LOWERING THE HIGH GROUND FOR EFFECT-BASED OPERATIONS

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Every revolutionary idea seems to evoke three stages of reaction. They may be summed up by the phrases: one, it's completely impossible; two, it's possible, but it's not worth doing; and, three, I said it was a good idea all along.

— Sir Arthur C. Clarke

The dawn of the space age set in motion the wheels of militarisation of space by the superpowers. They were soon joined by other nations that could afford the technology either through collaboration or indigenisation. While space has been utilised as a force enabler since the decade of the 1960s, it was only during the 1991 Gulf War that the true potential of space as a force multiplier for military operations was realised. Since then, nation-states have marshalled their resources to ensure better battlefield awareness than their adversary to retain the cutting edge. The US, considered the undisputed leader in pioneering the militarisation of space, found that all its space power could not deliver persistent situational awareness and communication to its war-fighters during the 2003 Iraq War[1]. On some occasions, the war-fighters were bereft of critical information at the

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1. Maj Andrew.J.Knoedler, "Lowering the High Ground: Using Near Space Vehicles for Persistence C3ISR", Centre for Strategy and Technology, Air War College, Maxwell, USA, at http://www.stormingmedia.us/46/4653/A465364.html

tactical level which led to a delay in successful execution of a time critical mission.

Since then, the US has been considering with renewed vigour two concepts that will help it ensure battlespace awareness on a 24x7 basis. These are Operationally Responsive Space (ORS) and the use of near space. While ORS focusses on employing satellites launched at short notice for specific missions, near space focusses on effect-based operations by employing sensors on platforms like balloons, airships or high altitude long endurance Unmanned Aerial Vehicles (UAVs) that are persistent, cost-effective, survivable and responsive. Considering that active employment of airships for military use has been discontinued since 1962[2], this renewed interest in Near Space Vehicles (NSVs) or High Altitude Airships (HAA) is noteworthy.

The interest has been rekindled due to many factors. First is the overwhelming domination of US air power in military conflicts. Second, the US military's demand for persistent surveillance, a function for which the aerostats and airships are well suited. Network-centric warfare approaches, increased emphasis on internal security and growing force protection demands in urban environments all call for "dominant battlespace awareness." Third, growing budget pressures in the US have encouraged the study of potential solutions to military problems that may reduce procurements, operations and maintenance spending[3]. Last, but not the least, are the technological advances in terms of propulsion technologies and breakthroughs in solar cell technology which have combined to make the allure of the NSVs a reality in the near future. According to a Congress Research Service (CRS) report for the US Congress in 2005,[4] more than 32 countries are actively involved in airship development.

India too joined the bandwagon at the beginning of the 21st century with work commencing on airship development and design in the Indian Institute of Technology (IIT), Mumbai. Though it is at a nascent stage, the final concept

2. The US Navy was the last to discontinue the use of airships for military employment in 1962. Over the last four decades, airships have been used only for commercial activities, barring the USAF use of tethered aerostats over the last decade.

3. Christopher Bolkcom, " Potential Military Use of Airships and Aerostats," *CRS Report for Congress*, May 9, 2005, at http://www.fas.org/sgp/crs/weapons/RS21886.pdf

4. n.2.

envisages the development of a stratospheric/ high altitude airship. It is expected that in future wars, NSVs will play a seminal role in the successful outcome of conflicts at all levels by providing a Common Operating Picture (COP) down to the tactical commander.

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CONCEPT OF NEAR SPACE

The realm of near space considered as the region between controlled commercial air space and Low Earth Orbit (LEO) has been a cultural blind spot for many years but is not a new phenomenon. It has been used for weather forecasting by hoisting free floating hydrogen balloons (up to 27 km), scientific balloons (up to 42 km)[5], by adventure balloonists who jumped from near space, and by the strategic reconnaissance platforms like the MiG-25, SR-71, U-2 and more recently the unmanned Predator and Global Hawk flying at the lower envelope of near space at 65,000-70,000 ft. However, of late, it is being seen as another medium which would offer new capabilities not accessible to orbiting satellites or manoeuvring aircraft, capabilities that are critical to emerging national defence needs.

Definition of Near Space

There are contrasting claims of the altitude band for near space. According to the International Aeronautical Federation, the near space region lies between the 75,000 ft (~23km) and 3,25,000 ft[6] (~100km). The US Space Command considers near space to be between 20 km and 300 km. However, in most nations, the controlled air space is considered up to, and including, 60,000 ft above mean sea level (Class A air space). To provide a buffer between commercial traffic operating at 60,000 ft and any NSV, this paper considers the start of near space as 65,000 ft or about 20 km. Ideally then,

5. "Near Space: The Shore of Our New Ocean," available at http:// www.hobbyspace.com/ NearSpace/
6. n. 2.

near space must extend up to the lowest altitude that a vehicle can maintain low earth orbit; defined as 490,000 ft or about 150 km. However, with the present technological advancements, the focus is on developing vehicles operating in the realm of 65,000 ft (20km) to 120,000 ft (36.6 km). We call it near space as it provides effects similar to what satellites have traditionally given us without having to go into orbit. It is a medium that we need to exploit to get space effects.

Thus, the near space concept involves floating payloads into a region of the stratosphere where winds are light and weather virtually non-existent. From that extremely high vantage point, the payloads have Line of Sight (LOS) for hundreds of kilometres to the horizon, becoming long-range communications relays or providing intelligence over theatre-sized areas.

This paper will examine near space and its environment, various NSVs on the anvil, advantages and disadvantages of operating in near space vis-à-vis aircraft and orbital assets, development of NSVs, and bring out the effects that NSVs can bring in towards persistent battlefield awareness.

THE NEAR SPACE ENVIRONMENT

The environment of near space differs considerably from the atmosphere and space in terms of temperature, winds, pressure and ozone effects while being free of ionospheric effects that are a cause of concern for spacecraft. While a complete discussion of the near space environment is beyond the scope of this paper, it is important to understand a few of the basic conditions that near space platforms will encounter. Contrasting them with air and space will give an understanding of the relative advantages and disadvantages of operating in each of the media.

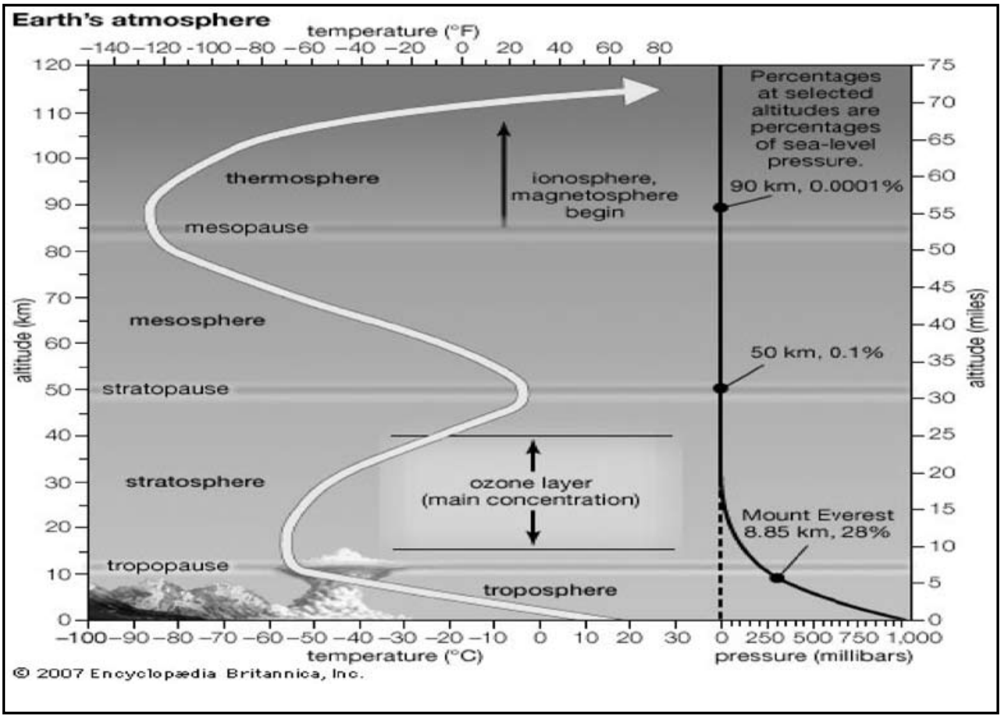
Temperature. In atmosphere, the temperature decreases at a lapse rate of -2^0C for every 1,000 ft rise in altitude up to 36,000 ft and thereafter remains constant at -59^0C up to 65,000 ft, i.e the start of near space. The temperature thereafter starts increasing up to -27^0C at 120,000, ft[7] as depicted in Fig. 1.

7. 2007 Encyclopedia Britannica, inc at http://media-2.web.britannica.com/eb-media/56/97256-003-96282CF1.gif

This is in contrast to space where surfaces facing the sun would be hot whilst others facing away or in the shadow would be extremely cold.

