Unmanned Aerial Systems' Near-space Operation Concept

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Abstract—**Space, as an extension to the air medium, is the ultimate high ground of today's militaries. Although space technologies have the potential to influence operations when dealing with different types of conflicts, they are vulnerable against counter operations. The near-space is where the vulnerability takes place and where it can be prevented. This space is located between the normal aircraft operations zone and satellite orbits. We propose a high-level strategy to reduce this vulnerability such that the main space technologies are backed-up with a network of Unmanned Aerial Systems (UAS) to fill any space operation gaps as near-space assets. The varying functionalities and capabilities of UAS can provide another layer of sensors for flexible, versatile and persistent air and space operations. The significant UAS capabilities in the near-space include GPS navigation aid in a jamming environment, communication relay and organic C4ISR asset. These capabilities with other air and space technologies can contribute towards network centric warfare (NCW) architecture. The emerging challenge is to identify the role of UAS in operational structure and versatile mission requirements; and possibly provide an integrative solution where space-based sensors and UAS platforms collaborate in achieving any given mission in the future of warfare.**

The aim of this paper is to address operational aspects of current and future applications and near-space concept of UAS in the context of anticipated future operating environment. The evaluation will focus on the efficiency of UAS in near-space environment and their impact on possible air and space operations. The research is expected to contribute to a more informed structural transformation of the modern militaries incorporating air, near-space and orbit level space technologies.

Keywords-unmanned aerial system; UAS; near-space; near-space asset; space-based sensor; space system; space operation; near-space operation

I. INTRODUCTION

As the technology and space concepts accelerate, air power becomes more dependent on space-enabled capabilities and more vulnerable to their disruption. The attributes of global coverage, flexibility, economy, effectiveness and robustness make Air Force unique to capitalize on the contributions of air and space systems.

Space power is derived from the exploitation of the environment above atmosphere by a variety of systems and enhances opportunities across the range of military opportunities. Space control is the means by which space superiority is gained and maintained to assure friendly forces can use the space environment while denying its use to the enemy [1]. But, the counter space missions carried out by adversaries to achieve space control objectives by gaining and maintaining control of activities conducted in or through the space environment dangers operations. Because of that, militaries that conduct space operations look for alternative mediums and platforms for space superiority and survivability of friendly forces. Also the shortfalls of air and space operations which are beyond-line-of-sight (BLOS) communication and persistent intelligence, surveillance, and reconnaissance (ISR) make near-space to be considered as an alternative domain for air and space as operationally responsive space capability.

There are many challenges ahead for Air Forces that are worth pointing out. Traditional development cycles are much too slow to respond to emerging battlespace requirements. The idea of "one size fits all" doesn't set a solution to problems. It is important to present insights regarding the likely nature of future challenges to Air Forces and find new ways to exploit and leverage existing assets to quickly meet air power needs. The challenge is to develop situational understanding from the situational awareness created by the technological exploitation of the intelligence provided by air and space capabilities.

Based on the objective, the question is that, what is the best way to give the battlespace commander a seamless, integrated picture of his theater and seamless, integrated communication with his command than to have all of the command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) assets become a layered, interleaved system of systems that are planned, acquired and operated by a command tasked with that mission? The concept is based on the ability to stare continuously at an area of interest, rather than scan the entire visible portion of the Earth with dedicated systems to spot targets much faster. The objective is to bring persistent space like effects and the right mix of air, near-space and space

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capabilities to the combatant commander and operationalize air and space power domains [2].

This paper first discusses what challenges are ahead for Air Forces, then what near-space is in terms of transformation of air and space power, and critical mission requirements, why near-space has the promise to become an operational domain and how the properties of near-space can provide an advantage in delivering space effects to the war fighter. After conceptual discussions it examines near-space platforms and sets the capabilities from an operations-based look at how near-space provides effects to the war fighter. Finally, it suggests a way of strategic thinking on achieving these space effects effectively.

II. TRANSFORMATION OF AIR POWER

Air Forces face a challenge in an era of dynamic change driven by rapid technological advancements, expanding information spaces and new roles expected from air and space power. However, the challenges are hard to overcome. The question of how Air Forces can restructure should be answered in the basis of requirements and capabilities. The platforms, sensors and their effects will contribute to the strategies in how Air Forces can react in warfare comprising conventional, asymmetric and hybrid tactics by assessing threats, requirements, capabilities and actions in future operating environments. NATO Allied Command Transformation emphasizes the vision in Multiple Futures Project;

> "Transforming any institution is an ambitious and complicated process that must begin with a deep grasp of the past and an open mind about the future."

