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HAPS: An Untapped Force Multiplier

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Abstract

Recently, there has been an increasing focus on new technology, such as tactical satellites or high-altitude long-endurance airships, as means of increasing communication and intelligence collection capabilities. Similar advances in the capabilities of medium-altitude and high-altitude unmanned aerial systems have resulted in their enhanced role in today's battlefield. Each of these vehicles has a unique niche in today's military, but the increasing capabilities of each are beginning to create substantial overlap in their use.

This brief is an attempt to address how the potential of 'High-Altitude Platform Systems (HAPS) or Pseudo-Satellites' can be leveraged for optimal gains in various domains to ultimately assist the war fighter in execution of

Key Points

- HAPS is an important technology waiting to be leveraged—presents multiple use-cases.
- The areas where HAPS scores over satellites are cost, footprint, persistence over target area.
- Challenges in terms of station keeping and envelope material. Trade-off of endurance vs payload weight.
- India need to have an Operationally Responsive Trans Troposphere (ORTT) initiative and mandatory strategy in place to leverage HAPS; it should also be linked with the Space domain.
- HAPS should be significantly used for communication, ISR, Electronic Warfare, provision of PNT signal as an alternate to GPS in degraded environment.

operations. In the era of dual-use technology, while HAPS have a prominent role to play in civil applications, the scope of this paper is restricted to military use cases only. The current investment in medium altitude, high altitude, and tactical space persistent ISR has been overshadowed with the use of drones & CubeSats. Although, they have their own inherent advantages, however, there is a need to address the benefits accrued from using HAPS and thereafter develop an overlap of capabilities to build in redundancy as well as persistent coverage of the area of interest.

Introduction

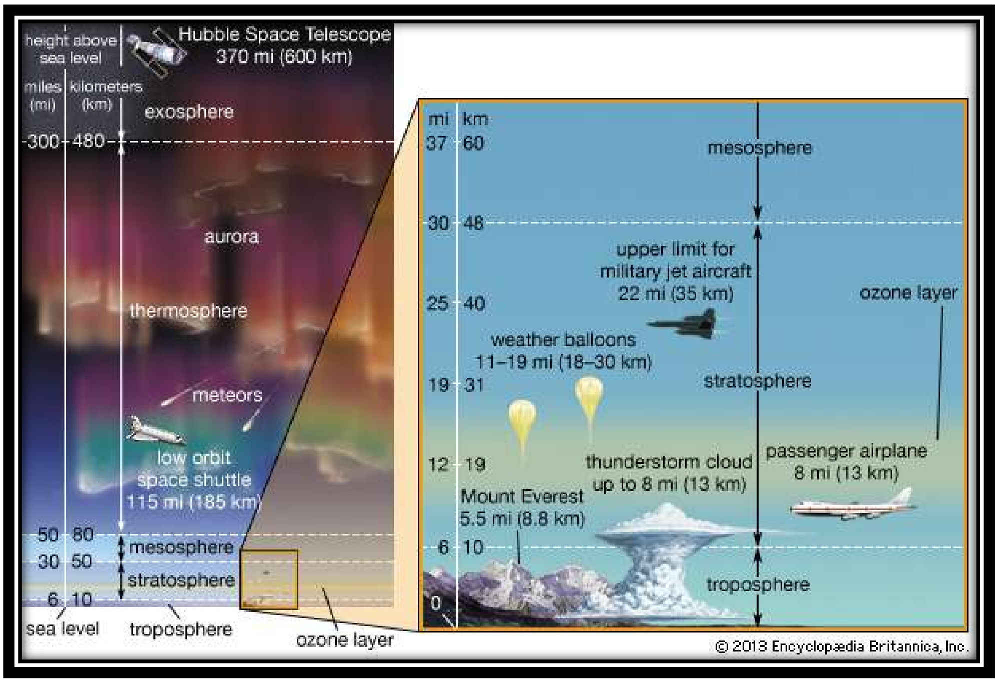
A viable question that arises is the purpose of bringing to fore the requirement of deliberation on High Altitude Platform Systems (HAPS). Open Source literature on the subject and aerospace technology oriented manufacturers have often discussed the civil use scenarios of HAPS. However, with sensor and payload technology growing exponentially, miniaturisation has ensured that HAPS gets to the top rung among discussions of aerial platforms to be used operationally by the forces. HAPS are also very lucrative when it comes to resolving high bandwidth requirements for the forces apart from being an alternative to costly platforms.

Airships or the Zeppelin[1] concept has been used historically for the purpose of scouts and bombing. However, in 1937, the Hindenburg disaster[2] saw the demise of these 'airships'. The focus shifted to aircrafts and more reliable aerial platforms (unmanned systems and drones) for military purposes. Satellites placed in various orbits have been extensively utilised to cater to the requirements of strategic importance, be it Intelligence Surveillance & Reconnaissance (ISR) or communications. The scope has also engulfed anti-satellite weapons to a large extent. Earlier, being the sole domain of a select few nations, the rising space- faring nations have delved into the use of nanosatellites or CubeSats, extensively attributed to the lower cost per launch for the latter. The cost to design, maintain and control, apart from launch costs, forecloses the requirement of satellites as dedicated platforms for standalone use-cases. Transition from expensive satellites to miniaturised tactical small satellites has resulted in a change in monitoring the tactical battlespace. Unmanned systems (drones and UAVs) have also been utilised to meet mission specific requirements with counter unmanned aerial system (c-UAS) technology playing catching up and forcing its hand to look for better alternatives. There is hence, an inescapable requirement of HAPS infield platforms that are economical and meet the mission requirements for a specified period. 'Operationally Responsive Trans Troposphere' (ORTT) initiatives are mandatory to tap into this domain for multi-fold gains.

