SATELLITE RECONNAISSANCE, ISR AND COUNTER-MEASURES

A.S. BAHAL

If you can be seen, you can be hit
If you can be hit, you can be killed.

—US Army Tactics of the Individual Soldier

The future regional crises and conflicts may require swift reaction in the form of cold start strategies and unconventional responses. The urgent response itself may underline the critical need to quickly collect, process, and disseminate operational and tactical information. Likewise, the enemy's ability to obtain information on own force deployments, order of battle, movements, and logistics, could jeopardise our ability to stage and deploy combat forces and successfully execute combat operations. Therefore, the capacity to control information has become decisive in conflict situations.

Over the years, satellite surveillance has been increasingly used in combat operations and regional conflicts. Satellites gather vital information through active and passive sensors that exploit the ultraviolet to thermal infrared and reflected radar wave portions of the electro-magnetic (em) spectrum. They are invulnerable to attacks except from weapons presently under development. Furthermore, satellites do not violate the air spaces of sovereign nations. Hence, they can carry out reconnaissance activities with impunity during peace-time. Analyses of space employment during the Gulf War 1991, Kosovo Operations

Group Captain **AS Bahal**, VM, is a senior member of the faculty at the College of Air Warfare, IAF.

1999 and Operation Iraqi Freedom 2003 clearly highlight that decisive victories were achieved by synergistically integrating space-based applications, specially those related to the employment of air power.

INCREASED SYNERGISM BETWEEN COMMERCIAL AND MILITARY SPACE APPLICATIONS

The growing technical competence of commercial space technology has bridged the gap between military and civilian space capabilities. The civilian satellite imagery services that were once restricted to select nations are becoming freely accessible to all users, including asymmetric fighters, at affordable rates. The launch of the Space Imagery Co. satellite (Ikonos) on September 24, 1999, brought the first high resolution imagery into commercial service. Subsequently, Digital Globe Inc, with the Quickbird satellite, provided sub-metre resolution (61 cm). The inherent proficiency of civilian satellites to make available high resolution data provides an opportunity to the military planners to integrate their employment with combat operations to achieve information dominance.

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Today, nations don't need to own satellites to obtain information from space-based systems; they can easily acquire it from numerous international space agencies. During Operation Iraqi Freedom, commercial imagery was used for intelligence preparation, mission planning, damage assessment, diplomacy and coalition building. Interestingly, the US National Imagery and Mapping Agency contracted Space Imaging for exclusive rights on all commercial Ikonos imagery of conflict areas in Central Asia, following 9/11, in a $1.9 million per month deal. Buying available capacity could work then, but increasing numbers of commercial satellites with high-resolution capabilities will eventually render this option less useful. **It has, therefore, become imperative that while we retain the ability to collect intelligence**

through space-based assets, we deny the same to our potential adversaries with the help of passive and active counter-measures.

SATELLITE IMAGING AND RECONNAISSANCE CAPABILITIES

> *The art of war is simple enough. Find out where your enemy is. Get at him as soon as you can. Strike him as hard as you can, and keep moving.*
>
> — Ulysses S. Grant

There are seven countries in the space race: the USA, Russia, China, Japan, France, India and Britain; and another three on the periphery: Indonesia, Pakistan and Australia. The Indian Space Research Organisation (ISRO), under the Department of Space (DOS), is responsible for research, development and operationalisation of space-based systems. The Indian satellites, IRS 1C and 1D, provide resolution of 5.8 m (multi-spectral resolution is 23.5m), Cartosat-1 2.5 m and TES one metre. The Chinese satellites such as CBERS-1/ CBERS-2 provide 20 m resolution, Zi- Yuan-2A 9 m and Zi Yuan-2B 3 m resolution. The People's Liberation Army (PLA) is experimenting with directed energy weapons (DEW) that can destroy satellites and is considering particle beam weapons that can engage ballistic missiles. The Chinese military is also experimenting with the use of micro-satellites that can be used as kinetic energy weapons to destroy other satellites or to render them ineffective when required.

