2005

The U.S. Air Force Remotely Piloted Aircraft and Unmanned Aerial Vehicle Strategic Vision

U.S. Air Force

The U.S. Air Force Remotely Piloted Aircraft and Unmanned Aerial Vehicle Strategic Vision

2005

THIS PAGE INTENTIONALLY LEFT BLANK

Table of Contents

* The terms RPA (Remotely Piloted Aircraft) and UAV (Unmanned Aerial Vehicle) are utilized in this document; however, these terms continue to evolve as joint doctrine is established (see Section V).

Figures

Executive Summary

The U.S. Air Force Remotely Piloted Aircraft and Unmanned Aerial Vehicle Strategic Vision (hereafter referred to as *The Strategic Vision*) examines the future role of Air Force remotely piloted aircraft (RPAs) and unmanned aerial vehicles (UAVs) and their integration with other Air Force and joint systems. *The Strategic Vision* is presented in five sections.

Section I presents an overview of the modern history of RPA and UAV development to provide context for the current situation.

Section II describes the current convergence of factors that make RPAs and UAVs attractive investments today.

Section III examines the RPA and UAV attributes that make RPAs and UAVs effective platforms for various missions. Attributes such as persistence and versatility contribute to highly capable systems improving the way we currently operate and allow us to do things previously impossible or impractical.

Section IV outlines some of the challenges facing RPA and UAV developers, operators, and planners. These challenges include budgetary constraints, training and organizational issues, and policy and legal issues. Section IV also suggests methods for addressing these challenges.

Section V describes the strategic vision of integrated RPAs and UAVs contributing to a more effective and efficient fighting force, and presents a series of recommendations to guide the development and integration of Air Force RPAs and UAVs into Air Force and joint plans, operations, and capabilities over the next 20-25 years. Recommendations include:

- The Air Force must work with the Department of Defense, Federal Aviation Administration, International Civil Aviation Organization, and other organizations to develop common definitions regarding unmanned systems.
- Unmanned systems must be robustly integrated with manned and space systems. They must also be integrated with other unmanned systems, including ground- and sea-based systems.
- Military RPAs and UAVs must operate in national and international airspace to ensure seamless integration.
- The Air Force and DoD must continue to fund research and development to provide the scientific foundation for technological advances.
- The Air Force must fund research and development for effective human-machine interfacing as a critical part of a UAV ground segment architecture.
- The Air Force must recognize that traditional cost metrics for manned aircraft do not account for the on- and off-board requirements unique to unmanned systems and must work with sister Services, the U.S. Special Operations Command (USSOCOM), and allies to mitigate such costs.
- The Air Force must review doctrine, procedures, policies, and legal requirements to determine how unmanned systems fit into the existing framework.

Because the above recommendations involve collaboration with organizations external to the Air Force, implementation will require an overarching organization responsible for integrating and synchronizing RPA and UAV efforts across DoD communities.

Introduction

Over the past decade, remotely piloted aircraft (RPAs) and unmanned aerial vehicles (UAVs) have proven their worth in operations around the world.[1] The Air Force and the Department of Defense (DoD) are working to increase the capabilities of existing unmanned systems and to develop new systems with improved capabilities. To this end, Air Force efforts are consistent with the Air Force Concepts of Operations (CONOPS) and the Air Force Transformation Flight Plan.

The creation of *The U.S. Air Force Remotely Piloted Aircraft and Unmanned Aerial Vehicle Strategic Vision* (hereafter referred to as *The Strategic Vision*) was recommended in the Air Force's *Future Capabilities Game 2004 Final Report* and approved by General John Jumper, then Chief of Staff of the Air Force. Its purposes are to describe the current RPA and UAV development in historic context; to describe the major challenges facing RPA and UAV developers, operators, and policy-makers; to make recommendations for overcoming those challenges; and to describe the path forward for development of Air Force RPAs and UAVs and their integration into Air Force, joint, and coalition plans, operations, and capabilities over the next 20-25 years.

The scope of *The Strategic Vision* is broad, including small and micro systems, medium to large systems (both armed and unarmed), fixed- and rotary-wing aircraft, and lighter-than-air and near-space[2] systems. However, this document does not attempt to resolve the myriad of issues associated with such disparate systems, but instead lays out a broad strategy for addressing issues as they arise.

Compilation of *The Strategic Vision* involved a thorough review of many of the war games and RPA and UAV studies conducted over the past few years. The process also included extensive discussion with representatives of the Air Force, sister Services, the Defense Advanced Research Projects Agency (DARPA), the Office of the Secretary of Defense (OSD), and industry.

Section I: Historic Context[3]

Over the past 50 years, the U.S. military has tested and employed numerous RPA and UAV systems with varying degrees of success. The first operationally significant Air Force UAV program was the Lightning Bug, which was based on a target drone. The Lightning Bug was used for tactical reconnaissance and flew nearly 3,500 sorties during the Vietnam War. In the 1960s and 1970s, the Air Force attempted to identify the proper application for other RPAs and UAVs. Some programs, such as the D-21 Tagboard/Senior Bowl program, suffered from cost overruns, test failures, and unchecked requirements growth ("mission creep"). Other programs, including Compass Arrow, failed to find missions in the face of changing political situations. Specifically, detente with the Soviet Union and rapprochement with China made U.S. leaders reluctant to allow reconnaissance overflights of those countries. Also, the emergence of surveillance satellites with near real-time capabilities overshadowed air-breathing collection platforms (manned or unmanned) at a time when persistence was not yet the driving factor in reconnaissance operations.

After the Vietnam War, the United States reduced spending on RPAs and UAVs and defense in general. In the late 1970s and early 1980s, there were practically no major Air Force RPA or UAV programs. A turning point came in the early 1980s as Israel successfully deployed a number of different unmanned systems that had been developed in the 1970s. The watershed moment came in the Bekaa Valley in Lebanon in 1982. In a carefully planned and coordinated operation, Israeli forces used unmanned systems to provide intelligence, surveillance, and reconnaissance (ISR) and to activate Syrian air defense systems, allowing manned aircraft and surface-to-surface missiles to destroy the air defenses.

After the Bekaa Valley campaign, the United States began to purchase Israeli unmanned systems, such as the Pioneer, and to develop new systems. The RQ-1 Predator ("Predator A") was developed as a joint program managed by the Navy and operationally run by the Army, with manning provided by all Services.[4] The Air Force took operational control of the program in 1996 and forward deployed the system to the Balkans as an ISR platform. Between 1996 and 2004, the RQ-1 Predator system evolved into a formidable combat support asset and was involved in every major military operation. It logged nearly 100,000 flight hours, with 68% of those hours flown in operational environments. The MQ-1 Predator, armed with the AGM-114 Hellfire missile continues to be one of the military's most requested systems, assisting in the execution of the global war on terror by finding, fixing, tracking, targeting, engaging, and assessing suspected terrorist locations.

Since its first flight in 1998, the RQ-4 Global Hawk has flown more than 7,000 hours. More than half of those hours were logged during combat operations in Afghanistan and Iraq. During Operation ENDURING FREEDOM, General Tommy Franks, Commander, U.S. Central Command, said:

> … Global Hawk unmanned aerial vehicles have been proven to be invaluable in providing long dwell surveillance, tracking, positive identification, and collateral and strike damage assessment. … Global Hawk, for example, flew sorties approaching 30 hours in duration and imaged over 600 targets during a single mission over Afghanistan.[5]

In Operation IRAQI FREEDOM (OIF), Global Hawk was given a chance to showcase new concepts in time-sensitive targeting with ISR assets. Although the U-2 had employed these concepts in 1999 in Kosovo, it was the Global Hawk's "unmanned" attribute that allowed its employment in the OIF missile engagement zone during combat operations. As a result, even though Global Hawk flew only 5% of the OIF high-altitude missions, it accounted for 55% of the time-sensitive targeting against enemy air defense equipment.[6]

Small UAVs, including Raven, Pointer, and the Force Protection Aerial Surveillance System (FPASS) played important roles in both Afghanistan and Iraq. These man-portable, low-altitude, short-range systems assisted in providing base security, force protection, reconnaissance, and targeting. Small UAVs are rapidly growing in type and offer a versatile family of capabilities.

From 1954 through 1999, the Services spent nearly $21 billion on major RPA and UAV programs.[7] As Figure 1 illustrates, the vast majority of the funding went to Air Force programs.[8]

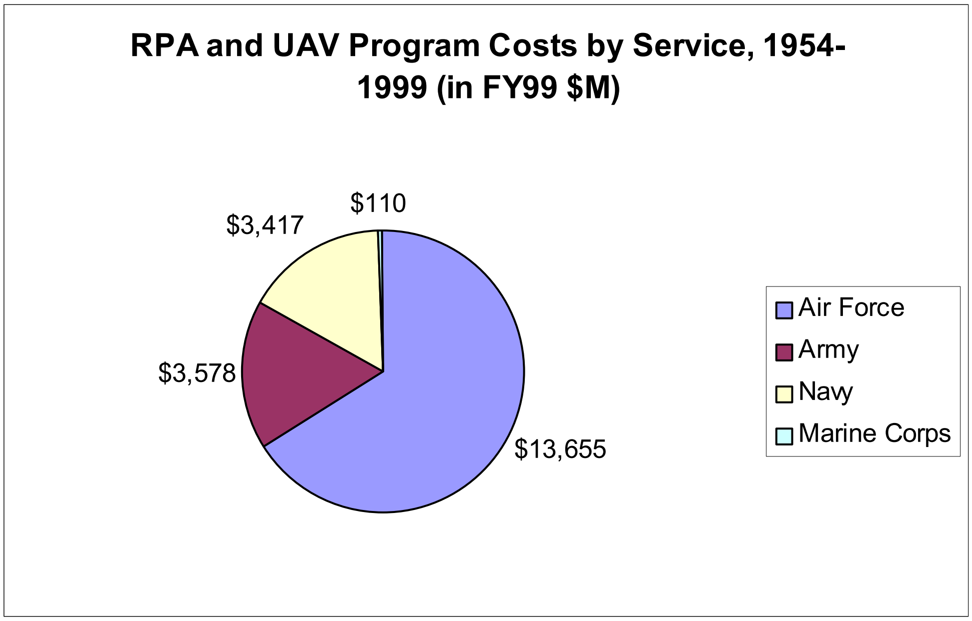

Figure 1. RPA and UAV Program Costs By Service

(Source: *Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation*, Colonel Thomas P. Ehrhard, June 2000)

Total DoD spending on RPA and UAV programs over the 1954-1999 timeframe averaged less than $500 million per year, and Air Force spending from 1962 through 1999 averaged slightly more than $350 million per year.[9] However, as shown in Figures 2 and 3, DoD and Air Force spending was uneven from year to year.[10]

In the 1990s, DoD spent more than $3 billion on RPA and UAV development, procurement, and operations. It is likely DoD will spend more than three times that amount in this decade.[11] Today, MQ-1 Predator, RQ-4 Global Hawk, and small UAVs are receiving sustained Air Force investment.[12] The Air Force is investing in new systems such as the MQ-9[13] and near-space systems and continues to develop a family of small unmanned systems to augment its successful larger RPA programs. On 5 July 2005, the Joint Requirements Oversight Council (JROC) established a jointly-manned organization named the Joint UAV Center of Excellence (JCOE) at Creech Air Force Base, Indian Springs, Nevada. Additionally, the Air Force plans to field an unmanned combat air vehicle (UCAV) in the next decade.