What are HAPS

High-altitude platforms (HAPs) are aircraft positioned above at approx. 20 km altitude, in the stratosphere, in order to compose a telecommunications network or perform remote sensing, for civilian or military applications. These aircrafts may be airplanes, airships or balloons, manned or unmanned.[3]

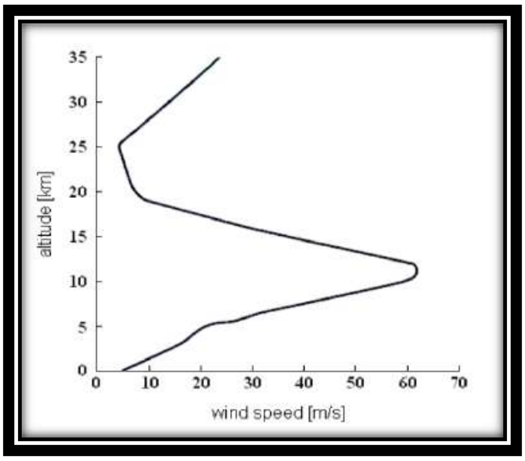
Figure 1: Layers of the Atmosphere



Source: Encyclopaedia Britannica/ "Earth's Atmosphere" Weather.gov.sg, 2021
http://www.weather.gov.sg/learn_atmosphere

Manned or unmanned, HAPS serve as one of the most feasible alternatives to expensive satcom and ISR activities. The need for HAPS is brought to the fore with use-cases such as last-mile communication, ability to handle heterogenous data, persistence over an area of interest as well as aiding in coordinated action by multiple agencies. HAP networks combine the advantages of terrestrial platforms as well as satellites. There are certain altitude zones that are selected for the use of HAPS.[4]

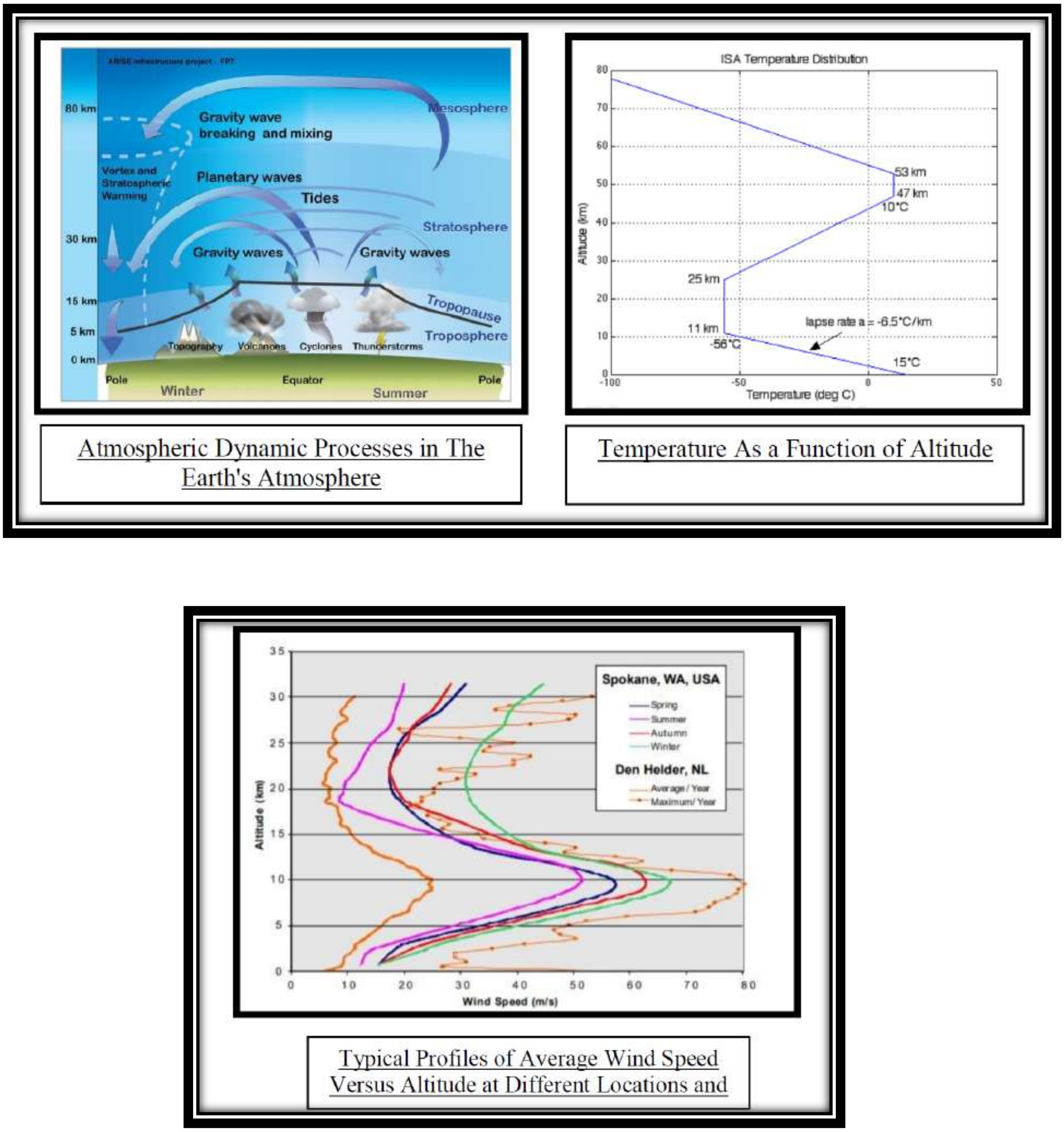
Figure 2: Wind Speed vs Altitude



Source: Malinowski, Andrzej, and Ryszard Zieliński. "High Altitude Platform — Future of Infrastructure." International Journal of Electronics and Telecommunications, 2013 https://doi.org/https://journals.pan.pl/publication/100248

These are generally placed between 17-25 kms generally for reasons of atmospheric stability. As seen in **Figure 2**, the wind speed at the altitude of operation is the least as compared to the effects of the troposphere or the more prominent 'jet stream' effects at lower altitudes. Other dynamic processes which lend HAPS to be operated at a specified zone of attitude are elucidated using schematic at **Figure 3**. 28 to 31 GHz and 48 GHz are the bands which have been found to be most promising for communication purposes.[5] However, one has to take into account the propagation losses at these frequencies which may result in attenuation. The range of communication can always be extended using inter-platform links that also serves the purpose of catering to outage contingencies. In the paper by Malinowski, an example of coverage of an area off 200 kms has been shown with a HAPS at five-degree elevation angle at 21km altitude. Such a coverage with a steerable imagery payload (skewed angle/ oblique image) or ELINT payload can prove beneficial as a military use-case.

