Defense Science Board Study

on

Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles

February 2004

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The DSB is a Federal Advisory Committee established to provide independent advice to the Secretary of Defense. Statements, opinions, conclusions and recommendations in this report do not necessarily represent the official position of the Department of Defense.

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OFFICE OF THE SECRETARY OF DEFENSE
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DEFENSE SCIENCE
BOARD

MEMORANDUM FOR THE ACTING UNDERSECRETARY OF DEFENSE
(ACQUISITION, TECHNOLOGY AND LOGISTICS)

SUBJECT: Report of the Defense Science Board Task Force on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles

I am pleased to forward the final report of the DSB Task Force on Unmanned Aerial Vehicles (UAV) and Uninhabited Combat Aerial Vehicles (UCAV). This Task Force was tasked to evaluate the current status of the UAVs and UCAVs and provide recommendations on how to better integrate UAVs and UCAVs into the force structure.

The Task Force concluded it is time for the Department of Defense and the Services move forward and make UAVs and UCAVs an integral part of the force structure, not an "additional asset". To do so requires appropriate planning, appropriate budgeting, and continued management attention from the Department of Defense and Service leadership.

The Task Force's findings and recommendations fall into eight subject areas:

Introduction of UAVs into the force structure

UAV unit production costs

UAV mishap rates

Communications constraints

UAV interoperability and mission management

Integration of UAVs into national airspace

Focus technology investments

Reduction of UAV combat vulnerability

I endorse all of the recommendations of the Task Force and propose that you review the Task Force Co-Chairmen's letter and the report.

William Schneider, Jr.

Chairman

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DEFENSE SCIENCE
BOARD

MEMORANDUM FOR THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Final Report of the Defense Science Board Task Force on Unmanned Aerial Vehicles (UAVs) and Uninhabited Combat Aerial Vehicles (UCAVs)

There is no longer any question of the technical viability and operational utility of UAVs. The success of UAVs in recent conflicts represents a historic opportunity to exploit the transformational capabilities inherent in UAVs/UCAVs.

The benefits and promise offered by UAVs in surveillance, targeting and attack have captured the attention of senior military and civilian officials in the Defense Department, members of Congress, and the public alike. Indeed, these recent combat operations appear to indicate that unmanned air systems have at last come of age.

The Task Force feels it is time for DoD and the Services to move forward and make UAVs and UCAVs an integral part of the force structure. To do so requires appropriate planning, appropriate budgeting, and continued management attention of DoD and Service leadership.

The Task Force found that the single most important recommendation is to accelerate the introduction of UAVs into the force structure.

The Task Force recommends the Secretary of Defense direct that UAV procurement be accelerated and systems moved into operational units at a faster pace, with focus on UAVs now in production or completing development. Where appropriate, a military Service should be encouraged to procure the system of another Service as necessary to realize this goal, or alternatively, implement joint operating arrangements with the parent Service.

The Task force found two areas where significant changes are needed – and without changes the potential of UAVs and UCAVs will not be realized.

1. Requirements generated cost growth has killed many UAV programs in the past. OSD should require each major UAV and UCAV program in system design and development or production stage to establish a well defined and well defended recurring unit production cost target per system. Deviation from that cost target will only occur by direction of the Service Secretary.

2. High mishap rates are frequently cited as a deterrent to more widespread adoption of UAVs into the force structure. Over the last 5 decades, investments in manned aircraft reliability have been made to drive equipment

failures to near zero. This implies that a considerable reduction in UAV accident rates can and should be obtained with reasonable investments.

During its deliberations the Task Force also identified five topics requiring increased attention and new developments.

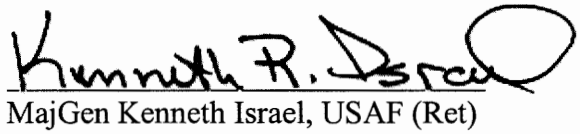
1. Address communication bandwidth constraints.

2. Consider approaches to common UAV mission management.

3. Work to allow UAVs unencumbered access to the National Airspace System outside of restricted areas here in the United States and around the world.

4. Address selected technology issues.

5. Carefully investigate approaches that could allow UAVs to operate with more persistence.



MajGen Kenneth Israel, USAF (Ret)
Co-Chair

Mr. Robert Nesbit
Co-Chair

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EXECUTIVE SUMMARY

Unmanned Aerial Vehicles (UAVs) have come of age.

Lessons from recent combat experiences in Kosovo, Afghanistan and Iraq have shown that UAVs can provide vastly improved acquisition and more rapid dissemination of Intelligence, Surveillance and Reconnaissance (ISR) data. They are one of the principal contributors to successful outcomes for the United States. in these campaigns. The benefits and promise offered by UAVs in surveillance, targeting and attack have captured the attention of senior military and civilian officials in the Defense Department (DoD), members of Congress, and the public alike. Indeed, these recent combat operations appear to indicate that unmanned air systems have at last come of age.

There is no longer any question of the technical viability and operational utility of UAVs. The success of UAVs in recent conflicts represents a historic opportunity to exploit the transformational capabilities inherent in UAVs/Uninhabited Combat Aerial Vehicles (UCAVs). Transformation is not a term, it is a philosophy. Transformation is a predisposition to exploring adaptations of existing and new systems, doctrine and organizations. True transformation is not the result of a one-time improvement, but of sustained and determined effort. For example, the American forces used multiple Predator UAVs during Operation Iraqi Freedom (OIF) to provide a far more comprehensive operational perspective across the theater to the Combined Air Operations Center by integrating the Predator common operating picture with the Falcon View mission planning system. There is now another mission imperative and that is distance. During this review the new concept of Global Persistence Surveillance has specifically focused on the contributions of UAVs and UCAVs.

During OIF Predator UAVs also enabled time-critical targeting via streaming video to strike platforms. Likewise one Global Hawk in the Iraqi theater from 8 March 03 to 23 April 03 accounted for 55% of the Time Sensitive Targets generated to kill air defense equipment. In 16 missions, Global Hawk located 13 Surface-to-Air Missile (SAM)

batteries, 50 SAM launchers, over 70 SAM transport vehicles and over 300 tanks. Notwithstanding the success of UAVs in OIF, UAVs have not been fully "embedded" in current Concepts of Operations (CONOPS) or valued with effects driven methodology. Future UAV programs must be conceived with this mix in mind, i.e. predefined operational concepts and effects driven methodology. UAVs are ideal systems to support the emerging joint character and the asymmetric nature of warfare.

The Task Force feels it is time for DoD and the Services to move forward and make UAVs and UCAVs an integral part of the force structure, not an "additional asset". To do so requires appropriate planning, appropriate budgeting, and continued management attention of DoD and Service leadership. The DoD and the Services have already started to integrate UAVs into their force structure plans. Currently there are UAV plans and roadmaps within the DoD and Services and the FY 04 budget also shows substantial increases in funding of UAV programs. While progress has been made in planning and funding for UAVs, the Services need to move from deconfliction to integration to interdependence. UAV capabilities should be assessed in the larger context of the Global Persistent Surveillance. UAVs can ideally complement current architectures for Future Imagery Architecture, New Imagery System, and Space Based Radar.