It is important for the air power to understand that "space" is a set of effects instead of a platform or a medium. The consideration of what system or combination of systems will provide the greatest effect on the battlespace for the least expenditure of resources compel to look for new capabilities to fill the gap between air and space. The most relevant concept of operations (CONOPS) is Space and C4ISR, which describes how the Air Force will harness capabilities to achieve horizontal integration of manned, unmanned and space systems, eventually through machine-to-machine interface of C4 and ISR to provide executable decision-quality knowledge to the commander in near real-time from anywhere [3].

Air power offers the warfighting components military resources that can cover great distances, survive, persist and gain desired lethal and nonlethal effects. Due to its speed and range, air power operates in ways that are fundamentally different from other forms of military power. The key tasks in high demand are persistent awareness, rapid air mobility, precision strike and integrated networks that pull together all force elements and coordinate execution.

Near-space primarily provides two distinct effects for the war fighter; ISR and communications. Near-space assets offer tremendous advantages to tactical and operational commanders providing the "space" effects of ISR and communications much more responsively, persistently and affordably than any envisioned satellite system [4]. The air power capabilities of communication, navigation and ISR satellites are limited to provide a constant, staring presence on a timescale of days, weeks or months over a selected target or area of interest without fielding a larger constellation of assets.

III. BATTLESPACE AWARENESS AND ISR

The key to successful military operations is a thorough knowledge of enemy capabilities derived from near-real-time information. The decisions made in the battlespace are vital not to practice trial-and-error strategies to lead to a solution. Battlespace awareness is directly related with the available information and the capability of evaluation. Battlespace awareness is the ability of commanders and all force elements to understand the environment in which they operate and the adversaries they face [5]. The concept of battlespace awareness describes the ISR mission. Because ISR is the driving requirement for current air operations, Air Forces are seeking for space-based ISR capabilities that can be fielded faster, at less expense and low risk. The capabilities of ISR, command and control (C2), communications and navigation tasks provide effects for the war fighter as force multipliers that set the ability to more efficiently prosecute the operation. The objective is to integrate intelligence assets into a Common Operational Picture (COP) [6]. The global war on terror in Afghanistan and Iraq has forced the militaries to concentrate on persistent, organic ISR and 24/7 over-the-horizon communications. Technology is also overcoming the lack of persistence that has been one of air power's traditional weaknesses: through space-based assets and high endurance Unmanned Aerial Vehicles (UAVs) [7].

The complex nature of hybrid warfare demands exquisite awareness of the operating environment. Versatile and adaptable airborne ISR systems are essential to detect and track a wide variety of threats and actions in hybrid war. The information gained from dynamic and complex environment requires an extensive collection network. To accomplish the full range of network centric tasks in future operating environment, the required systems will rely on technological advances and operational concepts. Because of that, it is important to analyze the platforms and systems as alternatives, make tradeoffs between cost, performance, risk and effectiveness to adapt to the future. The concept is very important in today's information-rich operating environment even more than in the past. War fighters can benefit from information traditionally held by higher-level commanders, and manned and unmanned platforms [8]. The idea of having the right information at the right time can be a significant force multiplier for militaries. No single sensor or approach can provide all the necessary information. Commanders value and need a layered ISR architecture to meet varied requirements [9].

Battlespace awareness and ISR enhance a commander's understanding of an adversary, enabling the development of an effective information campaign to shape an enemy's understanding and perceptions. In this realm near-space power contributes importantly, supporting understanding through functions such as intelligence gathering, surveillance and reconnaissance, integrated tactical warning and attack assessments, environmental monitoring and communications

transmissions [7]. Advanced technology, improved sensors, new collection platforms and improved concepts enabled by greater computing power have combined to increase battlespace awareness and reduce uncertainty for information superiority.

The current ISR assets orbiting the earth are frequently needed for preplanned, higher-priority missions and are so heavily tasked with strategic missions that they may not be readily available to operational or tactical commanders [10]. Satellite-based communications are very expensive to field and generally have limited bandwidth and availability. Near-space is a unique approach to battlespace awareness that can provide persistent ISR. Unlike low-earth orbit (LEO) satellites, which only briefly pass through the area of operations, near-space vehicles have the ability to loiter over the area of responsibility and provide the persistence necessary for current operations. Rather than requesting intelligence product, combatant commanders are in demand of the use of the collection method.