Figure 3: Dynamic Atmospheric Profiles



Source: Jamison, Lewis, Geoffrey Sommer, and Isaac R III. 2005. "High-Altitude Airships for the Future Force Army." Rand.org. RAND Corporation. October 2, 2005 https://www.rand.org/pubs/technical_reports/TR234.html

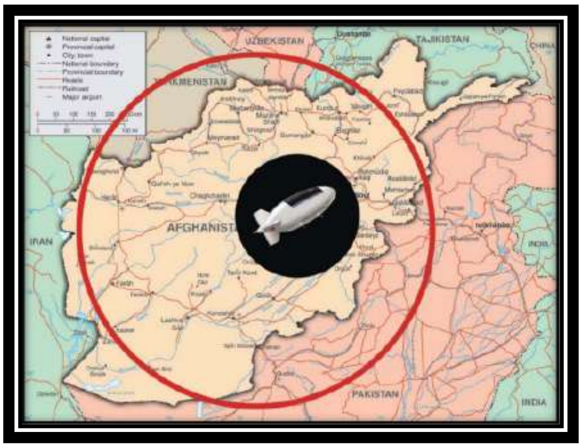
HAPS Missions and Payloads

Before we get into the details of various technologies involved, it is important to take cognizance of missions which can be planned keeping HAPS central to the military use-case. This in turn will help to decide the payloads which can be aboard these aerial platforms.

ISR Role. HALE airships can critically fill the voids which exists at the theatre level for ISR and communication capabilities. Their role as 'surrogate satellites' has also been stressed upon in the thesis work by Collier.[6] Shorter transmission distances and better link budgets are advantageous, thus making them less susceptible to EW measures. The thesis also covers their role in terms of having a larger footprint and better role as relays as compared to terrestrial systems. The deployment of these HALE airships above the jet stream in quasi-geostationary orbits provide advantages in terms of persistence in observation as well as communication relays. Better antenna design in terms of flexibility and larger aperture size can offset the disadvantages due to weight and power. The Integrated Sensor Is the Structure (ISIS) program of DARPA & HiSentinel powered airship of US Airforce Research Laboratory makes use of these advantages. The roles of HAPS vary from ISR to Reconnaissance, Surveillance and Target Acquisition (RSTA), maritime surveillance, missile warnings, EW, communication broadcast relays. In addition, these may be employed to provide an alternate to Position Navigation and Timing (PNT) Signals (serve as guidance beacons).

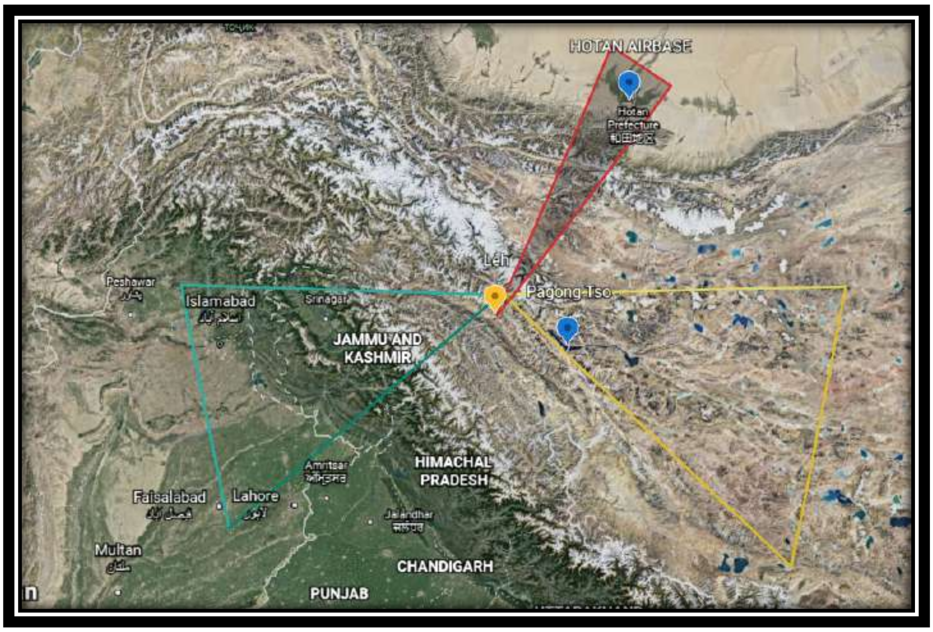
Airships, as with UAS's, are vulnerable to advanced enemy air defences. Owing to the airships' high-altitude, stationary position, and low radar &thermal cross sections, only the most advanced air defence platforms will be able to detect and target them.

Figure 4: Ground Coverage Area of a HALE at 65,000 feet



Source: https://doi.org/http://hdl.handle.net/10945/3934

Figure 5: Ground Coverage Area of a HALE at 65,000 feet in Indian Context



Source: Author's Own Rendition on Google Earth Platform[7]

HAPS, as part of ISR, can offer broad area mapping by using variety of payloads— EO/IR sensors, LIDAR, SAR, multi and hyper spectral imagers. Persistent surveillance over an area— day and night, can also be achieved by loitering over the area of interest.[8] Post-Strike Damage Assessment (PSDA), Direction of Own Arty Fire (DOOAF) as well as battle damage assessment can also be undertaken by HAPS.