This study identifies steps the Department of Defense and Armed Services can take to field a robust UAV and UCAV capability. The recommendations in his executive summary indicate the Task Force's top level recommendations. Additional recommendations can be found in the body of the report. The Task Force's findings and recommendations fall into eight subject areas and are described in this executive summary in order of importance.

The Task Force found that the single most important recommendation is to accelerate the introduction of UAVs into the force structure.

ACCELERATE THE INTRODUCTION OF UAVS INTO THE FORCE STRUCTURE

UAVs are not yet widely distributed across the Military Services or firmly integrated into Service force structures. Funding support has at times been tenuous, and consequently, the overall pace of introduction has been slow. The Task Force found that operational experience with Predator, Global Hawk, Hunter, and special purpose UAVs during recent conflicts demonstrated that, once employed by warfighters, the value of UAVs becomes immediately evident, ideas for new operational concepts are spawned, and strong advocacy begins to build.

- The Task Force recommends the Secretary of Defense direct that UAV procurement be accelerated and systems be moved into operational units at a faster pace, with focus on UAVs now in production or completing development. Where appropriate, a military Service should be encouraged to procure the system of another Service as necessary to realize this goal, or alternatively, implement joint operating arrangements with the parent Service.

Specific actions are recommended, in addition to currently funded efforts, as follows:

Army

- Procure Predator and/or employ Air Force Predator assets in the near term while formulating requirements for and developing the proposed Army-unique Extended Range UAV System.

- Field those Hunter UAVs remaining in storage, and selectively upgrade their systems as necessary.

- Consider Fire Scout UAVs as a vertical take-off and landing (VTOL) supplement to the fixed-wing Shadow 200 UAV fleet.
- More widely equip company-level units with man-portable UAV systems like Raven, Dragon Eye, or Pointer.

Air Force and Navy

- Merge the current USAF Global Hawk and Navy Broad Area Maritime Surveillance (BAMS) programs into a common-use High Altitude Endurance (HAE) UAV system that will meet the needs of both Services.

Navy and Marine Corps

- Secretary of the Navy direct a near term procurement of a small force of Fire Scout Vertical Take-off UAV (VTUAV) systems in order to provide the Fleet and Fleet Marine Force with a modern automated, ship-based VTOL UAV for developing operational concepts and requirements for a future naval ship-based VTOL tactical UAV system, and to serve as a potential contingency response resource.
- Navy-Marine Corps form a VTUAV tactical development squadron to serve as the Fire Scout operating entity in time to meet a proposed Initial Operational Capability (IOC) date of early 2006. The Coast Guard should be invited to participate.
- Pending development of a common Navy and Marine Corps VTOL system, the Marine Corps should procure Shadow 200 systems to replace Pioneer as needed to alleviate operational inventory shortages.

Joint

- Joint Forces Command (JFCOM) should be tasked to develop doctrine and tactics to integrate UAVs into the force structure with emphasis on employing existing systems and exploring cross-service use of assets

The Task force found two areas where significant changes are needed – and without changes the potential of UAVs and UCAVs will not be realized.

These recommendations address the need to cap UAV unit production costs and to reduce UAV mishap rates.

CAP UNIT PRODUCTION COSTS

During the Task Force deliberations the cost of UAVs and UCAVs was identified as one of the major factors potentially limiting the development, acquisition, and use of UAVs and UCAVs. If UAVs and UCAVs become too expensive to be employed in a high risk environment they will lose their utility. If this occurs, UAV and UCAV technology and operations will not evolve to their full potential. Accordingly the Task Force Recommends:

- Office of the Secretary of Defense (OSD) should require each major UAV and UCAV program in system design and development or production stage to establish a well defined and well defended recurring unit production cost target per system. Deviation from that cost target will only occur by direction of the Service Secretary.
- The recurring unit production cost target of the UAV/UCAV system must be established and justified in terms of what it costs manned platforms or other means to accomplish the same mission.
- OSD should undertake an initial program by program review of recurring unit production cost targets as soon as possible and set up mechanisms for revisiting these figures throughout the life of the programs.

REDUCE UAV MISHAP RATES

High mishap rates are frequently cited as a deterrent to more widespread adoption of UAVs into the force structure. Over the last 5

decades, investments in manned aircraft reliability have been made to drive equipment failures to near zero. This implies that a considerable reduction in UAV accident rates can be obtained with reasonable investments. 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.

A significant contributor to UAV mishaps is the experience level of UAV operators and maintainers. The services need to enhance the overall professional development of UAV/UCAV professionals. Most of our most experienced operators/maintainers separate from the service or rotate to other assignments at the height of their proficiency. A UAV/UCAC operator/maintenance personnel management plans need to address accession, retention, education and training, career path advancement and methods for developing a UAV career field that combines research, development, acquisition, operations and employment.

With regards to improving UAV mishap rates the Task Force makes the following recommendations:

- Develop and implement reliability specification standards as a function of the class / type of UAV. These specifications should become part of the acquisition strategy for the system.
- Institute a standardized data set for tracking reliability and system mishaps for UAVs. The manned aircraft community has this in place and with minor adjustments these same formats could, and should be used for unmanned systems.
- All UAV class A mishaps should be investigated using established Service procedures. The results should be documented and fed back into a system reliability improvement program.
- UAV system acquisition budgets should include resources for reliability improvement programs.

During its deliberations The Task Force also identified five topics requiring increased attention and new developments.

COMMUNICATIONS

UAV sensor data are highly sought after by a wide audience of users. The current architecture stresses the available bandwidth and results in less than desired distribution of data. A set of programs structured under the Global Information Grid (GIG) initiative will provide a marked improvement in the available bandwidth provided the Services make matching improvements to facilitate access. However, even with GIG deployment, distribution over the "last tactical mile" will remain a problem with Navy ships at sea and land forces at battalion and below most affected.

In order to better address communication bandwidth constraints the Task Force recommends:

- 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 and others).
- Ensure "reachback" capabilities have the necessary bandwidth and protection to support time sensitive targeting. The network centric infrastructure of Remotely Piloted Aircraft (RPA) command and control and data

flow have generated a worldwide "Virtual Crew" that adds tremendous capabilities and challenges to effective ISR employment. As long as UAVs have the unique attribute of being operated by virtual crews out of theater, information assurance will be paramount.

- Institute mechanisms to conserve communications bandwidth. These actions should include cost of communication as part of the Total Cost of Ownership (TCO) of a UAV system and continue to search for new paradigms of use, (e.g. sampling at the Nyquist rate and on-board target recognition[1]).
- Develop a common video data link between UAVs and manned ISR systems and attack assets. Video from UAVs should be sent to Joint Stars, Airborne Warning and Control System (AWACS), and MC2A etc. all using the same format and type of data link.