It has, therefore, become imperative that while we retain the ability to collect intelligence through space-based assets, we deny the same to our potential adversaries with the help of passive and active counter-measures.

The quantitative measure to establish the imaging capability of a satellite is its spatial and spectral resolutions. Spatial resolution is the ability to resolve two objects on the ground and **spectral resolution is its ability to differentiate between different bands of the measured wavelength.** Using multiple spectral bands to observe the same patch simultaneously allows discrimination between vegetation and soil, identification of thermal gradients in the ocean, measurement of surface moisture, and a variety of other tasks. Typically, the more spectral bands a sensor discriminates, the larger is its spatial resolution. An image produced by a sensor could consist of one very broad wavelength, a few broad bands or many narrow wavelength bands. The terms typically used for these three image categories are panchromatic, multi-spectral and hyper-spectral imageries.

The qualitative measure for assessing the utility of imaging and remote sensing satellites is timeliness. There are three variables affecting the timeliness of remote sensing: satellite revisit time, image processing time and image delivery time. Timeliness, therefore, refers to the time it takes from tasking the sensor to exploitation of the product. One variable in timeliness is the revisit frequency; it is the time taken, usually in number of days, for the satellite to overfly the same spot over the earth twice.

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SPACE SURVEILLANCE SYSTEMS

Orbital Information

The ground coverage of a satellite is predicted by viewing the geometry parameters of the respective sensors. The Convention on Registration (1976) requires a party to maintain a registry of space objects it launches and to provide basic orbital information. This information is available in two open websites, namely, www.celestrak.com and www.space-track.com. The information is in the form of a text-file that indicates catalogue number, year of launch, launch number, which launch, fraction of the day, derivation of mean motion, coefficient of drag, type of orbit, orbital inclination, perigee, etc. This orbital information could be used to calculate the revisit time of the satellites. Since the orbital information is obtained from open websites and can be corrupted, there is a requirement to have own satellite tracking and monitoring ground stations to maintain unobtrusive surveillance.

Manoeuvring of Satellites

Manoeuvring of satellites requires a large amount of fuel and, therefore, it either reduces the life of the satellites or increases their mass substantially to carry extra fuel. Generating a velocity change of 2 km/s with conventional propulsion technologies requires doubling the mass. Generally, satellites are manoeuvred during conflict situations or on specific occasions. Though advanced nations and commercial agencies may provide imagery to other countries, it is debatable whether they would manoeuvre their satellites to provide repeated intelligence to them. Though the revisit times calculated by interpolating orbital information would approximately be correct, for precise location of the satellite one would need to have a space tracking and surveillance system.

Tracking Satellites

There are many commercially available technologies which can be used to construct systems that detect, identify and track satellites. In fact, there exists a "Satellite Surveillance Organisation," a network of amateur satellite observers, who use maps, personal computers, telescopes/binoculars, and stopwatches to observe at twilight time, the position of satellites with reference to the starfield. Another mechanism of space surveillance utilises the charge coupled devices (CCD) detectors with computer-based software systems to develop an optical surveillance network.

More expensive space surveillance systems include phased array radars and the US Navy's NAVSPASUR system. This system uses powerful radio transmitters located at different places to detect satellites. Analysis of the signal provides the orbital parameters of the space objects down to a fraction of a kilometre. The data from the NAVSPASUR system provides important inputs to the US Air Force Space Detection and Tracking System (SPADATS). **There is a need for the Indian Air Force (IAF) to coordinate with Defence Research and Development Organisation/Electronic Research Development Establishment/Indian Space Research Organisation (DRDO/LRDE/ISRO) and develop an effective space surveillance system that could be integrated with ballistic missile defence (BMD) early warning**.

