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*The New Intelligence, Surveillance, and Reconnaissance Cockpit:*
**Examining the Contributions of Emerging Unmanned Aircraft Systems**

by

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## Abstract

The purpose of this paper is to examine how unmanned Intelligence, Surveillance, and Reconnaissance capabilities must change in order to meet the long term requirements of U.S. war-fighters. Contemporary non-strike capable Unmanned Aerial Vehicles and strike capable Unmanned Combat Aerial Vehicles (UCAVs) cannot match the speed and payload capacity of modern manned platforms; however there are significant changes on the horizon. This research paper addresses this subject using the evaluation methodology, analyzing five areas necessary for continued Unmanned Aircraft System (UAS) progress: UAS force structure, persistent coverage, asset sensor packages, improved lethality, and stealth developments.

While this paper emphasizes continued developments in unmanned capabilities, the first step that must take place in the development process is the minimization of procurement and employment duplicative efforts. For example, the U.S. Army and U.S. Air Force currently have similar yet separate UCAV programs, and both continue to research the development of comparable capabilities to meet war-fighter needs. The introduction of an UAS Executive Agent will allow the U.S. military to focus on UAS design improvements, and will also contribute to necessary changes in emerging UAS programs.

With an established joint interdependence, the Department of Defense (DoD) can then fully pursue new technological advances in unmanned capabilities – persistence, modular sensors, lethality, and stealth. Critical UAS research could potentially lead to the development of long endurance, low observable assets capable of fulfilling multiple war-fighter collection requirements, while providing a more robust strike capacity. By focusing on these elements, the DoD can create a more capable and lethal unmanned capacity to meet current and emerging war-fighter needs, through evolutionary and revolutionary research and development.

*The New Intelligence, Surveillance, and Reconnaissance Cockpit:*
**Examining the Contributions of Emerging Unmanned Aircraft Systems**

## Introduction

*Now it is clear the military does not have enough unmanned vehicles. We're entering an era in which unmanned vehicles of all kinds will take on greater importance—in space, on land, in the air, and at sea.*

*— President George W. Bush*
*Speech to Citadel Cadets*
*11 December 2001*

Until recently, manned airborne reconnaissance aircraft have offered the United States, its allies, and its adversaries a means to ensure adequate coverage of the entire battle-space from the relative safety of air and space. However, the end of the Cold War not only saw the conclusion of a stalemate between two world superpowers, but also witnessed the transition from traditional engagements of state actors, to irregular warfare and the struggle between state and non-state combatants. These failing nation-states and insurgent organizations, normally unable to match the military might of the United States, have embraced unrestricted warfare – war without rules.[1] This resurgent form of warfare requires a military force structure with the ability to provide persistent coverage in inhospitable environments.

The need arose for an asset capable of performing over extended periods of time with little to no degradation of proficiency, and able to help reduce the risk to human life in high threat environments.[2] While Intelligence, Surveillance, and Reconnaissance (ISR) platforms, such as the U-2 Dragon Lady[3] and RC-135 V/W Rivet Joint[4], remain the backbone of the U.S. surveillance and reconnaissance capability, these platforms are restricted by asset availability and aircrew endurance – impacting the ability to maintain persistent coverage.[5] The answer; a force readily and continuously available; able to find, fix, track, target, and if required engage time-sensitive targets.

The only airborne assets suited to fill this specific gap are the current and emerging Unmanned Aircraft Systems (UASs). Unmanned platforms bring an unmatched persistence capability to the battle-space, allowing these aircraft to remain on-station well beyond the capacity of a manned asset.[6] Contemporary Unmanned Aerial Vehicles (UAVs) and Unmanned Combat Aerial Vehicles (UCAVs) also employ modular sensor suites, providing a means to add and remove sensor packages and tailor the collection capability to specific missions.[7] In addition to this distinct ISR role, many unmanned assets are now capable of delivering a strike package; fulfilling a function unlike any other current manned ISR platforms. These same UAVs and UCAVs also possess an inherently small radar cross section, producing a unique low observable collection asset.

The U.S. Air Force employs unmanned airborne assets such as the MQ-1 Predator and RQ-4 Global Hawk to supplement an aging manned ISR capability with.[8] The U.S. Army, Navy, and Marine Corps also use small embedded unmanned assets to fill ISR gaps in daily tactical operations.[9] The removal of the onboard human factor from some ISR aircraft enables assets to remain on-station longer and maintain continuous "eyes-on" target.[10] However, the United States is still faced with the dilemma of not possessing an adequate number of operational unmanned aircraft. This factor limits the U.S. military's ability to provide adequate surveillance and reconnaissance coverage; a capability necessary to monitor and frequently engage a global enemy.

The fundamental question raised by this situation is: How must unmanned ISR capabilities change to meet the long term requirements of U.S. war-fighters? This paper seeks to address this question.

The continued development of a joint Unmanned Aircraft System (UAS) force structure and new ISR UAS technologies – particularly in the realms of persistence, sensor suites, lethality, and stealth – is essential in building a means to satisfy present and future Department of Defense (DoD) collection requirements.

While the U.S. military must maintain a means to support operations against a traditional adversary, force structure and capabilities must also evolve to meet the demands presented by a fluid combat and security environment. Although current U.S. manned ISR platforms are more than capable of providing the majority of surveillance and reconnaissance support to contemporary combat operations in Iraq and Afghanistan, war-fighters are beginning to recognize the benefit of the UAS.[11] The United States' UAVs and UCAVs have emerged as the mainstay of persistent near-real-time ISR support with an unmatched endurance capacity; complimenting the capabilities of current manned ISR platforms.[12] Yet, an extended on-station time alone will not allow the U.S. military to fulfill collection requirements. The United States must continue to pursue consolidated joint advancements in unmanned ISR capabilities in order to sustain a dominant ISR advantage.

The overall purpose of this research paper is to examine the long term impact of emerging ISR UAS technologies on DoD efforts. The evaluation methodology was used to explore all aspects of the research question. This study will focus on five important issues in order to address the research question: UAS force structure, persistent coverage, asset sensor packages, improved lethality, and stealth developments. A hypothetical scenario will help set the stage for an examination of the theoretical long term impact of the UAS. Section 1 defines UAS, provides a brief history of U.S. UASs, explores current ISR capabilities, and looks at the changing face of warfare. Section 2 identifies the critical standardized criteria required for evaluation, with particular emphasis on current UAS requirements. Section 3 compares existing and emerging ISR capabilities and more closely examines the contributions of future unmanned ISR systems. Section 4 examines the necessity for the evolution of unmanned capabilities such as persistence, integrated sensor suites, improved lethality, stealth, and the contributions of these emerging elements. The project concludes with recommendations for a more robust unmanned ISR force and infrastructure, allowing the United States to continue the fight against terrorism and maintain a U.S. presence globally.

## Hypothetical Scenario

Future collection and engagement requirements may be driven well beyond the means of human endurance, as state and non-state actors continue to pursue the defeat of the United States. The evolving joint service unmanned ISR and strike platform may hold the key to countering emerging threats and has the potential to transform the face of combat.