Communications. Wireless solutions using HAPS involve catering to the requirements of last-mile connectivity i.e. to provide high throughput data networks without relying on the traditional terrestrial infrastructure. Another advantage offered is in terms of centralised cell-reuse that are not dependent on the location of the base stations. Geometry of the HAP stations will help in exploiting the millimetre wave communications as the shorter slant range offers enhanced communication bandwidths and lesser attenuation factors in the link budget.[9]

'Flexible and reliable' re-use patterns will also help in the realisation of better formed networks which can cater to immediate response to a certain area of interest. Cost will also be substantially lower than that of a satellite constellation as well as numerous ground stations as part of the terrestrial network. HAPS are environment friendly as they leave behind substantially lower carbon footprint and also platform and payload upgradation can be done rather easily as compared to satellites.[10]

If HAPS are considered to be working with LEO satellites, there has to be a synergy among the space, stratospheric and terrestrial entities to utilise maximum benefit from the integrated approach of a satellite-HAPS based model. Various models can be thought of with variables such as inter HAP links, inter satellite links[11], on board processing over HAPS or these platforms to act as mere relays.

Terrestrial layer comprises user terminals— both fixed & mobile. HAPS or the stratospheric layer can consist of HAPS without on-board processing. HAPS thus, act as mere relays or hubs which transfer data at much higher data rates and without any ink budget disadvantages. The processing component is hosted in satellites and these satellites have the links established, both, to the respective ground stations as well as to HAPS to cater to redundancy. There could always be a possibility where inter-HAPS links are established to realise a truly meshed network. Also, the HAPS ground segment or stations caters to network management and resource allocation in the regional area covered by HAPS. HAPS and satellite based protocols will have to be designed to cater to bandwidth requirements as well ensure smooth handoff procedures to avoid jitter in communications.[12]

Mobility, extended coverage, payload versatility, frequent takeoffs and landings for maintenance and upgradation of payloads with favourable pathloss characteristics (with respect to terrestrial and satellite systems) are the main features which make HAPS attractive for a variety of applications and services. The paper by Capstick & Grace[13] compares the performance and complexity of two methods of steering an array of aperture antennas on a high-altitude platform for the provision of broadband fixed wireless access using cellular type frequency reuse. Another paper[14] describes intelligent beamforming antenna systems that can be used in the millimetre-wave band for HAPS. One is a Multi-Beam-Horn (MBH) antenna which provides high-speed transmission, and the other is an array antenna that digitally controls antenna beams. These antenna systems are designed to withstand the temperature ranges in the stratosphere (below −60◦C) and atmospheric pressure which is 1/20 that on Earth. Secure communication may also be extended by use of quantum cryptography techniques where HAPS may be employed to ‘store entangled photon source’ to distribute the keys to LEO satellites or other ground stations.

Optical Communication. There has been significant study in terms of optical communication using HAPS. In a paper[15] by Fidler et al, the components to be used as well as trials using various waveforms has been studied in detail. It describes how the pointing, acquisition and tracking of laser terminals on board a HAPS can utilise low divergent beams for multi gigabits per second transmission of data. Atmospheric impact in terms of scattering, beam spread and fading has also been covered. It lists out the techniques which may be utilised to mitigate these effects towards a high throughput. Optical communication for HAPS has been quoted to be studied under various scenarios, LEO satellites to HAPS & ground to HAPS & HAPS to HAPS. In all cases, works have been cited by Fidler claiming the increase in the data rate capacity with LEO links and a range of approximately 500 km radius with the HAPS at 20 km altitude (devoid of cloud interference and turbulence).

IoT and Network Relays. HAPS are competitors with terrestrial and satellite systems, which makes them good candidates for next generation communication systems. In addition, HAPS perform the role of a base station[16] that can establish communication with satellite systems using very tall antennas and can handle the increasing demand of broadband wireless access. IoT[17] presents challenges regarding diversity in nodes, large amounts of processing data, plethora of communication nodes, routing, security, energy consumed and coverage. Each challenge has important impacts on the performance of IoT systems. Communication technology is severely impacted by these challenges. Ground communication tends to have a very limited coverage (say, a few meters). The communication between nodes using HAPS will provide much larger coverage, especially extending internet signals, which are the mainstay of IoT communications. Similar analogy can also be extended for the Battlefield IoT (BIoT). There is also a case in point where HAPS may be equipped with IoT based sensors to ensure multi-sensor data capture and hence, fusion of these technologies.

A hybrid nanosatellite-HAPS model can be suggested where the communication range can easily be extended. Sensors can utilise the power on board HAPS. Low transmission power and low latency afforded by HAPS should be exploited in implementing communication and IoT models. Different satellite/HAP architectures allow multitude of applications, which makes IoT systems more versatile and scalable. Therefore, the proposed architectures are Satellite/HAP/HAP/IoT, Satellite/HAP/IoT and HAP/HAP/IoT. Backhaul limitations of the network architecture can also be mitigated to a large extent by the use of HAPS.[18]

Wireless Sensor Networks (WSNs). Similar to the architectures mentioned above for IoT, study has also been done for WSN models. Mitchell et al. further developed this idea and proposed two HAP/WSN architectures[19] appropriate for vital applications such as monitoring and security. One architecture bases itself on direct transmission to HAPS, hence reducing the energy consumed and is less complex. This is suitable for low data rates and large coverage. The other architecture comprises nodes setup in clusters with no direct communication between sensor nodes and HAPS. Data transmission and reception is based through the cluster head and is suited for high data rate application with very low latency requirements.

A model to connect two heterogenous networks such as satellites and HAPS has also been studied[20] by Raveneau et al. This architecture is called 'store-carry-and-forward', which is based on the Delay Tolerant Networking[21] (DTN) technique.

Private Internet Connectivity. While the present-day technology is looking for ways to extend internet to the last mile, HAPS can come in a big way to support this cause. HAPS are poised best for the setting up of core networks. They can be used to provide point to point (bearer) links. In all these respects, the use of HAPS is analogous to that of satellite and VSATs (Very Small Antenna Terminals). Providing higher bandwidths is where HAPS can be most gainfully exploited. The armed forces may use the same analogy for setting up of virtual private networks or VPNs.

Electronic Warfare (EW). Electronic Support(ES) Electronic Attack(EA) roles are most suited to HAPS as part of EW. MTI, ELINT & COMINT payloads, on board HAPS, can be invaluable assets. SAR' payload exhibits coverage for miles into an area of interest— land based or over the seas, and can definitely augment the capabilities of the surveillance grid.