LIMITATIONS OF SATELLITE RECONNAISSANCE AND REQUIREMENT OF INTEGRATED TACTICAL INTELLIGENCE, SURVEILLANCE, RECONNAISSANCE (ISR) ACTIVITIES OVER THE TACTICAL BATTLE AREA (TBA)

The major advantage of satellites is that they can image large areas without violating another nation's air space. However, satellites have their own drawbacks; they are expensive to launch and maintain, and are limited to fixed orbits around the earth. This makes them vulnerable to deceptive techniques such as emission control and camouflage. In addition, their view is limited by cloud cover. During the Gulf War, cloud cover made the difference between utilising seven available imaging satellites that could have provided updated pictures after every two hours, and having to rely only on a single satellite, the Lacrosse. It is a radar imaging satellite that can look through clouds but has a significantly lower resolution than the optical satellites.

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Satellites are difficult to "dynamically retask" for new assignments, and are very costly. The launch operations too are complex, time-consuming, manpower-intensive, and expensive. Satellites can cost anywhere from $100 million to $800 million each, and require over $300 million for launch. In addition, satellites do not provide direct links to the ultimate user and entail significant processing time by a third organisation, in our case, DIPAC, to convert data into usable media. This conversion time further delays dissemination to the operational users.

Another major limitation of the imaging satellites is that they cannot orbit or maintain station over one point. Hence, real-time tactical applications become severely restricted, especially those that are time critical. There is a need, therefore, to synergistically integrate tactical air power elements such as manned and unmanned aircraft that complement as well as fill the gap created by the limitations of the imaging satellites. **Hence, ISR operations need to be integrated activities that include space-based systems and air power elements**.

Many of the functions of the reconnaissance satellites could be substituted cost effectively by unmanned aerial vehicles (UAVs) or manned aircraft. The UAVs can maintain continuous surveillance over vital areas/vital points (VAs/VPs) for an extended duration of time. They also have the advantage of operating at approximately one-third the cost of manned aircraft. The UAVs provide a larger portion of the usable imagery of the target area in a much shorter timeframe than can be obtained from satellites. The modern UAVs such as the Global Hawk are designed to fly at 350 miles per hour, at altitudes of 65,000 ft and have endurance of more than 40 hours. The satellites and tactical air power integration should ideally be carried out in the following manner:

(a) During peace-time, use satellites to image those areas that are beyond the range of the UAVs/manned aircraft or sensitive locations within the range of the tactical sensors but those that are heavily protected. Satellites could also be used to cover island territories periodically to check any developments there.

(b) The UAVs are severely limited in area surveillance as they take four to five hours to survey an area as small as 3 km x 3 km. It is here that satellites could be used during peace-time or conflict situations to ascertain the presence of hostile elements in an area of interest and thereafter UAVs used to maintain continuous surveillance or provide precise information about target elements and their exact locations. This would optimally exploit the strengths of both systems.

(c) Satellites could be used to build strategic data bases, whilst UAVs could be used to collate target folders.

(d) Satellites could be used to ascertain changes in force deployments or new constructions that have come up over a period of time and tactical sensors could be used to identify the exact import of these changes and their detailed implications.

PASSIVE COUNTER-MEASURES AGAINST IMAGING SATELLITES

Passive counter-measures enhance survivability by reducing the enemy's ability to detect, identify, and engage own forces and equipment. The Russians define passive measures or *Maskirovka* (camouflage, concealment and deception

[CC&D]) as a **series of interconnected organisational, operational and technical measures to conceal from the enemy, objects, forces and equipment, thereby misleading them to obtain accurate information about the presence, disposition, composition, actions, intentions and plans of own forces.** The type of measures used and their scale would determine the level at which they are carried out, viz strategic, operational or tactical. The definition itself highlights a need for an integrated command and control structure that develops and integrates passive counter-measures at all levels of war.

