities infrastructure; and skilled personnel. These capabilities include the material for physical distribution within the theatre and from the continental United States by military or private vendors. Enhancements to new and improved material systems such as embedded sensors and prognostics, are essential to anticipating logistic requirements.

Control: Some of the most important logistics modernisation efforts fall under the tenet of control. These include the tactical force structure of the brigade combat teams; the theatre support command; and the single seamless army logistics organisation, the Army Readiness Command. Control also includes the necessary doctrine (at the operational and tactical levels) and law, policy and regulation (at the strategic level). Control encompasses the expert leaders and artisans who apply logistic capabilities to satisfy prioritised operational requirements.

20. McKay and Flowers, Ibid., p. 45.

The DBL is the envisioned RML end-state. The DBL will comprise a system of innovative policies, doctrine and concepts; reengineered logistic functional processes; redesigned organisations; new material systems with embedded sensors and prognostics; advanced information, decision-support and command and control systems; and well-led, highly trained soldiers and civilians to operate and manage it.

AMC's Role in RML

The Army Material Command (AMC) is primarily responsible for the army's revolution in military logistics. It is responsible for sustaining the force, power projection, weapon system management, and technology integration. However, the greatest challenge will be whether the AMC can successfully change its culture to effect transformation. It must transition from being the "owner" of the army's material and logistics systems to being the army's "integrator." Army personnel reductions, extremely slow acquisition processes, and limited budgets for research and development (R&D) and procurement are making it very difficult for the AMC to accomplish its currently assigned tasks and missions, let alone effect an RML. Additionally, the base realignment and closures (BRAC) and reductions mandated in the first Quadrennial Defence Review (QDR) have also had a significant negative impact on the AMC's own organisational structure by significantly reducing its force structure. Continued limited resources, increasing OPTEMPO, and an unclear threat are exposing the chinks in the AMC's armour. It's time for a new approach. One possibility is leveraging support from other Services, our allies and from industry. To manage the increasing work load with reduced resources, the AMC has formed a general officer-led Overarching Integrated Product Team (OIPT) to develop options and recommendations for reengineering the AMC so that it will be capable of accomplishing the mission of equipping and sustaining soldiers. The OIPT serves as a "guiding coalition" of leaders charged with devising and implementing a strategy to effect transformation and make the RML a reality. However, the effectiveness of OIPT's recommendations may depend upon whether the strategic leaders can adequately change the culture. This requires not only acceptance of the AMC, but also the acceptance of supported commanders in the field and their respective logisticians.

The army has transitioned from a threat-based force to a capabilities-based force. Presently, two divisions are converting to the new digitised Army XXI structure. Additionally, two "interim brigades" have been formed but are not operational and four additional brigades are planned to be converted. To support future contingency forces, the logistics system must become capability-based. The AMC commander has stated that his organisation must be "modular for flexibility, able to anticipate and predict logistics requirements sooner, have a total asset visibility, focus limited logistics resources at the point of need, and able to react faster than ever before." Moreover,[21] these functions must be synchronised with the rapid OPTEMPO of future operations.

UNITED KINGDOM

In July 2006, the UK Ministry of Defence (MoD) published an "Enabling Acquisition Change Report" document that reviews the current structures and processes in order to maximise the MoD's ability to deliver the key objective of "through life capability management." This document focusses on the costs and capabilities of equipment throughout its life. The report recommends the merger of the Defence Procurement Agency (DPA) and Defence Logistics Organisation (DLO) to form a new integrated procurement and support organisation. It was announced in October 2006 that the merged DPA and DLO will be called Defence Equipment and Support (DE&S).

SOUTH AFRICAN NATIONAL DEFENCE FORCE (SANDF)

Support to SANDF forces deployed in Africa is provided to a large extent by aircraft flying over foreign states. Although the countries have good diplomatic relations with South Africa, road and rail communications are not

21. Gen John G. Courn, "Logistics: Flexing Muscles for Army Transformation," *Army Magazine*, March 2001, pp. 11-12.

good. The magnitude of the logistical task is, thus, not to be underestimated. It is to the credit of the DoD and particularly the SANDF, that the logistics support provided is succeeding in keeping the forces deployed operational. Though the media coverage from time to time reports the results of poor logistics support, generally the SANDF has managed to adopt and adapt the military logistics system to the operational scenario.