INTEROPERABILITY AND MISSION MANAGEMENT

Currently, there are so many different UAV systems in various stages of development that they are outstripping the ability to evolve standards and approaches for common mission management.

It is clear that no single mission management system will fit all UAVs but common systems could be used for controlling certain classes and types of UAVs. At least 100 UAVs of 10 different types were used in OIF yet none of them allowed integrated direct data receipt. To date, individual Services have been reluctant to adopt common mission management systems or other interoperability approaches within similar types or classes of UAVs. Each Service has tended to initiate its own separate development program specifically tailored to its requirements rather than adopting an existing capability from another Service.

[1] Nyquist rate is the minimum theoretical sampling rate that fully describes a given signal.

To address the challenges of enhancing UAV interoperability and to achieve the benefits of common mission management systems for classes of similar UAVs, DoD should take the following actions:

- Designate the Deputy, UAV Planning Task Force as the DoD advocate for UAV interoperability. The Deputy, UAV Planning Task Force should advise the Under Secretary of Defense for Acquisition, Technology and Logistics (USD[AT&L]) about the potential for an existing UAV system from another Service to satisfy the new requirements as part of the Defense Acquisition Board (DAB) review for each new UAV system.
- Task JFCOM in concert with Strategic Command (STRATCOM) to more aggressively develop UAV doctrine and tactics. As part of its new ISR mission, JFCOM must be more aggressive in the development of doctrine and tactics to integrate UAVs more fully into the force structure. Both JFCOM and STRATCOM have equities for Global ISR missions and transition from a platform based garrison force to a capabilities-based expeditionary force.
- Evaluate a separate procurement of a common mission management system for all UCAV variants. UCAV, as it goes forward as a joint program, is a prime example of how a common mission management/vehicle control system could be derived for a UAV type that features different air vehicle platforms. The new UCAV Joint Program Office (JPO) should structure its acquisition with separate mission management procurement for a system to be used with all air vehicle variants.
- Fund the UAV Planning Task Force at $10M per year. The DoD UAV Planning Task Force should be given a budget to support requirements, architecture and standards trades and related analyses required to provide better advice to USD(AT&L) relative to UAV issues.

INTEGRATE UAVS INTO NATIONAL AIRSPACE

The DoD has an urgent need to allow UAVs unencumbered access to the National Airspace System (NAS) outside of restricted areas (airbases and military operating areas), here in the United States and around the world. The need stems from the requirement to transit to/from combat areas of operations and perform time-sensitive training. It can be expected that Predators, Global Hawks and someday UCAVs and high altitude airships will require rapid access to the airspace to fly from the U.S. to/from overseas locations. Access is critical to optimized force structure allocation during conflict. OSD recognizes this issue as a high priority and describes it in detail in the DoD UAV Planning Task Force UAV Roadmap, December 2002. The Task Force makes the following recommendations:

- DoD should become an active participant in National Aeronautics and Space Administration (NASA), Federal Aviation Administration (FAA) and industry efforts to accelerate "file and fly" capability for all classes of UAVs for operation in U.S. and international civil airspace as well as provide better integration of UAVs in military airspace during peace time training and in combat zones. It is absolutely critical that the DoD develop Detect, See and Avoid (DSA) requirements for all classes of UAVs that they intend to deploy in the NAS and International Airspace. Once these requirements are validated, then technology solutions should be developed and tested to DoD and FAA satisfaction.
- DoD should evaluate all types of Over The Horizon (OTH) communications to insure compliance with FAA requirements. This may include dual redundant satellite communication (SATCOM) links.
- Accelerate advanced research on autonomous vehicle operation, specifically focused on airspace situation awareness. This research would include speech recognition for Air Traffic Control (ATC), DSA compatibility with

Traffic Alert and Collision Avoidance (TCAS) and ADS-B and new approaches for lost-link recovery.

- Direct accelerated development of DSA and other technologies so as to permit safe flight of UAVs in mixed manned and unmanned aircraft environments.
- Direct Commander Joint Forces Command to develop tactics, techniques and procedures that will assure safe, yet combat-effective flight of mixed forces of manned and unmanned aircraft in combat theaters.

FOCUS TECHNOLOGY INVESTMENTS

The Task Force found that, generally, there is sufficient DoD investment in technology. In addition some technology advancement is being driven by the demands of commercial products, relative to which, any DoD investment would be small. For instance, the light-weight batteries being used in small UAVs were developed by the laptop computer and cellular phone industry.

Despite our general opinion that there is sufficient investment in DoD UAV technology, we did identify a few areas that are not getting sufficient investment. The following recommendations address these under-funded, high-payoff technologies:

- Expedite the development of specifications, Research, Development, Test and Evaluation (RDT&E) and fielding of heavy-fuel engines suitable for UAVs. This is a technology area that will not be addressed by commercial efforts and will benefit Predator, Army TUAV, Hunter, Navy VTUAV, Pioneer and other UAVs.
- Push technology to drive down the cost and weight, while maintaining performance, of all categories of sensors to maximize their utility on UAVs, as well as on manned and unmanned ground systems.
- Develop new technologies to allow integration of UAVs into the national and international airspace

- Implement auto-land and auto-takeoff technology for all UAVs with a gross weight of greater than 100 pounds. This will benefit Predator, Hunter, Pioneer and others.

In addition to the above specific recommendations, technologies that address the bandwidth constraint that is a limiting factor for all UAVs need continued investment.

REDUCE UAV COMBAT VULNERABILITY

Most of the UAVs in the inventory today are quite vulnerable to a variety of different air defense systems. Anti-aircraft artillery (AAA), shoulder-fired man portable systems, and radar directed low medium and high altitude surface to air missile systems can all be quite lethal to UAVs within their range. Current operational UAV systems have not explicitly included stealth or active countermeasure technology.

Vulnerability to air defenses has led to concept of operations employing UAVs in regions where the air defense threats have already been largely eliminated. However, UAVs would be quite useful in providing extended surveillance in denied areas prior to conflict, and operating early in a conflict in a tactical reconnaissance role. To do so will require improvements to UAVs and UCAVs in the area of cross-section reduction and/or active countermeasures.

Recommending development of Very Low Observable (VLO), high altitude, long endurance UAV would be an easy to recommend if unconstrained by costs. This approach is consistent with the desires expressed by senior personnel in OSD and USAF so there is a receptive audience. Persistent clandestine surveillance of deep, politically denied enemy airspace would be a terrific capability to have. However, there are a number of issues which must be considered in formulating a recommendation in this area. These include mission requirements and trades, survivability trade space, technical and operational feasibility, unit and opportunity costs.

The panel did not have access to current special access initiatives in these areas but many of the members have been fully accessed to

similar programs during the last 10-15 years. The following recommendations are made based on that experience.