Alternate PNT Signals. May be used to provide an alternate to work in GPS denied environments.[22] Forces, all over the world, are looking at methods to develop resilient PNT signals— a fact that has gained momentum after the GNSS jamming has been leveraged at the core of 'soft kill' methods against drones/ UAVs. HAPS may be utilised to provide navigation signals or set up 'localised positioning system' where the UAVS/ drones can use these 'beacons' to navigate safely and complete the assigned mission.

HAPS Technologies: Challenges Involved

It is pertinent to highlight the challenges involved through the kaleidoscope of relevant technologies which attributes to making HAPS a relatively low-cost force multiplier.

Control Over Aerial Drift. While fixed wing HAPS still lend themselves to be manoeuvred, it is the high-altitude balloon ('blimps', if we can call them) which will require extensive station keeping to focus on persistent targeting in view. 'Station keeping', thus assumes high importance— a term largely used with satellites to maintain the orbital parameters,it can also be extended to HAPS (pseudo satellites).

Although near-space altitude of 65,000-300,000 ft have a stagnant weather, however (i.e. storm, rain), wind still exists, which is important for HAPS. A paper[23] addressing this aspect brings out the difficulties in maintaining the sway & drift movement of this stratospheric bodies. HAPS are complex man-made machines and the dynamics of an airship is highly non-linear, coupled and complex. PID[24] based and fuzzy logic based approaches are also discussed in the paper ultimately leading to future scope of work involving practical tests. An important set of trials are being undertaken in Germany[25] for managing HAPS using advanced traffic control to monitor the climb and descent rates, weather based behaviour, route planning etc. This is one of the foremost programmes which highlights the integration of HAPS as part of aerospace management.

Envelope Material for Blimps. Lightweight and high strength envelope material is one of the bottlenecks for the development of stratospheric airships, which directly determines the long endurance flight performance and loading deformation characteristics of the airship.[26] More developments have to be made with respect to the uniaxial & biaxial stress the material has to undergo while in air. The problem is relatively simplified for fixed wing HAPS; however, thermodynamics and aerodynamics are the most relevant forces to counter and adjust the fixed wing solutions.

Payload Size. While aerial coverage, high throughput and persistence over an area of interest, are major advantages, the payload size is of major concern. A trade-off has to be reached based on the proposed employment between the weight of the payload and the endurance envisaged. As part of ISR activities, NATO had initiated a programme called the 'BalSAR'[27] or the 'Balloon-borne SAR' for maritime surveillance. The unique advantages (higher immunity against attack and wider coverage of the ground) offered by HAPS over the aircrafts and UAVs motivated this programme. Zephyr (Airbus), ISIS (Lockheed Martin) &

Radar Aerostat (Raytheon) are few HAPS programmes which are costly and have already been employed for ISR tasks. The BalSAR aims at a balloon that is capable of lifting a heavy payload of nearly 20 kg weight at an altitude of 30 km with its own telemetry system and recovery based on parachute system. SAR is implemented as a X-band radar architecture. The transmitted waveform is generated by a frequency synthesiser (phase locked loop based). This approach focuses on a compact, low cost and low power consumption solution that allows for the generation of large bandwidth and high chirp rate waveforms. With the accelerated advances in MEMS and VLSI, how much the weight of the payload can be shrunk is only limited by present day technology threshold as also that of the human brain prowess.

Captive Power Source. A combination of batteries (to power the attitude control, drift control and health maintenance of the HAPS) and high-grade solar cells (space-grade) are the ideal technology candidate for HAPS. This will ensure that HAPS stay afloat for months together. The several metres long wingspan of 'fixed wing HAPS' may be utilised to host the solar panels (**Figure 6**), while for balloons, the envelope material is a likely deployment area for solar cells. 'Zephyr T', one of the HAPS line-ups from Airbus[28] has a weight of 140 kilos and a wingspan estimated to be much larger than the previous variant 'Zephyr S' (25 metres).

Figure 6: Fixed Wing HAPS

Source: https://www.sae.org/news/2018/12/high-altitude-pseudo-satellites-new-battle-for-inner-space-part-i-copy

Majority of technologies involved are common to, both vis satellites and HAPS. However, a comparison with satellites will help gauge the effectiveness of using HAPS. Satellites suffer from some major disadvantages like no payload change possible once launched and steering the satellite to a brand new orbit (orbital manoeuvrability due to limited fuel on board).