In spite of its success in supporting its force deployments in various peace-keeping operations, it was felt that the overall SANDF logistical system and command and control in general has not been functioning well. As a result, the government announced that the organisation of the force needs to be restructured since the system introduced in the 1990s was based on business principles, and was not considered effective for the military environment. One of the weaknesses was the over-complicated logistics system. To its credit, the DoD published its logistical weaknesses in an unclassified form, stating that the main risk confronting the joint logistics services is in the field of maintenance and repair of facilities, vehicles and equipment as well as the lack of skills and experience of its personnel.

During 2005, the responsibility for the management of the SANDF property portfolio was transferred from the Ministry of Public Works to the DoD , for which the latter received R 845 million in addition to its R 22.4 billion budget for that year. During the financial year 2006-07, R 4971 million was spent on the repair and maintenance programme. In the Defence Budget Vote 2008, the amount added is listed as R 80 million for 2007-08, R 230 million for 2008-09, and R 200 million for 2010-11. The DoD / SANDF reported lack of funds to maintain its equipment, since there is a huge backlog in this respect. In specialised fields, there are serious shortages in logistics personnel. The Government of South Africa is considering allotting adequate funds to meet the logistics support to the operational units. The process of strengthening the logistics support system is high on the SANDF agenda. Towards this, automation in inventory management is being taken up on priority.[22] At the National Defence Headquarters, the logistics staff division will have a major

22. http:/209.85.175.104/search?-cache:TPCvIn Z: tq 14 j: https/ www.up.ac.za/ dspace/ bitsre…

role to play in acquisition of new equipment, the maintenance of it while in service, and the discarding of it at the end of its life span. Clearly, logistics is not only about the supply of material to the military for operations. It also includes the ability of the national infrastructure to equip, support and supply the military and to ensure that the transportation system exists to move the forces to be deployed, to resupply the force once deployed, and to extract the force after operations are completed.

NEW ZEALAND DEFENCE FORCES (NZDF)

Under the new guidelines, the NZDF needed to adopt an accrual accounting methodology and adhere to generally accepted accounting principles (GAAP), in that the New Zealand government would hold the force to the same financial and accounting standards as any public company. To conform to the government's reporting requirements, the NZDF would have to provide accounting information for virtually every asset it had but these assets were scattered across the globe and managed by different batch mode systems that had never been designed to communicate with one another.

In defence, probably the most important interface for finance is with the logistics system, says Derek Eade, financial controller for the NZDF. "That is where all the movements are. You have got huge amounts of equipment and people all over the world. You have engineering changes to the equipment, maintenance and repairs and in order for us to account for all this in a full balance sheet, our asset management capabilities had to improve a great deal."

NZDF officials understood that meeting the current and future needs of the force required more than patching the existing standalone systems. The NZDF needed a completely new start on a proven platform that would provide a foundation for a comprehensive, highly integrated financial and logistics system. Moreover, with the urgency demanded by military and humanitarian crises that were evolving ever more rapidly, NZDF officials understood that the defence organisation needed a system that was flexible

The supply chain management of such a diverse and huge inventory has to cater for storage, transportation and supply of serviceable items at the user location.

enough to support personnel from NZDF locations throughout New Zealand as well as from locations in the field, wherever they might be. The NZDF also needed team operational support, with one version of information that all the different parts of the operational team could access.

With these solutions requirements in mind, the NZDF issued a request for proposals and soon narrowed the respondents down to three serious candidates. The successful proposal met more than 90 per cent of the force's requirements with standard off-the-shelf software. Based on the formal evaluation process, the NZDF chose to adopt SAP software as the standard for its financial and logistical systems. Today, more than 2,500 NZDF users access the equivalent of the SAP, the enterprise resource process (ERP), from more than 40 sites across the New Zealand.

BELGIAN DEFENCE FORCES

The Belgian Defence Forces, in order to streamline their logistics management, adopted the integrated logistics information and automation system (ILIAS) in 2006. ILIAS provides a full inventory system, including multi-site optimisation, stock management and purchasing. These are integrated into maintenance to allow a "pull through" approach to the logistics chain. For management of foreign military supply cases, ILIAS has a standard built in and also contains a module for automated update of codification information of parts. ILIAS covers the entire work cycle for modifications, corrective, preventive and predictive maintenance, including cost and invoice facilities. With ILIAS, a strategic decision support environment is delivered, providing key information to the leadership, middle management and operational level.[23]

From the above, it is more than evident that armed forces the world over have either already gone in for increased automation in their inventory management,

23. www.visionwaves.com

including procurement functions or some of them are in process of doing so, learning from the experience of the advanced countries. This includes some of the smaller forces such as those of Kenya and Singapore to name a few.