A large B-2-like unmanned platform soars undetected over the battle-space maintaining an altitude of 60,000 feet, 20 hours into a 30 hour mission.[13] The unique multi-sensor UAV continues monitoring an isolated compound, prompting manned ISR asset collection – cross cueing – to ensure persistent coverage of the identified high-value targets. Intelligence professionals have determined, through near-real-time analysis of raw data that the gathering of insurgent leaders will soon disperse. The Joint Force Air Component Commander (JFACC), unwilling to lose these targets again, approves the launch of a fleet of medium-altitude UCAVs.[14] The semi-autonomous UCAVs arrive on station fully “aware” of the situation and the task at hand, due to their direct links with the manned and unmanned systems orbiting the area.[15]

The leadership meeting comes to a close, targets move to their respective vehicles and the convoy begins to travel down a single road through the desert. The “swarm” of UCAVs trail above and behind the single row transporting the high-value targets, inherent algorithms allowing the platforms to easily track assigned targets.[16] The vehicles eventually begin to separate, proceeding to their destinations and the UCAVs pair off to continue the pursuit. The unmanned systems are authorized to engage their designated objective as the semi-autonomous system deems necessary, after receiving strike authorization.[17] The high-altitude manned and unmanned ISR platforms orbiting overhead remain on-station to provide over-watch and supplement the battle damage assessment of their smaller, more lethal counterparts.

This scenario highlights the potential surveillance, reconnaissance, and engagement capabilities that future U.S. UAVs and UCAVs can bring to bear in support of combat operations. However, understanding the necessity for continued developments in UAS force structure and technologies, begins with the characterization of the UAS and a brief look at U.S. unmanned history.

## Background

*Defining UAS*

The establishment of clear unmanned asset definitions is an initial step in the examination of current and future unmanned systems. The aforementioned UAS focuses on the synergistic effects of unmanned systems; whereas Unmanned Aerial Vehicle (UAV) and Unmanned Combat Aerial Vehicle (UCAV) refer to the "flying component" of the UAS.[18] The UAV fulfills a nonlethal role in the U.S. arsenal, performing reconnaissance and surveillance missions over enemy territory or along U.S. borders.[19] The United States also employs UCAVs; an unmanned armed weapons system used to conduct combined ISR and combat operations.[20]

However, the most important aspect of the characterization of the UAS is the identification of the assets that do not fit this classification. UAVs and UCAVs are essentially powered aircraft that function without an onboard operator. While platforms such as cruise missiles and ballistic missiles are also unmanned, the key distinction is that UAVs and UCAVs are intended to be recoverable.[21] Although historic cruise missiles eventually contributed to the development of UCAVs, a guided missile's purpose is to simply impact the assigned target – a one-way mission.[22] An additional element that sets UCAVs apart from guided missiles is the armament employed. The warhead of a cruise missile is integrated into the airframe of the asset whereas the munitions used by a UCAV are launched, dropped, or fired.[23]

Given this definition – a recoverable and reusable unmanned asset – "lighter-than-air" platforms such as balloons and airships could potentially fall into the category of UAV.[24] Nonetheless, "lighter-than-air" assets will be excluded from the UAS examination for the purpose of this research. Instead, the primary focus for this investigation is on those aircraft employing the characteristics of aerodynamic lift.[25] Additionally, while these unmanned aircraft are also known as Remotely Piloted Aircraft or Remotely Operated Aircraft, the categorization of UAV and UCAV will be used to simplify asset classification.[26]

*A Brief History of the UAS*

Another integral factor in understanding the future of the UAS is establishing a succinct comprehension of the ancestors of the current UAVs and UCAVs. Surprisingly the UAV had very humble beginnings. The original unmanned flight technically occurred over two thousand years ago when the Chinese launched the first kites. Eventually kites were employed throughout China and Europe for military purposes, as a means of deception and signaling.[27] Like current unmanned assets, early operators controlled kites through direct downlink; although for these first UAVs this came in the form of a simple string.[28]

<u>World War I</u>. While the advent of lighter-than-air flight provided countries the ability to conduct both manned and unmanned flights; the introduction of powered flight and aerodynamic lift contributed to the development of new unmanned capabilities. During World War I military engineers focused on converting obsolete manned assets into guided bombs that delivered payloads utilizing preset controls. Early ancestors to both the cruise missile and UCAV during this period included the Elmer Sperry's Flying Bomb project and the Kettering Bug.[29]

<u>World War II</u>. United States unmanned endeavors continued in World War II as Airmen sought to perfect efforts in the development of offensive unmanned guided weapons. Again these Airmen focused on the conversion of current systems, as opposed to creating a UAV from the ground up. For example, the Army Air Corps attempted to employ a radio-controlled B-17 in the Aphrodite Program.[30] A pilot and technician were required to launch and stabilize the aircraft before radio control could be established due to existing technological limitations. The

Army Air Corps eventually cancelled the program due to the fact that every airframe launched failed to reach intended targets.[31] Post-war efforts in unmanned technology witnessed more success, as developers focused on the development of unmanned aerial targets.[32]

The Cold War and Vietnam. Events during the Cold War provided the necessary motivation to spur endeavors for the creation of a successful unmanned asset. The 1960 shoot down of the U-2 Dragon Lady conducting reconnaissance operations over the Soviet Union and subsequent 1962 loss of another U-2 during the Cuban Missile Crisis in 1962 reinvigorated U.S. efforts in UAV development.[33] Again the U.S. military focused on the conversion of targeting drones to create unmanned reconnaissance aircraft via the Red Wagon Program.[34] Although this initial program proved successful; the Big Safari program led to the manufacture of the Ryan 147A Firefly, later known as the Lightning Bug.[35] The United States successfully employed the AQM-34 Lightning Bug UAV during Vietnam; fulfilling imagery, electronic, and psychological operation roles.[36]

The Middle East and Beyond. United States military leadership continued to encourage UAV development efforts and hone UAS capabilities. With growing tensions in the Middle East, the Air Forces Systems Command (AFSC) pursued the means to arm unmanned assets with air-to-surface armament via the contract for the BGM-34A.[37] In 1971, AFSC successfully employed this early version of the UCAV in a Suppression of Enemy Air Defense role.[38] Yet, early UAVs and UCAVs could not compete with current manned systems, despite burgeoning unmanned capabilities.

*An Overview of Current Systems*

Manned ISR. Early UASs lacked the capacity of well established manned surveillance and reconnaissance aircraft, primarily because of smaller airframes and limited sensor capabilities. For example, the U-2 Dragon Lady, although a legacy asset, is still one of the most critical ISR airframes in the U.S. Air Force inventory. There is currently no other platform available, manned or unmanned, with the combined imagery and signals intelligence capacity of the U-2.[39] The RC-135 V/W Rivet Joint is another unmatched airframe, with a Signals Intelligence (SIGINT) sensor suite more robust than any current unmanned systems.[40] Additionally, the payload of the initial UCAVs provided no competition for the air-to-surface capacity of current Army, Navy, and Air Force manned assets. Yet, if unmanned ISR and combat systems have the capacity to replace and compliment manned counterparts, it is conceivable that the continued pursuit and development of UASs is a viable endeavor.[41]

Unmanned. By the 1990s the U.S. military finally emerged from a past unfavorable to the development of extensive UASs.[42] Today the United States employs UASs throughout every branch of U.S. military service. The success of early unmanned aircraft in the Persian Gulf War served as the turning point for UAV operations and opened the door for future development.[43] Current UAVs and UCAVs range in size from hand-launched tactical units to the large assets intended to replace the U-2. Three of the most prominent unmanned aircraft are the RQ-1/MQ-1 Predator, MQ-9 Reaper, and RQ-4 Global Hawk.[44]

The RQ-1 Predator debuted during the Kosovo conflict and provided near-real-time persistent ISR capabilities for U.S. war-fighters.[45] In 2001, the role of the RQ-1 Predator expanded to encompass UCAV capabilities and as an armed unmanned asset became the MQ-1 Predator.[46] This multi-intelligence, multi-role platform currently supports combat operations throughout the Middle East; supplementing airborne and ground ISR with persistent full-motion-video (FMV), signals collection, and air-to-surface strike capabilities. The MQ-1 is capable of carrying a 450 pound payload and has an endurance of 16 – 24 hours.[47] The successful design and capacity of the MQ-1 contributed to the development of unmanned assets such as the MQ-9 Reaper and UCAV variants employed by the Army.[48]