Similarly, other Services and the U.S. Special Operations Command (USSOCOM) are increasing funding for unmanned systems.[14] The Navy is assessing fixed-wing and rotary-wing RPAs and UAVs for fleet defense, reconnaissance, and broad-area maritime surveillance. A family of RPAs and UAVs is a major component of the Army Future Combat System, and USSOCOM and the Marine Corps are increasing their development, procurement, and employment of various small UAVs.

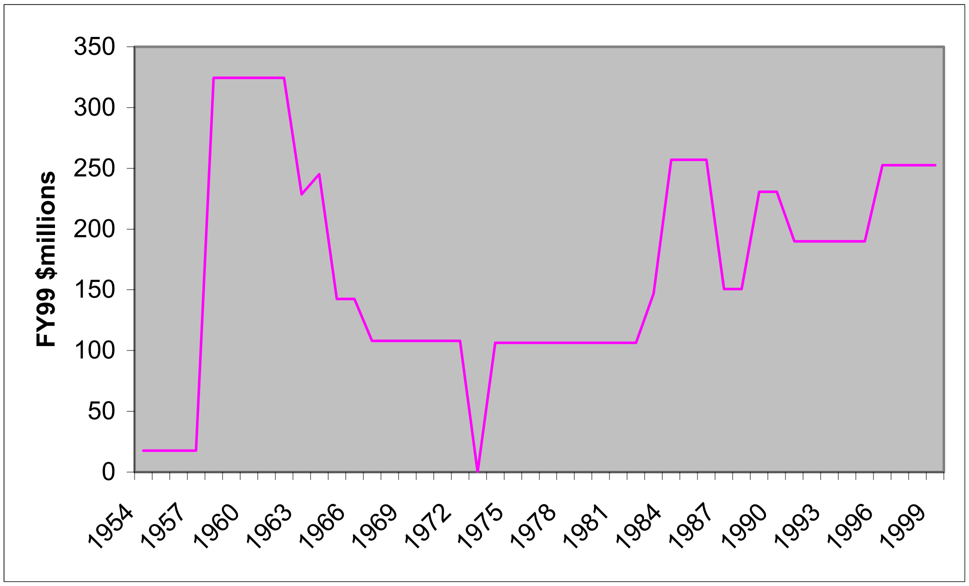

Figure 2. Major Non-USAF RPA and UAV Programs

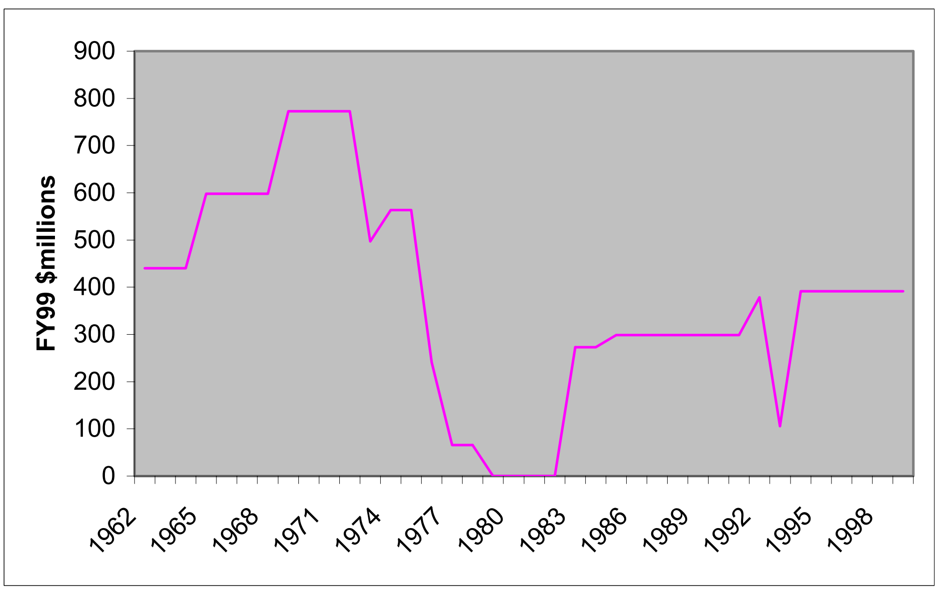

Figure 3. Major USAF RPA and UAV Programs

(Source: *Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation*, Colonel Thomas P. Ehrhard, June 2000)

Finally, the Air Force is supporting key allied and foreign partner requirements for RPA capabilities, with coalition interoperability as a baseline effect. In addition to fielded MQ-1 systems in Italy and United Kingdom personnel supporting MQ-1 operations at Creech Air Force Base, the Air Force is partnering with the German Air Force for an RQ-4 “Euro Hawk” capability and is assessing the requirements for high altitude, long endurance RPA capabilities in the Pacific Area of Operations.

In addition to the standard military uses[15] of RPAs and UAVs, there are many other potential uses for these systems. Such missions include special operations, homeland defense (including border patrol, anti-drug warfare, chemical, biological, and radiological detection, and maritime vessel identification and interdiction), civilian search and rescue, airborne telemetry collection and relay, point-to-point cargo delivery, weather data collection, environmental monitoring and other scientific research, and national/international emergency management.

Section II: RPAs and UAVs Today

The Air Force now has a unique opportunity to build on the recent successes in the Balkans, Afghanistan, and Iraq. Three major factors combine to make unmanned systems more attractive and feasible now than ever before.

First, technological advances provide significant leverage. New sensor and weapon payloads are smaller, lighter, and more capable, providing great capability per unit of weight. New data links, traditionally the Achilles heel of unmanned systems, can provide high-bandwidth connectivity for vehicle command and control, payload command and control, and data transfer.[16] Advances in microprocessor technology, software development, inertial navigation, and global positioning systems enable robust autonomous flight control systems and onboard processing of sensor data. New composite materials and improved propulsion systems result in lighter, smaller, and more stealthy airframes, with the resulting fuel efficiency leading to levels of endurance that exceed human tolerance.

Second, the diverse, ever-changing global situation presents unique opportunities for unmanned systems. As stated by the Defense Science Board, "UAVs are ideal systems to support the emerging joint character and the asymmetric nature of warfare."[17] Unmanned systems can operate in environments contaminated by chemical, biological, or radioactive agents. They can also operate in other environments denied to manned systems, such as altitudes both lower and higher than those typically traversed by manned aircraft. The long endurance of some RPAs and UAVs provides sustained support for more efficient time-critical targeting and other missions requiring greater persistence than that provided by manned aircraft or passing space systems.[18] Small UAVs provide a unique capability to get close to a target and provide the "bird's eye view." Their small size, quiet propulsion systems, and ability to feed information directly to Battlefield Airmen enhance the combat effectiveness of our forces.

Third, the attributes of RPAs and UAVs enable new CONOPS and advantages. Lessons learned from recent experience point the way to CONOPS that, to some extent, have already brought advantages to the Air Force and Combatant Commanders. Aircraft with endurance that exceeds human limitations bring persistent surveillance at reduced sortie levels.[19] Fewer flight hours are "lost" due to transit time otherwise needed by shorter range/endurance aircraft. Also, fewer take offs and landings mean reduced wear and tear and exposure to historic risks of mishaps. Ground crew operating tempos benefit from the reduced sortie generation. The ability to operate in distant theaters with ground stations at U.S. garrison bases, allows many crews to fly operational missions without deploying forward. This, in turn, reduces forward logistical footprints, support costs, and demands on force-protection assets and personnel. Crew duty periods become irrelevant to aircraft endurance, because crew changes can be made based on optimum periods of sustained human performance and attention. Fewer deployments reduce family stress and mean better retention of highly trained crews, thus reducing demand to train and develop new crews.

The advantages provided by high-endurance unmanned aviation cannot be fully reflected in aircraft unit costs. However, those advantages enable a future where counter-air operations, similar to Operations DENY FLIGHT, NORTHERN WATCH, SOUTHERN WATCH, and NOBLE EAGLE may quite conceivably be supported by crews, operational staffs, and Combined Air Operation Centers that substantially remain in either the United States or established headquarters far away from the point of intended operational effects. As the Air Force focuses on developing more sophisticated UAVs dedicated to air-to-ground strike missions, this will mark another step toward just such a capability.

It is important to keep in mind that, despite decades of experience with RPAs and UAVs, the Air Force is still in the early stages of exploiting their full potential. Arming the RQ-1 Predator with Hellfire missiles can be compared to the mounting of guns on biplanes early in the last century. Feeding live video from an MQ-1 Predator to a manned AC-130 gunship provides a narrow glimpse of the capabilities that net-centric operations can provide. Systems such as the MQ-1 Predator and RQ-4 Global Hawk that have 15 to 30 hours of endurance, considered to be "persistent" today, are but the first step in a path that may lead to increases in endurance by orders of magnitude.

We must not lose sight of the fact that DoD planning is based on capabilities and effects, not platforms. The unmanned attribute of RPAs and UAVs is neither a capability nor an effect. By using capabilities-based planning for effects-based operations, we can determine which mission areas are most appropriate for unmanned systems.

Section III: RPA and UAV Attributes

Persistent, Penetrating, Proximate

Some unmanned systems are able to loiter for extended periods of time, requiring breaks only for refueling and routine or emergency maintenance. Like manned aircraft, future RPAs and UAVs may use stealth characteristics and defensive measures to penetrate hostile airspace, loiter as long as fuel permits, leave the hostile airspace to refuel, and then return. However, unmanned systems will have much greater endurance than manned aircraft. This extended endurance results from significant advances in propulsion and aerodynamics; designers of manned aircraft have historically accepted trade-offs in these areas, because human pilots cannot take advantage of extended time aloft.

Persistence is enabled by a number of technologies. Fuel-efficient engines and airframes can be designed without regard to human factors limitations; the space and weight normally allocated to on-board aircrew and life support systems can now be made available for more payload and/or fuel, or they can be traded in order to design a smaller vehicle. Autonomous in-flight refueling, potentially with unmanned tankers, and advanced power sources will allow for increased endurance. Combined, these technologies could lead to systems, such as lighter-than-air and near-space vehicles, with endurance measured in weeks, months, or even years.

This level of endurance will change the way the Air Force plans and conducts missions. Multi-mission RPAs and UAVs will work in conjunction with manned and space systems to provide continuous coverage of an adversary's activity – and instant response. This synergistic integration will result in persistent dominance over a defined area, allowing us to shape, affect, and influence an adversary's actions.