In general terms the employment of air power has two gaps. Capability, the gap where the need for the effects of persistent communications and ISR and the gap in the altitudes covered by Air Force assets 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 war fighters [4].

IV. The Concept of Near-space

The fundamental guiding truths of air and space power employment are important to understand the concept of near-space. Air and space power is flexible and versatile. Flexibility allows Air and Space Forces to exploit mass and maneuver simultaneously to a far greater extent than surface forces. Versatility in air and space power stems from the fact that it can be employed equally effectively at the strategic, operational, and tactical levels of warfare. The effects that Air and Space Forces' action produces are synergistic.

Air and space systems are uniquely suited to persistent operations. Air and space operations must achieve concentration of purpose be prioritized. Given their flexibility and versatility, demands for air and space forces will likely swamp air commanders in future conflicts unless appropriate priorities are established [11]. But the nature of the threats and the way we choose to deter and fight those conflicts may change. Unforeseen requirements for imagery or communications arise constantly as a result of friction and the fog of war. It does not seem possible to predict every possible enemy or friendly action, so continually updated information is needed to allow the commander to direct his or her forces to the appropriate points to take appropriate actions. This information needs to be responsive enough that the commander can act inside the enemy's OODA (observe, orient, decide, act) loop [4].

Near-space is defined as the region between about 65,000 ft (20 km) and 100 km. Sixty-five thousand feet was chosen as the lower boundary in order to be above the current International Civil Aviation Organization (ICAO) controlled airspace limit of 60,000 ft. One hundred kilometers was chosen to be at the Karman line loosely defining the boundary of space [4].

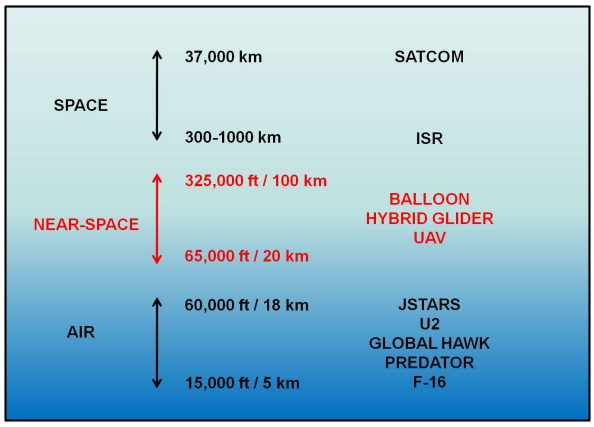

Figure 1. Graphical Depiction of Operational Domains [4]

Near-space enabled military strength depends on advanced sensors, NCW and precise weapons. Effects-based operations, NCW and rapid maneuver demand BLOS communications and persistent ISR. Admittedly, near space may offer a lower-cost solution than other capabilities [12]. Near-space assets can be on-station when and where a battlespace commander needs them to provide the answer to the needs for organic persistence. Near space assets have the promise to counter or pose simultaneous threats across a far wider geographical area, move quickly and decisively between the strategic, operational and tactical levels of warfare, and to move across and between operational theatres.

In the concept of near-space, the key characteristics are knowledge, networking, interoperability, expeditionary capability, adaptability/tailorability, endurance, precision, agility and lethality [13]. The enabling mission area known as C4ISR makes these characteristics possible. Near-space is an opportunity for militaries that results in a shift from strategic level of space to operational and tactical level. The concept aims to fulfill the gaps of persistent communication, intelligence, surveillance, reconnaissance and altitudes covered by military assets [4].

The acquisition and tracking problem is very difficult even without considering what sort of weapon could possibly reach them at their operating altitudes. Manned aircraft and surface-to-air missiles (SAMs) could be a threat at the lower end of near-space, but even if they were able to acquire, track and guide on a near-space platform, their probability of kill would likely be low [4]. Destroying a near-space asset requires targeting something other than the platform itself. In fact, the relatively small payload of a near-space asset is really the most vulnerable portion. Unless using lasers to carry their information, communications platforms are vulnerable to some radar-guided missiles, acting as a radar beacon at their communications link frequencies. The payload are vulnerable to directed energy threats (e.g., lasers and microwaves), as are similar payloads on satellites and UAVs, but their UAV-like unpredictability and the difficulty in acquiring and tracking them diminishes this threat [4].