As previously mentioned the U.S. Air Force developed the MQ-9 as an upgrade to the MQ-1 Predator. However, unlike its predecessor the Air Force designed and fielded the MQ-9 Reaper as a UCAV. Formerly known as the Predator B, the Air Force categorized the larger and more capable Reaper as both an ISR and strike asset.[49] The integrated sensor suite provides near-real-time FMV coverage, similar to the MQ-1, and includes Synthetic Aperture Radar/Moving Target Indicator (SAR/MTI) capabilities.[50] The MQ-9 is also capable of carrying over 3,000 pounds more armament than the MQ-1 and remains on-station 14 – 20 hours.[51] The key to continued successful employment of this dual-role unmanned asset is striking a critical balance between persistent collection and the "hunter-killer" role.[52]

The largest contemporary UAV in the U.S. military inventory, the RQ-4 Global Hawk is a high-altitude platform capable of on-station times greater than 24 hours.[53] Unlike the MQ-1 and MQ-9, the Air Force designed the RQ-4 to the replace the legacy U-2 and fulfill a strict ISR collection role. The Global Hawk's employment of multiple intelligence packages – Electro-Optical/Infra-Red imagery sensors, a SIGINT sensor suite, and Synthetic Aperture Radar/Moving Target Indicator – provides critical complimentary support to current efforts.[54] Although the U-2 remains one of the most capable ISR assets in the U.S. military inventory, the capacity of the RQ-4 Global Hawk makes it a potential, albeit less capable alternative.

## The Role of the UAS

Unmanned Aircraft Systems cover the entire gamut of tactical and strategic airborne capabilities – ISR support for Intelligence Preparation of the Operational Environment, base defense, and strike missions.[55] These systems provide commanders with the essential means to find, fix, track, target, engage and asses; fulfilling all six phases on the kill chain process.[56] The very nature of the UAS, persistence and sophisticated sensor suites, allow these assets to quickly and efficiently find, fix, and track time-sensitive targets. Near-real-time communication between unmanned platforms, operators, and the war-fighter provide an unprecedented ability to validate applicable targets. The efficiency of the UAS does not end with targeting, as the onboard weapons of current UCAVs allow combatant commanders to promptly engage fleeting targets. The persistence and sensor payload also allows UAVs and UCAVs to provide the integral final element of the kill chain – battle damage and effects based assessments.[57]



*Current UAS Requirements*

Dull, Dirty, and Dangerous. The UAS was specifically developed to accomplish missions that are considered to be dull, dirty, and dangerous.[58] Lackluster operations that require continued on-station support for extended periods of time pose a threat due to aircrew fatigue – dull.[59] Although this is not a significant hazard for aircraft such as the Rivet Joint which can carry multiple crews and is capable of air-to-air refueling, not every manned asset has this luxury.[60] The UAV, on the other hand, quite often has a much greater loiter time than comparable manned assets, and crews can be swapped mid-flight; minimizing the affects of a dull mission.[61]

Missions categorized as dirty, such as the monitoring and detection of radiological events, also pose a considerable threat to piloted aircraft.[62] The WC-135 fulfills current requirements for similar dirty missions; however these roles could easily be filled by unmanned assets.[63] Unmanned aircraft in a dirty environment eliminate the risk to human aircrews and allow persistent on-station collection, only jeopardizing the UAV. In the event of the actual employment of a nuclear or radiological device during conflict, unmanned assets would be much more suited to monitor the situation.[64]

Manned assets conducting reconnaissance and strike missions are also placed in a dangerous environment based on their relative proximity to the enemy.[65] Similar to dull and dirty missions, unmanned aircraft are the appropriate asset for extended operations in or near denied airspace.[66] While a complete shift from manned to unmanned systems is not necessary, missions associated with extensive vulnerability periods should be reserved for the UAS.[67] Yet, understanding the necessity for the employment of unmanned assets to accomplish dull, dirty, and dangerous missions requires a closer examination of the current roles of UAVs and UCAVs.

<u>UAVs</u>. Traditionally U.S. military services have employed unmanned assets to fulfill five ISR roles: brigade/division asset for Reconnaissance, Surveillance, and Target Acquisition; ship-borne asset for reconnaissance and weapon support; small unit asset for over-the-hill reconnaissance; survivable asset for strategic penetrating reconnaissance; and high altitude endurance asset for standoff reconnaissance.[68] These five variations can be further defined as fulfilling tactical and strategic service requirements. However, the five historical reconnaissance roles do not encompass all aspects of the requirements leveraged against unmanned combat support.

UCAVs. One of the first modern UASs to continuously and successfully accomplish every aspect of the military "kill chain" – find, fix, track, target, engage, and assess – was the U.S. Air Force's MQ-1 Predator.[69] Originally designed as an asset to fulfill a reconnaissance and surveillance role, the U.S. Air Force funded the research and development for modifications to the existing platform to execute emerging requirements. Building upon the success of the MQ-1, the Army developed the multi-purpose Improved-Gnat-Extended Range "Warrior Alpha" and the Air Force fielded the MQ-9 Reaper.[70]

The key is that these assets, the Warrior Alpha and Reaper, were created using an ISR framework; adding to the platform to create a multi-purpose/dual-role asset.[71] Now these unmanned ISR aircraft can conduct traditional fighter-bomber operations such as Armed Reconnaissance and Close Air Support (CAS), in conjunction with collection activities.[72] Although the additional weight of the UCAV's munitions reduces asset on-station times and overall endurance, the unmanned aircraft is still capable of accomplishing military reconnaissance and surveillance requirements.



*Manned versus Unmanned*

Historically and even today, U.S. combat air forces have heavily relied on manned assets and the precision of high-quality, high-resolution ISR sensor suites brought to bear by these aircraft. Legacy ISR platforms provide indispensable support to every aspect of the kill chain – identification, tracking, targeting, and battle damage assessment – despite a typical standoff collection posture.[73] The superb performance, reliability, and basic capabilities of manned platforms have created a unique ISR niche; performing functions unmatched by existing unmanned assets. However, UAVs and UCAVs have hammered out a place in global counterinsurgencies, supporting combatant commanders and war-fighters with unique characteristics. Unmanned systems supply enduring coverage for boots-on-ground operations, reconnaissance to support planning, and occasionally employ munitions. Essentially, both manned and unmanned aircraft perform distinct roles in fulfilling collection requirements, but are most effectively utilized cooperatively and collaboratively.