The primary aim of CC&D is to avoid detection. During the Gulf War, Iraq used *Maskirovka* to effectively hide its capability of surface-to-surface missiles (SSMs) (Scuds) in the face of persistent Coalition attacks. The camouflage and deception techniques employed in the Kosovo War were extremely effective. They used wooden decoys as well as phased out aircraft, surface-to-air missiles (SAMs), armour and tracked systems. They also used thermal decoys such as burning tyres close to major targets to confuse thermal imagers. The successful use of CC&D highlights the growing requirement of low cost, cheap and ready-to-use passive counter-measures to defeat not only reconnaissance devices but also precision strikes. The last 10-15 years have seen the emergence of new CC&D techniques for signature control and for concealment of mobile objects.

A number of satellites use CCD detectors. A **CCD is an extremely small silicon chip, which is light sensitive**. The essential principle of a CCD is that it converts impinging light into electricity. The number of elements per unit length determines the spatial resolution of the camera. In layman terms, we call that pixel size. Multiple band sensing can be achieved by using filters to select wavelength intervals that individually are associated with a CCD array. Presently, a majority of the CCD systems are in visible and near IR (VNIR) bands.

High-resolution photography satellites usually travel around the earth in low altitude polar orbits to take advantage of a good sun angle. Hence, CC&D techniques are most effective in the visual portion of the electro-magnetic spectrum. The three limiting factors that affect optical surveillance by satellites are darkness (night), cloud cover and camouflage. The passive counter-measures that could, therefore, be employed against satellite reconnaissance are:

(a) Manoeuvre and evasion.
(b) Concealment and hiding.
(c) Camouflage.
(d) Deception.
(e) Smoke screens/obscurants.
(f) Radio/radar silence.
(g) Radar reflectors.

Manoeuvre and Evasion

Normally, revisit times of reconnaissance satellites are known, hence, mobile assets could be moved to prevent detection. Further, there would be periods when no satellite observes our area of interest and this is the time to move these assets or accomplish those activities that one intends to hide such as the May 1998 Shakti series of nuclear tests. It would be very difficult to keep track of mobile forces from space as it takes approximately 18-24 hours to complete the targeting process that involves obtaining reconnaissance information from low earth orbit (LEO) satellites performing imagery analysis and integrating the identified targets with command air tasking orders. **If critical target systems are moved after 10-12 hours, a high degree of survivability in relation to satellite reconnaissance could be factored**. It is here that the side carrying out reconnaissance would need to take a holistic view and integrate satellite reconnaissance with tactical reconnaissance elements of air power.

Concealment and Hiding

Reconnaissance sensors cannot pick objects located inside built-up areas or underground structures. **Objects that cannot be seen are difficult to identify and target.** Crucial equipment, components or weapons, therefore, need to be kept in underground structures/buildings and should be moved in coordination with the revisit time of different satellites. If one intends to conceal sensitive ballistic missile or nuclear weapon programmes, then one would need to conceal these structures within other built-up structures to hide obvious signatures of these programmes. In addition, to time their overt activities, keeping in mind the revisit times.

Camouflage

Prior to the space era, camouflage and concealment measures were mainly adopted during crisis situations and during hostilities. With satellite reconnaissance, these measures would need to be adopted throughout the year and especially during the revisit time of potential hostile satellites. The optical band of the em spectrum in daytime is between 0.38-0.76 microns, electronic through night vision 0.38-2 microns, photography 0.38-0.9 microns, UV 0.1-0.38 microns, TV 0.38-2.0 microns, laser 0.38-10.6 microns, heat 2-15 microns, MMW 1-10 microns, thermo microwave 0.3-21 cm, specialised radio 0.01-100 m and sound 20-20,000 Hz. The present generation of synthetic camouflage nets and painting schemes provide protection usually up to one micron wavelength. They are adequate to conceal small objects from space sensors but may not be able to conceal large objects such as runways, refineries and power generation systems. However, critical sub-systems like pumping stations, command and control centres and oil pipelines can and must be camouflaged or concealed. The **camouflage techniques used should cater to visual/radar/IR signatures.**