Hence, for operational use in near space, the designs of vehicles, airships and payloads need to cater for moderately cold temperatures as opposed to having to deal with a hysteresis of extreme temperatures in atmosphere and space.

Fig.1: Temperature and Pressure Variation in Atmosphere and Near Space



Wind. Wind patterns are also different in near space as opposed to space. Compilations of surveys of the general wind condition in near space had shown that for equatorial regions such as India, wind speeds average at 15 knots, with speeds gusting up to 40 knots 95 percent of the time. However, as the density of the atmosphere in near space ranges between 7 percent of sea level down to 0.5 percent of sea level at 120,000 ft, gusts and transient changes in wind speed will have minimal effects as there are very few air

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molecules to transfer momentum. Only sustained winds will cause an object to slowly accelerate to the ambient wind velocity, so all-in-all, the environment can be characterised by 15 to 30 knots of ambient wind speed[8]. By designing the correct types of propulsion, it would technically be feasible to design a vehicle to overcome such speeds, as has been demonstrated by the National Aeronautical Space Agency's (NASA's) Helios solar powered UAV which has achieved up to 150 knots at 96,500 ft.[9]

Another difference between space and near space is **pressure**. In space, pressure is essentially negligible[10]. In near space, pressure is a significant factor, especially for structures based on gas-filled volumes. All else being equal, when external pressure decreases, there must be a corresponding increase in volume. Thus, when the atmospheric pressure decreases by half, the volume of a closed balloon must increase by a factor of two. Between about 65,000 ft and 120,000 ft, the pressure halves with every change of approximately 15,000 ft, implying that such an ascent would approximately double the volume of a balloon[11]. These large changes in volume can be a severe design constraint for near space platforms using helium lift.

The corrosive and harsh solar radiation environment that the near space region presents differs from that of space and the atmosphere below 65,000 ft. In the atmospheric region, ozone is the primary absorber of ultraviolet (UV) radiation. However, at higher altitudes, the ozone concentration reduces significantly, and very little UV radiation is absorbed. As such, designers would have to design vehicles to accommodate UV damage. To escape UV damage, one could fly in the lower portion of near space. However, the

8. Matthew K. Heun, "Maneuverable Platform Wind Environment," Global Aerospace Corp (June 2000).
9. Maj Joeh Leo, "Tech Edge: Near Space, Near Future," *Pointer Journals*, vol. 33. no.1,2007.
10. See Fig. 1.
11. Lt Col Edward B. Tomme, "The Paradigm Shift to Effects-Based Space: Near Space as a Combat Space Effects Enabler," Research Paper 2005-01, Air Power Research Institute, USA.

density of ozone increases up to thirty times as much as that at 120,000 ft which makes the vehicle then susceptible to the corrosive effects of ozone[12]. Hence, although not impossible to accommodate, designing the near space vehicle would have to trade-off between ozone corrosion and UV protection, depending on its intended operating altitude.

NEAR SPACE ENABLED BY TECHNOLOGY

Recent advances in technology have enabled countries like the US to foray into developing UAVs and airships that can operate in near space. The success of near space technology will help countries derive the advantages of satellites without sending the vehicles into orbit while improving upon the endurance of their air breathing brethren. Some technologies contributing to this revolution in capability are[13]:

- Power supplies, including thin, lightweight solar cells, small, efficient fuel cells, and high-energy-density batteries.
- Extreme miniaturisation of electronics and exponential increase in computing power, enabling extremely capable, semi-intelligent sensors in very small, lightweight packages.
- Very lightweight, strong, flexible material that can resist degradation under strong UV illumination and is relatively impermeable to low-atomic-mass gases.

These technologies, when synergised, culminate into a force multiplier called the NSV which allows a revolutionary, transformational increase in capability. These NSVs, with their compact payloads powered by long-lasting and efficiently renewable power supplies, operating at extremely high altitudes, can perform many of the missions currently performed by satellites, in many cases just as effectively and in a more timely manner than their more traditional brethren. In effect, one needs to treat near space more as an effects enabler than a medium like space.

12. n.7.
13. Heun, n.8.

By virtue of being placed high up in the air, NSVs provide large area coverage for either communications or surveillance functions.

ADVANTAGES OF NEAR SPACE VEHICLES

Use of NSVs is limited only by the ingenuity of the payloads that can be put on them. The advantages of near space platforms as force enablers are discussed below.

Wide Area Coverage

By virtue of being placed high up in the air, NSVs provide large area coverage for either communications or surveillance functions. The lack of obstacles between earth and near space enables the maximum communication range, assuming that the power output of the radio is high enough to propagate through this distance. Or that the lens used is wide enough to capture the full area of operations for surveillance type functions. At 30 km, the minimum expected LOS range would be 720 km as calculated by the LOS equation,[14] while a radio atop the tethered aerostat balloon hoisted at a height of 5 km provides an LOS range of 300 km. Tests carried out by the US Air Force (USAF) Space Battle Lab under the Combat Sky Sat balloon programme[15] revealed that the range of the PRC-148 radio increased from 16 km on the ground to 650 km when used from an altitude of 20 km.

High Resolution, Better Sensitivity

Near space platforms operating at 30 km are at least 15 to 20 times closer to earth than their orbital counterparts. Considering that similar optical infrared (IR), Multi-Spectral Imaging (MSI), or Synthetic Aperture Radar (SAR) sensors onboard the satellites are employed as payloads on NSVs, they would be expected to provide 10-20 times better resolution. Distance is critical to resolving features in images and receiving low power signals. The power received by a passive antenna decreases as the square of the free space distance to the transmitter, while that of an active transmitter/antenna system decreases as the fourth power of

14. The LOS range is calaculated using the formula $R_{Nm} = 1.23(\sqrt{H1}+\sqrt{H2})$ where H1 and H2 are the height of the antenna on ground and height of the balloon in thousands of feet, at http://www.tscm.com/rdr-hori.pdf
15. Hampsten Stephens, "Near Space," *Air Force Magazine*, July 2005.

the transmitter/target distance[16]. A passive antenna on a satellite that received one watt of power from a transmitter in its footprint would receive between 100 and 400 watts on a near space platform, implying that it could detect much weaker signals (10 to 13 dB weaker). The signal strength improvement for active systems such as Radio Detection and Ranging (RADAR) or Light Detection and Ranging (LIDAR) would be factors of 10,000 to 160,000 (40 to 52 dB) for near space platforms. These examples at nadir are *best* cases for the satellites, too. Any off-nadir angle only increases the distance differential, increasing the near space signal strength and resolution advantages markedly.[17]

Near space platforms are inherently survivable. When compared to their air breathing counterparts, they are immune to enemy ground fire, Man Portable Air Defence Systems (MANPADS) and the vagaries of weather.

Another advantage of NSVs over satellites as discussed in the near space environment, is that they are free from the ionospheric effects like long range HF and VHF fades which is a common occurrence with satellite communication due to solar flare activity.

Survivability

Near space platforms are inherently survivable. When compared to their air breathing counterparts, they are immune to enemy ground fire, Man-Portable Air Defence Systems (MANPADS) and the vagaries of weather. Again, in comparison with orbital platforms, they are immune to attacks from space-borne weapons or accidental collision with debris or other orbiting satellites. With increasing range of air launched weapons, there is a belief that large balloons and airships can be targeted by air-to-air missiles/guns. However, if such an attempt by the US and Canada in the late 1990s is any indication, it would be a futile attempt, more so because of the low price and redundancy of these NSVs. In August 1998, Canadian scientists lost control of a 100-m diameter weather balloon. Fighter jets from three nations were scrambled to shoot it down as it first flew across

16. Tomme, n.11.
17. Ibid.

If the platform is survivable, then targeting the payload is another option to render the platform useless.

Canada, then the North Atlantic, Norway, Russia, and into the Arctic Ocean. Canadian F-18 fighters fired an estimated 20-mm cannon shells into the balloon, which obstinately continued flying for another six days[18]. Unlike the older generation balloons which used the highly flammable hydrogen gas, the modern ones use highly inert helium gas that does not burn.

If the platform is survivable, then targeting the payload is another option to render the platform useless. However, the slow speed of the platform with respect to modern fighter aircraft ensures that the platform remains in the doppler slot of the Airborne Interception (AI) radars and, hence, goes undetected. Even if the movement is discernible, the relatively low radar and thermal cross-section of the payload (radar/communication) make it difficult to acquire and track and, thus, target them by Anti-Radiation Missiles (ARMs). Estimates of their radar cross-sections are on the order of hundredths of a square metre[19], about the same as a small bird. The threats to near space platforms, specially in the lower fringes of near space (65,000-1,00,000 ft) emerge from the 5/6th generation aircraft capable of much higher operating altitude and equipped with better air-to-air missiles or from high altitude UAVs like the Predator if equipped with air-to-air missiles. Aircraft equipped with laser pods capable of targeting incoming air-to-air missiles may also pose a threat to these payloads. Alternately, present day ground-based Directed Energy Weapons (DEWs) like Anti-Satellites (ASATs) can also pose a threat to radar and communication payloads in near space. These threats can, however, be overcome by using Laser Radars (LADARs) which are designed to be passively stealthy using Low Probability of Intercept (LPI) techniques. The biggest challenge would lie in acquiring and tracking the near space platforms at those altitudes, and once tracked, targeting the payload and scoring a direct hit is another challenge.