The Allure of the Unmanned Cockpit. Unmanned assets, historic and modern, have established a set of inherent advantages that appeal to both commanders and combatants. UAVs and UCAVs have demonstrated an ability that far exceeds human endurance, providing unmatched persistence and swift attack capabilities.[74] Remaining on-station well beyond the capacity of a manned system provides opportunities for system and customer to become intimately linked in mission execution. Removing the human factor from the aircraft equation also provides intrinsic options for increased levels of operational risk. The smaller and stealthier aspects of contemporary and emerging UASs would allow them to potentially slip into denied airspace and conduct vital missions with no threat to human life.[75] Even if detected, higher performance unmanned systems fielded in the next five to ten years could easily execute escape maneuvers that exceed human endurance and limitations.[76]

The Reality of Existing Requirements. The modern war-fighter's collection requirements often dictate the surveillance and reconnaissance asset employed in order to successfully satisfy the collect. The FMV and near-real-time downlink capabilities of the MQ-1 Predator and MQ-9 Reaper while integral in long-endurance constant stare operations, cannot fulfill the collection needs of a unit requesting high-resolution imagery of a target. Instead collection managers would likely seek to accomplish the tasking with the U-2 Dragon Lady.[77] The RQ-4 Global Hawk could be employed in this situation; however, as previously highlighted, unmanned platform sensors do not typically provide the same quality as the legacy Dragon Lady.[78] On the other hand, a ground commander's mission or air unit's operational success could hinge on specialized signals support. The logical choice for collection managers, if the asset is available, will be the U.S. Air Force's SIGINT workhorse – the Rivet Joint. The RC-135 V/W brings to bear an extensive sensor suite and operator support unmatched by any existing UAS.[79]

Combined Efforts. In effect, the successful application of ISR support throughout any combat environment is not a matter of manned versus unmanned assets. While both types of platforms provide unique advantages in fulfilling collection requirements, the synergistic approach of combining surveillance and reconnaissance capabilities is much more effective. Utilizing manned assets to locate and identify high-value or time critical targets, and then cross-cueing with a persistent unmanned asset will allow combatants to maintain continual situational awareness. Continuing through the kill chain, manned and unmanned assets can sustain development and tracking, easing the process of target engagement by a manned strike platform or UCAV.[80] The overall key to success is the appropriate application of suitable capabilities; using the right tool at the right time and maximizing the effectiveness of low density, high demand assets.[81] Emerging technologies may allow UAS capabilities to surpass those of their contemporary manned ISR counterparts in the next five to ten years; however, current advancements have also already created a divergence in UAS functions.[82]

*UAV versus UCAV*

Ultimately the payload carried by the UAV defines the true role of the aircraft.[83] The successful employment of munitions added another role to some historic and modern unmanned platforms such as the BGM-34A and MQ-1 Predator; contributing to the evolution of the

UCAV.[84] Other unmanned systems, like the MQ-9 Reaper and the multi-purpose Improved-Gnat-Extended Range "Warrior Alpha" were designed to fulfill the dual role of ISR support and combat strike aircraft.[85] The next evolutionary step in UAS development may very well be the emergence of a UCAV with the exclusive role of munitions employment; executing CAS, tactical engagements, deep strategic strikes, and potentially air superiority missions.[86] Based on these evolving characteristics there may eventually be an unmanned asset capable of supplementing or replacing manned aircraft throughout the U.S. military inventory.

Singular Focus. A true UAV, an unmanned asset with the singular purpose of conducting surveillance and reconnaissance, provides war-fighters with a dedicated intelligence collection capability. An unmanned aircraft equipped with FMV, electro-optical/infrared imagery, SAR/MTI, multi-spectral, or SIGINT sensor suites can essentially conduct operations throughout the entirety of the ISR spectrum.[87] Much like the U-2 Dragon Lady and RC-135 V/W Rivet Joint, an ISR UAV contributes to the capability of planners and operators to prepare the operational environment, sustain battlefield surveillance, engage in critical targeting, and conduct battle damage assessment.[88] The UAV also provides a platform and capability researchers can build upon, or give developers the flexibility to build an asset around a sensor suite without the constraints of weapons placement. However, UAVs cannot accomplish the engagement aspect of the kill chain, despite the inherent flexibility and persistence of these collection assets.

Multi-Purpose. On the other hand, current UCAVs are more than capable of finding, fixing, tracking, targeting, and engaging a target if necessary. The UCAV also possesses the means to conduct thorough battle damage and effects-based assessments following an engagement.[89] Manned aircraft traditionally performed this dual role of ISR and strike asset, prior to the inception of the armed UAS. Commonly referred to as non-traditional ISR (NTISR), fighters with an air-to-ground capability continue to be tasked to provide surveillance and reconnaissance support for identified or ad hoc targets.[90] If necessary, ground commanders can request support from an armed high-speed NTISR asset. The fact that the asset is already airborne makes the aircraft quite flexible and response times are drastically reduced. Manned NTISR is essentially much faster than contemporary UASs, and can also carry a payload that far exceeds the capabilities of even the largest UCAV, the MQ-9. Yet, the primary limitation associated with manned assets performing in a dual-role capacity is on-station times.

A Collaborative ISR Environment. Each unique category of unmanned asset performs a specialized role in the U.S. airborne arsenal. From the high resolution imagery of the RQ-4 Global Hawk to the battle-tested time critical target engagement of the MQ-1 Predator; the UAS has proven its worth tenfold.[91] Providing both over-the-hill surveillance for ground operations and strikes against critical targets with inhuman flexibility has made the UAV and UCAV a vital component of the current combat force.[92] Even so, the UAS is not a completely standalone capability, and requires a full complement of single and multi-function assets. Like the synergistic effects of cooperative manned and unmanned assets, the combination of UAV and UCAV capabilities is vital to the continued success of the UAS and U.S. military forces.

## The Future of the UAS

*In order to fully exploit the potential of UAVs, the Air Force must think of them as new and complete systems with new combinations of advantages and disadvantages, rather than as vehicles with a single outstanding characteristic or as a slight variant of an existing vehicle.*

*-USAF Scientific Advisory Board*
*UAV Technologies and Combat Operations*
*6 December 1996*

*A Way Ahead For Airborne ISR*

Given the continued military technological advances of adversarial global superpowers, such as Russia and China, operations conducted against nation-states will likely see emphasis remain on strategic theater asset employment; with the introduction of greater strategic capabilities and methods to combat an adversary's growing ability to counter U.S. collection efforts. However, in conflicts involving non-nation-states the future of airborne surveillance and reconnaissance will likely see a shift from a strategic collection concentration to theater and tactical assets in urban environments, given the persistent requisite support to low-tech engagements. The U.S. military will witness an increase in the use of NTISR assets as well as an increase in the number of UASs employed throughout the combat environment, with this move to theater and tactical coverage. Additionally, this paradigm shift will require greater interoperability and interaction between strategic, theater, and tactical manned and unmanned sensors.

<u>Surveillance and Reconnaissance in a Conventional Conflict</u>. Although the threat of a traditional force-on-force conflict like World War II does not seem to be a viable concern for the immediate future, the risk of such a clash may someday arise. For example, a clash involving Taiwan and China could potentially lead to conventional warfare.

The current infrastructure of the U.S. airborne ISR capability is in part the direct result of approximately 50 years of preparation to face the ultimate conventional adversary – the Former Soviet Union.[93] High-altitude, long range reconnaissance assets such as the U-2 Dragon Lady were designed and fielded to continuously monitor Soviet force build-up and order-of-battle changes.[94] Legacy ISR platforms remain viable contributors to the ongoing counterinsurgency operations in Iraq and Afghanistan. Additionally, unmanned assets such as the RQ-4 Global Hawk, which was developed to replace the U-2, have become a significant force multiplier contributing to the existing capabilities of manned platforms.[95]

Yet, gone are the days of long-established conventional warfare; created and tested on the battlefields of World War I, World War II, and Korea. The engagement of a new or existing conventional enemy would be considerably different from historical fielded force conflicts.[96] Years of documented warfare have provided excellent examples of U.S. tactics, techniques, and procedures. Like current U.S. adversaries, future opponents could potentially use these observations to adjust force capabilities to counter a once unique U.S. force capacity. These lessons learned combined with technological advancements, from countries such as Russia or China could help create a formidable adversary.