- Compile "lessons learned" from past programs in this overall area – with full security access to each. Make these lessons available to the ongoing/future efforts to guard against making the same mistakes.
- Establish an independent Red Team to review all aspects of the pre-conflict persistent mission vehicle. Develop a clear understanding of the intended threat sophistication, mission requirements, and concepts for survivability. Presence, persistence, operability, sensing, reporting and survival must be achieved essentially simultaneously and the analyses cannot deal with them one at a time.

INTRODUCTION

This report summarizes the deliberations and conclusions of the Defense Science Board Task Force on UAVs and UCAVs. The Defense Science Board (DSB) was asked to conduct a comprehensive review of DoD plans for development and fielding of Unmanned Aerial Vehicles (UAVs) and Uninhabited Combat Aerial Vehicles (UCAVs). The study was commissioned by the Under Secretary of Defense (Acquisition, Technology and Logistics), the Assistant Secretary of Defense (Command, Control, Communications, and Intelligence)[2], and the Director, Strategic and Tactical Systems.

The study was conducted at this time due to the substantial increase in operational employment of UAVs and UCAVs over the last decade in conflicts as well as the complementary role that UAVs and UCAVs fill, supporting existing intelligence and attack assets.

The Task Force Terms of Reference states in part that "transforming the U.S. military requires rebalancing existing forces and capabilities. Global situation awareness and the global war on terrorism mandate responsive worldwide airborne intelligence, surveillance and reconnaissance." The Sponsors identified several areas of concern with UAVs and UCAVs that the task force should explore. These included:

- Affordability and increasing costs
- Interoperability disconnects
- Communications architectures to include bandwidth and redundancy
- Accident rates

[2] Note: The Office of the Assistant Secretary of Defense (Command, Control, Communications, and Intelligence) (ASD (C3I)) was reorganized as an Under Secretary of Defense for Intelligence (USD (I)) and as an Assistant Secretary of Defense (Networks and Information Integration) (ASD (NII)) during the conduct of this study. For the purposes of this study we will use the new designation ASD (NII).

- Operational control in both FAA airspace and military restricted airspace
- Survivability
- Military utility analysis
- Management approaches.

The Task Force was asked, based on the areas of concern shown above, to identify the principal impediments to full and rapid exploitation of the joint warfighting potential of UAV and UCAV systems and to make recommendations on how these constraints might be mitigated or removed.

Task Force Composition and Deliberations

The DSB Task Force on UAVs and UCAVs conducted a thorough review of UAV, UCAV systems, capabilities, affordability, interoperability, accident rates, operations control (air space issues), utility, and management

The Task Force reviewed the overall pace of fielding of UAVs, as well as approaches being taken by the Armed Services in integrating UAVs and UCAVs into their operations and inventories, and provided key recommendations relating to items specified in the terms of reference.

Mr. Robert Nesbit and Major General Kenneth Israel, USAF, (Ret) chaired the Task Force and conducted the study along with 8 additional members. The Task Force Executive Secretary was Mr. Dyke Weatherington, Director of the UAV Planning Task Force in the Office of Strategic and Tactical Systems. A full listing of Task Force members can be found in Appendix II.

To perform this review the Task Force conducted seven meetings over an 8-month period. Meetings were held with Office of Secretary of Defense, the Military Services, the Joint Staff, Defense Agencies, Service Laboratories, the Coast Guard, and UAV industry representatives.

CHAPTER 1. ACCELERATE INTRODUCTION OF UAVS INTO THE FORCE STRUCTURE.

As with most new military concepts, the path to acceptance of UAVs and recognition of their worth has been long and not without obstacles. Unmanned aircraft as target vehicles and air-to-surface weapons date back many years and were employed in World War II. For ISR purposes, camera-equipped Ryan Firebee drones enjoyed great success during the Vietnam War, flying some 3,400 sorties over heavily-defended North Vietnam, including a few missions launched from aircraft carriers. But despite the promise of early experiments and operational deployments, the U.S. military has been slow to invest in UAV development and reluctant to incorporate unmanned systems into the regular force structure. Looking back, it appears that earlier introduction of UAVs was impeded by several factors – culture, immature technologies, and a general lack of recognition by advocates that unmanned systems demand aerospace-quality treatment in the design, manufacture and operation of the systems.

Over the past several years, a confluence of events and developments has brought about a distinct change in how the military worth of UAVs is perceived by operational commanders and senior officials in the Military Services and OSD. These include:

- Dramatic increases in computer processing power.
- Advances in sensor technologies that reduce sensor size and weight, provide high resolution, and permit detection of fixed and moving targets under a variety of environmental conditions.
- Improved communications, image processing, and image exploitation capabilities.
- Pressure on the military by political authorities and the general public to minimize casualties and capture of aircrews by the enemy.

- Emergence of the requirement for continuous or "persistent" surveillance of the battlespace, providing commanders with what is, in effect, a low hanging, near-stationary satellite. Hence, the quest for long endurance UAV systems which, if manned, would tax or exceed the limits of human endurance.
- Availability of robust, long endurance UAV platforms resulting from visionary investments by DARPA and the DoD in the 1980s and 1990s – Amber, Predator and Global Hawk – sometimes in the face of resistance from the Services.
- And perhaps most importantly, the generally high marks accorded Predator and Hunter during Operation Allied Force in the 1999 air war against Serbia, and as indicated above, to Predator and Global Hawk during Afghanistan operations, and to UAVs overall in Operation Iraqi Freedom.

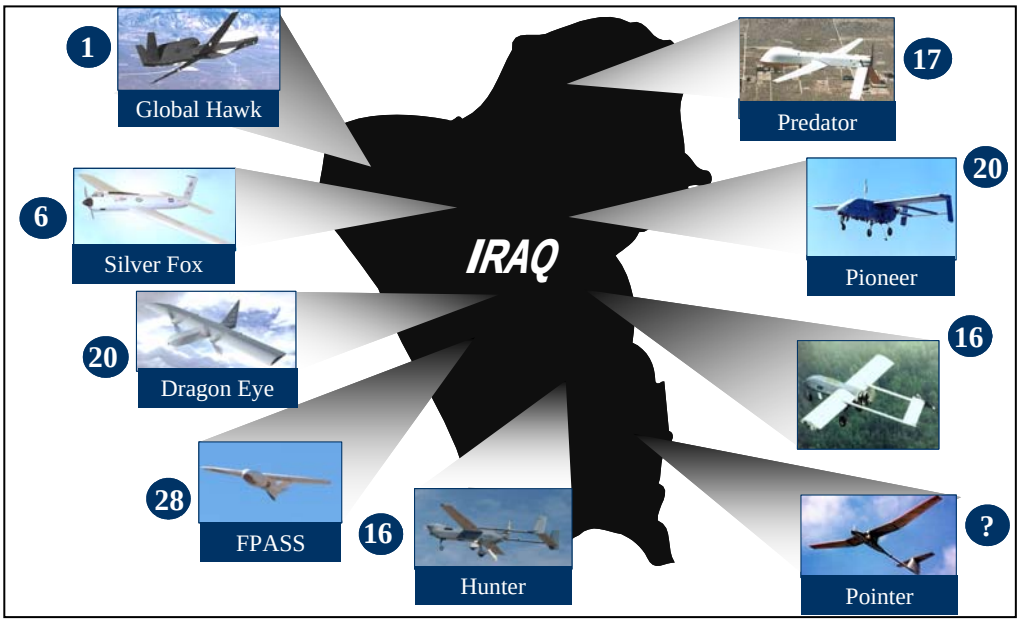

Figure 1.1 UAVs in Operation Iraqi Freedom

Despite this increased recognition of military worth and the advances made, UAVs are not yet widely distributed across the Military Services or firmly integrated into Service force structures. Funding support has at times been tenuous, and consequently, the overall pace of introduction has been slow. Indeed, as of early summer 2003, only 175 UAVs of Pioneer/Shadow-size or larger were operational throughout the DoD, with the Navy and Marine Corps significantly behind the other Services in numbers and in fielding modern systems.