The absence of on-board aircrew mitigates the historic limitations of aircrew fatigue.[20] Unmanned systems can combine advanced sensors, human-machine interfaces, machine-to-machine integration, and communication architectures on long-loitering platforms capable of dynamic retasking. There is the potential in the future for one human to manage many vehicles. This capability will be dependent on advances in automation, human-machine interfaces, airspace integration policies, and manning policies. Advances in these areas may help offset any decrease in situational awareness that may result from the lack of an on-board pilot, with Human Systems Integration being a key component to increasing total system performance.

RPAs and UAVs operate at a variety of altitudes and can contribute to persistence and redundancy by participating in a layered sub-surface, surface, airborne, near-space, and space-based ISR and communication relay network. In the near term, the persistence and flexibility of unmanned systems can contribute to blue force tracking. In the future, RPAs and UAVs will also assist in combat identification of neutral forces, adversary forces, and noncombatants. This layered network can back up and augment terrestrial and space-based communication systems.

Some unmanned systems will be ideally suited to penetrate an adversary's defenses, get close to targets, and, possibly, attach themselves to those targets. Small UAVs have great unrealized potential in this area. By taking advantage of their small size, increased maneuverability, and low-altitude flight, small UAVs can assist in defeating camouflage, concealment, and deception techniques to locate and identify targets.

Integrated, Interdependent

Unmanned systems are coming of age in an era of data networking, and they are taking full advantage of this technology. Numerous studies have indicated net-centric command, control, and battle management is crucial for the success of RPAs and UAVs.[21] Net-centric operations enable RPAs, UAVs, and networked munitions to conduct missions more effectively and increase the effectiveness of manned and space platforms. To realize the full potential of net-centric operations, network protocols and platforms must be compatible with an information-based approach to systems development and must deliver security, interoperability, supportability, sustainability, and usability.

Using a net-centric approach, command and control of unmanned vehicles and their payloads can be conducted in ground-, sea-, or air-based command centers remotely via communication links. Additionally, sensor information can be separated from aircraft command links, allowing sensor data to flow directly to distributed analysts, decision-makers, and global customers. This construct has the potential to free the platform from bandwidth constraints normally associated with the legacy data link constructs ("stovepipes") that required raw information to pass through a proprietary ground control station before processed data is distributed to end users.[22] It also facilitates maximum dissemination of sensor information by making that information available to users regardless of their locations.

For maximum effectiveness, RPAs and UAVs must be integrated into the global network to such an extent that they are interdependent with sub-surface, surface, airborne, near-space, and space-based systems. The capability of each platform, manned or unmanned, increases as additional platforms join the network. Interoperability, network integration, and intelligence sharing agreements must remain guiding principles for Air Force security cooperation efforts providing RPA and UAV capabilities to allies and foreign partners.

"Interoperability is all about what capabilities I have that can make your operations better. Interdependence is all about what you need done that you can't live without, (and) my capability is the only capability you have." – General Ronald E. Keys, Commander, Air Combat Command

"UAVs will complement the manned and space forces by incorporating the advantages of unmanned systems to make the 21st Century Aerospace Force more capable." – Air Force Scientific Advisory Board

"Consistent human systems integration, which incorporates human factors engineering, manpower, safety, and personnel to name a few considerations, is a necessary answer to the challenges of developing and fielding usable, effective, and safe systems." – Air Force Scientific Advisory Board

The ability to off-load mundane tasks through machine autonomy is one of the key attributes of unmanned systems. Many aviation tasks involve monitoring conditions that rarely change, and these tasks are ill-suited to humans. Computers do this better, reporting only when an item needs attention. Proper development of autonomy can off-load many human-managed direct tasks. Improvements in autonomy show potential for increasing the efficiency and ability of humans to manage many separate aircraft. However, this is also a challenge, since many of the necessary technologies have yet to be developed.[23]

Although autonomy may seem to be contrary to integration, autonomous operation actually enhances integration and interdependence. Autonomous flight and dynamic mission assessment by unmanned systems allows operators to focus on higher-level planning and decision-making. These capabilities allow mission planners to treat unmanned systems similarly to manned systems, reducing or eliminating the need for deconfliction through time or airspace. Also, autonomous systems may be able to connect to and disconnect from the network as needed, providing network services when connections will not compromise the mission at hand and shutting down those connections when appropriate. Even when disconnected from the network, appropriately-programmed autonomous systems can continue to carry out their missions.

Each RPA or UAV operator may control multiple vehicles concurrently, depending on the mission and system complexity. Battle management can be resident in a forward-deployed Combined Air Operations Center, a surface or airborne platform, or in the United States. Information can be transmitted to the remote location via direct line-of-sight communications, airborne communication relay nodes, or space-based communications. Though direct connection to the Combined Air Operations Center or airborne platforms is limited to line-of-sight communication, communication relay nodes and satellites enable control from standoff distances. These communication relay nodes could be theater RPAs and UAVs, mobility aircraft carrying communication relay packages, or ground- or sea-based platforms. Also, each RPA and UAV should be pre-programmed with guidance for the contingency of partial or total communication failure. This guidance could include loitering in place while continuing the mission, attempting to re-establish communications, and, after a communications time-out, returning to base or proceeding to another pre-determined location. Guidance for full system failure must also be established.

As RPAs and UAVs are integrated into the force structure, they will become force multipliers. Situationally-aware remote operators will be able to coordinate the air-to-ground weapon employment of multiple platforms in multiple locations.[24] These integrated strike operations can be coordinated and controlled by the Joint Force Air Component Commander who is linked through surface, airborne, and space-based communication relays. In addition, allies and foreign partners operating RPAs and UAVs must be integrated into coalition operations, further enhancing Combatant Commanders' operational flexibility and asset availability.

Versatile

Unmanned systems provide commanders a great degree of versatility with their capability to employ multiple sensor payloads. Every future RPA and UAV, regardless of primary mission, is likely to be capable of performing ISR, target cueing, and weather data collection. On-board sensors and processors will also allow RPA and UAVs to contribute to combat assessments. Many will be capable of blue force tracking using next-generation identification friend or foe technology. Also, most RPAs and UAVs will be capable of acting as airborne communication relay nodes.[25] All of these secondary and tertiary missions could take place without adverse effect on the primary mission. However, the cost of the added capability must be evaluated against roles and fiscal resources required to acquire the capability.[26]

Like advanced manned aircraft, future unmanned systems may carry enhanced on-board processors that enable them to develop actionable intelligence from raw sensor data. This capability, coupled with high-speed machine-to-machine data links and appropriate command and control, has the potential to significantly decrease the time required to engage time-critical targets to seconds or single-digit minutes. Appropriately equipped unmanned systems may be capable of locating, identifying, and nominating potential targets autonomously, while providing combat assessments to decision-makers and warfighters in real time via the layered network.

Weaponized unmanned systems can, in certain circumstances, provide lower-cost, lower-risk alternatives to manned missions. Operating in strike packages with manned aircraft or other unmanned aircraft, armed RPAs and UAVs can carry out destruction or suppression of enemy air defense missions by using a combination of kinetic and non-kinetic weapons. Taking advantage of the real-time sharing of information on the network, armed RPAs and UAVs can employ distributed operations with manned strike platforms. Unmanned systems can act as forward-deployed scouts for manned aircraft, reporting adversary locations and, in some cases, activating air defense systems in order to expose the location of those systems. In addition, a long-endurance, survivable RPA or UAV could remain on station to provide ISR even after it has expended its weapons.[27]

Armed RPAs and UAVs can capitalize on low-observable characteristics and long endurance, working alone or in hunter-killer pairs, to destroy high-value and time-sensitive targets deep in enemy territory. Future RPAs and UAVs may be capable of carrying mixed loads of kinetic and non-kinetic weapons. On-board electro-optical cameras, infrared sensors, radars, and other collection systems will provide real-time combat assessments and targeting capabilities on many unmanned platforms. Using a combination of active sensors on unmanned systems and passive sensors on manned systems can help reduce the need to radiate from manned platforms, preserving their relative stealth capabilities.

Compliance with common data formats and interface standards is key to achieving modularity and enabling RPA and UAV versatility. Modularity is an alternative to equipping a single airframe with every capability, thus helping control weight issues. Modular payload bays, reconfigurable airframes and attachment points, and responsive flight control software that conform to common standards can allow for rapid re-tasking of vehicles at any time.

Some of the general categories of potential RPA and UAV payloads include communication relay, sensors and processors, logistics resupply, and weapons. Weapons include several basic types: traditional kinetic munitions, non-kinetic weapons (including non-lethal), and information operations payloads. Weaponized RPAs and UAVs can conduct traditional transient missions, such as airborne electronic attack, and new long-endurance missions, such as persistent area dominance.[28] Depending on the mission profile and anticipated threat environment, payloads may contain a mixture of kinetic weapons and tailorable non-kinetic weapons. As with manned systems, smaller, inexpensive, low-yield precision munitions will permit surgical strikes against the strategic nodes of an adversary's infrastructure with minimal collateral damage. Use of non-kinetic weapons may also contribute to reduced collateral damage.

Unmanned systems might also conduct information operations. They could contribute to psychological operations missions by broadcasting to adversary troops or dropping leaflets. RPAs and UAVs might also conduct high-risk, high-payoff electronic warfare missions, such as jamming specific communications nodes or providing persistent suppression of enemy air defense missions against high-threat systems. Unmanned systems might also contribute to military deception operations.

Mission flexibility and effectiveness will increase given the more acceptable level of risk compared to manned operations. Because unmanned systems may be employed without having to wait for search and rescue assets to become available, commanders have increased flexibility in developing a campaign plan, prosecuting targets more quickly, conducting suppression of enemy air defense missions earlier in a campaign, and providing greater force protection to the full range of air, land, and sea operations. Also, some unmanned systems may be capable of supporting or conducting combat search and rescue missions.

Many RPAs and UAVs may require less forward-deployed operational support, resulting in reduced force protection requirements. A number of factors will contribute to unmanned systems having a reduced operational footprint. First, a single operator may be able to control multiple RPAs or UAVs, potentially requiring less manpower per vehicle. While this may require a greater number of operators to man the ground control stations during long-endurance missions, those operators need not be forward deployed. Second, unmanned systems that are air-refuelable and capable of autonomous take-off and landing may not require forward-deployed operators for launch and recovery.[29] Such a vehicle could take off from the United States, complete its mission, and return to the United States or an airfield that is not in the theater of operations.[30] Third, RPAs and UAVs that have increased range and persistence place less of a burden on theater air refueling assets. Fourth, in many UAVs, especially small UAVs, electro-servo motors will replace high-maintenance hydraulic systems. Finally, modular or morphing airframes may someday allow a single platform to perform multiple disparate missions, resulting in a reduced number of aircraft deployed and a further reduction in support needed.