18. "America's Rogue Balloon Lost at Sea," *BBC News Online*, August 31, 1998 at http://news.bbc.co.uk/1/hi/world/americas/162084.stm.
19 ."Vulnerability to Jamming Underscores Need for Navigation Back-up," *Air Safety Week*, September 7, 1998, at http://findarticles.com/p/articles/mi_m0UBT/is_/ai_50342689.

Responsive Persistence

Satellites are non-responsive to launch, taking an estimated eight days in the case of the Evolved Expendable Launch Vehicle (EELV) of the US to 27 days in the case of China. Once in orbit, satellites cannot be steered at will. Even a small change in orbital inclination requires expending the onboard fuel which shortens the lifespan of that satellite. Hence, changes in orbital altitude or inclination are generally undertaken only in the case of a physical threat to the satellite from orbital debris and /or other satellites.

Once on station, their persistence can be measured in terms of months and they also pose a less operational risk due to the single launch and recovery cycle.

Air breathing vehicles (aircraft and UAVs) are extremely responsive and can be launched in minutes to hours. They can be brought to bear on the area of interest in time and space for real-time information unlike the satellites which are limited by their orbital periods.

When compared with their orbital counterparts, NSVs are far more responsive, and are as responsive as their air breathing counterparts. Their launch preparation is a matter of a few hours and once launched, their ascent to their operating altitude (say 120,000 ft) would take about two hours considering an ascent rate of 1,000 ft/min. Once on station, their persistence can be measured in terms of months and they also pose a less operational risk due to the single launch and recovery cycle.

Once a near space vehicle is launched, it is expected to be on station for weeks to months at a time. In addition, near space avoids the traffic and vulnerability found in commercial air space, thus, avoiding frequent shifts in position due to conflicting traffic. This allows the payload to provide persistence surveillance / communication services to battlefield commanders at specified locations round the clock, with no gaps in coverage, unmatched by those of the satellites or even the most advanced UAVs like the Global Hawk (maximum of 30 hours).

Cost

Near space vehicles offer tremendous cost advantages over satellites or aircraft.

The surveillance cost per hour would also be the cheapest in the case of NSVs when compared to other assets.

When compared to the cost of acquiring one Heron UAV, at a cost of US$4 million from Israel, a SU-30 MKI at a cost of US $ 47 million from Russia or an Airborne Warning and Control System (AWACS) at a cost of US $350 million from Israel/Russia, the cost of a free floating balloon would be less than US $ 1,000. Even at the high end of the spectrum, the US $ 50 million cost of a strategic high altitude airship with payload would be less than that of an AWACS, even if more than a UAV, and comparable to that of the SU-30 MKI. Comparing the cost of an NSV to that of a satellite, we find that satellites are much more costly. The surveillance cost per hour would also be the cheapest in the case of NSVs when compared to other assets due to the saving in expenses in terms of refuelling, maintenance, major upgrades, payload reconfiguration, launch infrastructure and manpower for operation as it will be designed to stay on station for months at a time. Thus, we can say that when it comes to cost taken over the life cycle of an NSV, it has no peer.

Payload

As regards payload (sensor/communications), there is a limitation of the amount one can place on a satellite considering the cost/kg of launch and the fact that the payload can neither be retrieved nor upgraded. Similarly, in the case of aircraft and UAVs, the sensor payload is one of the many factors that need to be factored in during the design stage. Unlike the case of satellites, payload onboard aircraft and UAVs can be upgraded but at a considerable cost which involves reengineering of the platform to fit the payload. Even if the payload is a kind of plug and play and carried outside the platform, it would affect the range and endurance of the platform. The more advanced Global Hawk[20] UAV of the US is capable of carrying a total payload of 850 kg to 65,000 ft and provides persistence of about 42 hours. When compared with these assets, NSVs are being designed to carry more than 1,000 kg to above 100,000 ft

20. "RQ-4A/B Global Hawk High-Altitude, Long-Endurance, Unmanned Reconnaissance Aircraft, USA," at http://www.airforce-technology.com/projects/global/

and provide persistence for months together without any major maintenance. The payload can be changed by retrieval of the NSV or a new NSV can be launched. In essence, the type of payload is independent of the platform, and volume is not a major design constraint. Further, not being exposed to the high levels of radiation common to the space environment, payloads flown in near space do not require the costly space hardening required for orbital assets. Near space payloads also are not exposed to high gravitational forces during launch, as are satellites. Operating in near space obviously eliminates a great deal of expense involved in space sensor construction.

LIMITATIONS OF NEAR SPACE VEHICLES

The two most prominent limitations are launch constraints and legal constraints. Balloons and airships require large open areas/hangars for inflating them before launch. The launch preparation times can be of the order of a few hours during which their susceptibility to low-altitude wind needs to be factored into the design constraints of such near space vehicles. The same would be the case during their ascent and descent through the troposphere; recovery; and deflation. However, these problems are surmountable as has been seen in the case of very large balloons that have been routinely launched for years with similar constraints, and lightweight, inflatable hangars suitable for deployment are already available in the commercial market[21]. Such considerations are required to ensure seamless coverage of the area of responsibility. Additionally, construction of hangars for near space platforms is a relatively minor project when compared with construction of the launch infrastructure for other types of platforms such as satellites and aircraft. However, from the military perspective, these large open areas/hangers present lucrative offensive counter-air (OCA) targets for the adversary just like aircraft hangers and runways and, hence, would need the requisite terminal defence systems for launch site protection.

Freedom of overflight is another limitation for NSVs. Historically, the Karman Line at 100 km altitude has been considered as the boundary separating air and space

21. Tomme, n.11.

> **Historically, the Karman Line at 100 km altitude has been considered as the boundary separating air and space and, thus, the application of air law and space law.**

and, thus, the application of air law and space law. This implied that below 100 km was the sovereign air space of a nation, and above it, the satellites had overflight rights. With the advent of NSVs having the ability to operate above 20 km and being relatively invulnerable to enemy air defences, there is considerable disagreement among legal analysts over whether overflight rights exist for NSVs similar to satellites. A recent memo from the USAF General Counsel addressing the matter stated, "Although we have not defined the boundary between air and space, it will be higher than near space."[22] In other words, the USAF position is that near space over a country will be treated as sovereign territory and air law will prevail. If the US as the leader in near space regime were to change its legal position, then such rights may open up the near space environment over one country to reciprocal overflights by foreign powers. Considering the low cost nature of developing and launching near space vehicles, many aspiring space-faring nations would join the more affordable near space race. In such a scenario, it would be difficult for countries to guard against an adversary's NSV operating in one's sovereign air space. The legal quandary surrounding overflight is not a fatal flaw for the near space concept. The simple reason being that, during hostilities, just as aircraft operate in an adversary's air space with their attendant vulnerabilities, near space platforms can also be expected to operate in a similar fashion. However, during peace-time operations, they can be positioned over own air space or over international waters to provide up to 400 km coverage of the adversary's air space.

While legal constraints can be overcome or violated subject to the interests of the country operating the near space vehicles, and launch constraints will possibly be surpassed with the passage of time, the advantages of near space for military use can be gleaned only with the change in mindset of the armed forces from medium/platform-centric operations to effect-based operations. Military planners historically tend to go with what they know, and often, it takes a great deal of push from a vocal minority within their

22. Ibid.

ranks to get them to adopt new ways of doing business. If the mindset is conditioned to adapt to effects delivered from near space, there appear to be no scientific or engineering obstacles that cannot be overcome in short order, provided that sources of funding can be found.

The advantages and limitations of NSVs when compared with air breathing platforms and satellites are tabulated below (Table 1).