Research at the Naval Postgraduate School of the most effective platform for ISR and communications missions confirmed the usefulness of near-space airships. Their analysis considered traditional UAVs, near-space platforms and tactical satellites concluded (using weighted measures of effectiveness across an array of potential missions) that near-space platforms provide the maximum benefit to the war fighter [14].

V. NEAR-SPACE PLATFORMS

The types of near-space platforms currently in use, in development and envisioned are free-floaters, steered free-floaters and maneuvering vehicles [15]. The representative examples of near-space platforms are balloons, airships, hybrid gliders and UAVs. All the platforms have significant critical capabilities and performance attributes preferable for air and space operations.

Free-floaters are essentially large balloons that float with the wind which are inexpensive in terms of construction and launch techniques. Free-floaters may be useful in low-threat situations where maneuvering has no limitations while attempting payload recovery, the obvious tactical implication to this limitation in higher-threat situations is that only expendable, lightweight payloads are likely to be launched on such platforms [4].

Figure 2. Skysite Balloon

The next type of near-space platform in order of increasing complexity and increasing utility are the steered free-floaters. They use the different winds at different altitudes to enable reasonably accurate steering of the platform. In theory, steered free-floaters could be navigated with a fairly high degree of precision, generally going with the flow of the prevailing latitudinal winds but being able to speed up, slow down and move perpendicular to those winds to various degrees. Although the limited steering could allow the platform to stay on station for short periods, it is not enough to maintain persistence. The payloads for steered free-floaters could be more complex than free-floaters' as they could be navigated to a depot, recovered, repaired and reflown [4].

Figure 3. Northrop Grumman Long Endurance Multi-Intelligence Vehicle (LEMV)

The last type of near-space platform is maneuvering vehicles. They are able to launch, maneuver to a specified point and remain there for very long times providing true stay-and-stare capability. Maneuvering vehicles 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 a tactically controlled UAV [4].

Figure 4. Helios

High altitude airships (HAA) are steerable and controllable airships that slowly maneuver around in those extreme altitudes. A geostationary airship offers the same capabilities as a satellite has but at a fraction of the cost and is also significantly less costly to deploy and operate than other airborne platforms such as Airborne Warning and Control System (AWACS) and Joint Surveillance Target Attack Radar System (JSTARS). Instead of small, disposable or recoverable free-floating assets, the theater commander's interest would likely lie in the more capable maneuvering vehicles with their unique attributes of responsiveness and persistence. It would be easy to classify near-space platforms, especially maneuvering vehicles, simply as extremely high-altitude UAVs.

VI. NEAR-SPACE CAPABILITIES

The space effects needed at the tactical and operational levels of war are persistent and responsive communications and ISR, both of which enable C2. C2 includes both the

process by which the commander decides what action is to be taken and the system which monitors the implementation of the decision. The commander has a continuous requirement for ISR and communications—he cannot afford sporadic availability as it could afford the enemy sanctuary times, deny the commander the ability to act at the time of his choosing, or both [4].

Near-space platforms could function as UAS mounted satellite transponders as surrogate satellites, offering the advantages of shorter transmission distances and shorter ranges for sensor surveillance [11], organic C4ISR assets for tactical commanders, pseudo-satellites as communication relays, GPS accuracy augmentation and GPS navigation in a jamming environment [16].

Despite spot systems, persistency in a wide area demands multiple sensors on different axes. Transmitting the key data to a variety of locations is a way to share battlespace awareness. Near-space platforms are high enough to provide space effects and much closer to targets in terms of higher resolution and better sensitivity. The platforms are survivable with their small radar and thermal cross sections making them relatively invulnerable to most traditional tracking and targeting methods [17]. One of the most unique aspects of near-space platforms is their ability to provide responsive persistence, the ability to deliver their space effects to battlespace commander with no gaps in coverage. Air-breathing assets provide responsive, close-up and staring persistence for the duration of their limited loiter times. In contrast, one near-space platform currently receiving technology demonstration funding will be able to stay on station for six months and planned follow-on are projected to stay aloft for years [4].

During hostilities, airspace sovereignty over enemy territory is no longer a consideration; near-space assets can operate above the same locations that air-breathers can, subject to similar enemy threats. Near-space assets can then provide organic C4ISR. Battlespace commanders desire organic communications and ISR primarily due to the necessity for responsiveness; they require communications and imagery when and where they need it. When a battle is raging, they do not want to have to ask to task assets controlled by other commanders, never knowing for sure if the effects they require will be delivered [4]. They want direct control of the assets so they are guaranteed access when and where they need it. UAVs provide exactly this sort of local control, but the footprint of a UAV can be much smaller than that of a higher-flying near-space asset, and the near-space platform has the persistence advantage [4].