Small UAVs provide their users a great deal of flexibility in mission planning by contributing to tactical reconnaissance, blue force tracking, combat assessments, weather data collection, and force protection. Man-portable UAVs can also contribute to urban combat operations and stability operations by providing support for the missions mentioned above, plus low-altitude ISR, communications relay, and psychological operations. Small UAVs should continue to decrease in size, weight, and human interface complexity, thus easing the support burden on Air Force users. These systems may become so inexpensive as to become disposable as are munitions.

Section IV: Challenges

Limitations Similar to Manned Systems

With all aircraft, vehicle weight is an issue. Payload capacity and endurance (fuel capacity) are inversely related. New materials and construction techniques can decrease weight, thus increasing range and payload. Also, advanced propulsion systems have the potential to be lighter while providing greater thrust and fuel efficiency. However, this potential exists only to the extent that it is not otherwise offset by expanding mission requirements that commensurately drive total weight back to earlier levels.

Like manned aircraft, unmanned aircraft are susceptible to extreme weather conditions and vulnerable to kinetic and non-kinetic weapon threats. This is especially the case with relatively large, slow-moving, low-altitude RPAs and UAVs that are not equipped with next-generation survivability (i.e., capable of day and night operations in hostile environments). Also, due to the range limitations of some non-kinetic weapons, both manned and unmanned aircraft employing these weapons must engage targets from low altitude, increasing their vulnerability. Like manned aircraft, unmanned vehicles can mitigate their vulnerability to enemy attack through low observable integrated aircraft system design, dynamic mission re-planning, air-to-air weapons systems for self-defense,[31] electronic countermeasures, other active defenses such as chaff and flares, and support from other aircraft, both manned and unmanned. Also, RPAs and UAVs can be made more "intelligent" and unpredictable, much like manned systems, using advanced processors and mission management software to present a more difficult targeting problem for adversaries. New airframe designs must necessarily incorporate an investment in airworthiness and survivability consistent with mission importance.

Like early manned aircraft, current unmanned systems suffer from shortcomings in reliability. However, as the MQ-1 Predator and RQ-4 Global Hawk programs transition from Advanced Concept Technology Demonstration (ACTD) vehicles to production vehicles and operators become more proficient, mishaps rates are declining. As Figure 4 demonstrates, the average accident rate for the RQ-1/MQ-1 Predator from 1999 through 2004 was approximately 24 mishaps per 100,000 flying hours. However, the overall trend is downward. Also, while the accident rates for the Predator and Global Hawk are each an order of magnitude greater than the accident rate for Air Force manned aircraft, they are below the rates established in the operational requirements documents for those systems.

YR	Class A Rate	Class A Accidents	Hours Flown
CY 99:	**37.0**	2	5,404
CY 00:	**43.4**	3	6,914
CY 01:	**9.7**	1	10,324
CY 02:	**30.0**	6	20,011
CY 03:	**8.9**	2	22,431
FY 04:	**15.9**	5	31,357

Figure 4. RQ-1/MQ-1 Class-A accident rate per 100,000 flying hours, 1999-2004[32]

(Source: Air Combat Command)

Improved operator displays, more advanced flight controls (including automated take-off and landing for the MQ-9), and increased training should contribute to this trend. It is anticipated that the accident rate goals established by the 2002 *OSD UAV Roadmap* will be met or exceeded.

The reliability issue is directly tied to cost. Repairing and replacing damaged or destroyed systems quickly becomes expensive. Also, as redundant subsystems are incorporated into RPAs and UAVs to prevent accidents, reliability increases, but so do system costs. Continued investment in subsystem redundancy, where practical and cost-effective, will continue to improve reliability.[33] For example, most current RPAs and UAVs are single-engine systems. Twin-engine systems may prove to be more reliable, but the need for reliability must be balanced against the added cost, weight, and complexity. Also, improved training, increased operational experience, and advances in flight control software are resulting in reduced mishap rates. The Air Force must continue to invest in improved human interfaces, increased operator and maintainer training, and the development of new career paths. Such investment should result in increased system flexibility and a reduced number of mishaps attributed to human factors.

In the near term, it is not likely that unmanned systems will demonstrate the same reliability as manned systems. The 2002 *OSD UAV Roadmap* challenged the Services to "decrease the annual mishap rate of larger model UAVs to less than 20 per 100,000 flight hours by FY09 and less than 15 per 100,000 flight hours by FY15."[34] The 2004 Defense Science Board UAV Study offers a number of recommendations for reducing the RPA and UAV mishap rate, including incorporating reasonable reliability standards into the acquisition process. The Air Force concurs with these recommendations and is working to improve reliability without increasing costs to an unacceptable level.

The changing threat environment and accelerated technology lifecycles create their own challenges for the Air Force. Current aircraft, including unmanned systems, are somewhat limited in their payload and mission options. As our adversaries are increasingly using commercial technologies with short life-cycles, future systems must be able to adapt and incorporate new capabilities. In other words, the Air Force must find ways to adopt and integrate a particular technology before the next major advance makes that technology obsolete. The Air Force must exploit new technology areas, such as lighter-than-air and near-space vehicles, morphing structures, advanced propulsion systems, advanced human-machine interfaces, and directed energy systems. Also, the Air Force must develop defenses against those technologies, because adversaries may be investing in them as well.

Airspace Integration and Management

Unmanned systems must be integrated into national and international airspace. Operation of RPAs and UAVs inside restricted and warning areas in the United States is conducted at the discretion of the Air Force. Operations in the National Airspace System require a Federal Aviation Administration (FAA) Certificate of Authorization (COA), as well as a COA or Letter of Authorization negotiated with the appropriate FAA region.[35] The Air Force currently has several COAs on file with the FAA, and all have enabled RPAs and UAVs to operate outside of restricted or warning areas when required in order to complete mission requirements. As with manned systems, to operate in or through another nation's sovereign airspace will generally require obtaining advance overflight clearance.

The 2002 *OSD UAV Roadmap* instructed the Air Force to "coordinate revising FAA Order 7610.4 to replace the requirement for using the Certificate Of Authorization process for all UAVs with one for using the DD175 form for qualifying UAVs." Similarly, the 2004 Defense Science Board UAV Study made a number of recommendations for integrating RPAs and UAVs into national airspace. The Air Force concurs with these recommendations and is working to revise FAA Order 7610.4. Also, the Air Force is working with other Services, USSOCOM, and U.S. Government agencies to develop technologies, such as sense-and-avoid systems, that will increase flight safety.[36] The near-term goal is for RPA operators to be able to file a flight plan and fly above or below commercial air traffic, with some restrictions on climbing and descending through airspace that is also used by commercial aircraft. By 2025, RPA and UAV operators may be able to file an instrument flight plan and fly anywhere in national or international airspace.

As unmanned systems increase in number and type, the Air Force must be prepared to manage their proliferation in national, international, and combat airspace. The Air Force must move beyond the deconfliction of manned and unmanned aircraft and work toward integration. RPAs and UAVs are operating and will continue to operate at the same altitudes and airspeeds as other unmanned and manned platforms. Integration procedures must be refined to permit maximum flexibility in the battlespace, while minimizing the potential for mishap. Procedural deconfliction may be necessary to allow for the sheer number of smaller UAVs operating at lower altitudes. In combat airspace, larger RPAs that operate at higher altitudes where conflicts with manned aircraft are more likely must participate in the Air Tasking Order/Air Coordination Order process. However, responsive, agile integration procedures that permit rapid changes within the airspace must be developed as well, permitting RPAs and UAVs to enhance rather than hinder mission performance. Joint procedures and standards for information collection and dissemination will enable decision makers at all levels to perform flexible command and control to execute the mission. These procedures will allow RPAs and UAVs to perform both preplanned and time critical/time sensitive missions. In addition to their C4ISR capabilities, many RPAs and UAVs possess strike capabilities, giving them the capability to fill multiple roles, often on the same sortie.

In civilian airspace, air traffic controllers must be able to interact with unmanned vehicles using the same procedures used to interact with manned aircraft, where applicable. This presents a great challenge as the Air Force, other Services and agencies, and other countries introduce various RPAs and UAVs into their inventories.[37] For example, each country manages the radio frequency emitters within its borders, and the frequencies used to control a vehicle in one country may not be available for use in another country. Again, new technologies such as improved sensors and software-programmable radios will assist in addressing the challenges faced during both combat operations and peacetime situations.

Ideally, every base that supports manned aircraft should be able to accommodate RPA and UAV operations in the normal course of business, not as separate unique events. This involves, among other things, fielding of new position, navigation, and timing systems, publication of accurate charts for each airfield, development of an approved set of navigation and collision avoidance systems for all unmanned systems, and implementation of common transit alert handling procedures. Today's patchwork of base- and platform-unique solutions must give way to solutions robust enough to satisfy FAA and international airspace requirements for most classes of airspace and most airfields.

Cost

Currently, the per-unit and per-pound development and procurement costs of medium and large unmanned vehicles are similar to the costs associated with manned vehicles. The Air Force must continue to emphasize the application of advanced technology and processes for unmanned as well as manned platforms, using common subsystems where feasible. Additionally, the systems engineering process should look for every opportunity to "off-load" system requirements and gain design space due to the removal of the human from the aircraft. The relocation of the aircrew should always result in efficiency improvements.

While per-unit procurement costs may rival the costs of manned systems, life-cycle operating and maintenance costs may be significantly less. For example, operator training potentially can be conducted using robust mission simulators, reducing or eliminating the need for dedicated training flights with the actual aircraft. Reduced use of the aircraft for training results in less maintenance and greater availability for operational use.

Based on recent studies and current projected funding levels, there is no need for large increases in research and development funding in the area of low-observability technology. Unmanned systems can use a combination of current low-observable technology, electronic counter-measures, active defenses, and high-altitude flight to achieve a level of protection comparable to advanced manned systems.[38] However, propulsion technologies and technologies that enable autonomous operation, including robust human-machine interfaces for operator situational awareness and system oversight, require increased emphasis; many of the potential attributes of unmanned systems can only be realized through advances in these areas that are not currently programmed or fully funded.[39]

Unmanned systems, with their long loiter times, are collecting vast amounts of imagery, but there is currently no Air Force policy or methodology for retaining or aggregating this data. Each unit is developing policies for archiving and eventually disposing of the images they take. This increases local costs for hardware and manpower without a firm basis in requirements. The Air Force must work with DoD to establish policy for image reconnaissance data disposition in order to drive down these costs.

Tradespace is a significant challenge that unmanned systems will face as manned and unmanned systems both grow in cost and complexity. The challenge is in finding the proper mix of manned and unmanned systems in a "revenue-neutral" environment; the result may be a lower number of total systems. Addressing this challenge requires innovative thinking. For example, when designing new RPAs and UAVs, the Air Force and other Services should consider whether a larger number of small, inexpensive systems could provide the same or better capability provided by a smaller number of larger, more expensive systems. Also, joint purchases may bring economies of scale and lower per-unit costs.