This paradigm shift will require U.S. ISR forces to once again focus on the surveillance and reconnaissance of conventional forces while maintaining the capacity to engage fluid non-traditional adversaries.[97] Manned ISR platforms such as the U-2 Dragon Lady and RC-135V/W Rivet Joint will continue to provide integral support to the war-fighter. However, with the re-emergence of a credible threat to these assets, manned collection tracks will transfer back to standoff positions.[98] Although this could potentially lead to a degradation of collection support by manned assets, continued improvements to platforms and sensor suites will likely counteract any significant impact. The most critical change will come in the form of increased collaboration between manned and unmanned ISR aircraft.

The UAS will fill the increasing gap in collection efforts in denied airspace, if manned ISR assets are forced to assume traditional roles.[99] Although tasked with accomplishing the most dangerous missions of a conventional conflict, unmanned systems will by no means be considered a disposable resource.[100] A high threat environment established by advanced surface-to-air and air-to-air adversarial capabilities will require distinctive flexibility and survivability in emerging UASs. Future UAVs and UCAVs utilized to find, fix, track, target, and possibly engage fielded forces will likely employ stealth or low-observable technology to facilitate operations in such environments.[101] These unmanned systems will also be required to maintain an unprecedented persistence and sensor suite in order to detect and track an enemy utilizing innovative denial and deception techniques.[102] Last, but certainly not least, the UAS in a re-emerging conventional engagement will need to possess the capability to deliver a more lethal payload.[103]



A Continuation of Unrestricted Warfare. Today low density, high demand ISR platforms are utilized extensively in combating the unrestricted warfare tactics of insurgent forces throughout Iraq and Afghanistan.[104] Legacy manned assets such the U-2 Dragon Lady and RC-135V/W Rivet Joint execute collection missions in over-flight tracks, taking advantage of uncontested air superiority over the battlefield and a previously unprecedented proximity to the fight.[105] High resolution imagery and improved accuracy in signals reporting are some of the added benefits of this immediacy to conflict. NTISR and UCAV assets also play an intimate role in supporting boots-on-ground operations and prosecuting time-sensitive targets.

Continuous direct support to ground operations throughout the entire kill chain – find, fix, track, target, engage, and assess – is an essential element for the conduct of successful operations in asymmetric warfare.[106] The strategic air-to-ground strikes carried out during the opening phases of conflict are important to the achievement of initial successes; however current counterinsurgency missions have transitioned to support for ground operations. Units such as the Army's Brigade Combat Teams (BCTs), a leaner more technologically dependent force, are currently conducting these operations. BCTs have also become much more reliant on the capabilities brought to bear by ISR assets, especially the UAS.[107]

Herein lies the most significant issue faced when engaged in asymmetric warfare; as previously indicated ISR assets, both manned and unmanned, provide low density capabilities.[108] While current UAVs and UCAVs are capable of conducting long airborne surveillance missions, beyond the limits of manned flights, there is a considerable intelligence collection gap in the counter-terrorism environment.[109] Even with additional support provided by flexible and versatile NTISR aircraft, there are clearly not enough surveillance and reconnaissance assets to satisfy every collection requirement submitted. The Army's response to this significant shortfall was to develop and field theater level UASs on par with the MQ-1 Predator – the Sky Warrior and Improved-Gnat-Extended Range "Warrior Alpha."[110] The intent of Army leadership was to create a UAS controlled by ground commanders, able to persistently support ground missions without being pulled for JFACC higher priority requirements.[111]

However, there is also an inherent problem with Army and Air Force ISR system interoperability. The Army has determined that the over-watch and collection support provided by the CAOC and corresponding manned and unmanned ISR assets were unresponsive and unreliable at best. The Sky Warrior and Warrior Alpha were designed to support the ground commander, but linking with the CAOC centralized control and a theater-wide communication system was not an immediate concern.[112] The Army has essentially fielded a divergent, yet redundant weapons system; contradictory to the Joint concept of Service interdependence – allowing each Service to minimize organic "redundant functions."[113]

This redundancy is actually a deterrent to continued progress and success in both conventional warfare and counterinsurgency.[114] The solution would be a Joint endeavor to maximize the strengths of service specific contributions. Such a construct would allow the Army to focus on the training and development of soldiers to support ground operations, as opposed to fielding a standalone organic UAS. An Army shift in battlefield concentration would also provide an opportunity for the Air Force to minimize the funding and effort committed to the deployment of Airmen to fulfill traditional Army combat roles. The Air Force could then refocus on the development and fielding of manned and unmanned ISR assets; intimately linked systems capable of satisfying Joint requirements.[115] More importantly, this reallocation of Air Force research and funding could lead to revolutionary transformation in contemporary and future UASs.[116]

*Future UAS Force Structure*

The separate and distinct UAS architectures of the U.S. Army and Air Force have succeeded in satisfying service specific requirements. However, as witnessed, interoperability and command and control issues have created a UAS fissure between the two Services.[117] As indicated, effective UAS transformation begins with establishing a joint way-ahead and infrastructure for future unmanned systems.

Two current methods employed by the DoD to manage ISR assets worldwide, including UASs, is the use of the Joint Functional Component Command for ISR (JFCC-ISR) and Secretary Gates' ISR Task Force (ISR-TF).[118] JFCC-ISR, a component of U.S. Strategic Command, is responsible for monitoring the employment of theater-level ISR globally.[119] Although this component has no direct control over the application of these critical assets, JFCC-ISR is responsible for providing recommendations to the Secretary of Defense concerning platform allocation.[120] The ISR-TF was established by the Secretary of Defense and tasked with the responsibility of thinking "outside-the-box" of ISR application and delivering innovative improvements to ISR programs.[121]

Despite the apparent benefits of an organization charged with examining the efficiency of global ISR application and a task force pioneering progressive ISR employment, the service ISR requirement split has not improved. The Army's bid to develop an unmanned organic capability has successfully fulfilled ground commander collection requirements; however Air Force officials portray the Army's method as redundant and cost ineffective.[122] Instead, the Air Force favors a "joint approach," consolidating service-wide UAS efforts under an UAS Executive Agent.[123]

<u>Joint Interdependence</u>. As U.S. military forces continue to engage non-state actors in Iraq and Afghanistan the demand for ISR support will expand exponentially; higher demand on low density assets.[124] Although the likelihood of achieving a UAS capacity to satisfy all collection requirements is improbable, the "sufficiency problem" is not a "lack of responsiveness".[125] The aforementioned divergent programs of the Army and Air Force, while satisfying respective service needs, stovepipe overall capabilities and split DoD UAS funding. The UAS Executive Agent will not eliminate existing UAS programs, but instead focus DoD

service-wide medium- and high-altitude UAV design, procurement, and employment efforts.[126] The executive agent will also allow the DoD to harness the synergistic affects of inter-service capabilities; building on the strengths of each individual service as opposed to developing duplicative programs. This proposal will create an environment in which U.S. military branches can hone service-specific core competencies, and rely on "sister Services to do the same".[127]

The DoD Executive Agent. The question remains, which U.S. military service is postured to effectively fulfill the role of UAS Executive Agent? Although the Army, Navy, Marine Corps, and Air Force have experience in the development and employment of medium- and high-altitude unmanned systems, the Air Force has been the lead in this realm for decades. The Air Force also possesses the means to operationally control current and planned UAVs operating in coordinated altitudes, as demonstrated by the capabilities of the CAOC.[128] The appointment of an Air Force Executive Agent would allow the Air Force to integrate interoperable systems during the programming and acquisition phases of future UASs. The expeditious delivery of usable intelligence to the war-fighter is another integral element in the future of the U.S. military UAS. The Air Force has successfully built and employed the most "robust ISR collection, processing, analysis, and dissemination architecture;" allowing the Service to stand alone as a leader in the overall intelligence cycle.[129] These elements combine to make the U.S. Air Force the most logical candidate for the role of UAS Executive Agent. However, no matter which Service is selected to lead the development of a new UAS architecture, there is no doubt that a new infrastructure design will also contribute to necessary changes in emerging UAS programs.