The stay-and-stare capability, wider field of view, and near-UAV-quality resolution provided by near-space assets could easily enable much more effective use of high-demand UAV assets by acting as a cuing mechanism. Near-space can act as a key link in the find, fix, assess, track and target portions of the time-critical targeting (TCT) kill chain [4]. Unfortunately, a break in any of the links in the kill chain provides an advantage to the enemy [18]. With near-space, the defense-in-depth approach simply adds another layer with capabilities that complement the existing space and air-breathing approaches [4].

The envisioned strategic missions that near-space assets can and do perform are currently performed by the U-2 and RC-135 variants. The stand-off imagery and signal intelligence (SIGINT) missions could easily be performed by near-space assets much more effectively due to their comparatively long loiter times. The sensor suite mounted on a HAA with the collected data above the atmosphere at 65,000 ft planned would allow HAA to see almost 50 percent further inland than the RC-135 and due to its years-long loiter capability the adversary would not have the luxury of simply turning off their equipment as they occasionally do when the Rivet Joint is on station. With near-space, the defense-in-depth approach simply adds another layer with capabilities that complement the existing space and air-breathing approaches and the layered approach makes the defenses harder for an adversary [4].

Precision navigation and timing are currently performed by a constellation of semi synchronous Global Positioning System (GPS) satellites orbiting at about half GEO altitude. Although the GPS mission is currently accomplished with satellites to ensure efficient global coverage that is not the only way it can be done. The Air Force Space Battlelab is currently working a preliminary investigation of GPS accuracy augmentation and GPS reconstitution using near-space platforms, and the Air Force Unmanned Aerial Vehicle Battlelab recently conducted a similar investigation that successfully demonstrated the usefulness of a UAV as an aid to GPS navigation in a jamming environment [16].

TABLE I. RELATIVE STRENGTHS OF SATELLITES, NEAR-SPACE AND AIR-BREATHING ASSETS [4]

	Satellites	Near-space	Air-breathers
Persistence		+	
Responsiveness		+	+
Footprint	+	+	
Resolution		+	+
Overflight	+		
Cost		+	

VII. CONCLUSION

To be effective and efficient in changing environment and warfare, airpower needs to rapidly adjust and adapt to the dynamic environment. The core air and space power characteristics act together synergistically to produce additional strengths. Integrating different capabilities to achieve effects not available individually provides a key advantage to militaries. Although the concept is a key enabler, it is important to analyze the opportunities and challenges inherent in the concept of near-space.

In terms of operationally responsive space, near-space can provide persistent and cost effective effects. Exploiting near-space capabilities to achieve battlespace awareness can be a solution for superiority. The future's transformed and

integrated battlespace will demonstrate new technologies and approaches specific to near-space beside air and space with the right mix of platforms to solve the shortfalls of air and space operations. Near-space assets can form an additional layer of persistence between air-breathers and satellites, complementing both and making the combination of systems more survivable and redundant by their presence. Near-space can also be a deterrent to opponents' counterspace efforts, a distinctly strategic defensive mission.

It is important to understand that it is effects that matter on the battlespace instead of the platform or medium from which the effects are delivered, near-space makes much more sense for many applications. The point is that a layered approach whose goal is to enable space effects in the most economical, effective way will direct the acquisition of the appropriate platform using the appropriate medium, turning the current acquisitions methodology of medium-then-platform-then-effect on its head. Beyond concepts, air power should care about effects, not about what platforms or locations the effects come from. In the concept of near-space, space is no longer just a strategic asset, but tactical and operational commanders can produce their own space effects. The militaries that have transformed successfully addressed and identified the specific military problems clearly. The purpose of transformation is to extend key advantages and reduce vulnerabilities.

Near-space is a new strategic environment. The integration of existing capabilities will provide a key advantage to militaries. It is important to maximize the utility of air, near-space and space domains that will provide battlespace superiority. The speed, range and precision of air and space power will allow it to dominate the entire range of military operations in the air, on land, on the sea, in near-space and in space. The approach should be to specify the requirements of missions, capabilities provided by air, near-space and space systems, compare mission requirements and capabilities, and decide if the requirements are satisfied. Ultimately, the concept of incorporating near-space systems will expand mission flexibility and efficiency.

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