Acquisition and Sustainment Strategy

As is the case with many revolutionary capabilities, unmanned systems in the current operational inventory were developed largely as a result of technology "push" rather than requirements "pull." Both RQ-1 Predator and RQ-4 Global Hawk began as ACTD programs and were quickly pressed into operational service without going through the traditional requirements and acquisition processes. Similarly, the Joint Unmanned Combat Air Systems program was a

Capabilities Demonstration Program that did not result from a formal requirements process or mission area analysis.

While the ACTD process has rapidly fielded technology that has proven useful to the warfighter, there are drawbacks to using ACTDs for acquisition. In some cases, the end results are stove-piped, proprietary systems that are not fully integrated with other systems. Often, they do not have operations, training, maintenance, and support plans or associated employment concepts. The lack of engineering drawings, flight test data, software documentation, and system maintenance data often results in the failure to develop accurate simulations for operator training. ACTD-based acquisitions are less likely to provide for adequate stocks of spare parts. These shortfalls increase operations and maintenance costs and hamper the Air Force's ability to take maximum advantage of the revolutionary capabilities provided.

The primary benefit of the ACTD process is that cycle times for introducing commercial technologies are shorter, but they are often shorter than the traditional provisioning process can accommodate. This is particularly true for computer- and network-based RPA and UAV control shelters. The Air Force should consider shifting from hardware-based configuration management to interface-based configuration management for these items and consider local off-the-shelf purchases rather than life-of-type buys for truly commercial items.

The standard acquisition process is sometimes viewed as hampering innovation and not being sufficiently transformational. Such criticisms ignore the need of the operational command to satisfy validated requirements, integrate Human Systems Integration, sustain the weapon system, and integrate new weapon systems into a larger force structure. The Air Force must foster the development of technologies and concepts that can assist in meeting requirements that are validated through the Joint Capabilities Integration and Development System.[40]

Also, spiral development is helping to expedite the acquisition process to provide operational systems to warfighters more quickly.[41] Operational use leads to the development of further spirals, in turn leading to ever more capable systems. However, spiral development may result in increased costs due to lower quantity buys for each system configuration. It also makes configuration control difficult, impacting supply chain management, technical data currency and applicability, and aircraft availability due to modification retrofits. Multiple system configurations entail increased numbers of disparate parts to keep in inventory until the systems produced under earlier spirals are retrofitted. Some critical subsystems also have a major impact on system capability; an example of this is the effect that propulsion efficiency has on aircraft range and endurance. Design choices must minimize the total system cost and maximize operational capability with future spiral upgrades taken into account. The Air Force must weigh these factors before pursuing new spirals of development.

The acquisition process for RPAs and UAVs, whether it follows the traditional acquisition model or continues to use the ACTD process, must consider life cycle costs, including reliability and maintainability, as design constraints. Unmanned systems, particularly long-endurance RPAs and UAVs, show the promise of dramatic reductions in maintenance man-hours per flying hour.[42] This, along with reduced operator training flight requirements, has the potential to transform maintenance manning requirements from workload-based to skills-based. The Air

Force logistics and training paradigms must be reengineered to adjust to and capitalize on this shift.

Those responsible for sustainment of RPAs and UAVs should consider performance-based support contracts and public-private partnerships for depot-level sustainment, supply chain management, engineering support, and configuration management based on the best-value option for the Air Force.

Regarding logistics and inventory control, the Air Force must come to terms with the treatment of RPAs and UAVs that are considered "aircraft" versus airframes that may be treated as expendable or attritable equipment. Aircraft are issued tail numbers and have lifecycles over which costs are amortized. When aircraft are damaged or destroyed, mishap investigations are conducted. On the other hand, some smaller UAVs are purchased, tracked, and maintained in a manner similar to disposable equipment items or parts; if they are lost or damaged beyond repair, they are simply deducted from the inventory. UAVs that are intended to be truly expendable must be accounted for in a manner similar to consumables or munitions. Many small UAVs will fall into one of these categories.

The Air Force must decide how much protection and redundancy to build into each system and at what point it becomes cost ineffective to retrieve or repair that system. In addition, ground stations and all their supporting equipment (e.g., antennas, servers, displays, modems), are, in effect, the cockpits of the aircraft and are non-expendable, non-attritable equipment. As such, they require the same level of security and protection as the aircraft.

It is paramount that RPAs and UAVs be viewed with a balanced acquisition approach as systems that include those elements that provide launch and recovery, vehicle command and control, sensor control, and communications. Each RPA and UAV system must also be viewed and acquired in the larger construct of a system-of-systems approach, including both manned and unmanned aircraft operating in a network-enabled environment consisting of processing, exploitation, and dissemination architectures.

<u>Command, Control, and Communications</u>

An adversary may view an unmanned system's command and control links as vulnerable and may attempt to jam, spoof, or kinetically target those links. Capabilities for mitigating these threats include data links designed for low probability of detection and interception, secure, hardened, and redundant communication hardware and software, and on-board decision aids that capitalize on autonomous operations to minimize transmissions or complicate detection and interception. Work in all of these areas is underway. In the event that command and control links have been completely severed between an unmanned system and the command center, the RPA or UAV should be pre-programmed either to attempt for some fixed period of time to re-establish communications, to execute a fully automated egress from the battlespace, or to independently complete the mission, as dictated by the rules of engagement. Improvements in automation are required to realize the capabilities needed for a vehicle to complete a mission without command and control. Additionally, the Air Force must address the doctrinal, tactical, and policy issues of allowing unmanned aircraft, especially those that are armed, to operate without direct human oversight.

Unmanned systems are inherently dependent on communications and bandwidth for control of the aircraft and for transmission of collected data to other networked vehicles, ground facilities, and commanders. A critical enabling capability for unmanned systems is agile frequency spectrum management. As RPAs and UAVs proliferate within a given theater of operations, agile management of the frequency spectrum is required to maximize operations within the limits of any frequency band. Traditional frequency spectrum management relies on, among other things, static or ground-mobile transmitters and receivers. In this environment, frequency assignments are made to specific systems with few changes over time. In an environment with highly-mobile RPAs and UAVs, frequency spectrum management must cover a wider range of dynamic capabilities. This spectrum allocation process must allow flexible frequency reassignments between organizations and Services in a joint environment. Such a capability will provide leadership a means to ensure frequency supportability to the assets with the highest priority missions.

The Air Force must work with DoD and other Government agencies to establish overall bandwidth requirements for unmanned systems and prioritize them relative to all other connectivity demands. This is particularly important for more specialized, secure, jam-resistant links required for command and control purposes. The communication links of unmanned systems must be integrated with manned and space systems and other unmanned systems using open standards and architectures, not tied to a particular vendor's solution (i.e., "stove-piped"). In accordance with the 2002 *OSD UAV Roadmap*, the Air Force is working to migrate all unmanned system data links to Common Data Link-compatible formats for line-of-sight and beyond-line-of-sight communication. Furthermore, the Air Force concurs with the recommendations of the Defense Science Board and will act on those recommendations:

- Maintain strong support for Net Centric Transformation. This includes the following efforts: Network Centric Enterprise Services, Transformational Communications Architecture, Joint Tactical Radio System, Wide Band Satellite Communications, Global Information Grid Bandwidth Extension (GIG-BE), Information Assurance Horizontal Fusion and Power to the Edge.
- Initiate development of a UAV communications relay program to provide the "last tactical mile" connection to and among mobile forces. Consider Global Hawk or Predator for near term and extreme endurance systems for long term. Build on the Defense Advanced Research Projects Agency (DARPA) program base (AJCN [Adaptive Joint C4ISR Node] and others).
- Ensure "reachback" capabilities have the necessary bandwidth and protection to support time sensitive targeting.
- Institute mechanisms to conserve communications bandwidth.
- Develop a common video data link between UAVs and manned ISR systems and attack assets.[43]

Incorporating the net-centric capabilities offered by the Family of Beyond-line-of-sight Terminals will further realize the full potential of net-centric operations for several systems, including MQ-1 Predator, RQ-4 Global Hawk, MQ-9, and future UCAVs. Also, replacing legacy ground satellite communication terminals with a new family of interoperable terminals will improve commonality and maintainability across RPA and UAV platforms and will reduce operator training requirements.

In order to realize many of the desired capabilities of unmanned systems, the proper design of operator interfaces is paramount. A major challenge is to maintain maximum operator situational awareness and mission flexibility given autonomous, net-centric vehicle operations and limited bandwidth availability. Operator interface design must be based upon a thorough analysis of the mission, task, and workload requirements to ensure that displays, controls, and staffing are appropriate to satisfy those requirements with sufficient reserve capability for anticipated failures and contingencies. A determination should be made as to the conditions in which tasks should or should not be automated. This requires a better understanding of how to effectively and dynamically allocate tasks between humans and unmanned systems so as to support, not hinder, overall mission performance. A properly designed operator interface will maximize the effectiveness of humans and unmanned systems by capitalizing on the strengths of each, thus enhancing overall mission effectiveness.

In many cases, unmanned systems will be designed and built to take advantage of existing tactics, techniques, and procedures. For example, air-refuelable RPAs and UAVs should use existing refueling assets and infrastructure.[44] In other cases, existing tactics, techniques, and procedures should be modified – or new tactics, techniques, and procedures developed – to accommodate the unique capabilities that unmanned systems bring.

Organization, Manning, and Training

The Air Force faces a number of organizational issues regarding unmanned systems, including vehicle operator qualification, operator-to-vehicle ratio, and weapon system maintenance support. The Air Force is actively working to address these issues. Currently, the MQ-1 Predator and RQ-4 Global Hawk are operated primarily by rated pilots serving a three-year career-broadening tour, while a few are navigators who hold commercial certificates with instrument ratings. However, the Air Force vision is to develop a new career field to man these billets. Part of this transformation will be the creation of an RPA training program for new Air Force officers and enlisted personnel to transition directly into RPA and UAV major weapon systems. In some cases, the Air Force may supplement uniformed RPA and UAV pilots, logisticians, and maintainers with civilian employees or contractors. Such a decision will require careful consideration of what functions are “inherently governmental” and thus not subject to contracting out. Additionally, consideration should be given to the extent, under domestic and international law, to which civilians may participate in hostilities. Related issues may include tailoring manpower guidelines and other policies to reflect the degree of command authority required over participants in the warfighting enterprise. Also, as part of the Air Force Future Total Force initiative, Guard and Reserve operators and maintainers will operate and maintain their own RPAs and UAVs in some cases and will Associate with active duty squadrons in other cases.

Air Force small UAVs, such as Pointer, Raven, and FPASS, are operated by enlisted personnel. The Air Force must address the level of effort and training required for small UAVs and the development of operators of those systems. Air Force Special Operations Command, as the lead command for small UAVs for the Air Force, will work with other Air Force organizations to determine the appropriate level of competency and training for those personnel selected to operate small unmanned systems.