*The Potential Long Term Impact of the UAS*

UAVs and UCAVs will continue to perform missions considered to be too dull, dirty, or dangerous for manned aircraft. However, as can be expected, the historic employment of the UAS is not a definitive indicator of future unmanned asset roles in the operational environment.[130] Emerging technologies and an ever-changing combat environment will promote unmanned asset transformation, while the principle objectives of a UAS will remain the same – reduce the risk to human life and accomplish the mission. Emphasis will remain on filling gaps left by manned assets in both ISR and combat operations; supplementing collection efforts and providing critical over-watch for combat troops on the ground.[131] In addition to current requirements, future battle-space constraints and criteria will make upgrades to the UAS's persistence, payload, lethality, and stealth a necessary endeavor.

The Concept of Improved Persistence. In addition to flexibility and versatility, persistence is one of the three intrinsic attributes of air and space power employment.[132] Agencies like the Defense Advanced Research Projects Agency are focused on advancing UAS endurance; pushing the airframe beyond the realm of human stamina and survival. The Vulture program is an endeavor in which researchers have proposed the development of UAVs and UCAVs achieving on-station times of up to five years.[133]

The Vulture program proposed a high-altitude, self-sustained platform.[134] A "solar-powered fuel cell" would allow the aircraft to recharge fuel cells during the day and utilize power stored in these cells to conduct night-time operations. Depending on the sensor payload, a Vulture program UAS will essentially be a low orbit satellite, capable of extended persistent collection.[135] However, the sheer size and low speeds associated with the proposed propulsion systems will limit such an unmanned asset to standoff tracks or over-flight conducted in permissive environments.[136] Yet, the advent of a UAS capable of multi-year missions in the next five to ten years would transform the current understanding of flexibility and persistence despite such limitations.[137]

The "in-flight servicing model" is another approach to accomplish the feat of achieving on-station times measured in years versus the current limits of hours and days. This concept involves the development of assets capable of conducting unmanned air-to-air refueling and servicing.[138]

In the end, an extended on-station capability gives commanders throughout the area of responsibility an increased number of options compared to an asset with limited persistence, such as a manned platform.[139] As a result, emerging programs focused on extending unmanned asset endurance are a critical necessity in building an unmatched air and space combat capability. However, persistence is only a fraction of the equation in designing and fielding the next UAS, as increased payload and improved sensor capacity will facilitate enhanced support to the ground warrior.



Merging Sensor and Structure. War-fighter requirements for emerging UAVs will exponentially expand, as irregular combat continues to take hold. This will inevitably require the development and incorporation of larger technologically advanced sensors and an airframe design able to accommodate these new sensor suites. The proposed process is the integration of multiple intelligence sensor suites into the vehicle structure.[140]

The U.S. Air Force Research Laboratory is working with Northrop Grumman, Boeing, and Lockheed Martin to design a new UAS for the Sensor-Craft project.[141] Preliminary testing of airframe design has resulted in the identification of the ideal ISR platform infrastructure for a sensor-structure configuration – the flying wing and the joined wing aircraft.[142] Researchers have also begun construction and initial testing of a “honeycombed composite structure,” creating a vehicle of composite materials and integrated load-bearing flat-panel sensor arrays.[143] The composite design removes the necessity for a bulky sensor turret or other large sensor suites affixed to the exterior of the airframe. Additionally, with the flying and joined wing designs, developers can place imagery, SAR/MTI, and signal collection sensors along the top and bottom leading and trailing edges. The program concept will not only aid endurance and stealth, but also provide a unique integrated 360-degree sensor capability.[144]

Northrop Grumman (Figure 1), Boeing (Figure 2), and Lockheed Martin are currently developing prototypes for a UAS built from the ground up and designed around a sensor suite. The overall intent is to fill the role of an asset capable of providing battle-space information dominance through persistent deep-look, multi-functional, multi-intelligence ISR.[145] The project also focuses on shortening the “kill chain” and fulfilling the conventional needs of the war-fighter; finding hidden ground enemies and augmenting legacy manned and space-based ISR assets.[146] Once a contract is awarded and the UAS fielded, the Sensor-Craft aircraft will be a highly survivable, high-altitude, long-endurance unmanned vehicle able to provide a rapid response to worldwide contingencies.[147]

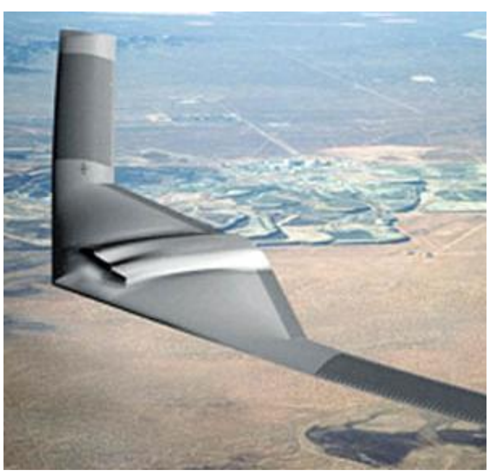

Figure 1. Northrop Grumman Sensor-Craft High Altitude Long Endurance UAV[148]

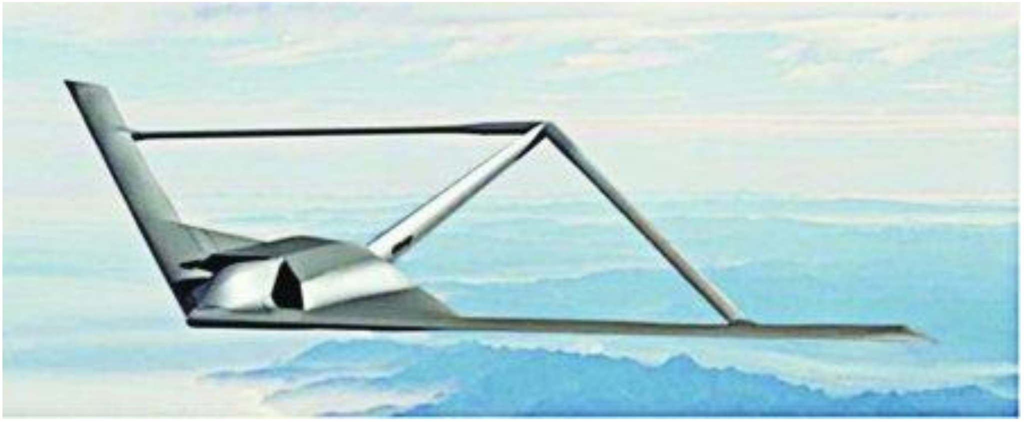

Figure 2. Boeing Sensor-Craft Autonomous Airborne Surveillance System[149]

Existing UASs with integrated payloads and sensor suites have essentially taken the first step in fulfilling present and future requirements of combatant commanders, ensuring the continued demand for specialized unmanned capabilities.[150] Similar to contemporary manned aircraft, future UASs must assume multiple specialized roles in the U.S. arsenal. Emerging technologies will allow for the development of integrated composite intelligence collection payloads, contributing to war-fighter situational awareness.[151] Additionally, advancements in unmanned airframes may lead to the creation of UCAVs focused solely on performing long range, long endurance strike missions.