Table1:Relative Strengths of Satellites, NSVs and Air Breathing Assets

S. No.	Attribute	Satellites	NSVs	Aerial Platforms
1	Cost		✓	
2	Sensor Payload		✓	
3	Persistence		✓	
4	Coverage	✓	✓	
5	Responsiveness		✓	✓
6	Resolution		✓	✓
7	Overflight	✓		
8	Survivability		✓	

PLATFORMS FOR NEAR SPACE

Lighter Than Air (LTA) balloons, the precursors to present day near space vehicles/airships have been used for military operations since the invention of the hot air balloon by the Montgolfier brothers in 1780[23]. However, the golden age of airships began with the German built rigid airships called the Zeppelins at the beginning of the 20th century[24]. Their use continued at a reduced scale during World War II due to the advent of aircraft. However, the Hindenburg disaster[25] and the United States' ban on export of helium gas sounded the death knell for the military use of airships by other countries,

23. K.V. Gopalakrishnan, *Impact of Science and Technology on Warfare* (New Delhi: National Book Trust, India 2003), pp.72-73 and "How is an Airship Made?", at http://www.answers.com/topic/airship. Between 1783 and 1900, airships and hot air balloons were used in the French-Austrian War, the Franco-Prussian War and the American Civil War.
24. The successful use of Zeppelins for reconnaissance missions by Germany during World War I spurred other countries' development of airships and by the end of the war, the UK, Italy, France, USSR and USA had operated rigid/non-rigid airships for the scouting and tactical bombing role.
25. The Hindenburg, an 804-ft-long rigid hydrogen filled balloon, returning from a transatlantic flight to New Jersey on May 6, 1937, burst into flames at the Lakehurst Naval Air Station while attempting a landing in inclement weather, killing 36 people, http://americanhistory.about.com/od/hindenburg/Hindenburg_Disaster.htm

US success in the use of tethered aerostats up to 10,000 to 15,000 ft in providing redundancy to existing ground and airborne platforms over theatre sized areas when deployed in an overlapping arc, has rekindled interest in their use from higher altitudes.

and their use was limited to adventure sports and sight-seeing activities, except in the US[26]. Between 1934 and 1961, crewed balloon flights, however, were used to conduct research in the stratosphere with pressurised capsules allowing crews to go as high as 100,000 ft (30 km). In 1961, the advent of space flight made many of these experiments obsolete[27] .Thus, the advent of aircraft and satellites foreclosed options for their gainful military use.

Over the last two decades, US success in the use of tethered aerostats up to 10,000 to 15,000 ft in providing redundancy to existing ground and airborne platforms over theatre sized areas when deployed in an overlapping arc,[28] has rekindled interest in their use from higher altitudes, along with other reasons discussed earlier. Unlike their tethered counterparts, the LTAs in near space come in a variety of forms. While some simply drift with the wind, others are able to manoeuvre and station-keep, providing persistent surveillance and communications and various other defence related tasks over the area of interest.

Not constrained by the orbital mechanics of satellite platforms or the high fuel consumption rates of airborne platforms, many envisioned near space systems are being designed to stay on station above a specified site almost indefinitely, providing persistent coverage in all three dimensions. The various types of platforms and their developments are discussed below.

Free Floaters

The most mature near space technology available today is the free floating balloon platform which has been used for high altitude weather monitoring

26 n.7.

27. "How is a Hot Air Balloon Made?," at http://www.answers.com/topic/hot-air-balloon-vehicle

28. n. 2.

over the last century. They are very straightforward to construct and launch, and very inexpensive (a Sky Site balloon costs US $100[29]). Once launched, they are at the mercy of the existing winds. Limited steering is possible by variable ballasting, causing the balloon to float at different altitudes to take advantage of different wind directions and speeds. Free floaters can travel as high as 49 km (160,000 ft), carry up to 4,000 kg, and stay afloat for as long as 700 days[30]. No single platform, however, has achieved all of these parameters in one mission till date. Free floater systems have already demonstrated commercial viability as communications platforms. The International Telecommunication Union (ITU) has allotted two frequency bands, 28GHz and 47/48 Ghz, for use by near space vehicles where, at present, the spare spectrum is plenty[31].

The two drawbacks with this platform are the requirement for continuous replenishment and loss of payload once the balloon bursts in near space. While their inexpensive nature allows for periodic replenishment, technological advances have helped overcome the loss of payload by employing a parachute/glider-borne payload attached to the balloon. The parachute/glider facilitates detachment of the payload from the balloon after the end of the mission or at a predetermined time, and allows retrieval of the payload for reuse. A variety of such hybrid glider/balloon systems is available off the shelf today[32], ranging from extremely inexpensive plastic gliders with limited payload capability (tens of kilograms) to much more complex and capable composite gliders such as those designed to land payloads on Mars. Efforts are on in the US[33] to design Global Positioning System (GPS) guided, extremely manoeuvrable high speed gliders which are capable of delivering the payload to the predetermined location and, thus, ensure their safety in times of operations

29. Mary Ann Stewart, Lt Col Kevin Frisbie, Gary Trinkle, "High Altitude Surveillance," *Geo Intelligence*, July 1, 2004, at http://www.gaerospace.com/press-releases/pdfs/HighAltitudeSurveillance.pdf
30. Ibid.
31. Sandeep Relekar and Rajkumar S. Pant, "Airships as a Low Cost Alternative to Communication Satellites," at http://www.aero.iitb.ac.in/~airships/WEBPAGES/PDFs/npaper05.pdf
32. Leo, n.9.
33. Bill Sweetman, "Taking a Dive," *Aviation Week*, November 12, 2007, at http://www.aviationweek.com/

Steered Free-Floaters

The steered free floater platforms generally drift with the wind but they can be controlled with a small degree of precision by a steering mechanism. Thus, although steered free floaters are capable of station keeping, their accuracy is insufficient for effective persistence, thereby requiring deployment in large numbers. The steered free floaters rely on the wind differential in two altitude bands. While the balloon floats at an altitude of about 115,000 ft, the steering mechanism is tethered 15 km below and takes advantage of the denser air at altitudes of 65,000 ft to provide trajectory control to steer the balloon. The StratoSat[34] (using super pressure ultra long duration balloons built by NASA) developed by Global Aerospace Corporation of Altadena, California, is one such example.

No integrated steered free floater has yet been flown, although most of the component parts have been tested individually. Having the capability for steered flight, payloads could be more complex than those flown on basic free floaters as they could be navigated to a depot, recovered, repaired, and reflown.

Manoeuvring Vehicles

Even more sophisticated persistent and responsive high altitude long loiter (HALL) options involve near space platforms like airships, aerodynamic balloon bodies, UAVs and hybrid systems that are able to manoeuvre and, thus, fly to, and station keep over, the specified points. Such platforms are the functional cross between satellites and airborne platforms, providing the large footprint and long mission durations commonly associated with satellites and the responsiveness of tactically controlled UAV. Manoeuvring vehicles are designed to have low mass, are highly aerodynamic, and are designed to fly in low air density conditions that do not support traditional flight. At the lower end of near space, the air is thick enough for high-efficiency propellers to provide effective propulsion for these large vehicles. Higher up, propeller requirements increase significantly in the thinner air, and other propulsion methods begin to become more efficient.

34. Relekar and Pant, n.31.

Some vehicles vary their buoyancy, ascending and descending within an altitude band during operations[35].

DEMONSTRATED/ DEVELOPMENTAL NEAR SPACE PLATFORMS

Many countries are developing near space platforms and accessories or researching on their exploitation for communication and surveillance purposes. The US is spearheading the race with parallel research and development by various organisations like NASA, Defence Advanced Research Project Agency (DARPA), USAF Space Battle Lab, while Japan and South Korea have tested small scale models of their proposed stratospheric airships. The various airship programmes that are under development are discussed below.

Space Data Corporation's Free Floaters

USAF Space Battle Lab's quest for finding and quickly demonstrating innovative solutions to top war-fighter needs led it to employ the Space Data Corporation's free floating balloons[36] to test the effectiveness of its tactical communication radio system, the hand-held PRC-148 used by US troops in Iraq and Afghanistan. The normal LOS range of the radio is 15 km. However, in 12 tests carried out in March 2005, the radio communications range increased from 15 km to more than 650 km. A balloon floating over the battlefield between 65,000 and 95,000 ft relayed LOS broadcasts from radios on the ground and in the air. The March demonstrations employed members of a tactical air control party on the ground and an F-16, A-10, and E-8 Joint Strategic Target Attack Radar System (JSTARS) aircraft in the sky to

35. Helios is an example of this kind of HALL system. Developed by AeroVironment of Monrovia, California, in cooperation with NASA's Environmental Research Aircraft and Sensor Technology Programme, Helios is a large solar-electric, flexible–wing stratospheric satellite that has 12 small engines across its wingspan. The wing flexes in the wind like that of a bird. Helios has been tested to 96,500 ft, carrying payloads of 1,100 kg for almost two days, achieving speeds of 150 knots.
36. On the commercial front, the free floaters have been in use by oil and gas companies in Texas and Oklahoma to monitor data from wells spread across thousands of square miles across sparsely populated areas. Two to three balloons are launched every day to provide persistent communications. The balloons with digital communication sets called Sky Sats provided uninterrupted communications in post-disaster management operations in the aftermath of Hurricanes Katrina and Rita in the US.

explore how such extended-range communications could improve Battlefield Air Support (BAS) missions. With the repeater on board the balloon, ground controllers were able to communicate with the strike aircraft over hundreds of kilometres to enable 'talk onto the target' which also allowed dynamic retasking. The success of the tests resulted in a US $ 49 million investment over a period of five years by the USAF Space and Missile Centre's Development and Test Wing for supply of Space Data Corporation's balloons and more improvised communication sets[37].