Due to its peculiar security concerns and British inheritance, the military supply chain in India is quite complex. The sources of supply, the maintenance infrastructure and storage depots are scattered and diverse in nature.

DEFENCE LOGISTICS MANAGEMENT IN INDIAN SCENARIO

War, being a national effort, dictates a closer interaction and integration of national agencies and resources respectively, to achieve synergy in support of our combat echelons. This was amply demonstrated during Operation Vijay and Operation Parakram. Further, despite the commonalities in the system, equipment as well as their sources of supply and procurement, we lack a common logistics philosophy. Each Service has its own organisation structure, procedures, supply chain and distribution networks to manage its logistics needs. This has resulted in divergent approaches, and duplication in holdings, training and infrastructure. The fallout of these individual systems working in isolation is a lack of convergence and holistic approach to defence needs, resulting in sub-optimisation of resources and efforts.

In India, our defence forces are heavily dependent on imports for a majority of the hardware and associated spares. In fact, the imported items account for almost 55 to 60 per cent of the total inventory. For a major period since independence, most of the military equipment was sourced from the erstwhile USSR and now Russia and other Commonwealth of Independent States (CIS) countries. Presently, we are importing military equipment from a number of countries such as France, the UK, USA, Australia, Austria, Israel, Germany to name a few. Import from such diverse sources, with peculiar nomenclatures and codification regimes and special terms and conditions, add on to the supply chain management matrix. The indigenous sources are mainly defence public sector undertakings (PSUs), original equipment manufacturers (OEMs), ordnance factories and other trade sources. The supply chain management of such a diverse and huge inventory has to cater for storage, transportation and supply of serviceable items at the user location. Further, the repairable assets have to be serviced and put back to use. The main concerns which affect both cost-effectiveness and responsiveness of this supply chain are inadequate communication throughout the supply chain, long lead times, huge inventory, user satisfaction, high supply chain costs, non-performing assets and unutilised items.

Due to its peculiar security concerns and British inheritance, the military supply chain in India is quite complex. The sources of supply, the maintenance infrastructure and storage depots are scattered and diverse in nature. Therefore, to maintain a high state of serviceability and operational preparedness, it is imperative to have automation in inventory management almost as a prerequisite. Also an effective communication and transportation network is the key to ensure deliverance of the right item at the right place in the right time and right quantity. Our armed forces have been in the forefront to recognise this aspect of logistics management well in time.

As regards the automation of inventory management, certain functions of provisioning and procurement were taken up almost as soon as computers were introduced in the country. However, these were specific to the requirement and almost standalone kind of modules. In the mid-Nineties, the three Services felt the need to have a comprehensive and integrated logistics management system.

Accordingly, the three Services individually launched their programme to have computerised inventory management systems. The Army Computerised Inventory Control Programme (CICP) was sanctioned in July 1994 to install an on-line inventory management system for the army. The first phase of the project was inaugurated in October 2002. The navy has its Integrated Logistics Management System (ILMS) which was the first ever automated systemised logistics management system of the armed forces. It was implemented in March 1997 and its mission statement stated, ''…reaching out for customers' delight through network-centric operations while cultivating total asset visibility.''

The aim of ILMS is to achieve transparency and strengthen aggregate control, while reducing, if not eliminating, delay causing transaction specific controls. The total users number approximately 1,350 with additional 50 dial up users. The air force has commissioned its Integrated Material Management On Line System (IMMOLS) which is an ERP solution developed by Tata Consultancy Services (TCS). The project started in 1993-94. It took a long and arduous journey of thirteen years to operationalise the IMMOLS. But the Indian Air Force (IAF) is now owner of a truly ERP solution software application. IMMOLS is operationalised at all the self-accounting units across the IAF and was dedicated to the nation by the Raksha Mantri on October 9, 2006. The vision statement of IMMOLS reads, "Establish IMMOLS in the IAF to create and sustain e-logistics environment for cost and time effective e-management of logistics activities to effectively support current and future operations in the IAF."[24] The impact of IMMOLS has been to create total asset visibility, providing a quality tool, standardisation of business processes, and inventory carrying costs. IMMOLS also provides for a centralised spares data bank, price history, on- line audit (EQUOLS & AUDOLS) and visibility, and accountability. It enables optimal inventory holdings, effective AOG/ demand management realistic provisioning, dynamic supply status and on-line concurrence and transactions.