<u>Building a Better Unmanned Strike Asset</u>. An aircraft's payload defines the operational role of each manned and unmanned airframe. Many airborne ISR platforms have traditionally been specialized assets, strictly focusing on reconnaissance and surveillance. However, UASs such as the MQ-1 Predator, MQ-9 Reaper, and Improved-Gnat-Extended Range "Warrior Alpha" have assumed a dual- or multi-purpose role becoming UCAVs.[152] UCAVs conduct operations similar to manned NTISR assets, flying into combat armed with both an ISR and

strike payload. The addition of a strike capability to such flexible and persistent assets ensures a continued need for unmanned systems.

Merging endurance and armament allows UCAVs to accomplish every step in the kill chain; from identifying a high-value individual to putting bombs-on-target. However, as warfare continues to evolve combatant commanders will require the persistence of a UAS, the speed and maneuverability of a modern fighter, the sensor suite of a manned ISR asset, and the payload of a bomber.[153]

While current UCAVs are quite competent in environments which lack significant anti-aircraft threats, their inherent vulnerabilities would make them ineffective against layered air defenses.[154] However, several models are being designed and tested to create the "unprecedented long-range hunter-killer capabilities" to fill this unique role.[155] Two approaches focus on improving the survivability and lethality of unmanned assets. These concepts involve the construction of large B-2-like strike assets and the development of airframes and algorithms to employ swarms of autonomous and semi-autonomous UASs.[156]

The Sensor-Craft program could potentially be adapted to produce a UCAV capable of long-range, long-endurance strike missions. Combining the reduced weight of the "honeycombed composite structure" and limiting the collection capability of the asset would provide a means to incorporate internal weapons stores and applicable deployment mechanisms.[157] Additionally, making use of the proposed Sensor-Craft size, the new UCAV could carry a significant strike payload; incorporating surveillance and precision engagement.[158] A UCAV designed with these aspects could maintain a high-speed stealth capability, much like the F-22 Raptor and F-35 Joint Strike Fighter, and deliver a package on par with current precision bombers.[159] Yet, research for the development of an improved UCAV does not focus solely on designing an enormous long-endurance strategic strike capability.

There is also growing interest amongst the United State's leading research institutions to harness and apply a unique insect-like behavior in next-generation UAVs and UCAVs. Researchers are attempting to employ the power of swarming to conduct ISR and strike missions.[160] The innovative application of swarming in the unmanned realm will basically allow numerous inexpensive UAVs and UCAVs to operate autonomously or semi-autonomously.[161] Also, unlike other ground-breaking unmanned concepts the focus is on the development of software and computing power as opposed to platform design.[162]

Organizations such as Boeing's Phantom Works, the U.S. Army's Unmanned Autonomous Collaborative Operations Program, the US Navy's Surface Warfare Center, and the U.S. Air Force Research Laboratory are working to create the computing systems necessary to develop artificial intelligence and achieve swarming.[163] Artificial intelligence will not only aid research endeavors to attain UAS teaming, but such revolutionary software developments will also contribute to system autonomy. DoD research laboratories have identified 10 levels of UAS autonomy; beginning with "remotely guided" systems and culminating in "fully autonomous swarms" (see Figure 3).[164]

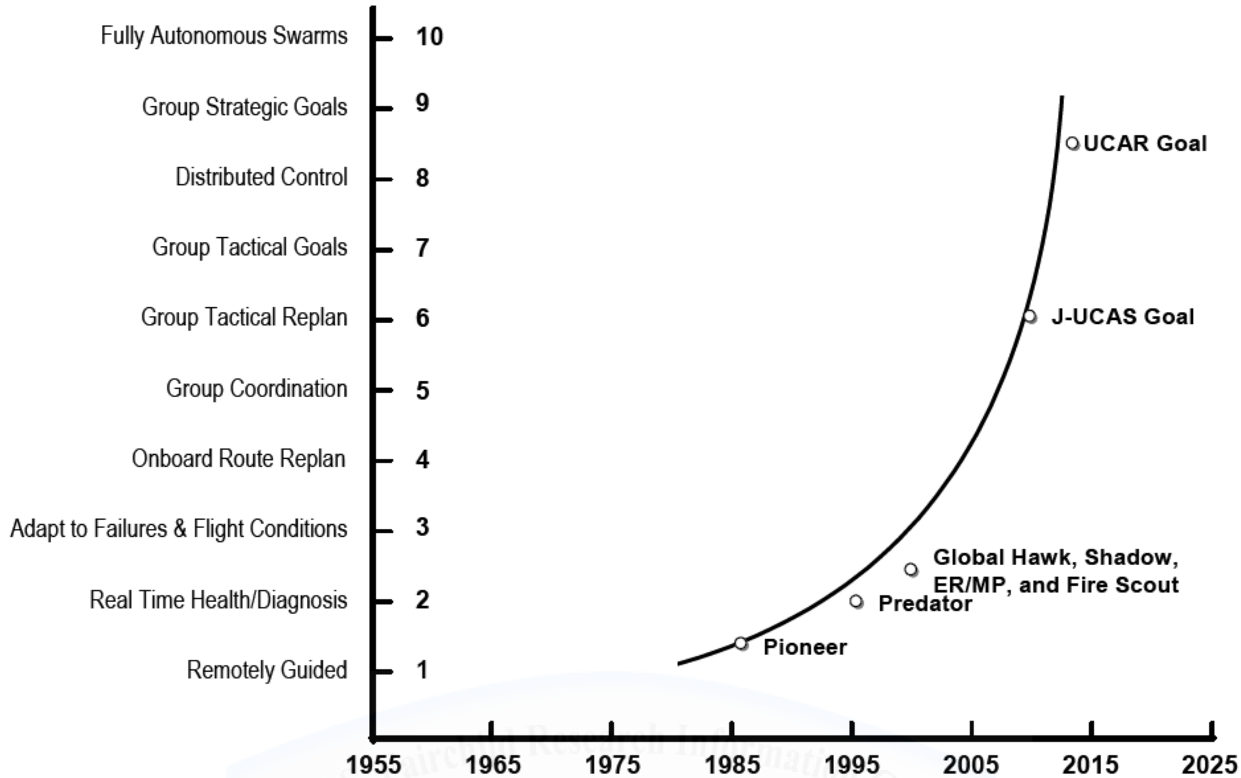


Figure 3. Trend in UAS Autonomy[165]



Computer algorithms may someday not only remove the human from the cockpit, but also from the intuitive interpretations and calculations of mission execution.[166] This capability for cognitive reasoning – conducting autonomous or semi-autonomous operations – in turn helps reduce human operator transmissions and relieves the strain placed on current bandwidth requirements.[167]

Two schools of thought currently exist on the development of algorithms that mimic the collaborative performance of insects. The first focuses on the formulation and testing of "cooperative behavior" algorithms; a system involving course of action trees and the subsequent weighting and ranking of decisions.[168] These algorithms will help aircraft to collectively process images and environmental changes to make autonomous decisions based on swarm judgment, similar to the architecture of the right hemisphere of the brain.[169] The other method involves the development of software-based pheromones; borrowing from the genetic behaviors employed by ants and termites.[170] UAVs and UCAVs employing this theoretical technique can essentially mark coverage areas and targets with "digital pheromones."[171]

Both concepts are being designed to allow relatively inexpensive unmanned aircraft to cue other assets within the swarm; acting and reacting to develop a group strategy based on changes in continuously evolving combat environments. The swarm will be able to identify, track, and possibly engage potential targets; operating and making effect contributions to strategic and tactical operations throughout the entire kill chain with limited human interaction.[172]

The increasing lethality of UASs and ground commanders' reliance on the flexibility of these systems makes the combined ISR and strike capabilities of the UCAV the perfect match for an evolving combat environment. Based on this proven capability, the continued research and design of an armed UAS is an absolute necessity. Increased lethality through UAS development will be vital to future war-fighters; yet detection minimization is another critical factor for future unmanned systems.