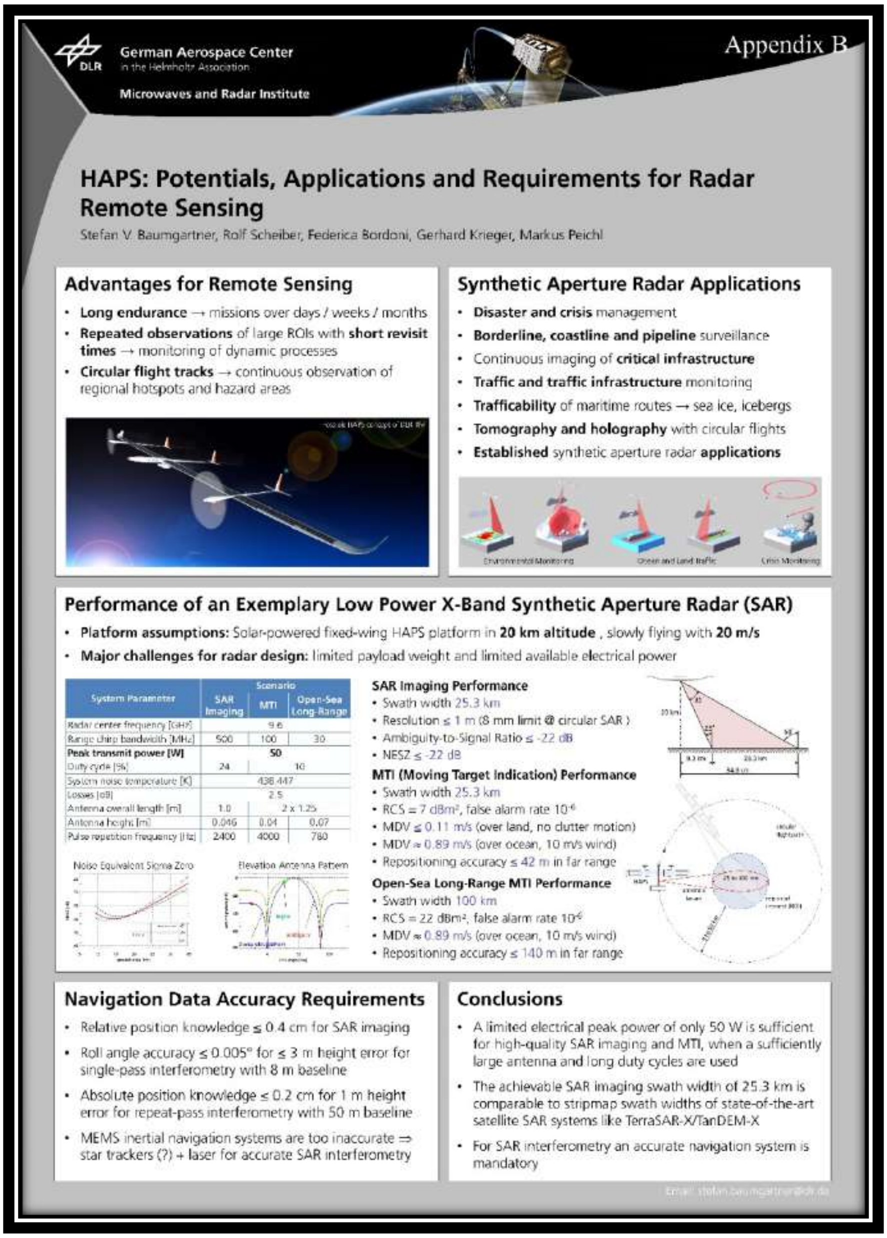
Questions to be Pondered: HAPS Development Matrix

India is trying to catch up with respect to HAPS development. While there has been news of indigenous development[29], any progress is yet to be confirmed.Before delving into the questions as part of the development matrix, it will be prudent to consider deployment scenarios as hypothesis which can aid in the process of framing questions.

Scenario 1: Remote Sensing

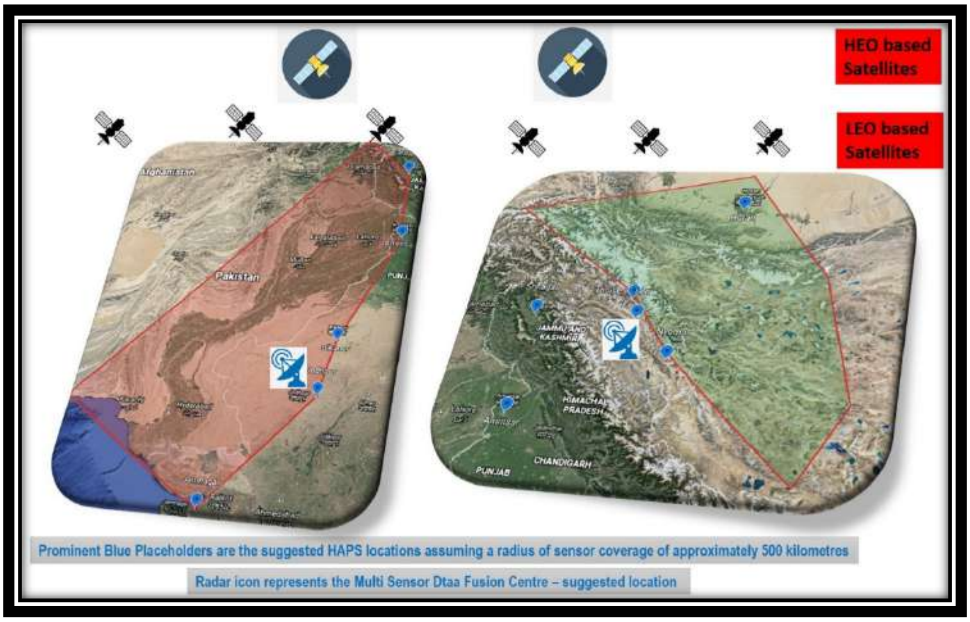
The aspect of remote sensing may be viewed with two options vis. Standalone HAPS (SA-HAPS) and Satellite Augmented HAPS (Sat-HAPS). While SA-HAPS will be purely a HAPS based network, Sat-HAPS can augment the reach of satellite deliverables to the ground. Various developments have been made in terms of ISR payloads ranging from SAR to 3D Mapping and affording optical communication payloads. Throughput of 30 Mbits per second[30] has also been demonstrated as part of broadband communication to transmit high resolution data to ground control. A tally of three scenarios for the use-case of HAPS involving SAR, MTI and long-range surveillance has been illustrated in **Figure 7.**[31] A proposed coverage for ISR on the Northern, Western and Eastern borders is reproduced below with likely HAPS coverage **(Figure 8)**. The system represented can be employed as SA or as a Sat-HAPS model.