In all cases, the RPA or UAV operator is considered the pilot in command (whether rated or unrated, officer, enlisted, or civilian) and is responsible for the aircraft. It is important operators of airborne unmanned systems, especially those operators in command of armed systems, have a thorough understanding of the application of air power.

Improved mission management software could allow one operator to control multiple vehicles, reducing the number of operators required per mission. However, depending on the mission, operating airspace, and capabilities of any given RPA or UAV, it may be necessary to have one operator per vehicle.

Training is important to the development of RPA and UAV systems and in the development of operational concepts. As mentioned earlier, lack of training is one shortcoming of the ACTD process, increasing operations and maintenance costs and hampering the Air Force's ability to take maximum advantage of the revolutionary capabilities provided. Increased training contributes to a reduced number of aircraft mishaps. Keeping the operators' training concurrent with the aircraft configuration will increase operator proficiency by, for example, keeping the operators informed of any aircraft changes that result from spiral development. Likewise, ensuring system maintainers are appropriately trained and have detailed technical data available will further ensure system availability and accuracy. Taking training into account at the beginning of the spiral development process will allow the training capability to be "in step" with the aircraft and keep the warfighters' training current.

Recruiting, manning, and training are all long-lead items, especially regarding the funding to provide appropriate training opportunities to meet requirements. The Air Force must develop a process by which the acquisition, personnel, and operations communities develop organizational, manning, and training requirements and address issues as they arise.

Ground support personnel for RPAs and UAVs will likely be a combination of military and contract civilian personnel providing the Air Force with the best option for a technically qualified, deployable workforce to support peacetime training as well as worldwide combat operations. Future plans for military personnel may include a separate Air Force Specialty for maintaining RPA and UAV aircraft and ground stations. Selected options will be based on best fit and value for the Air Force.

Air Force migration to net-centric systems must be considered in RPA and UAV weapon system planning, reach-back architecture planning, maintenance career field development, and maintenance training plans. The Air Force will be a leader in this technology migration, which may require changes to existing practices. For example, the development of maintenance courses currently relies on the availability of technical orders. For reach-back architectures in particular, system implementations will continually evolve with maintenance training requirements but may not have formal maintenance technical orders. The Air Force must be able to respond to rapid technology cycle times and provide the necessary training.

<u>Mobility, Support</u>

Recent wargames and studies have indicated that RPAs and UAVs must be pre-positioned or self-deployable to be operationally relevant in a rapidly-developing situation.[45] Air refueling capability is essential for larger systems. The ability of such systems to self-deploy will result in a reduced forward logistics footprint. Smaller systems may be containerized and require shipment to the theater of operations, impacting logistics and mobility. While RPAs and UAVs will use existing infrastructure to support beddowns to the maximum extent, in some cases RPAs and UAVs may require unique infrastructure. Air Force Major Commands and applicable bases are working in conjunction with RPA and UAV program offices to address beddown issues and associated funding requirements. The implications for support require further study and input from Air Mobility Command and U.S. Transportation Command.

The Air Force should begin examining the feasibility and practicality of unmanned cargo delivery and air refueling systems. Unmanned systems should assist in providing mobility solutions rather than taxing existing infrastructure. To this end, lighter-than-air systems should be explored for mobility applications.

Policy and Legal Issues

Future unmanned systems, especially those that are armed, may have implications for escalation prior to overt hostilities.[46] An adversary's inability to distinguish between armed and unarmed systems could lead to misunderstanding. As previously discussed, operating an unmanned system over another nation's airspace without prior permission would generally be viewed as a breach of that nation's sovereignty. While such a breach may be justified under the inherent right of self-defense, one must be mindful of the potential for an adversary to inaccurately portray such actions as acts of aggression. New systems must be developed within existing legal and policy constraints, such as arms control agreements, or relief from those constraints must be sought. Certification and compliance review processes, such as radio frequency management, must be shortened. In many cases, these processes take longer than the development cycles of the systems.

The Air Force must continue to address RPA and UAV export policy. The sale of U.S.-manufactured, interoperable RPAs and UAVs to key allies and foreign partners enhances coalition capability, and an integrated production strategy provides advantages to the U.S. industrial base. Currently, the Missile Technology Control Regime (MTCR) limits the export of MQ-1 Predator, MQ-9, and RQ-4 Global Hawk, severely constraining RPA security cooperation activities with allies and foreign partners. The Air Force must continue to advocate updates to the MTCR and U.S. Government export policy to fully develop interoperable coalition capabilities that support U.S. national security objectives.

Significant legal issues that must be addressed include the implications of the law of war on various armed RPA and UAV scenarios, limitations on the use of contractors for operational activities, and impacts of International Civil Aviation Organization (ICAO) requirements on international operations.

Similarly, the Air Force must address the issues inherent in autonomous weapon employment. As weapon systems that can identify and engage targets autonomously replace those that are pre-programmed or under positive human control, the Air Force must develop rules of engagement, tactics, techniques, and procedures, and effective command and control systems to prevent fratricide and collateral damage. The 2002 *OSD UAV Roadmap* instructed the Air Force to "define security measures required for positive control of weapons employment on weaponized UAVs," with a suspense date of Fiscal Year 2008.[47] The Air Force is working with sister Services and USSOCOM to define these measures.

Section V: Vision and Recommendations

The Air Force will integrate unmanned aviation with existing and future air and space systems to provide a more capable force, implement Human Systems Integration, and continue to lead and innovate RPA and UAV development and employment. As RPAs and UAVs prove their worth, lessons learned will be applied to enhancing the next generation of unmanned systems. Toward that end, the recommendations that follow will carry this vision forward.

- The Air Force must work with DoD, FAA, ICAO, and other organizations to develop common definitions regarding unmanned systems, taking into consideration rotary-wing, hypersonic, lighter-than-air, and near-space systems. Joint Publication 1-02, *DOD Dictionary*, provides the following definition of a UAV:

  > A powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or non-lethal payload. Ballistic or semi-ballistic vehicles, cruise missiles, and artillery projectiles are not considered unmanned aerial vehicles.[48]

  There is much inconsistency in the usage of terms such as "UAV," "RPA," "unmanned aircraft," "unmanned system," "drone," and "cruise missile," despite numerous attempts to classify RPAs and UAVs by size, weight, mission, altitude, and regulatory requirements (such as the need for a pilot to operate in the National Airspace System).

  > *Way Ahead: The Air Force will work with OSD, sister Services, USSOCOM, other domestic and international organizations, and allied countries to develop common definitions for various classes of RPAs and UAVs.*

- Unmanned systems must be robustly integrated with manned and space systems. They must also be integrated with other unmanned systems, including ground- and sea-based systems. To provide maximum effectiveness, RPAs and UAVs must conduct operations seamlessly and concurrently with manned aircraft, in shared airspace. To this end, unmanned systems should be integrated appropriately into net-centric operations. In realizing this goal, RPAs and UAVs will simultaneously collect, produce, and distribute everything from raw data to actionable information, depending on vehicle size, mission requirements, and bandwidth availability. In some cases, information will be filtered and fused onboard and presented in a decision-quality format, allowing commanders to act in anticipation of events rather than reacting to those events. This integration will reduce the time required to complete the "kill chain" process to seconds or single-digit minutes.[49] By enabling the change from a linear process to one that is parallel and nearly instantaneous, unmanned systems will allow commanders to conduct operations in a coordinated, simultaneous manner, rather than sequentially.

With the sheer volume of information collected and downloaded simultaneously comes the need to avoid "stovepiping" – restricting the number of users with access to this data. All data collected from surveillance, reconnaissance, or "combination" missions provides detail on enemy activities and disposition crucial to overall awareness of a conflict's status and progress. That awareness is a vital input to the Predictive Battlespace Awareness process that drives follow-on collection planning (and better use of collection assets), as well as improved Intelligence Preparation of the Battlespace, targeting, and assessment.

New procedures for requesting and receiving RPA and UAV support, whether ISR or attack, must be developed and coordinated by the Services and USSOCOM. One option is for requests for support from unmanned systems to mimic requests for close air support. In this model, ground commanders would use existing channels to request RPA or UAV support. Information from the RPA or UAV could then be downlinked directly to the ground commander. This process could be coordinated through the unit's Battlefield Airmen who are in direct contact with the RPA or UAV crew.

As it migrates to a net-centric environment, DoD is establishing a Distributed Common Ground System (DCGS). Each Service and USSOCOM is developing components that will be linked across a common integrated backbone. As is the case with other intelligence collectors, RPAs and UAVs will feed information to DCGS. The goals are to improve information sharing, enhance the quality of information and situational awareness, enable collaboration and mission agility, and enhance sustainability and speed of command – all of which are critical to a theater commander's decision making.

Intelligence products derived from RPAs and UAVs are available through a number of sources and can be transmitted directly to units in the field through intelligence networks served by DCGS. Evolving net-centric capabilities will make those products more accessible, eventually enabling end users to subscribe to intelligence information from all sources. The demands for RPAs and UAVs and their products place ever greater demands on RPA and UAV operators to become more efficient. Developing and exploiting new technology for analysis, manning, and efficiency are key to ensuring intelligence products are available to commanders at the right time and in the right place to produce the desired effects. Developing agile dissemination paths, which permit users at all levels to access intelligence information, either directly from unmanned systems or from DCGS, is key to timely intelligence product delivery. As coalition partners field RPA and UAV systems, intelligence sharing agreements and CONOPs must be proactively addressed to leverage coalition capabilities for the U.S. warfighter.

For maximum effectiveness, unmanned platforms must have redundant, secure communication links for command and control and payload operation, where practical (based on mission requirements, vehicle size, and cost). Larger unmanned systems require high-bandwidth communication links, both line-of-sight and satellite-based, needed to carry the large volumes of data to be shared on the layered network. Network redundancy can be enhanced by tactical, medium-altitude, and high-altitude RPAs and UAVs all acting as communication relay nodes. Laser communications will help solve the high-bandwidth data movement requirement that is facing the high-altitude endurance fleet. Some Air Force RPAs and UAVs will take advantage of high-bandwidth laser communications as this technology matures.

Also, a number of methods can be used to reduce bandwidth requirements. Studies have shown that these methods can reduce the amount of bandwidth needed by several orders of magnitude.[50] First, some analysis of the raw data gathered by the platform sensors can be performed on-board the vehicle with only the most pertinent data or target information disseminated to other entities on the network. Second, through the use of automatic target recognition and 'data chipping,' RPAs and UAVs can transmit a compact list of coordinates and/or probable target classifications rather than large imagery files. Finally, when it is necessary to transmit large volumes of data, advanced data compression can be used to reduce bandwidth requirements.

The Air Force must engage DoD to aggressively pursue the allocation of radio frequencies that meet military requirements while reducing the impact on civilian national and international allocations. Some current systems use frequencies that currently conflict with or will conflict with other allocated frequencies. The Air Force must work with DoD to migrate these systems to new frequencies.