Visual reflectance is characterised by colour and contrast. The longer the range, the less important colour becomes as it tends to merge into a uniform tone. It is here that **reducing contrast would considerably reduce target visibility**. Effective camouflage must ensure that patterns are not created. This can be done by minimising target contrast with its background. However, very few camouflage materials or techniques provide broad band protection. Natural camouflage materials matching local colours and textures are perhaps the most effective against both direct and photographic observation. Planted rapid-growing weeds, grasses, vines, bushes, and small trees could be used to conceal permanent and semi-permanent installations. The controlled mowing of grasses is another technique sometimes used in the camouflage plans of airfields and rear-area installations. The aim should be to blend target features with the environment/terrain conditions. **Natural blending camouflage is the best option to conceal assets of value.**

Two important considerations for camouflage are **choice of position and camouflage discipline**. The choice of position relates to selecting a background, which visually absorbs the target elements. In this, natural cover and defilade are desirable. Proximity to landmarks should be avoided as they attract attention to themselves. Sometimes, an appropriate choice of background would not require any construction or camouflage work at all. Camouflage discipline implies avoiding those activities that reveal the presence of objects of interest. For example, tracks, waste products and debris are some of the common signs that give away the presence/location of critical target elements. The methods employed for camouflage are as follows:

(a) **Blending**. An object and its camouflage materials are concealed by blending it with the environment in a manner that it merges with the background.
(b) **Hiding**. It conceals the identity of the object with the help of a screen.
(c) **Deceiving.** It changes the visual/IR/ radar signature of the objects.

Deception and Decoys

Deception masks the real intent of combat operations and aids in achieving surprise. Deception counter-measures can delay effective enemy reaction by disguising information about friendly intentions, capabilities, objectives, and locations of vulnerable units and facilities. On the other hand, **decoys are imitations of real objects** and they could be used to deceive the enemy in terms of numbers and location of the assets. Large scale production of decoy aircraft, tanks, artillery guns and air defence (AD) weapon systems that provide nearly the same visual and IR signatures needs to be undertaken. Dummy radar and communication antennae could also be used to confuse the enemy.

Decoys should be located in those areas that place them very close to where the actual target systems would be deployed. For example, aircraft decoys should be placed at tarmacs, operational readiness platforms (ORPs) and aprons. If fighter aircraft decoys are placed on soft ground, they could easily be identified as decoys. Presently, inflatable balloons that closely resemble an aircraft's visual signature are commercially available in India. Decoys made of fibre glass turrets and gun tubes made out of steel/ PVC pipes are also available to simulate realistic tanks. Inside these decoys, burning charcoal could be kept to create appropriate thermal signatures.

A panchromatic image can identify spatial variations in the visual properties of surface materials but it cannot perform spectral discrimination. Therefore, **a decoy painted realistically could easily fool an interpreter of a panchromatic image, if it conforms to a realistic environment**. Hyper-spectral systems record a large number of narrow contiguous bands starting from the blue visible part of the em spectrum to nearly 2,500 nm. The military applications of this technology include detecting and identifying hidden targets in an operational theatre. Hyper-spectral sensing has the ability to discriminate between wooden/ inflatable decoys and metallic objects. However, high resolution commercial applications of this technology are still in the developmental stage. Further, **life expired equipment/ weapons could be used as realistic decoys to counter this technology**. Hence, the key to convincing an enemy that it has found the real target are as follows:

(a) **Decoy fidelity (realism)**, which refers to how closely the multi-spectral decoy signature represents the actual target signature.

(b) **Deployment location**, which refers to whether or not a decoy is deployed correctly and the enemy recognises it as typical for that target type.