Figure 7: HAPS' Potential



Source: https://elib.dlr.de/113651/1/haps4esa_2017_Baumgartner.pdf

Figure 8: HAPS Coverage on India's Borders (Suggested Representation - Not to Scale)

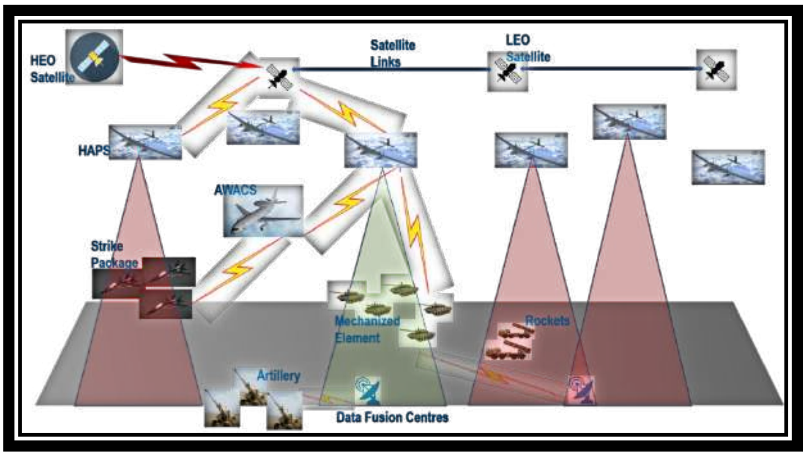


Source: Author's Own Interpretation of the Deployment Scenario

Scenario 2: Control of Assets: Land, Air & Sea Based

Autonomous systems are now becoming synonymous with weapon platforms. HAPS can be used to cover the area of responsibility entrusted to other platforms as well. An overlap can ensure high probability of mission accomplishment. The scenario is represented by the graphic at Figure 9. Loitering munitions as well as controlling a swarm of drones is also practically possible with such an employment of HAPS.

Figure 9: Control of Assets in a Theatre (Representation Only)



Source: Author's Own Interpretation & is Merely Suggestive

Scenario 3: Communication Network Establishment

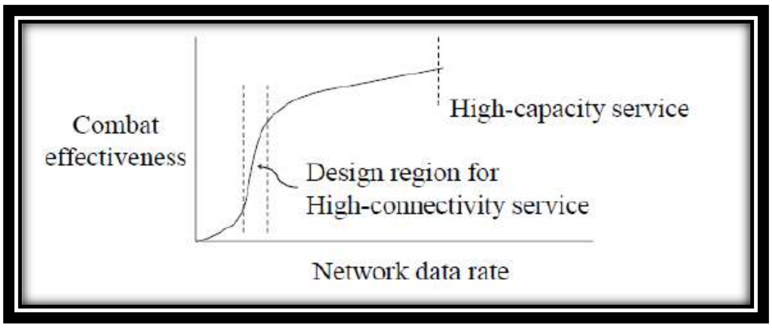
With growing impetus on private LTE and 5G networks being tried, tested and evaluated by the forces, HAPS can be leveraged in providing the war fighter with a truly meshed communication network with inbuilt redundancies.

A range of frequencies has been shortlisted by the WRC for the use of and to accommodate the growing interest around HAPS. HAPS can use the following frequency bands: (a) 1885 – 1980 MHz, 2010 – 2025 MHz and 2110 – 2170 MHz for base stations in the mobile service according to RR5.388A and Resolution 221(Rec.WRC-07); (b) 6440 – 6520 MHz and 6560 - 6640 MHz for HAPS gateway links in countries listed in RR5.457 and pursuant to Resolution 150 (WRC-12); (c) 27.9 – 28.2 GHz and 31 – 31.3 GHz for HAPS in the fixed service in countries listed in RR5.537A and 5.543A and pursuant to Resolution 145 (Rev.WRC-12); (d) 47.2 – 47.5 GHz and 47.9 – 48.2 GHz for HAPS in the fixed service pursuant to Resolution 122 (Rev.WRC-07). Also, as per WRC-19, fixed service in the frequency bands 31-31.3 GHz and 38-39.5 GHz will be identified for worldwide use by HAPS. They also confirmed the existing worldwide identification for HAPS in the bands 47.2 – 47.5 GHz and 47.9 – 48.2 GHz that are available for worldwide use by administrations wishing to implement high-altitude platform stations. They agreed to the use of frequency bands 21.4-22 GHz and 24.25-27.5 GHz by HAPS in the fixed service.[32]

The communication field is leading the way in development of HAPS for commercial use, driven by Google and Facebook.[33] Their aim is to extend Internet access to those who do not have it, and HAPS is one of the means to do this. Google's project is called 'Project Skybender' which uses Solara 50— a solar powered HAPS with a wingspan of 50 m and manufactured by Titan Aerospace. Facebook's HAPS 'Aquila', made of carbon fibre, has a wingspan of 42 m and runs on solar power. Its targeted non-stop flight time is three months.

With laser communications from the ground to the HAPS, the HAPS radiates radio waves in a diameter of approximately 50 kms directly below itself, and the transmission is expected to be at a single-digit Gbps. 'Robustness versus Capacity' are one of the main trade-offs when it comes to designing a military-grade network. Moreover, these performance indicators are to be valued against the metrics of constrained resources, limited budget and an ever-shrinking spectrum. One also has to see the greater reliance of forces as they transition from being network enabled to network centric in their approaches. The increased attack surface thereby provided to the adversary imposes further emphasise on the requirement of a robust network. John and Vincent in their work[34] have suggested a high connectivity network which ensures that all nodes are connected at all times, hence, providing near-real time information towards establishing a Global Information Grid (GIG).

Figure 10: Design region for high-connectivity service



Source: IEEE, Milcom Conference, 2010

With the increase in the data rate, the effectiveness to coordinate operations also increases. A steep gradient is seen in the 'S' shaped curve implying a jump in the effectiveness within the high connectivity region. This region is found to be most suitable for ensuring higher mission effectiveness as compared to a high capacity service which, although has higher benefits, but entails a considerable cost penalty when seen in terms of hardware/ infrastructure (marginal cost principle). A 'dependable capability' will be more preferred over 'data quantum'.

Scenario 4: Electronic Warfare

With reference to the use of HAPS in Electronic battles, immense use- case scenarios can be imagined in ELINT, COMINT as well as limited EA systems. A constellation of HAPS can work well for direction finding tasks by making a reasonable baseline for interferometry operations. Persistence over an area can also help in ensuring denied spectrum especially PNT signals for the adversary. However, high power jammers seem unfeasible onboard HAPS due to heavy power requirements for the required radiated power.

Scenario 5: Situational Awareness

Battlefield situational awareness afforded by IoT can be greatly enhanced by use of HAPS.[35] As shown in **Figure 9** earlier, the coverage of HAPS, by establishing fail-safe links can increase the real time awareness of the war fighter by communication, video and data feed.