Way Ahead: The Air Force will continue to partner with industry where possible and emphasize research and development in the areas of on-board data analysis, auto-target recognition, autonomous flight capabilities, autonomous sensor operation,[51] *and data compression. The Air Force will align this Strategic Vision with the Air Force and DoD Communications Visions and will work with DoD and other Government agencies to develop a bandwidth management strategy for all networked systems.*

- Military RPAs and UAVs must operate in national and international airspace to ensure seamless integration. Ideally, operators of unmanned systems operating in national airspace will be able to file a flight plan and fly using the same process that governs manned aircraft.[52] For worldwide operations, sense-and-avoid capability, compliance with international air traffic management regulations, and adherence to communication, navigation, and surveillance equipage standards are required. Integration of manned and unmanned aircraft in and around airfields and during en route operations must be transparent to air traffic control. The operations tempo at mixed airfields (serving manned and unmanned aircraft) must not be diminished by the integration of unmanned aircraft. Unmanned systems must require no special provisions that impede other air vehicles from sharing airspace with unmanned assets.

Way Ahead: The Air Force will integrate RPAs and UAVs with manned aircraft using common architectures and standards. The Air Force will work with sister Services, USSOCOM, OSD, DARPA, allies, and private industry to develop these architectures and standards. This effort will include a focus on air space management/air traffic control and, when practical, common mission management software and commonality in *ground control systems. Regarding air traffic control, the Air Force will continue to work with sister Services, OSD, other U.S. Government agencies, and allies to modify pertinent FAA, EUROCONTROL, and ICAO regulations as necessary. Also, work will continue on the development of appropriate technologies and procedures, such as sense-and-avoid technologies, Global Air Traffic Management, and Reduced Vertical Separation Minimums, to assist in airspace integration and integration into combat operations.*

- The Air Force and DoD must continue to fund research and development to provide the scientific foundation for technological advances. It is important that some funding for pure research be kept separate from programs that are intended to field operational systems. Also, the Air Force must work with sister Services, USSOCOM, and OSD to coordinate development of new unmanned systems and consider the development and integration of new non-kinetic weapon systems with unmanned platforms.

  Way Ahead: The Air Force will continue to conduct UAV studies on a regular basis. The Air Force will exploit this intellectual groundwork by reducing the cycle time of building testbed systems (X-planes) to prove concepts and harvest technologies. Separately, the Air Force will continue to fund and participate in Advanced Technology Demonstration and Advanced Concept Technology Demonstration programs to accelerate the fielding of promising technologies. The Air Force Research Laboratory will continue to work with the sister Services' equivalent organizations, USSOCOM, other U.S. Government agencies such as the National Aeronautics and Space Administration, and private industry. Areas of focus will include, but will not be limited to, sensors, airframe materials and design, and propulsion methods.

- The Air Force must fund research and development for effective human-machine interfaces as a critical part of a UAV ground segment architecture, addressing:

  - Maintaining operator situational awareness, addressing ergonomic concerns to reduce fatigue from long-duration flights, minimizing time delays and applying techniques that allow an operator to stay ahead of the vehicle, and simplifying display information;
  - Designing effective communications panels and intercom systems that integrate all radios, telephones, audible warnings, and crew intercoms with standard interfaces and a single screen or panel; and
  - Determining requirements for designing and acquiring operator interfaces that optimize usability and safety by means of accepted human machine interface practices, including error prevention and error trapping.

  Way Ahead: The Air Force must leverage its intellectual capital and investment in cockpit design as well as the Air Force Research Laboratory's work in human-machine interfaces to address RPA and UAV crew situational awareness by evaluating operator mission, function, task, and workload requirements and applying appropriate technologies to optimize the interface usability and safety. Examples of possible design changes include incorporating multi-function displays, incorporating touch-screen *and/or voice control technologies, addressing ergonomic concerns, simplifying menu locations, selection, and manipulation, incorporating effective communications panels and intercom systems, and designing appropriate flight displays.*

- The Air Force must recognize that traditional cost metrics for manned aircraft do not account for the on- and off-board requirements unique to unmanned systems. For example, many RPAs and UAVs require sheltered, deployable ground-stations for mission planning, navigation, collection operations, automated landing capability, and command, control, and communications. The Air Force must work with sister Services, USSOCOM, and allies to mitigate such unique costs.

  The Services and USSOCOM must develop common vehicles, ground control stations, software, and payloads, when practical. With the large number of unmanned systems that are part of the Army Future Combat System, there are tremendous opportunities for joint development of RPAs and UAVs. Open architectures, modular payloads, air refueling, and low-observable characteristics should continue to receive emphasis where required. The Air Force must invest in new systems based on validated requirements and require new RPA and UAV programs to establish defined recurring per-unit costs. Unnecessary, cost-additive requirements must be discarded or postponed until they become necessary and cost-effective, with deviations from cost targets occurring only with approval of the Secretary of the Air Force.[53]

  When evaluating the capability of new unmanned systems to meet requirements, the Air Force must consider whether unmanned, manned, ground-based, airborne, or space-based systems – or an appropriate mix of some or all of these of the categories – will best meet those requirements.

  Way Ahead: The Air Force will seek lower per-unit costs inherent in economies of scale by partnering with other Services, Government agencies, and allies. To this end, the Air Force will continue to procure the MQ-1 Predator, the MQ-9, and the RQ-4 Global Hawk and will continue to work with the other Services, USSOCOM, U.S. Government agencies, and allies to determine if those systems may meet the needs of other Services or allies. Also, the Air Force will examine other Service, non-DoD Government agency, and allied RPAs and UAVs for suitability for Air Force applications. The Air Force will continue to work with DARPA incorporating new capabilities through spiral development using open system architectures and modular payloads. The Air Force will continue to evaluate and expand its small unmanned systems needs and requirements and work with the other Services and USSOCOM to ensure joint capabilities are maximized. Future unmanned systems will be developed based on validated requirements, defined per-unit costs, open architectures, and modular payloads.

- The Air Force must review doctrine, procedures, policies, and legal requirements to determine how unmanned systems fit into the existing framework. This includes assessing the capacity of the natural infrastructure (e.g., air, water, and land) early in the planning process to facilitate compliance with environmental regulations without adversely impacting mission capability. In some cases, unmanned systems must be designed to fit within the existing constraints. In other cases, policies, guidance, and laws should be revised to accommodate the technology.

Way Ahead: The Air Force will work with sister Services, USSOCOM, and OSD to develop rules of engagement and tactics, techniques, and procedures for autonomous operation, including weapon delivery. It is especially important that the Air Force work with the Army to determine the roles and missions of the various RPAs and UAVs in the Army Future Combat System. The Air Force will work with sister Services and the Combatant Commands to improve RPA and UAV command and control in joint air operations. Where applicable, other Service RPAs and UAVs will be coordinated with the Air Force Theater Air Control System and Air Tasking Order process. The Air Force will develop vision documents based on capability areas, such as mobility, strike, and ISR. Each vision will address the role of manned, unmanned, ground-based, airborne, and space-based systems in supporting these capability areas. The Air Force will work with OSD to properly address and characterize RPAs and UAVs in export control regimes and policies to facilitate RPA and UAV security cooperation activities with allies.

- Finally, because the above recommendations involve collaboration with organizations external to the Air Force, implementation will require an overarching organization responsible for integrating and synchronizing RPA and UAV efforts across DoD communities.

Way Ahead: The Air Force, sister Services, and USSOCOM will establish an organization responsible for improving interoperability among various unmanned systems and facilitating the development of common operating standards, capabilities, joint CONOPS, and training. The Air Force will emphasize these standards with our allies and foreign partners. In the near term, this organization will take the form of a Joint UAV Center of Excellence in conjunction with a Joint Unmanned Aerial System Materiel Review Board.

Acronyms and Abbreviations

ACTD	Advanced Concept Technology Demonstration
AFRL	Air Force Research Labs
AFSAB	Air Force Scientific Advisory Board
AJCN	Adaptive Joint C4ISR Node
ATD	Advanced Technology Demonstration
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
COA	Certificate of Authorization
CONOPS	Concept(s) of Operations
CY	Calendar Year
DARPA	Defense Advanced Research Projects Agency
DCGS	Distributed Common Ground System
DoD	Department of Defense
DSB	Defense Science Board
FAA	Federal Aviation Administration
FPASS	Force Protection Aerial Surveillance System
FY	Fiscal Year
GIG-BE	Global Information Grid-Bandwidth Expansion
ICAO	International Civil Aviation Organization
ISR	Intelligence, Surveillance, Reconnaissance
OEF	Operation ENDURING FREEDOM
OIF	Operation IRAQI FREEDOM
OSD	Office of the Secretary of Defense
PAD	Persistent Area Dominance
ROA	Remotely Operated Aircraft
RPA	Remotely Piloted Aircraft
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Air Vehicle
U.S.	United States
USAF	United States Air Force
USSOCOM	United States Special Operations Command

THIS PAGE INTENTIONALLY LEFT BLANK

Bibliography

Defense Science Board Study on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles, OUSD(AT&L), Feb 04

Future Capabilities Game 2004 Final Report, AF/XPXC, 16 Jul 04

Future Capabilities Game 2004: Integrating Unmanned Air Vehicles, AF/XPXC white paper in support of Future Capabilities Game 2004, Jan 04

Innovative Development: Global Hawk and DarkStar, HAE UAV ACTD Program Description and Comparative Analysis, RAND, MR-1474-AF, 2002

Global Maritime Fight: 2030 and Beyond, Chief of Naval Operations' Strategic Studies Group XXIII Quick Report, Jul 04

Hearing Highlights: HASC/Tactical Air and Land Subcommittee, 26 Mar 03

Implications of Unmanned Air Vehicles for the Future of the Air Force: Executive Summary, RAND Documented Briefing, Aug 01

Initial Capabilities Document (ICD) for Small Unmanned Solutions (SUS), AF/XO, 12 Apr 04

The Joint Transformational Potential for High Altitude Long Loiter (HALL) Capabilities, JFCOM Project Alpha Rapid Assessment Process Report, 28 Jul 2004

Joint Unmanned Combat Air Systems, Capability Demonstration Program Overview, DARPA briefing, 20 Apr 04

Joint Unmanned Combat Air Systems, Common Operating System Integrator/Broker Overview, DARPA briefing, 20 Apr 04

Joint Unmanned Combat Air Systems, Common Systems and Technologies Organization & Common Operating System Overview, DARPA briefing, 20 Apr 04

The Predator ACTD: A Case Study for Transition Planning to the Formal Acquisition Process, Michael R. Thirtle, Robert V. Johnson, and John L. Birkler, RAND, MR-899-OSD, RAND, 1997

Report on Human-System Integration in Air Force Weapon Systems Development and Acquisition, Air Force Scientific Advisory Board executive summary and annotated brief, SAB-TR-04-04, Jul 04