Smoke Screens/Obscurants

Smoke and obscurants can block or degrade the spectral bands used by an enemy's target acquisition and weapon designation systems. Recently developed obscurants are able to degrade non-visual detection systems such as IR imaging, selected radars and laser systems. High value assets, for example, supporting infrastructure of aerostat radars, command and control centres and communication nodes could be hidden by smoke screens during the revisit of the imaging satellites. Since the satellites travel at approximately 7 km/sec, the satellite would observe the area for a very short period of time. Hence, smoke screens and obscurants may help. However, IR defeating obscurants and chemical resistant paints may be able to break up IR signatures but may not be able to defeat IR sensors. Also, the smoke screens do not completely hide all the target elements. **Hence, at best, it is only a measure that supplements existing passive measures.**

Other Passive Techniques

Other passive counter-measures include radio/radar silence to defeat commercial intelligence/electronic intelligence (COMINT/ELINT) satellites and use of radar reflectors that enhance the radar signal reflectance thereby distorting the objects shape and size. Radar reflectors could also be used on decoys. However, such measures would be more applicable against satellites using synthetic aperture radars for imaging purposes and satellites carrying early warning detectors.

ACTIVE COUNTER-MEASURES

Active counter-measures could be used during hostilities or conflict situations. James G. Lee, a US Air Force (USAF) officer, whilst carrying out studies for his master's degree in the Advanced School for Air Power Studies, identified certain operational centres of gravity in the orbital, communication and ground segments of satellite operations that could be targeted to render satellites ineffective. Crucial vulnerabilities in the orbital segment identified by him include the satellite itself or its sub-systems that are vital for task achievement such as satellite altitude control and mission sensors, uplink/downlink antennae, and power generation systems.

The crucial vulnerability in the communication segment is the communications link, the radio frequency used to pass information to and from the satellite. Attacking the downlink, rather than the uplink, is usually easier and more reliable for disrupting a space system. Successfully attacking the downlink directly attacks information flow and has a more immediate effect. The crucial vulnerabilities in the ground segment include satellite launch facilities, command and control centres and processing stations. The entire ground segment is vulnerable to attack from various means such as clandestine operations and air and ground attacks.

The crucial vulnerability in the communication segment is the communications link, the radio frequency used to pass information to and from the satellite.

Kinetic energy weapons cause physical destruction of the orbiting satellites. The examples include fragmentary and guided non-explosive warheads. DEW could also be employed to achieve a hard kill, a non-destructive soft kill or a non-lethal temporary disruption or degradation. Examples of DEW are lasers and high-power microwave weapons. Lasers use electro-magnetic radiation (light) for both lethal and non-lethal attacks. Depending on their power, lasers could damage, disrupt, or destroy a satellite by overheating its surface, puncturing the outer surface of the spacecraft to expose internal equipment or blinding critical onboard mission or control sensors.

On the other hand, high-power microwave weapons employ radio frequencies to damage satellite electronics. Unlike kinetic energy and laser attacks, high-power microwave weapons achieve satellite sub-system failure rather than vehicle neutralisation. It is possible today to construct a microwave radiation weapon with a satellite soft kill capability of about 500 km. In addition, microwave radiation at lower power levels can be effectively used for satellite jamming.

The value of an anti-satellite (ASAT) weapon is not only as an offensive weapon intended to conduct an attack against an opponent's satellite systems, but it also acts as a weapon deployed to deter attacks on own space systems. If deterrence fails, the ASAT could then be employed to restore the balance by counter-attacking the enemy's satellites. The very fact that LEO satellites can be accurately tracked and that too at relatively short ranges, makes it possible to use any of the following active counter-measures:

The value of an anti-satellite (ASAT) weapon is not only as an offensive weapon intended to conduct an attack against an opponent's satellite systems, but it also acts as a weapon deployed to deter attacks on own space systems.

(a) Large fluxes of energy focussed on the satellites could damage/spoil the sensor/image since the very functioning of the sensors depends on concentrating bursts of incident light on small sensitive detectors. An example is the tests carried out by the US Army in

1997 using mid-infrared advanced chemical laser (MIRACL) against an orbiting air force satellite.

(b) Direct ascent (ASAT) weapons can be fired from mobile launchers. However, such technologies are still in the developmental stage.

(c) Certain DEW are in various stages of research, development, testing and evaluation. However, weapon quality lasers require a large amount of power to prevent diffusion and absorption.