There are multiple reasons for this slow pace of introduction and utilization of UAVs, with some key ones being:

- Culture and policy. The culture of any large institution of long standing almost always militates against ready acceptance of new concepts or, in the case of the military, new weapons systems.
- Competition with legacy and other new systems for funds. As a relatively new type of military weapon system, UAVs are in competition for funds with older systems or even other new systems that are viewed as front line mainstays of a Service's force structure. In such an environment, it is often the case that a new kind of system, like UAVs, falls to the bottom of the priority list.
- The program start-stop-start syndrome. The unfortunate practice of starting a military program and then, when production is about to commence, canceling it in favor of a supposedly more promising system, has plagued the UAV world for years. Each such sequence adds years of delay in equipping the operating forces with UAVs. Past program examples include the Navy/Marine Corps Amber, the Hunter Short-Range UAV, the Mid-Range UAV, and the first joint Tactical UAV (TUAV) program. And recently, Navy production and Fleet introduction of the already-developed Fire Scout has suffered from uncertainty over requirements.

- Greater than expected costs, high accident rates, unreliable systems, and combat survivability concerns. A reason often given in the past for a military Service not making a strong commitment to UAVs is that these new systems cost more than anticipated, suffer from high accident rates because of subsystem unreliability and operator error, and lack the combat survivability features of manned aircraft. These concerns are valid, but all are solvable if the requisite attention is paid to them during the requirement formulation and development process.
- Reluctance of one military Service to use the UAV system of another. Although this may smack of the "not invented here" syndrome, it is an understandable characteristic of some validity. A commander feels most secure if he owns and completely controls a system that is fundamental to accomplishing his mission. But there are obvious cost and operational advantages for the DoD if multi-Service use can be achieved – overall system development costs are reduced and UAV force levels can be increased more rapidly. Here, "use" is defined in two ways. The first is for one Service to acquire and operate a system developed by another Service. And in the case of ISR, the second is merely to make use of the information generated by the UAV system of the other Service.
- Radio Frequency (RF) bandwidth constraints and lack of interoperability. The Task Force believes that RF bandwidth capacity limitations, interoperability problems, and imagery processing/exploitation issues are near the top of the list of impediments to a more rapid introduction and utilization of UAV systems. Each of the military Services suffers from these constraints to varying degrees, with the Navy's ships at sea and Army and Marine Corps units at battalion level and below being the most adversely affected.

Status Today. Despite the slow pace of introduction, the Army and Air Force are now operating modern UAVs and the two Services have systems in production as well. The Air Force is committed to Global

Hawk production, continues with Predator procurement, and is developing a more capable Predator B system. The Army is fielding its Shadow 200 tactical system in increasing numbers, continues to employ the Hunter UAV, and has plans to increase use and introduce small man-portable systems like Pointer and Raven.

The Navy has no UAVs in production and none in its operating forces. However, the Navy has committed to purchasing two Global Hawks for experimentation and has plans to put in service both high altitude long endurance and ship-based tactical ISR UAV systems at the end of this decade.

The Marine Corps has some 32 aging Pioneers, a small land-based tactical system developed in the 1980s, which were used with mixed effectiveness during Operation Desert Storm as well as the Kosovo and Iraq campaigns. Additionally, the Marines have begun to introduce the small man-portable Dragon Eye system to serve units at battalion level and below. A listing of current DoD UAV systems is shown in Figure 1.2 below.

	System	Manufacturer	Lead Service	First Flight	IOC	Total Aircraft	Aircraft /Grnd Stn Available	Status
small	Raven	AeroVironment	Army & Air Force	2002	2004	15	15/5	555 (Army) 126 (AF)
small	Dragon Eye	AeroVironment	USMC	2000	2003	40	18	933 planned
small	Desert Hawk (FPASS)	Lockheed Martin	Air Force	2002	2002	120	60	60 to be delivered 1QFY04
medium	RQ-2/Pioneer	Pioneer UAVs, Inc	Navy & USMC	1985	1986	32	21/3	Extended life
medium	RQ-7/ Shadow 200	AAI	Army	1998	2003	40	24/17	164 planned (41 systems)
medium	RQ-5/Hunter	IAI / Northrop Grumman	Army	1991	N/A	39	39/6	Extended life
medium	RQ-8/Fire Scout	Northrop Grumman	Navy & Army	1999	N/A	5	0	Test / CONOPS
large	MQ-1/Predator	General Atomics	Air Force	1994	2004	53	40/8	68 planned
large	MQ-9/ Predator B	General Atomics	Air Force	2001	TBD	2	0	TBD
large	RQ-4/ Global Hawk	Northrop Grumman	Air Force	1998	2006	4 (ACTD) 1 (Prod)	2 (ACTD)	51 planned

COTS/ Developmental/Operational System **Current as of Dec 2, 2003**

Figure 1.2 Current DoD UAV Systems

In the aggregate, the Naval Services, which once led the Defense Department in developing and fielding UAVs, are now lagging the other Services in gaining operational experience, developing operational concepts, and exploiting the transformational warfighting potential offered by unmanned air systems. Absent a dramatically increased involvement with UAVs, the Navy and Marine Corps run the risk of falling further behind, not fully exploiting the benefits offered by Army and Air Force systems, and lagging in efforts to shape the direction new UAVs systems will take in the future.

Looking to the future, DARPA is pursuing a number of UAV advanced technology demonstrations in concert with the military Services – fighter-like air vehicles for lethal missions (Joint Unmanned Combat Air System [J-UCAS]), rotorcraft for attack and long endurance ISR (A160, CRW, Unmanned Combat Aerial Rotorcraft [UCAR]), and small or micro-UAVs for urban combat.

As stated in the Executive Summary, there are UAV plans and roadmaps within the DoD and Services and the FY 04 budget (See figure 1.3 below) shows substantial increases in funding of UAV programs. While progress has been made Service leadership still has not fully embraced the integration of UAVs into the force structure.