Report on Unmanned Aerial Vehicles in Perspective: Effects, Capabilities, and Technologies, Air Force Scientific Advisory Board , SAB-TR-03-01, Sep 03

UCAV Roles and Missions for Offensive Combat Operations, RAND Restricted Draft, DRR-3235-AF, Dec 03

Unmanned Aerial Vehicle (UAV) End to End Support Considerations, RAND Restricted Draft, MG-350-AF, forthcoming

Unmanned Aerial Vehicle (UAV) Update, USAF Response to Congressional Reporting Requirement, HAC-D Report # 107-532, Feb 03

Unmanned Aerial Vehicle Reliability Study, OSD, Feb 03

Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation, Johns Hopkins University PhD dissertation by Colonel Thomas P. Ehrhard, Jun 00

Unmanned Aerial Vehicles: Changes in Global Hawk's Acquisition Strategy Are Needed to Reduce Program Risks, GAO Report, GAO-05-6, Nov 04

Unmanned Aerial Vehicles: Major Management Issues Facing DOD's Development and Fielding Efforts, GAO Report, GAO-04-530T, 17 Mar 04

Unmanned Aerial Vehicles Roadmap 2002-2027, OSD, Dec 02

Unmanned Combat Air Vehicle System Demonstration Program: X-45 UCAV Overview, DARPA/USAF briefing, May 03

Unmanned Combat Air Vehicle System Demonstration Program: X-45C Overview, DARPA/USAF briefing, May 03

U.S. Department of Defense: The Case of the Unmanned Aerial Vehicles, Harvard Business School case study, N1-300-109, 29 Feb 00

Notes

[1] "Remotely piloted aircraft" is synonymous with "remotely operated aircraft" and refers to larger unmanned systems such as the MQ-1 Predator and the RQ-4 Global Hawk that operate in controlled airspace. "Unmanned aerial vehicles" refers to systems such as the Raven and Pointer small unmanned systems that do not operate under positive air traffic control and may not require rated operators. The term "unmanned aircraft system" includes the ground element (control stations, launchers, etc.) in addition to the vehicle itself and is more accurate than "unmanned aerial vehicles"; however, the term "unmanned aerial vehicles" is more commonplace. This document uses "unmanned systems" in the generic sense to refer to RPAs and UAVs collectively.

[2] Near-space systems operate at altitudes above controlled airspace and below low-earth orbit. For purposes of this Strategic Vision, this range is nominally between 65,000 feet (20 km) and 325,000 feet (100 km).

[3] The most comprehensive unclassified history of RPA and UAV testing and employment through 1999 is *Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation*, by Colonel Thomas P. Ehrhard. Colonel Ehrhard submitted this definitive work as his PhD dissertation at Johns Hopkins University in 2000. This section of *The Strategic Vision* is derived primarily from his work. Sources for other information, primarily information regarding RPA and UAV development and employment since 1999, are cited separately.

[4] All current Air Force "Predator A" systems are now designated MQ-1. The RQ-1 designation is still used in a historical context.

[5] General Tommy R. Franks, 27 Feb. 2002.

[6] Combined Air Operations Center analysis.

[7] All figures are in FY 1999 dollars.

[8] It is unclear what portion of some joint and intelligence programs was funded by the Air Force.

[9] The first major Army UAV program started in 1954, and the first major Air Force program started in 1962.

[10] For the programs listed, only total program costs were available. The total cost of each program was averaged over the life of that program to provide these graphs. While the results are not precise, they provide a good overview of relative levels of funding and highlight the limited investment in unmanned systems in the 1970s and early 1980s.

[11] 2003 *OSD UAV Roadmap*, p. iv.

[12] Sustained investment in airframe development may, in some cases, yield airframes with less than complete capability (e.g., lacking mission payload equipment). Sustained investment in other areas, such as payload development, is required, as well.

[13] The Air Force has not yet named the MQ-9, sometimes referred to as "Predator B."

[14] USSOCOM is the only Combatant Command with Title 10 acquisition authority.

[15] Current and future RPAs and UAVs may be effective platforms to support counterland, information operations, special operations, surveillance and reconnaissance, and all other air and space power missions.

[16] The Air Force will tightly integrate this *Strategic Vision* with the Air Force and DoD Communications Visions in order to ensure the availability of bandwidth for unmanned systems.

[17] *Defense Science Board Study on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles*, OUSD(AT&L), Feb 04, p. iv (hereafter referred to as the 2004 DSB UAV Study). Other studies have identified candidate mission areas that are ideally suited for future UAVs. These studies include *Unmanned Aerial Vehicles in Perspective: Effects, Capabilities, and Technologies*, Air Force Scientific Advisory Board study outbriefing, 27 June 2003 (hereafter referred to as the 2003 AFSAB UAV Study) and the 2004-2005 series of Air Force Research Lab UAV mission area analyses.

[18] For example, the RQ-4 Global Hawk has the ability to fly out 3000 nautical miles and remain on station for eight hours. In comparison, a U-2 can fly out 3000 nautical miles but has no loiter time at that range. Instead, a U-2 detachment would have to be deployed - an act that would take five days. The RQ-4 Global Hawk can collect within 24 hours instead of five days. This combination of responsiveness and endurance contributes to more efficient time-critical targeting.

[19] In many cases, space systems are immediately available and have long persistence. Some space assets can provide 24/7 coverage. It will become increasingly important to determine the proper mix of airborne and space-based systems.

[20] The ground-based aircrew will remain an integral part of the mission but will have added mission flexibility.

[21] These studies include the 2003 AFSAB UAV Study and the *Future Capabilities Game 2004 Final Report*.
[22] While some constraints may be mitigated through this approach, other constraints may remain. Bandwidth is not limitless; growing DoD RPA and UAV bandwidth requirements must be managed effectively.
[23] The MQ-1 Predator is flown using a combination of pilot input (through a joystick and rudder pedals) and autopilot functions in which the aircraft follows a pre-programmed flight path. The RQ-4 Global Hawk and many small UAVs follow pre-programmed flight paths or waypoints that can be changed en route. Most future systems will have such autonomous flight controls, but some systems may require positive manual control throughout flight.
[24] Studies such as the 2003 AFSAB UAV Study have indicated that due to mission complexity it is likely that manned platforms will maintain the primary responsibility for air-to-air combat engagements. However, unmanned aircraft may take part in air-to-air engagements in self-defense or in coordinated attacks with manned aircraft.
[25] However, due to the need for low probability of detection on certain missions, some sensors and communication equipment may be temporarily deactivated to increase overall stealth capability.
[26] Also, each mission capability comes with added equipment, and therefore added weight. This extra weight may affect vehicle performance.
[27] In the 2004 Air Force Future Capabilities Game, one Joint Force Commander effectively used UCAVs in this manner.
[28] According to the Air Force Global Persistent Attack CONOPS, "...PAD employs long-endurance loitering platforms with integrated munitions and sensors using autonomous target recognition to compress the kill chain."
[29] Some RPAs, such as the MQ-1 Predator, are stored and shipped in containers and then unpacked prior to use. Others, such as the RQ-4 Global Hawk and future medium to large systems, will be self-deployable. The MQ-1 Predator, which is flown manually and requires a forward-deployed ground control station, requires much logistical support. However, studies such as the 2003 AFSAB UAV Study indicate that air-refuelable self-deploying vehicles can dramatically reduce the amount of forward-deployed support needed.
[30] This describes a flight profile similar to that of the B-2 Spirit bomber. In the 2004 Air Force Future Capabilities Game, some long-endurance, penetrating unmanned systems were used in this manner.
[31] The MQ-1 Predator has flown with Stinger anti-aircraft missiles.
[32] In January 2004, OSD requested all further reporting by fiscal year. Therefore, the FY 2004 period covers January through September 2004.
[33] In the words of the Defense Science Board, "UAV systems should be designed to a set of specifications that takes into account the total cost of the system, the environment it is going to be used in, and the expected / acceptable loss rate." 2004 DSB UAV Study, p. viii.
[34] *OSD UAV Roadmap*, December 2002, pp. v, 64.
[35] FAA documents use the term "remotely operated aircraft" or "ROA" to describe unmanned systems.
[36] The addition of such technologies to some platforms may not be practical or feasible due to the added size, weight, and cost. Also, in the near term, the integration of manned and unmanned aircraft may result in mission penalties, such as inefficient altitude assignment or alternate, less optimal means of deployment.
[37] The Army Future Combat System calls for a large number of unmanned aircraft of various sizes operating at various altitudes.
[38] See, for example, the 2003 AFSAB UAV Study.
[39] For example, current power supplies for small and micro unmanned systems cannot achieve extended loiter times. Also, current jet engines for larger systems are not optimized for altitude, endurance, and the electrical power requirements of some payloads.
[40] For an explanation of the JCIDS process, see Chairman of the Joint Chiefs of Staff Instruction 3170.01, "Joint Capabilities Integration and Development System."
[41] For an explanation of the spiral development process, see DoD Instruction 5000.2, "Operation of the Defense Acquisition System."
[42] Potentially, this number could be reduced from the high teens to low single digits.
[43] 2004 DSB UAV Study, pp. ix-x. "Wide Band Satellite Communications" includes associated terminal programs such as the Air Force's Family of Advanced Beyond-Line-of-Sight Terminals.
[44] Air refueling is one of the most promising enablers for RPA and UAV operations.
[45] See, for example, *Future Capabilities Game 2004 Final Report*, p. 7-14.
[46] This was borne out in the 2004 Air Force Future Capabilities Game. See *Future Capabilities Game 2004 Final Report*, p. 8-2, for more details.
[47] *OSD UAV Roadmap*, December 2002, pp. v, 63.

[48] While this definition differentiates UAVs from cruise missiles, it does not rationalize the distinction. Some future system concepts may be both recoverable and capable of carrying warheads to targets. Increased UAV lethality, reduced system costs, and improved cruise missile persistence will soon blur the distinction between lethal UAVs and loitering munitions. The addition of sensors and data links to cruise missiles will compound this problem.

[49] The traditional "kill chain" has six steps: find, fix, track, target, engage, and assess. The term "kill dot" has been used to capture the magnitude of the change to a compressed "kill chain."

[50] See, for example, the 2003 AFSAB UAV Study, p. 12.

[51] Although current technology allows for a single pilot to control multiple aircraft, the technology does not yet exist for a sensor operator to control sensors on multiple aircraft. Such technology could include the capability for sensors to place automated requests to the autopilot for platform maneuver within the pilot-defined operating airspace.

[52] Operators of small and micro UAVs that fly below controlled airspace may not be required to file flight plans. However, they will coordinate with the Combined Air Operations Center, or equivalent, for flight clearance in combat situations.

[53] Recommendation of the 2004 DSB UAV Study. Also, the Air Force must work to ensure that its validated requirements are included in joint service requirements documents.