(d) Jamming or spoofing measures could be used against satellite or ground station signals. Jamming could be carried out by blocking the transmitted signal and by overpowering it with noise. Spoofing could be carried out by deliberate alteration or replacement of the signal. A satellite system could also be made inoperative by manipulating the telemetry, tracking and control system. However, these measures would require jammers to be located in the near vicinity of the ground stations. Destruction of ground stations during hostilities could be a method of direct attack. It may require covert measures with special agents or direct action by using SSMs/fighter aircraft.

(e) The Chinese have developed nano-parasitic satellites. These are in the testing stages. They could be attached to an orbiting satellite and could either disrupt the functioning of the satellite or could destroy it when required, and activated from the ground.

CONCLUSION

Aerospace power could be defined as synergistic application of air, space and information systems. This synergistic combination has an overwhelming influence on the economic and military power of a nation. Satellites can collect valuable information through active and passive means in much of the electro-magnetic spectrum, from ultraviolet wavelengths to thermal infrared and reflected radar waves. However, there are limitations to satellite reconnaissance and, hence, the ISR operations need to be integrated activities that encompass space-based systems and air power elements.

Various passive and active measures can be taken to prevent/neutralise imaging of objects of interest. The passive measures comprise manoeuvre and evasion, concealment and hiding, camouflage, deception, obscurants, etc.

However, the most effective measures include hiding overt activities when the satellite passes over areas of interest, concealing important objects within constructed structures, constructing underground infrastructure for command and control centres as well as for sensitive programmes and moving objects after the satellite has made its pass. The active measures include kinetic energy weapons that cause physical destruction of the orbiting satellites or directed energy weapons that could cause hard kill, a non-destructive soft kill or a non-lethal temporary disruption or degradation.

RECOMMENDATIONS

The following recommendations would significantly assist in countering satellite recconnaissance:

(a) DRDO/LRDE/ISRO and the IAF should work towards establishing a viable space surveillance network and towards counter-space measures. Further, these systems could be integrated with the BMD Early Warning and Aerospace Command, as and when it comes up.

(b) There is a need to evolve an aerospace doctrine that enumerates various defensive and offensive counter-space tasks. The inter-relationship between counter-space and counter-information should clearly emerge in the recommended counter-space construct. The doctrine should relate to a national space policy that has been worked out jointly with the armed forces. Some work towards this end has been carried out by the Chief of Integrated Defence Staff (CIDS).

There is a need to evolve an aerospace doctrine that enumerates various defensive and offensive counter-space tasks.

(c) There are limitations to satellite reconnaissance and, hence, there is a need to put in place an integrated space and air power ISR network. An Aerospace Command would be an inescapable necessity to effect this coordination. An effective command and control structure needs to be set up.

(d) The effective passive counter-measures include carrying out covert activities when satellites are not visiting the area, hiding objects within buildings or underground structures and moving the overground elements after the satellite has passed over that area.

There are limitations to satellite reconnaissance and, hence, there is a need to put in place an integrated space and air power ISR network.

(e) Identify camouflage nets and materials that provide wide band protection. Blend the objects by using terrain and natural cover to maximum effect or merging the objects with their background. Maintain camouflage discipline to prevent giving away target locations.

(f) Do not attempt to camouflage everything as it would be very costly, time consuming and impractical. Discriminate between the important and critical, and camouflage only the critical objects. The theme should be to give some information so as to hide what is critical. Further, camouflage on some unimportant equipment should also be carried out for deception purposes.

(g) Procure realistic decoys of critical target elements. Preferably, use old and discarded equipment that is realistically painted and is able to give a similar visual and IR signature. In fact, all life expired aircraft/equipment should be used to make cost-effective realistic decoys.

(h) The development of KALI (kinetic attack loitering interceptor) and DURGA (directionally unrestricted ray gun) should be progressed to their logical conclusion.

(j) Nano-satellites developed by ISRO should be experimented towards ASAT technology.