Not all encompassing, however, the five scenarios as mentioned above, pose certain questions.

- Are we treating Space as a domain with HAPS as an inherent part of it?
- Is the use of HAPS leading to a clear meeting of futuristic requirement of the war fighter?
- What policy and strategy do we need to adopt? Are DPSUs and private players ready to contribute? How can Space agencies carry this project forward?
- What are the implications of HAPS as a cost-benefit analysis?
- What shorter term actions should we take to test the efficacy of this platform?

HAPS Implementation Strategy

HAPS' use is in perfect sync with what should be the 'Space Modernisation Strategy'. Three main pillars of this strategy revolves around persistent ISR, high bandwidth and throughput enabled communication & net-centric operations. HAPS have all the features of coverage, access and flexibility making it a potent ISR tool. Being in a quasi-stationary orbit allows better gathering of data while at the same time obviates the requirement of a forward area footprint. It can almost be launched along with the operation or combat pulse. The implementation strategy for utilising HAPS will entail points as elaborated further.

- ***Advanced concept and technological demonstration*** of HAPS using prototypes is mandatory. Players such as HAL in India as well as private players as part of Indian Space Association (ISpA) can pitch in to nurture this field. Civil, military and academia fusion is mandatory.
- ***Multi-sensor data fusion (MSDF) is key.*** Use sensors planned to be used with HALE UAVs with the advantage that, these are already optimised for operating at the intended altitude. AWACs, UAVs, Ground telemetry stations, maritime vessels can all be linked to receive data from HAPS. Battlefield IoT can also benefit greatly with the use of this trans-troposphere platform. Locations where HAPS may be utilised, once finalised, 'should result in them being used as a theatre asset to begin with'. This later need to proliferate to a lower operational level asset that is completely under the control of the commander on ground.
- ***Mesh HAPS as Part of Algorithmic Warfare.*** With immense use of HAPS as a communication platform resulting in meshed networks which are in-built

with redundancy, a dedicated team (Project MAVEN[36]) should be established to look at developing AI based models which can, not only help to control the platform, but also yield in better software to develop systems to assist the soldier.

- ***Inaccessible and difficult terrain can act as test bed for communication capability testing for HAPS.*** Unlike the conventional macro Base Stations (BSs), the envisioned HAPS mounted Super Macro Base Stations (SMBS) [HAPS-SMBS] not only enhances coverage and capacity, but also supports data acquisition, computing, caching, and processing in a plethora of application domains. Compared to UAVs, HAPS systems, which are inherently quasi-stationary, have a larger footprint, more computational power, and better LOS communication links. HAPS-SMBS can therefore be regarded as powerful platforms to enhance connectivity. HAPS-SMBS systems, however, are not alternatives to terrestrial BSs; instead, they are a complementary solution for network management and control. The wide footprint of HAPS systems is ideal for providing greater coverage to high number of IoT devices each with low-rate links. In addition, IoT devices might be located in areas where there are no terrestrial network coverage.[37]

Future of HAPS

According to recommendations provided by Kurt Et Al, HAPS should have a wide footprint of about 500 km in radius.[38] A network of multiple HAPS can extend the coverage to serve the whole country. For example, a HAPS constellation of 18 nodes is estimated to be sufficient to cover all of Greece, including all of its islands. HAPS have become an inseparable part of the new generation of wireless networks. Technology enablers such as free space optics, LASERS, VLSI, structural and material sciences, avionics and antenna design have resulted in never seen before changes in communication technology. The cited work [39] has incorporated the role of reconfigurable intelligent surfaces (RIS) as we graduate towards 6G as well as Faster Than Nyquist (FTN) signalling.

As has been brought out in this brief, HAPS can provide aerial control over drones and other UAVs through edge computing and taking the computation load off from these platforms. Swarms can also be seen within the ambit of its applications. HAPS are also being viewed as portable data centres for highly dense computer networks.

One major concern which will need to be addressed is the acceptance of HAPS as part airspace policy over a country. ICAO regulations[40] will need to be suitably tweaked to include these platforms. HAPS Alliance (industry based consortium) also works in areas of aviation and commercialisation to build a strong HAPS ecosystem. In addition, areas of concern includes the continuous RF/ Optical beam pointing and steering on HAPS platforms due to its 'near circle like orbit' which will cause continuous steering mechanisms to be in place. Also, the self-healing and self-organising networks as part of the HAPS architecture need greater research.

Conclusion

Like any new concept (although the concept of HAPS definitely is dated), there is bound to be skepticism surrounding the topic as more than the strategic value or utility, the concept of marginal cost and similar economic factors come into the picture. Cost effectiveness is certainly paramount, however, if HALE airships/ HAPS/ Pseudo satellites can serve as an alternate means to fill in the gaps in multiple capabilities, it is definitely worth experimentation.

Sheer vastness of our frontiers, varied terrain and with neighbouring countries displaying aggressive tendencies, the 'theatres' as perceived will fall short of sensors to aid in maintaining ascendancy as well as prevent strategic and tactical surprises. Proponents of technology and evangelists alike may brush aside the concept of HAPS' utilisation. However, prudence dictates that worthiness of HAPS be further studied based on operational and strategic requirements.

Stratosphere berthed HAPS can support the tactical / operational commander with real time information resulting in a responsive OODA loop. This will also accrue benefits of not being burdened with issues of station keeping etc. while also reducing the logistical and administrative functions.

With regards to HAPS, there are several issues that need to be addressed. HAPS should not be seen as the finale in terms of platforms or technologies which will lead to the most robust of systems or a high-point in technology asymmetries, but should be seen as a stepping stone towards enhancing the 'already existing satellite systems' and complement the constellations of nanosatellites/ CubeSats that are planned to be placed in orbit for various roles. Responsiveness of space-based assets will definitely be improved by HAPS as also the requirements that emerge out of a surge in activities due to adversarial actions. HAPS should definitely not be seen as a 'Maginot line' in space.

End Notes

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