<u>A New Stealth Capability</u>. While existing UAVs and UCAVs do not employ manned asset stealth features, unmanned assets do possess an inherent low observable characteristic based primarily on size, with a few exceptions.[173] Stealth, coupled with the maneuverability of smaller agile unmanned airframes, contributes to the overall survivability of the UAS in hostile environments.[174]

Although there are presently no UAS programs focused solely on the manufacture and fielding of stealth or low-observable airframes, these aspects are being incorporated into multiple proposed UAV and UCAV assets. The concept of incorporating stealth into an unmanned program would allow decision makers and war-fighters to conduct ISR and strike operations in denied airspace with no threat to a manned asset.[175] The airframe design of choice for low-observable UAVs and UCAVs is the flying wing, similar to that of the B-2. By utilizing such a design researchers can successfully develop an unmanned asset with a reduced radar cross-section, capable of operating in "complex air defense environments."[176]

Building a UAV or UCAV from the ground up with a stealth capacity will provide a means to design an asset capable of conducting missions throughout all three distinct segments of ISR and combat operations – standoff, over-flight, and denied.[177] Operating in a standoff capacity, recognizing and maintaining the sovereignty of another country's airspace, can be carried out by manned and unmanned assets alike. On the other hand, a stealth UAS would be more suitable than a manned platform when tasked to perform operations within sovereign airspace – over-flight – or within airspace with a credible enemy threat – denied.[178] An unmanned asset equipped with a true "stealth" or low observable capacity will significantly contribute to the operational requirements of future combatants.

With a demonstrated success rate, the dependence and confidence of commanders throughout the combat environment will facilitate the revolutionary development of new and improved unmanned capabilities. Furthermore, the continuous improvements to the persistence, payload, lethality, and stealth of unmanned systems will once again revolutionize UAS contributions to counter-land warfare.[179]

## Conclusion

Since the inception of unmanned airborne platforms, pilotless aircraft have offered combatant commanders and war-fighters a unique set of force employment capabilities. Whether utilized to reduce the risk to human life or to maintain an inhuman constant operational over-watch, the UAS has secured a place in the U.S. military arsenal. However, the force multiplying aspects of the UAV and UCAV cannot be allowed to stagnate. The continued development of new ISR UAS technologies is essential to securing information superiority and maintaining persistent presence over future battlefields.[180] Subject matter experts throughout the Intelligence Community have identified a need for capability improvements and occasionally the complete replacement of contemporary ISR manned and unmanned airframes. The principal driving factors behind the need for UAS transformation are the new requirements leveraged against collection and strike assets as a result of the altered face of modern and future combat.

Although collection assets have traditionally provided low density, high demand capabilities, the distinct characteristics of unrestricted warfare have created an ideal combat environment for the advent of the unmanned system.[181] War without rules has been a tactic employed throughout history by technologically or numerically inferior state and non-state actors.[182] As U.S. adversaries continue to embrace the transition from large fielded force engagements to irregular warfare, the requirement for continued UAS technological advancement emerges as a critical necessity. Force structure and capabilities must transform to meet the demands presented by a fluid security environment. Focusing on these new requirements will allow U.S. research and development institutions to overcome the emerging capabilities of U.S. adversaries. Yet, the United States cannot forgo the development of unmanned systems also capable of countering a conventional threat.

In order to respond to both warfare requirements the UAS will continue to witness evolutionary and revolutionary transformation. The capabilities of the contemporary UAV and UCAV evolved with the transition of the RQ-1 to the MQ-1 Predator, by simply adding a strike payload to an existing platform.[183] The modern UAS then took a ground-breaking step in counterinsurgency operations, facilitated by the emergence of new technologies such as the MQ-9 Reaper.[184] Through the success of the UAS in Iraq and Afghanistan, unmanned platforms have proven the competence of the UAV and UCAV in long-established manned collection and strike roles.

As the role of the UAS continues to mature there is more emphasis placed on existing and emerging systems to perform multi-role and more complex missions.[185] Although contemporary UAVs and UCAVs can already outperform modern ISR and strike manned airframes with regards to unrefueled on-station capacity, research has turned to the development capabilities to aid persistence.[186] UAS capability advancements will also lead to the introduction of a more capable and lethal unmanned airborne military assets. Additionally, improvements to the inherent stealth capability will allow UASs to continue unhindered operations in an unrestricted environment, and possibly create a platform capable of deep penetration collection and strike in denied airspace.[187]

## Recommendations

*UAS Executive Agent*

The low density, high demand status of the DoD's ISR arsenal has contributed to an apparent lack of responsiveness to Army collection requirements.[188] As a result the Army developed a flexible Predator-like unmanned asset with a limited mission-set – the multi-purpose Improved-Gnat-Extended Range "Warrior Alpha" – in order to fill this critical gap in the ISR support to the technologically dependent BCT.[189] The U.S. Army also succeeded in establishing a distinct and disconnected program focused on the continued development of future Army UASs. Yet, this divergent pursuit of separate service-specific medium- and high-altitude unmanned systems is one of the greatest deficiencies in DoD UAS programs.[190]

Although JFCC-ISR is tasked to monitor the employment of theater-ISR globally and subsequently provide applicable allocation recommendations to the Secretary of Defense, their visibility does not include the design and use of embedded UAVs and UCAVs.[191] In order to resolve this inefficient application of resources the DoD should create a centralized agency responsible for the research, development, and subsequent fielding of emerging unmanned programs. The UAS Executive Agent will focus DoD efforts in the realm of the UAS; promoting the concept of joint interdependence.[192] While the service component selected to fill this role is not as important as establishing the office, the Air Force remains the logical choice for the UAS Executive Agent; based on the robust UAS architecture this Service possesses.[193]

*Building the Future of ISR*

The future of U.S. military ISR depends on the capitalization of existing manned and unmanned assets, while focusing on the development of new capabilities. The United States is engaged in conflict with an enemy that takes advantage of a fluid combat environment, and the potential for an emerging state-sponsored adversary continues to be a looming threat.[194] In order to counter current and future enemies the United States must maintain a force structure commensurate with the threat. This requires a dedication to the research and development of military force capabilities that will allow U.S. war-fighters to retain a technological advantage.

The DoD must continue funding the exploration of new UAS platforms and capabilities in order to retain this advantage. While the continued development of manned strike, ISR, and multi-role assets is vital to force capabilities; emerging unmanned technology will provide an unprecedented complimentary benefit. Fielding modular systems for contemporary unmanned assets and new UAVs and UCAVs with improved capacities will deliver a distinct and often unmatched capability for the modern war-fighter. Additionally, the anticipated success of Sensor-Craft or Swarming programs will expand the boundaries of unmanned flight, and open the door for future projects.[195]

Ultimately changes to the UAS force structure, persistence, sensor suites, lethality, and stealth will lead to a revolutionary transformation of unmanned U.S. capabilities. However, despite the potential advantages brought to bear by these new capabilities, the UAV and UCAV are not intended as a replacement for manned ISR and strike systems. While current pilotless airframes continue to reduce the risk to human life, remote piloting also removes human intuition and adaptability from the equation, making the UAS more susceptible to environmental changes. With this in mind, the best course of action is the incorporation of UAVs and UCAVs into current and future force structures. In the end, the UAS will best serve the DoD in a complimentary role to manned systems; continuing to fulfill the primary task of performing "dull, dirty, and dangerous" missions.[196]

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