Since the free floater balloons cannot be recovered, the payload is retrieved by use of a parachute which deploys once the balloon bursts. However, the vulnerability of military communication payloads falling into enemy hands during their parachute descent to the ground has led the USAF Space Command's Space Innovation Development Centre to conceptualise the "Talon Topper" project under its Tactical Exploitation of National Capabilities Operations (TENCAP). The Talon Topper is a glider constructed from very high-tech polymers to return payloads to designated locations by using a plug and play cargo bay that can carry a variety of payloads and then return safely using GPS guidance[38]. The programme, estimated at US $ 9 million, is into its third phase of development, that of demonstrating delivering/retrieving even the balloon to the desired location[39].

Hi-Sentinel

Aerostar International of Sulfur Springs, Texas, USA, is developing a flaccid launch airship called the Hi-Sentinel for the US Army Space and Missile Defence Command. The project is focussed on developing small near space airships for inexpensive tactical communications and Intelligence, Surveillance and Reconnaissance (ISR) applications[40]. Hi-Sentinel is a conventional, 140m

37. "Near Space System Improves Battlefield Communications," August 31, 2006, at http://www.gizmag.com/go/6081/.
38. Knoedler, n.1.
39. Sean Meade, "Space Bound Balloon," at http://aviationweek.typepad.com/ares/final_frontier/
The airship has been developed in coordination with the Southwest Research Institute, Raven Industries and US Air Force Research Lab.
40. "Stratospheric Airship Reaches Near-Space Altitude During Demonstration Flight," at http://

long, non-rigid airship designed to fly above 60,000 ft for at least a week. Its innovations include very low structural weight and an internal, steerable solar array. The first flight in 2005 carried a 60 lb payload and telemetry pod to 74,000 ft and achieved powered flight for 1.5 hours during a five-hour flight. The historic flight saw the largest stratospheric airship ever to achieve powered flight in the stratosphere and only the second stratospheric airship to do so[41]. The second flight planned for 2009 is attempting to extend the endurance demonstrated during the first flight.

Lockheed Martin's High Altitude Airship (HAA)

The most ambitious of the HAA military programmes is being undertaken by Lockheed Martin. Under contract to develop a HAA platform for the US Missile Defence Agency (MDA) since 2003 as part of an advanced concept technology demonstrator, Lockheed Martin was to execute the programme's third phase to build, flight test, and demonstrate the prototype HAA vehicle. The prototype under development is planned to have a mission life of one month, operating above 60,000 ft (18.3 km), while providing 10 KW of power for 227 kg/500 lb (operational version would carry 1,813 kg/4,000 lb) payload[42]. The HAA vehicle would be 152 m (500 ft) long and 46 m (150 ft) wide. Photovoltaic cells and fuel cells would power the HAA. Electric-powered propeller technology would be used to propel the HAA and help it to maintain geostationary location[43]. The HAA would be retaskable in flight and can be recovered and reconfigured as required for specific mission requirements. The operational vehicle is expected to provide mission times in excess of one year for a wide variety of applications like ballistic and cruise missile defence, theatre surveillance, environmental / weather monitoring and post-national disaster support, maritime domain awareness and

www.gizmag.com/go/4901/

41. Erik Schechter, "Airships on the Rise- Blimps to Challenge UAVs as ISR Craft," September 1, 2008 http://www.c4isrjournal.com/story.php?F=3633681
42. "High Altitude Airship," at http://www.globalsecurity.org/intell/systems/haa.htm
43. Lewis Jamison, Geffory S. Sommer, Issac R. PorcheIII, "High Altitude Airships for the Future Force Army," Technical Report prepared for the US Army, RAND 2005.

broadband communications connectivity[44]. The US MDA has transferred the operational management of the project to the US Army Space and Missile Defence Command (USASAMDC) in April 2008[45]. Budgetary constraints have shelved the project for the time being. However, it can be revived at a short notice.

Another subscale prototype airship system, the High Altitude Long Endurance-Demonstrator (HALE-D) is also under development. The performance goals for this prototype HAA include sustained operations for at least two weeks at 60,000 ft altitude, while providing 500 watts of power to a user-defined 50 lb payload suite. Driven by two electric propulsion motors, the HALE-D is powered by thin-film solar cells and rechargeable lithium ion polymer batteries. The HALE-D will demonstrate long-endurance station keeping and flight control capabilities during its planned demonstration in the summer of 2009.[46]

Sanswire's Stratellite

Sanswire Networks, a subsidiary of the US-based GlobeTel Communications Corporation, has been researching on HAAs for quite some time and has proposed several variants on such airships though with rigid frames rather than the overpressure, non-rigid design favoured by Lockheed Martin. Each Stratellite was to be approximately 70 m in length, have a payload capacity of "thousands of pounds", and be powered by a series of solar powered hybrid electric motors and other regenerative fuel cell technologies. The payload was more oriented towards communications to commercial users, with cell, phone services and data relay in place of terrestrial cables. Work ended when Sanswire's parent company experienced financial difficulties. Both Sanswire's and Lockheed Martin's programmes may return in some form[47].

44. "High Altitude Airship," at http://www.lockheedmartin.com/products/HighAltitudeAirship/index.html
45. USASMDC is the army specified proponent for space, high altitude, ground-based mid-course defence and serves as the army operational integrator for global missile defence; and conducts mission-related research and development. USASMDC conducts space and missile defence operations and provides planning, integration, control and coordination of army forces and capabilities in support of the US Strategic Command.
46. "HALE-D," at http://www.lockheedmartin.com/products/HighAltitudeAirship/index.html
47. Edward Herlik, "Unmanned Aerial Systems Becoming More Like Satellites," March 20, 2008, at

Disposable Spy Ships

The Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, USA, is researching on disposable unpiloted spy ships. The High Altitude Reconnaissance Vehicle (HARV) would operate in near space, staying in one spot for roughly two weeks to 30 days. It would provide persistence surveillance of select areas on earth to the armed forces. The HARV would be ejected from either a cruise missile or possibly a reusable rocket. A second booster would propel the vehicle to about 300,000 ft above sea level, and then the HARV would inflate and descend to hover over a target area at about 100,000 ft.

The High Altitude Reconnaissance Vehicle (HARV) would operate in near space, staying in one spot for roughly two weeks to 30 days.

HARV could carry out radar and imaging missions, protect and track friendly forces, appraise battle damage and carry communications nodes. After about two weeks to a month, the vehicle would either disintegrate or be destroyed. However, problems like the ability to recharge the air vehicle's power source and anchoring the HARV in the right location need to be overcome over a period of time[48].

StratoSat

Sponsored by the NASA Institute of Advanced Concepts, Global Aerospace Corporation of Altadena, California, developed StratoSat, a steered free floater. StratoSats use super pressure Ultra Long Duration Balloons (ULDBs), developed by NASA and manufactured by Raven Industries that float at 115,000 ft. On a 15-km tether beneath the balloon is an aerobody-like device, known as the Strato-Sail that takes advantage of denser air at lower altitudes of 65,000 ft to provide trajectory control to steer the balloon[49]. The Strato-Sail can also contain sensors for imaging, positioning, and communications.

http://www.homelandsecurityresearch.net/2008/03/20/unmanned-aerial-systems-becoming-more-like-satellites/

48. Leonard David "Sky Trek To The 'Near Space' Neighborhood," November 9, 2005, http://www.space.com/businesstechnology/051109_airships.html
49. Stewart, et al., n.29.

Defence Advanced Research Project Agency's (DARPA's) Vulture Programme. DARPA has announced work on a fixed wing, heavier-than-air Unmanned Air Ship (UAS) called Vulture. The programme envisages an unmanned air vehicle capable of being on station for five years with a 450 kg/1,000 lb payload, 5 KW of onboard power, and sufficient loiter speed to stay on station for 99 percent of the time against winds encountered at 60,000-90,000 ft. Reports indicate DARPA plans to complete risk reduction during 2012 and decide on prototype development then. Three firms have been given the contract to develop a system meeting DARPA's requirement over a period of five years.

Odysseus

Of the three firms short-listed by DARPA for its Vulture programme, Aurora Flight Science's winning design is called "Odysseus". The solar-powered concept aircraft is as radical as the mission it is designed to accomplish, combining three self-sufficient "constituent aircraft" in a unique Z wing configuration that spans almost 500 ft (150 m). The modular design provides several advantages. The shape of the aircraft can be adjusted to maximise the solar collection properties during the day and spread flat for aerodynamic efficiency at night-time, when energy stored in onboard batteries is used to drive the aircraft's electric motors. Because each of the constituent vehicles is capable of autonomously docking at altitude, the design also facilitates the replacement of one section of the plane whilst it is still aloft, meaning continuous flight can be maintained even if something goes awry[50]

Each autonomous section of the plane has three high efficiency electric brushless motors giving the aircraft the ability to cruise at 63 m/s during day-time and 45 m/s during night-time and carry a payload of 500 kg. The onboard batteries are designed to be recharged each day via double-sided cells optimised for energy collection efficiency at high latitudes, and adding to the redundancy built into the plane's architecture, Odysseus' electronics are adapted from spacecraft designs which have already proven their reliability in missions lasting several years.