Another area of concern is the need to have total asset visibility (TAV). In a military supply chain, asset visibility is of paramount importance as it provides a ready-made input for commanders to take timely decisions. Asset visibility encompasses inventory in motion, including controls during the transit of an item of equipment that are supposed to allow the sender and receiver to know the location and status of specific items in that inventory at any time. It is an accepted fact that efficient and effective management of inventory throughout the supply chain significantly improves the ultimate service provided to the troops. This implies a high degree of assurance and responsiveness, inventory control, asset placement, speedy restoration to serviceable state of the repairable stock and casualty evacuation.

24. IMMOLS Project Team Presentation Slide on Vision Statement.

Another well established practice increasingly being adopted by all major armed forces is the preferred option of shedding excess logistics baggage to service providers, especially in non-core areas.

Now, with the availability of more accurate means of computer-based simulations and intelligence, it is possible to make more efficient logistics plans, and forecast the distribution pattern much before any operation is undertaken. In a computer-based system, the "resource manager" can evaluate and provide various options to the commander. He can also give an objective opinion. For an operational commander, the basic issue is that of responsiveness from its logistics elements.

In an environment of shortages and deficiencies in equipping our forces, the "asset vision" will be used as a medium for the commanders to develop and evaluate plans where the effective and innovative use of resources can influence decisions as much as the dictates of the operational situation. This will be particularly useful in the case of specialists and maintenance engineers where a higher commander can ensure better equipment sustenance and maintenance. Integral logistics units will also not have to carry all kinds of spares too far ahead in the area of conflict. There is also a need to make our distribution system more responsive to the user's requirement. Efficiency and economy can only be ensured in an automated environment while meeting the requirement. If we can quickly 'bar-code' our material and medical support and put this data on-line where password protection can ensure secrecy, we can have all kinds of advantages. Commanders and logisticians can keep track of material in motion.

Another well established practice increasingly being adopted by all major armed forces is the preferred option of shedding excess logistics baggage to service providers, also known as third party logistics (3PL), especially in non-core areas. This has a twin advantage. Firstly, the armed forces personnel can be more efficiently used for core operational duties, thereby, improving 'teeth-to tail' ratio. Secondly, the armed forces the world over are being put to greater financial scrutiny and public debate over the budgetary allocations. This is more true in a democracy like ours. Media and public awareness have made the armed forces cost conscious and accountable on the economic front. Our three Services are aware of the need for outsourcing certain non-core areas of logistics management to service providers. However, presently the process is being undertaken by each Service in an individual manner. Also, the pace is yet to gain the desired momentum.

SUGGESTED ROADMAP FOR LOGISTICS TRANSFORMATION/ INTEGRATION

Addressing the need purely at a macro level of logistics management would have to take place at three levels: first, at the national level; second, at the ministerial/inter-Services level; and third, within each individual Service on a functional basis. It would also necessitate a holistic approach to acquisition, operation and maintenance of weapon systems/equipment.

The above analysis clearly indicates an urgent need to have a relook at/ understand the entire strategic planning process. Thereafter, we need to evolve a logistics management system to ensure that the acquisition and maintenance of defence needs are conducted efficiently and effectively in order to achieve the operational objectives of the armed forces in their furtherance/support of national security aims. Perhaps, this introspection could be aided by an understanding of the systems in vogue in the more militarily advanced nations like the USA, UK, etc.

National Level

A National Logistics Council (NCL) should be created, with a wide political, government and industrial representation. Pakistan already has a National Logistics Cell, which is playing a major role in the harnessing and mobilisation of its national resources; a case in point is its role during the Pakistan Occupied Kashmir (PoK) earthquake relief operations. The NLC could either be established as an independent body like the National Security Council (NSC) or made a part of the Planning Commission. The functional scope of this body could include determination of a broad framework for building infrastructure for both developmental and defence needs, providing broad policy guidelines at a strategic level on areas including transportation infrastructure, industrial effort of war, strategic stockpiling, energy utilisation, satellite utilisation, etc, and act as a coordinating agency between different functional ministries.

MoD/Tri-Services Level

Creation of an organisation on the lines of the DLA/DLO of the US/UK at the ministerial/inter-Services level would enable integration of logistics management to the extent feasible. This organisation could be placed either as an independent body under the MoD or could function under the Chief of Defence Staff (CDS) (when implemented) or the Chiefs of Staff Committee (COSC). It could oversee the performance of the Defence Research and Defence Organisation (DRDO), Director General of Quality Assurance (DGQA), ordnance factories and other defence PSUs and act as a link with the NLC to coordinate defence needs and mobilisation of national resources during war. The existing Defence Acquisition Council/Defence Procurement Manual (DAC/DPB) will be unable to perform this task even if allotted.