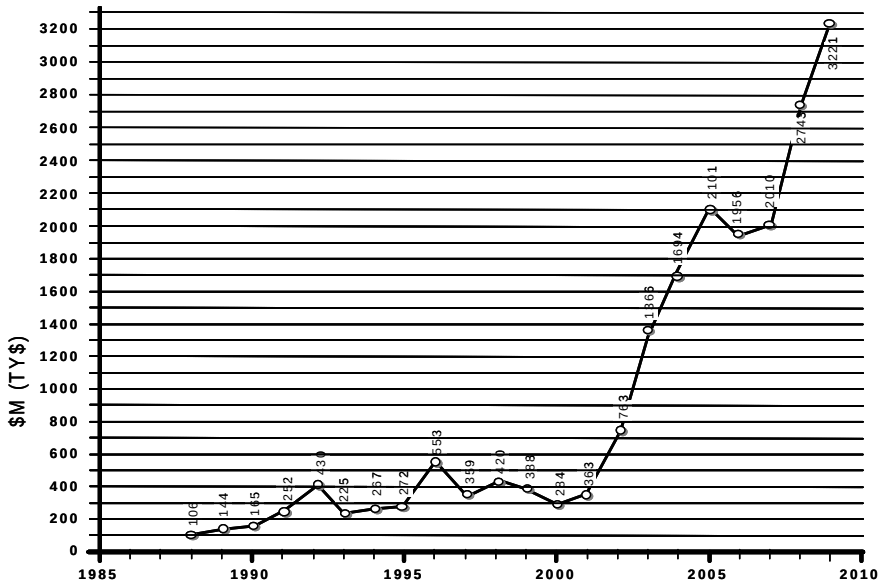

Figure 1.3 UAV Yearly Funding Profile - FY04 data

The Task Force also notes that strong support for UAVs exists in Office of the Secretary of Defense, with the regional Combatant Commanders, and in the Congress. Therefore, it makes sense for the Military Services to capitalize on the current positive climate and move out with dispatch to exploit the momentum that has been established.

Operational Experience the Key. The Task Force found that operational experience with Predator, Global Hawk, Hunter, and special purpose UAV systems during recent conflicts demonstrated that, once employed by warfighters, the value of UAVs becomes immediately evident, ideas for new operational concepts are spawned, a constituency is formed, and strong advocacy begins to build. Hence, the lead element of a strategy to increase employment of UAVs should be to accelerate the introduction of those systems that are in production or have completed development. To this end, the Task Force believes that:

- Requirements generation is best approached from the perspective of mission needs and effects rather than that of platform ownership or base location;
- Acquisition or employment of UAVs developed by one Service should be considered by other Services in their plans to more rapidly introduce UAV capabilities into their force structures and new development programs should be initiated only if an existing system or modification cannot provide the desired effect; and
- Essential enhancements to Command, Control and Communications (C3) and information exploitation systems must be made concurrent with accelerating the introduction of already-developed UAV systems into the Military Services.

Assessment: Accelerated Fielding of UAV Systems is Imperative

In assessing the UAV situation today, the Task Force finds that the U.S. has made progress over the last three to four years in moving to exploit the potential offered by unmanned air systems. Little doubt

remains as to the operational utility and military worth of UAVs. They have proven themselves in combat and warfighters want them, particularly since UAVs are now seen as essential to realizing all-important persistent surveillance of the battlespace.

Notwithstanding these positive developments, the pace of UAV introduction is slow. Much remains to be done before the military can fully realize the potential benefits offered by these transformational systems. The Task Force believes the key to making more rapid progress is to get UAVs into operational units on an accelerated basis. And here the focus should be on those UAVs now in production or which have completed development and offer significant operational utility; these include Global Hawk, Predator, Shadow 200, Fire Scout, Raven, Dragon Eye and Pointer.

Concurrently, the Military Services must move vigorously to eliminate or significantly mitigate interoperability deficiencies as well as those in C3 and imagery exploitation systems equipment and infrastructure that constrain the use of modern airborne ISR systems, such as Predator and Global Hawk, by ships at sea and Army and Marine Corps forces ashore.

RECOMMENDATIONS

ACCELERATE INTRODUCTION OF UAVS INTO THE FORCE STRUCTURE

The Task Force recommends the Secretary of Defense direct that UAV procurement be accelerated and systems moved into operational units at a faster pace, with focus on UAVs now in production or completing development. Where appropriate, a military Service should be encouraged to procure the system of another Service as necessary to realize this acceleration goal, or alternatively, implement joint operating arrangements with the parent service. Specific actions are recommended as follows:

Army

- Procure Predator and/or employ Air Force Predator assets in the near term while formulating requirements for and

developing the proposed Army-unique Extended Range UAV System.

- Field those Hunter UAVs remaining in storage, selectively upgrading their systems as necessary.
- Consider Fire Scout as a VTOL supplement to the fixed-wing Shadow 200 UAV fleet.
- More widely equip company-level units with man-portable UAV systems like Raven, Dragon Eye, or Pointer.

Air Force and Navy

- Merge the current USAF Global Hawk and Navy BAMS programs into a common-use HAE UAV system that will meet the needs of both Services. The two Services would join to develop, procure and operate a system suitable for both the overland and maritime ISR missions. In their joint approach, the two Services should increase the system production rate above that now planned in order to realize operational and cost benefits, and also explore the potential for a joint arrangement with the Department of Homeland Security and its agencies. The Memorandum of Agreement between the two Services should include delineation of responsibilities for requirements development, R&D, procurement, operations, and logistics support. The current EA-6B program should be considered as an initial MOA model.

Navy and Marine Corps.

- Secretary of the Navy direct a near term procurement of Fire Scout VTUAV systems in order to provide the Fleet and Fleet Marine Force with a modern automated, ship-based VTOL UAV for developing operational concepts and requirements for a future naval ship-based VTOL tactical UAV system, and to serve as a potential contingency response resource.

- Navy-Marine Corps form a VTUAV tactical development squadron to serve as the Fire Scout operating entity in time to

meet a proposed IOC date of early 2006. The Coast Guard should be invited to participate.

- Pending development of a common Navy and Marine Corps VTOL system that satisfies the tactical UAV requirements of both Services, the Marine Corps should procure Shadow 200 systems to replace Pioneer as needed to alleviate operational inventory shortages.

Joint

- JFCOM should be tasked to develop doctrine and tactics to integrate UAVs into the force structure with emphasis on employing existing systems and exploring cross-service use of assets

CHAPTER 2. CAP UNIT PRODUCTION COSTS

During the Task Force deliberations the cost of UAVs and UCAVs was identified as one of the major factors potentially limiting the development, acquisition, and use of UAVs and UCAVs. If UAVs and UCAVs become too expensive to be employed in a high risk environment they will lose their utility and be treated similarly to manned aircraft. If this occurs, UAV and UCAV technology and operations will not evolve to their full potential. 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.