50. "Odysseus: Aurora's Radical, Unlimited Endurance, Solar Powered Aircraft," from Aero Gizmo, at http://www.gizmag.com/auroras-radical-odysseus-solar-powered-aircraft-unveiled/9261/

Zephyr

Zephyr is an ultra-lightweight carbon-fibre aircraft with a wingspan of up to 18 m/ 59 ft, but weighing just 30 kg/ 66 lb. Launched by hand, by day, it flies on solar power generated by amorphous silicon arrays on the wings that are no thicker than sheets of paper. By night, it is powered by rechargeable lithium-sulphur batteries that are recharged during the day using solar power. On July 28, 2008, the Zephyr flew for 82 hours 37 minutes[51], The system provides autonomous navigation and orientation control together with command and data communications links to ensure timely and robust operation. Passive electro-optical systems capable of submetre resolution and communications relay packages have been built and tested. Many of its design approaches and technologies will be leveraged for the Vulture as QinetiQ, a British firm, is a major partner of Boeing which is one of the three contractors for the Vulture programme.

Helios

Helios is the most ambitious of NASA's solar UAV projects to date. With a 247-foot wingspan (greater than a 747 Jumbo Jet), 62,120 bi-facial solar cells and a projected maximum flying altitude of 100,000 ft, Helios is the peak of two and a half decades of solar aviation research[52]. Built by AeroVironment, Helios has been used on the Environmental Research Aircraft and Sensor Technology (ERAST) programme of NASA. Helios applies hybrid technology[53] – solar energy using photovoltaic cells by day and fuel cells by night. Helios was designed to be the forerunner of high-altitude unmanned aerial vehicles that

51. "QinetiQ's Zephyr UAV Flies for Three and a Half Days to set Unofficial World Record for Longest Duration Unmanned Flight." QuinetiQ Press release dated August 21, 2008, at http://www.qinetiq.com/home/newsroom/news_releases_homepage/2008/3rd_quarter/qinetiq_s_zephyr_uav.html It exceeded the current official world record for unmanned flight which stands at 30 hours 24 minutes set by the Global Hawk in 2001 and the Zephyr's previous longest flight of 54 hours achieved last year.
52. NASA evinced interest in solar powered HALE UAVs in the late 90s. It revived the high altitude long endurance solar (HALSOL) drone project of AeroVironment and went on to produce solar UAVs like Path Finder, Path Finder Plus and Centurion which was redesigned and modified to become the Helios.
53. Iddo Genuth "Solar UAV to Set a New World Record," *The Future of Things*, March 9, 2007, at http://thefutureofthings.com/articles/51/solar-uav-to-set-a-new-world-record.html

could fly ultra-long duration environmental science or telecommunications relay missions lasting for weeks or months without using consumable fuels or emitting airborne pollutants. On August 13, 2001, Helios demonstrated its capability when it reached an unofficial altitude record for non-rocket-powered aircraft of 96,863 ft. Unfortunately, on June 26, 2003, during a test flight over the Pacific Ocean near Kauai, Hawaii, the Helios[54] prototype was lost due to a structural failure caused by control problems.

Japanese Sky Net HAA

Sky Net is a major HAA project funded by the Japanese government, and aims to provide TV and communication services with an inter-connected network of about 10 airships covering Japan[55]. The aeronautical aspects are coordinated by the Japan Aerospace Exploration Agency (JAXA) and the applications areas (telecommunications), are coordinated by the National Institute of Information and Communications Technology (NICT). Conceptualised in 1998, the project has matured to the second phase with very successful results, especially in areas of launch and recovery, development of airship materials and its construction, station keeping and power management. Tests in this regard were carried out (during Phase one) with the help of a 47 m airship in August 2003 and with a 67 m long airship in November 2004 at an altitude of 4 km. The programme is envisaged to be achieved in three phases. The second phase is slated to be completed in four years from commencement with the development of a full size stratospheric airship (approximately 200 m long). Phase three envisages full commercialisation by Japanese industry[56]. The specific end applications are disaster relief/event servicing, both 3G and broadband, broadcast HDTV, broadband fixed access to users and broadband mobile access to long distance trains and other vehicles.

54. Ibid.
55. Tim Tozer, David Grace, Jon Thompson, Peter Baynham, "UAVs and HAPs-Potential Convergence for Military Communications," at http://www.elec.york.ac.uk/comms/pdfs/20030506170424.pdf
56 Patrick Hendick, Laurence Hallet and Dries Verstraete, "Comparision of Propulsive Technologies for a HALE Airship," 7th AIAA Aviation Technology, Integration and Operations Conference (ATIO), September 18-20, 2007.

NICT, in close coordination with JAXA has examined tracking and control techniques for stratospheric flight, and developed a range of hardware for use with experiments. These include a number of telecommunications trials using NASA's Pathfinder Plus solar powered aircraft in Hawaii, USA, at approximately 20 km altitude. Overall, this Japanese national project has received funding of more than Euro 100 million to date. JAXA is currently lobbying the Japanese government for funding for the second phase, where it is anticipated that the total financial package will be a mix of public and industry funding.

The South Korean National Project

Close on the heels of Japan, in 2000, South Korea launched a 10-year programme, which consists of three phases, to develop an unmanned stratospheric airship. The purpose of the project is to develop a stratospheric airship platform and a ground system for basic operation and control of the airship. The airship could carry onboard payloads consuming l0 KW power and weighing up to l,000 kg. Station keeping within a limited boundary above 20 km altitude is planned to be achieved by autopilot. The project is supported by the Ministry of Commerce, Industry and Energy (MOCIE) of the Korean government[57]. The project consists of three consecutive phases to reduce developmental risks and actively cope with technical challenges. The Korea Aerospace Research Institute (KARI) was approved as a prime contractor for the first phase development. The first phase (which included the development and test of a 50 m unmanned airship, capable of flying to an altitude of 3 km and carrying a 100 kg payload, as well as a wide range of engineering trials and achievements) was finished in 2004 and the second phase has started. The target of the second phase is to develop a Stratospheric Prototype Airship (SPA), which will demonstrate the practical possibility of developing the stratospheric airship system[58]. It will demonstrate station keeping ability around 20 km altitude and also some possible missions such as communication relay and ground observation, etc. Through the second

57. Yung-Gyo Lee, Dong-Min Kim, Chan-Hong Yeom, "Development of Korean High Altitude Platform Systems," *International Journal of Wireless Information Networks*, vol.13, January 2006.
58. Dr Rajkumar S. Pant, "Global Developments and Critical Technology Review of Stratospheric Airships," Presentation at ADRDE, Agra, on Stratospheric Airships in 2005.

The Korean government clearly anticipates that HAAS will be a significant future technology that it can use to further strengthen its technical and manufacturing base.

phase development, the mission of the Korean stratospheric airship will be specified. A full scale commercialised airship system will be developed through the third phase.

The Korean government clearly anticipates that HAAS will be a significant future technology that it can use to further strengthen its technical and manufacturing base. They also see significant Asian and worldwide export potential for both the platforms and electronics.

SUB-ORBITAL ROCKETS AS NEAR SPACE SENSORS AND WEAPON PLATFORMS

The advent of commercially viable sub-orbital vehicles operating above 30 km may hold the prospects of military exploitation. Vehicles like Burt Rutan's Space Ship One or some of the DC-X type vehicles that are being worked on by companies like TGV Rockets of Norman, Oklahoma, may be used for ISR purposes[59], as these sub-orbital rockets will be able to carry significant sized sensors and they can be launched at short notice; like aircraft, they will be able land back with their imaging data preserved onboard or, if necessary, transmitted to a ground station as with a UAV or satellite.

Sub-orbital rocket vehicles have also been proposed as launch systems for testing target warheads and decoys for missile defence. If they are able to fulfil their low-cost promise, they could make it much easier to carry out large-scale missile defence simulation exercises without having to fire off expensive target rockets. The same mechanisms that a sub-orbital rocket would use to launch warhead targets could also be used to launch real weapons[60]. This raises the possibility of *combat in near space* between rival rocket planes. This may sound like science fiction but any craft used to carry out military information gathering is a legitimate target and may legitimately defend itself. From there,

59. Taylor Dinerman, "Near Space: A New Area of Operations or a New Pentagon Buzzword?" *Space Review*, September 20, 2004, at http://www.thespacereview.com/article/230/1
60. Ibid.

it is a short step toward being able to fire weapons at targets on the ground.