Integration at Tri-Services Level

Some functions of the Services, like medical, postal, works, movement control, common user ammunition and main grades of fuel, rations, and so on, have already been integrated on inter-Services basis. Integration achieved thus far has paid dividends in economy and unity of purpose. Notwithstanding the present levels of integration achieved, vast scope still exists in crucial areas such as standardisation. Standardisation of equipment amongst the three Services will lead to major savings and would facilitate the process of integration. Also, codification of common items amongst the Services will improve asset visibility and assist procurement and disposal. Similarly, an integrated transportation system, including air and sea, will result in optimum utilisation of existing tri-Service resources.

Integrated Defence Logistics Staff

With the creation of Headquarters Integrated Defence Staff (HQ IDS), it would be worthwhile and logical to integrate defence logistics under the CDS (presently COSC). This organisation within the CDS/COSC can study areas of integration, work out integrated procedures and put into motion the process of integration of tri-Service logistics.

The armed forces must revolutionise their logistics programme and provide support on time. It must become predictive, anticipatory and responsive.

Service Level

There is a need to integrate all logistics functions within each Service and adopt a holistic view of logistics, right from induction to disposal of a system. This would necessitate an appreciable change in mindsets, as power equations within the organisation would get affected. It would also enable a better appreciation of the feasibility of outsourcing, thereby, availing the opportunities provided by industrial infrastructure and capability. This would enable us to review our maintenance and supply echelons and take a pragmatic view on centralisation vis-à-vis decentralisation.

CONCLUSION

The armed forces' need to transform is like that of many other organisations undergoing change. The Services are facing many of the same challenges. World class companies must transform their support structure if they expect to continue to dominate their business sectors. To sustain their competitive edge, these commercial industries have reengineered their processes, contracted out services and products where such outsourcing provided better performance at a lower cost, incorporated emerging technologies, and overcame institutional resistance when many wanted to maintain the status quo. The armed forces must revolutionise their logistics programme and provide support on time. It must become predictive, anticipatory and responsive.

Our logistics system must be able to anticipate problems before they occur. Technology can enable accurate predictability. Through state-of-the-art information systems, the forces can monitor consumption of expendable supplies such as fuel, repair parts, ammunition, rations on a daily basis. Fully exploited, these systems can also automatically deliver supplies at the level required, consistent with the resources on a competing priority basis.

Automatic identification technology (AIT) includes bar codes, radio frequency (RF) tags, satellite tracking, "smart cards", and laser cards. COTS satellite tracking provides real-time monitoring of transportation assets and customer products. The visibility of goods and assets in storage, in transit, and in process has resulted in reduced inventory levels and order and ship times and improved overall responsiveness to customers.[25]

The module of military transformation being adopted by the US and other multinational forces deployed in conflict at far off distances from their own geographical locations with almost negligible opposition may not necessarily be followed by our forces; however, certain universally acknowleged best logistics practices followed by the armed forces and in the commercial sector are equally applicable and desirable for us as well and need to be taken up on priority.

The above analysis brings out a noticeable trend for evolutionary change in Indian defence logistics. There is a need for a revolutionary change in the way we support the forces. This revolution is about more than providing equipment and supplies better, cheaper and faster, although these initiatives are crucial for readiness and modernisation today. It is also about rethinking logistics functions and processes that will enable decisive victories well into the future. This revolution spans the depth and breadth of military logistics. It includes integrating logistics functions; replacing volume with velocity, reducing demand and lightening the logistics load on the ultimate customer—the soldier.

25. Larry Smith, "Commercial Logistics Best Practices for the Revolution in Military Logistics," *Army Logistician*, January- February 1999, pp. 137-141.

My team is having trouble thinking outside the box. We can't agree on the size of the box, what materials the box should be constructed from, a reasonable budget for the box, or our first choice of box vendors.

— Randy Glasbergen

FORM IV (SEE RULE 8)

Statement about ownership and other particulars about newspaper (Air Power to be published in the first issue every year after the last day of February .*

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I, **Jasjit Singh**, hereby declare that the particulars give above are true to the best of my knowledge and belief.

Date: **February 2009** — **Sd/- Jasjit Singh**

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