Findings

- Requirements driven cost growth is a continuing problem for aircraft development programs. It is a particularly acute problem for unmanned aircraft programs because of their lack of maturity and lack of rigor in the requirements definition process.
- There is a history of major requirements driven cost growth for joint unmanned aircraft programs because of frequent program starts and stops, low production rates, and lack of competition all of which exacerbate the cost issues.
- Without extraordinary attention and decisive management controls, most UAV programs will face a low likelihood of transitioning from development to production because of significant increases in unit costs.

Cost Cap Determination

The UCAV cost cap should be based on a rational percentage of the current market cost of a similar manned aircraft such as the F-16 aircraft equipped for all weather air to ground combat. The F-16 Fighting Falcon is a compact, all weather, multi-role fighter aircraft. In an air-to-surface role, the F-16 can fly more than 500 miles (860 kilometers), deliver its weapons and return to its starting point,

however it is not as stealthy as a UCAV should be. The F-16 empty weight is 8,500kg (18,739 lbs) and the unit cost of the F-16 C/D was approximately $27M in FY98$. A suggested UCAV unit cost could be based on the ratio of the empty weight of the UCAV vs. the F-16. E.g. the planned X-45B, which is estimated to have an empty weight of approximately 14,500 lbs. would be 77% of the F-16 empty weight. The unit cost of an X-45B, for this example, would be capped at approximately $20.8M (FY98$). However, the empty weight of the X-45C model is estimated as 18,000 lbs which is about 96% of the F-16 C/D, therefore the cost would be capped at approximately $26.5M (FY98$).

The cost cap for the UCAV would cover the recurring unit production cost of an integrated aircraft consisting of: airframe, engine, flight control system, navigation system, low observable treatments, C2 communications, sensor systems needed for the basic mission including sensor processing and sensor communications. Excluded are any self-defense systems, weapons and ISR specific sensors since the cost of such sensors and weapons is very dependent on the specific mission. Cost of the sensor system alone can be a high percentage of the cost of the basic aircraft. The recurring unit production cost should be based on a reasonable quantity buy (e.g. > 50 aircraft) using rate manufacturing tooling.

The Role of Competition

Lack of competition in developing new-concept UAV systems can be a significant factor in program cost growth. This is an important issue since, in recent times, UAV system Advanced Technology Development Programs (ATDs) are increasingly turning into acquisitions. A winner of a single ATD paper downselect is aware of this trend and can be counted on to push hard for a sole-source acquisition. And once such as contract is signed, the government becomes, in a sense, hostage to the contractor who won the paper contest, this at least two years earlier than would be the case had final selection been made after a competitive fly-off. It is not unusual in such cases for the contractor's top design and management team to be pulled off the project and reassigned elsewhere immediately after winning a no fly-off contract. As a consequence, problems begin to

emerge, schedules slip, and development costs increase. It is critical that UAV programs be structured to result in reasonable production quantities or affordable cost will never be achieved. Many programs to date have suffered from this problem.

Hence, the Task Force believes that taxpayers and the military would be better served by carrying competition for complex, state-of-the-art UAV systems through a fly-off demonstration rather than selecting only a single contractor to build and fly his prototype design. Maintaining two teams through fly-off would foster innovation, give the customer additional time to decide what he really wants, and reduce development time and cost as well as overall time to Initial Operational Capability (IOC). Importantly also, it would keep on the pressure to control cost growth.

DARPA and the Army are now headed down a no fly-off competition path for the UCAR, which promises to be a dramatically different, highly complex system, perhaps more so than J-UCAS. The stated reason for this approach for UCAR is the added cost of carrying both Lockheed Martin and Northrop Grumman through flight demonstration, an amount estimated at $160M. Since near-years dollars are hard to come by, the points above about innovation, reduced overall cost, a more certain match to requirements, and shorter time to IOC must be forcefully presented. Realization of a fly-off competition may well require intervention by the Secretary of Defense.

RECOMMENDATIONS

CAP UNIT PRODUCTION COSTS

- OSD should require each major UAV and UCAV program in System Design and Development or Production stage to establish a well defined and well defended recurring unit production cost target per vehicle. Deviation from that cost target will only occur by direction of the Service Secretary.
- The recurring unit production cost target and the total cost of ownership of the UAV/UCAV system must be

established and justified in terms of what it costs manned platforms or other means to accomplish the same mission.

- OSD should undertake initial program by program reviews of recurring unit production cost targets as soon as possible and set up mechanisms for revisiting these figures throughout the life of the programs.
- OSD should always approach UAV/UCAV development with the intent to begin with competition and keep competition through early flight test. OSD should establish a competition advocacy team that can make the case to Congress on the benefit of competition.
- The Secretary of Defense is requested to establish competition through fly-off as the norm for new-concept UAV system developments and acquisitions. In the near term, the current DARPA/Army UCAR program should be restructured to provide for two-contractor competition through fly-off.

CHAPTER 3. REDUCE UAV MISHAP RATES

UAVs have been under development by the Department of Defense since the late 1950s. During the period from 1950-1970 most of these systems were relatively small, less than 2,000 pounds, and were used for local area reconnaissance. During the Vietnam War the systems were modified for many different applications including armed reconnaissance, Signals Intelligence and Psychological Operations. These systems were still relatively inexpensive compared with manned aircraft of their day.

In the early 1970s DoD began developing and testing larger UAVs characterized by the Compass Cope series of systems. While still only a fraction of the cost of manned systems the cost of UAVs was beginning to increase as the size of the UAV increased and most importantly the size of the payload increased. The payload cost can often be of the same order as the cost of the airframe.

Many of these early systems were not developed or procured under classical 5000 series acquisition rules. As such, specifications on system reliability were often absent. In 1994 the HAE program office placed a specification of no more than one loss per 2000 flight hours on the demonstration systems. The goal of the Army TUAV program for the operational system is one mechanical beyond economic repair (BER) per 1200 flight hours. The Predator system was built with highly reliable subsystems, with the exception of the propulsion system. The propulsion subsystem has caused the vast majority of the system losses that were not combat losses. Predator was first procured in 1995; there was no system reliability specification levied at that time.

Current Status. The DoD is currently procuring and/or operating the following UAV systems on a routine basis: Global Hawk, Predator, Army TUAV, Navy Vertical Take-Off UAV (VTUAV), Pioneer, and Hunter. These systems are operating in several different theaters and at training bases in the United States. These systems still have relatively few flight hours compared with manned aircraft. All of these systems exist in limited numbers ranging from 2 operational

Global Hawk air vehicles to approximately 9 operational Pioneer systems, consisting of 5 air vehicles each. Even after 17 years the Pioneer system has less than 20,000 flight hours.

As the systems get larger and more costly an increased emphasis on system reliability is warranted. The desire for increased reliability is also being driven by the need to routinely operate in the National Airspace. Current statistics on the loss rate of the Predator, Pioneer and Hunter are compared with military and general aviation aircraft per 100,000 flight hours in Table 3.1.