There is a host of other programmes which are focussed mainly at providing high speed broadband communication services to commercial users. These aim at overcoming the infrastructural constraints of erecting and operating cell phone networks to cater to the ever increasing demands from consumers. Just like satellites, these platforms can be of dual use. The European countries have carried out many experiments since 2000 in this regard through various programmes like the European VI framework programme called the Communications From Aerial Platform Networks Delivering Broadband Communications for All (CAPANINA)[61] and HELIPLAT, a high altitude very-long endurance solar powered platform for border patrol and forest fire detection and high speed broadband communication[62]. The use of NSVs will also overcome the last mile connectivity problem associated with such networks.

Sub-orbital rocket vehicles have also been proposed as launch systems for testing target warheads and decoys for missile defence.

NEED FOR NEAR SPACE VEHICLES FOR THE INDIAN ARMED FORCES.

The discussion to justify near space vehicles in the Indian military context, if projected at this stage, would seem to be too premature to be of any use, with apparently no proven system in operation on date, as seen from the above discussion. However, one needs to envision the integration of near space vehicles into the overall military Concept of Operations (CONOPS) for employment by the next two decades to meet the increasing demands of surveillance and communication to fight the future wars.

The lessons learnt from the recent high-tech wars/campaigns conducted by the US and its allies and the regional level conflicts like Kargil in India and

61. The CAPANINA project will develop broadband capability from aerial platforms to deliver cost-effective solutions providing a viable alternative to cable and satellite, at http://www.capanina.org/

62. G. Romeo, G. Frulla and E. Cestino, "HELIPLAT®: A High Altitude Very-Long Endurance Solar Powered Platform for Border Patrol and Forest Fire Detection," at http://library.witpress.com/pages/PaperInfo.asp?PaperID=15157 and http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.43.6955

the Second Lebanon War by Israel, bring out the imperatives of persistent, organic ISR and 24/7 over-the-horizon communications. The Kargil conflict of 1999 was a wake-up call for India as regards the inadequacy of effective and persistent surveillance and reconnaissance assets for national defence. In the light of the Kargil Committee report, India launched the experimental Test Satellite (TES) satellite, with one metre resolution. The CartoSat II A satellite launched on April 28, 2008, also provides a good measure of military grade surveillance. However, India depends on foreign satellites to get better imagery which may not be forthcoming in times of war at the frequency at which India needs it.

As regards communication, the armed forces communication networks are largely terrestrial, based on Tropo, ASCON, AREN supplemented by the DOT and HF network. Because of India's vast geographical size and nature of terrain and the changing nature of warfare towards net-centric operations, there is an increasing demand for bandwidth which India seeks to address through fibre optic links and satellite communication. A fixed fibre optic network in a dynamic war-fighting environment may not fulfil the needs at the operational and tactical levels. On the other hand, satellite-based communications are very expensive to field and generally have limited bandwidth. The availability gets further reduced due to heavy demand and fierce competition for transponders for civil uses.

From the foregoing, it can be analysed that the future requirement of a constant, staring presence on a time-scale of days, weeks, or months over a selected target or area of interest or to provide persistent communications is a difficult proposition. Even an increase in the number of satellites will not give us a persistent surveillance capability due to the constraints of revisit times of satellites. For example, most LEO satellites have a specific target in view for less than 15 minutes at a time and revisit the same sites only infrequently. Additionally, satellites can carry only limited amounts of manoeuvring fuel so their orbits and times overhead are very easily predicted, making them lucrative targets for ASAT weapons by the adversaries.

Evaluating the airborne platforms as another means of providing persistent

ISR efforts, we find that they are bound by an upper operating limit (of approximately 18.5 km) due to their engine limitations and the inability to achieve better aerodynamic effects. Though much more responsive than orbital assets and capable of providing much higher resolution imagery, the limited number of airborne assets still cannot always provide the persistent look needed by battlefield commanders. On the aerial reconnaissance front, India had phased out its strategic reconnaissance platform, the MiG-25 in 2006. Presently, none of India's air assets is capable of replicating the roles of the MiG-25. The tactical reconnaissance payload like the LORAP on board the Jaguar has become outdated technology. The fighter aircraft-borne reconnaissance assets are the VICON payload on the Jaguar and MiG-27. While the advent of Fuel Refuelling Aircraft (FRA) increased the endurance times of manned aircraft, they are limited by crew fatigue and availability of number of aircraft. On the naval front, the Indian Navy has the Kamov helicopters for performing Airborne Early Warning and Control (AEW&C) roles and the TU-142 Dornier for Long Range Maritime Patrol (LRMP) roles. However, considering our strategic interests stretching from the Strait of Hormuz to the Strait of Malacca, these assets will be inadequate to meet the demands of the Indian Navy. The increased instances of Indian commercial ships being hijacked as far as Somalia have further reinforced the need for an efficient surveillance system for the Indian Navy.

The future requirement of a constant, staring presence on a time-scale of days, weeks, or months over a selected target or area of interest or to provide persistent communications is a difficult proposition.

The use of more than 100 UAVs by all the three Services addresses India's tactical reconnaissance needs at present. However, both manned and unmanned airborne platforms are also exposed to the risk of enemy engagement while carrying out across the border activities.

India seeks to address its gaps in ISR by acquisition of AWACS, AEW&C platforms, tethered aerostats and ground surveillance radars. Three AWACS have been contracted for with Israel of which one may see operationalisation

India seeks to address its gaps in ISR by acquisition of AWACS, AEW&C platforms, tethered aerostats and ground surveillance radars.

by 2009, with the other two joining service by 2011. In April 2008, India signed for an additional three AWACS from Israel[63]. In addition, the Defence Research Development Organisation (DRDO) has contracted for three Embraer ERJ 145 platforms from Brazil to be fitted with an indigenous AEW &C system. India purchased two tethered aerostat systems from Israel in 2004, with four more on the anvil at the cost of US $ 300 million to beef up its ageing Air Defence Ground Environment System (ADGES) surveillance capabilities[64]. The Green Pine radars for Ballistic Missile Defence (BMD) architecture will also strengthen the overall network. On the orbital front, India plans to launch a network of five satellites for surveillance by 2012. Additional communication satellites with dedicated transponders for the armed forces are also on the anvil.

Thus, it would seem that by 2015, India would have an impressive array of ISR assets. But the fact of the matter is that all these assets have advantages and disadvantages in terms of responsive intelligence gathering and dissemination to the tactical level. In short, as a result of being tied to expensive, limited quantity platforms operating in the traditional media of space and air that do not have the capability to stay on station for extended periods of time, and the limited range and mobility of the ground radars, a battlefield commander has only a limited chance of being provided with all the information or communications capability he needs, where and when he needs it. Further, the physical limitations due to orbital mechanics and fuel consumption prevent long-term persistence for both orbital and airborne platforms. Thus, all the assets discussed herein are manpower and infrastructure intensive, incurring recurring expenditure in terms of maintenance and upgrades and

63. "Indian AWACS Moving Forward on 2 Fronts," *Defence Industry Daily*, September 18, 2008, http://www.defenseindustrydaily.com/Indian-AWACS-Moving-Forward-on-2-Fronts-04855/
64. "Did Flying LTTE Tigers Help Spur India's Aerostat Radar Buy from Israel," *Defence Industry Daily*, May 18, 2007, at http://www.defenseindustrydaily.com/flying-ltte-tigers-help-spur-indias-aerostat-radar-buy-from-israel-03309/

force protection, especially in the case of AWACS platforms.

India, thus, has two handicaps. The first is in terms of capability, where the need for the effects of persistent communications and ISR goes unfilled. The second is in terms of the altitudes covered by military assets. These two handicaps can be simultaneously filled through the use of near space platforms. Near space platforms operating in the altitude gap can provide the missing persistent communications and ISR effects desired by the armed forces as well as for internal security situations and disaster mitigation.

Considering India's increased strategic interests and the growing role it will be expected to play at the international level, these assets would just not be sufficient for India to provide the kind of persistent surveillance and communication needs of its armed forces. Near space vehicles as a functional cross between satellites and aircraft can bridge the capability and altitude gap of airborne and orbital assets. These vehicles can perform a multitude of roles for the armed forces enabling effect-based operations from the strategic to the tactical level.

DEVELOPMENT OF NSVs IN INDIA

The programme for development of airships in India was initiated at the behest of the Technology, Information, Forecasting and Assessment Council (TIFAC) an autonomous body under the Ministry of Science and Technology, in the year 2001. The programme was to assess airships as a means of transportation in the hilly regions of Uttaranchal soon after it got its statehood[65]. IIT, Mumbai was chosen as the premier agency for conceptual studies modelling and simulation of an airship.

Accordingly, a national Reseach and Development (R&D) project called Programme on Airship Design and Development (PADD) was launched at IIT, Mumbai, in 2001, with team members drawn from various national aerospace organisations, the central government and faculty members from IIT, Mumbai [66]. The first phase of the project was completed in 2003. As

65. P. V. Indiresan "A Tale of Two Attitudes," *The Hindu*, January 1, 2001, http://www.hinduonnet.com/2001/01/01/stories/05012524.htm
66. "Program on Airship Design & Development (PADD) LTA India," http://spot.colorado.edu/~dziadeck/airship/india.htm

Near space vehicles as a functional cross between satellites and aircraft can bridge the capability and altitude gap of airborne and orbital assets.

part of this study, two remotely controlled airships, the PADD Micro (with a payload capacity of 1.0 kg) and PADD Mini (with a payload capacity of 3.5 kg) were designed and developed. Successful demonstrations were carried out at the 90th Indian National Science Congress at Bangalore in 2003, as well as at other locations in the country[67].

The project, in part, was also aided by the Aeronautics Development Agency (ADA) at Bangalore. The scope of the project has increased over the years and a number of players have joined in. More notable amongst them are the Aerial Delivery R&D Establishment (ADRDE), Agra, for envelope and system engineering, National Aeronautics Limited (NAL), Bangalore, for propeller and propulsion system, Defence Research and Development Laboratory (DRDL), Hyderabad, for guidance, control, navigation and payload requirement, Indian Space Research Organisation (ISRO), Bangalore, for onboard power generation, storage system and payloads, and Tata Institute of Fundamental Research (TIFR), Hyderabad, for launch and recovery experiments. The initial aim was to develop a 70-m long aerostat which would be able to fly at 15,000 ft and carry up to two tons of weight. However, the programme seems to have been delayed as the prototype flight is still awaited[68]. Conceptual studies have also bee112n carried out by PADD for employability of HAA for pseudo satellite navigation in 2005. Possibly, with the development of an indigenous HAA, India may field such a system to reduce its dependency on the GPS and its own GAGAN.

Of late, there have been reports that the Indian government has constituted a high level committee to focus on the stratospheric airship development project in India under the aegis of NAL, Bangalore, headed by Mr M. L. Sidana

67. "A Flying Ship for India's Hilly Terrain," http://timesofindia.indiatimes.com/articleshow/1655548806.cms

68 This was evident from the paper presented by the research team of PADD at 26th International Congress of the Aeronautical Sciences in September 2008. Amol C. Gawale, Amool A. Raina, Rajkumar S. Pant, Yogendra P. Jahagirdar, "Design, Fabrication and Operation of Remotely Controlled Airships in India," at http://www.aero.iitb.ac.in/~airships/WEBPAGES/PDFs/jahagirdar.pdf

(ex-director of ADRDE, Agra).[69]

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MILITARY UTILITY OF NEAR SPACE

From the foregoing, it is apparent that near space holds immense potential for military operations and is limited only by the ingenuity of the user and the payload on the platform. Some of the potential military applications of near space platforms are discussed below.

- Signals Intelligence (SIGINT) payloads on near space platforms would enable persistent gathering of information and data collection of the enemy's electronic order of battle without giving him the option of switching off his sensors as is the case at present whenever an adversary carries out the task with manned/unmanned platforms.
- A network of NSVs with surveillance and communication payloads deployed over the international waters will enable seamless coverage of our area of interest (from the Strait of Hormuz to the Strait of Malacca) without violating the sovereign air space of any nation. This will enable persistent real-time actionable intelligence to the Indian Navy. It will enable the Navy to carry out a multitude of operations and effectively thwart any air attack on coastal regions/hinterland using the sea route.
- During hostilities, air space sovereignty over enemy territory is no longer a consideration; near space assets can operate above the same locations that aircraft can, subject to similar enemy threats. This will enhance line of sight communications to forward troops and overcome the effects of having to move with their communication networks, thus, enabling a lean and mean force to fight the war. Further, with the right kind of equipment and interface, the troops at the tactical level will be able to access the imagery being streamed by an NSV much like that of a UAV rather than wait for satellite

69 Interactive Correspondence and Exchange Reviews with Dr. Raj Kumar S. Pant, Director PADD, Mumbai, on October 11, 2008.

updates from the hinterland.

- Communication and surveillance payloads on NSVs will avoid fratricide in the Tactical Battle Area (TBA) by providing early identification of adversary aircraft and assist own aircraft to carry out Battlefield Air Support/Battlefield Air Interdiction BAS/BAI missions with more dwell time on target.
- NSVs, with their payloads, enable faster rates of data downlink and uplink which will enhance network-centricity of operations.
- NSVs could be controlled by the theatre/tactical commanders just like UAVs and aircraft, while providing space effects as against the control of orbital assets at the strategic level where it is time consuming and difficult for a theatre commander to get a responsive tactical picture of the operations area.
- Near space platforms have immense potential to increase space situational awareness. Being above the atmosphere for 99 percent of the time, large telescopes with membranous, holographically corrected and/or adaptive optically corrected mirrors could provide much better resolution of space assets than their earth-bound brethren that are limited by looking through significant distortion of the atmosphere.[70]
- The availability of near space platforms can act as a deterrent for the adversary to attack and destroy our orbital assets as NSVs will provide redundancy of operations, and adversaries' objectives will be defeated.
- Deployment of NSVs for pseudo satellite navigation in the theatre specific environment will provide redundancy against GPS jamming by the adversary.
- Armed forces are routinely tasked for post-disaster management operations. The availability of NSVs with their payloads will help them in search and rescue operations in the high seas or inhospitable terrains.
- NSVs' use in missile defence architecture is immense. It is in near space that both boost phase and terminal phase intercepts will take place. NSVs,

70. Lt Col Edward B. Tomme, "The Pardigm Shift to Effects-Based Space: Near Space as a Combat Space Effects Enabler," Air Power Research Institute, Research Paper, 2005-01, College of Aerospace Doctrine, Research and Education, USA.

with their ability to provide the surveillance in both the lower and upper reaches of the atmosphere and space, will enable sufficient early warning of the missiles during their ingress and egress through near space.

- Use of sub-orbital rockets is envisaged for adventure activities in the near future. However, once they are tested for their reliability, the same can be used for ISR collection or to simulate as decoys for ballistic missiles providing a relatively inexpensive way for testing and training our BMD architecture.
- With more than one stratospheric airship radar, and/or with naval or surface forces, or with other airborne systems, there is a very significant opportunity for bi-static radar operations. These might include quickly adding new radar antennas and other electronic equipment to the airship as a 'truck' concept, with internal room for various radar antennas, making the stratospheric airship an ideal vehicle to exploit the bi-multi-static system.
- Surveillance and tracking payloads on NSVs will also enable cruise missile defence over a wide area of coverage, enabling their successful interception. Presently, the US employs the Joint Land Attack Cruise Missile Defence Elevated Netted Sensor (JLENS)[71].
- As near space systems mature, there may be a possibility of launching kinetic energy interceptors for anti-ballistic missile defence, since the systems will be able to carry greater payloads and stay on station for longer periods.

Thus, near space vehicles will form another layer of our defence in-depth architecture, enabling effect-based operations to be carried out from the strategic to the tactical level, combining the benefits of both satellites and aircraft.

71. The JLENS consists of an aerostat with radars to provide over-the-horizon surveillance for defence against cruise missiles. JLENS is primarily intended to tackle the growing threat of cruise missiles to US forces deployed abroad. The system enhances cruise missile detection and engagement ranges with current air defence weapons such as the PATRIOT, Navy SM-2 missile, the advanced medium range air-to-air missile, and ultimately the medium extended air defense system and the corps surface-to-air missile system. http://www.fas.org/spp/starwars/program/jlens.htm

Most importantly, this technology gives a cheaper and quicker access to space-like conditions as compared to getting a launch to orbit.

CONCLUSION

Over the last century, militaries all over the world had become overly obsessed with the effects generated by rocket, aircraft and satellite technologies towards winning the conventional wars, hardly realising that they were overlooking a cheaper and more effective substitute to these technologies in the form of near space technologies. The beginning of the 21st century seems to have at last changed the mindset, considering the renewed interest in near space vehicles

Most importantly, this technology gives a cheaper and quicker access to space-like conditions as compared to getting a launch to orbit. The cameras at that high altitude can see for several hundred kilometres farther than with aerial photography, and access to a given area is more flexible than with the infrequent overflights by remote sensing satellites. Enhanced communications systems, network relays, and intelligence-surveillance-reconnaissance capabilities could all use the near space realm to quickly meet battlefield needs. Lighter-than-air vehicles operating in near space could quickly and inexpensively provide the capabilities that troops and commanders demand.

However, the technological breakthroughs which permitted the envisioning of NSVs are still at a nascent stage and the complete technological challenges are unknown. Even though these systems are likely to remain in a no-weather area, they will have to withstand significant ultraviolet radiations and other tough environmental conditions like handling high levels of corrosive ozone. Other problems like weight vs volume, endurance and regenerative power sources need to be overcome.

More importantly, we need to find the right synergistic mix of air, space, and near-space capabilities to produce the battlefield effects our combat commanders need. Near space is, thus, the *obvious and correct solution* to the armed forces surveillance and communication needs, forming an additional layer of effects delivery medium between satellites and air-breathers and enhancing the survivability and redundancy of such battlespace awareness systems.