UAV Mishaps	Aircraft Mishaps
Predator – 32*	F-16 – 3
Pioneer – 334*	General Aviation – 1
Hunter – 55*	Regional Commuter – 0.1
* much less than 100,000 flight hours	Large airliners – 0.01

Table 3.1 Class A Mishap Rates Per 100,000 Flight Hours

More of these UAV mishaps can be avoided. There are several factors at work contributing to UAV mishaps. These include the original design requirements, maturity of the UAV systems, resources applied to identify and correct problems, and consequence of failure.

These UAV systems have very limited flight hours compared to manned systems. Of significance is that the manned system programs are deliberately structured to provide resources to find and fix reliability related problems. The cost of the manned airframe is high and the cost in human terms is high. The UAV programs have not had the resources necessary to fix root cause problems to a level necessary to drive the systems towards manned aircraft reliability.

The dominant causes of UAV mishaps are presented in table 3.2.

UAV Mishap Cause	Percent
Power and Propulsion	37%
Flight Controls	25%
Human Error	17%
Communications	11%
Miscellaneous	10%

Table 3.2 Causes of UAV Mishaps

Findings

UAV power and propulsion related failures have been well documented. The need for highly reliable, heavy fuel engines capable of operating at the altitudes, temperatures and military operating environments expected for UAVs has been a documented requirement since the mid-1980s.

UAV flight control failures are usually failures of the actuator subsystem. The primary reason has been cost. These are typically off the shelf subsystems, which were designed for a very different operating environment than the UAV uses them in. Some use manned aircraft quality components, (i.e. Predator), but some do not, (i.e. Pioneer).

Many of the human error induced accidents occur on takeoff and landing. The Global Hawk and Army TUAV systems have moved to totally hands- off takeoff and landing technology. The Army specifically required this in their TUAV solicitation based on their historic loss rate with Hunter and the Navy loss rate with Pioneer. These auto-takeoff / auto-land systems have been proven reliable across a wide range of UAVs. There are several types, each with features specific to a class of UAV system.

Figure 3.3 below shows that UAV systems can achieve manned aircraft like reliability if the resources are applied to achieve that goal.

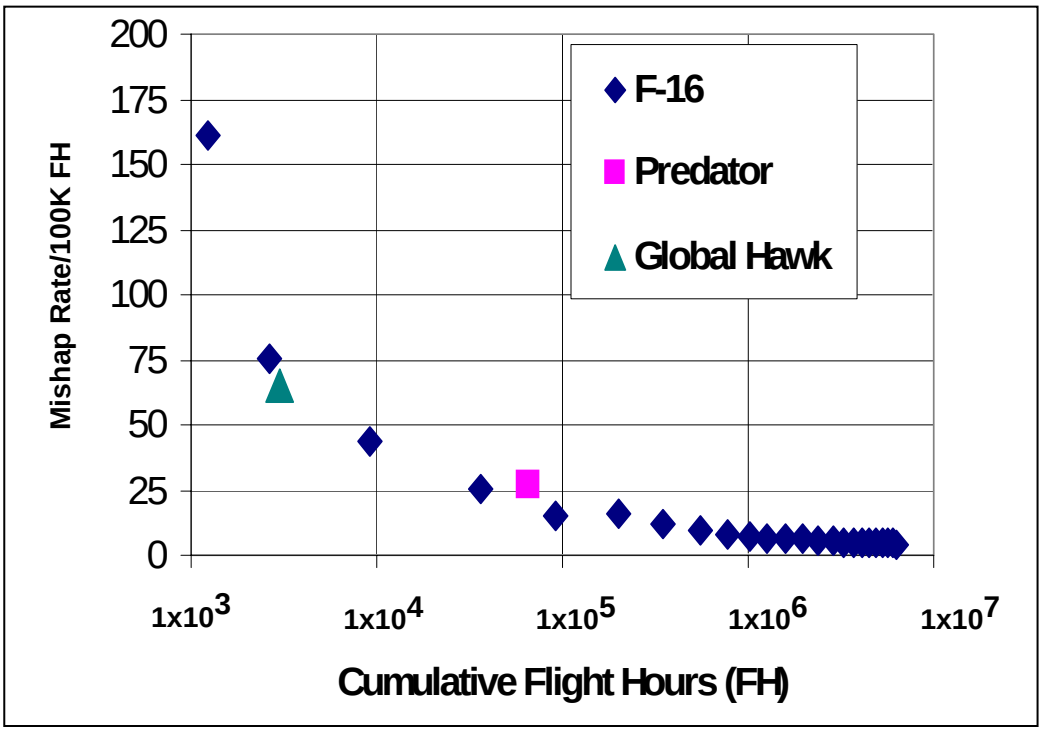

Figure 3.3 – UAV vs. F-16 Mishap Rates

Predator is currently coming down the same historic line that the F-16 did. However, the known problems with the Predator propulsion system and the known issues with manned takeoff and landing errors are not being adequately addressed.

RECOMMENDATIONS

REDUCE UAV MISHAP RATES

While UAV systems could have been designed, fabricated and tested to manned aircraft specifications, that has not been the case.

UAV systems should be designed to a set of specifications that takes into account the total cost of the system, the environments it is going to be used in, and the expected / acceptable loss rate.

Several actions should be taken:

- Develop and implement reliability specification standards as a function of the class / type of UAV. These specifications should become part of the acquisition strategy for the system.
- Institute a standardized data set for tracking reliability and system mishaps for UAVs. The manned aircraft community has this in place and with minor adjustments these same formats could, and should be used for unmanned systems.
- All UAV class A mishaps should be investigated using established Service procedures. The results should be documented and fed back into a system reliability improvement program.
- UAV system acquisition budgets should include resources for reliability improvement programs.

A careful examination of all subsystems contribution to the overall accident rate of UAV systems should be conducted to provide DoD with a baseline. Given that an overall reliability specification has been provided to the contractors, it is not necessary for the Government to specify the subsystem level requirements in a solicitation. The contractors should be held responsible for that allocation. If the contractor believes significant resources are required for a particular subsystem to meet the overall system requirement it will be reflected in their bid to the Government.

Unmanned Air Vehicle systems were long viewed as overgrown model airplanes. Today's systems are a long way from that early perception. These are sophisticated systems carrying expensive payloads performing critical military missions. The utility of these systems is no longer in question. The ability to task the systems and have confidence they are going to be ready to fly, fly the mission successfully, and return to begin the cycle over will require

improvements in the overall reliability of these systems. If the desire is to achieve manned-aircraft-like reliability, substantial additional investment will be required. For many classes of UAVs, that additional level of investment is not warranted. This trade-off should be recognized in the requirements process and both requirements and performance expectations should match the resulting decision.

CHAPTER 4. COMMUNICATIONS

There is widespread concern that UAVs are consuming increasingly large amounts of communication bandwidth. While true, this is also an indication that UAV sensor products are highly sought after by a wide audience. On-board processing and algorithms to survey large areas and reliably select only targets of interest for transmission could decrease the communications load – but this technology is not yet available. A set of programs structured under the Global Information Grid (GIG) initiative will provide a marked improvement in the available bandwidth provided the Services make matching improvements to facilitate access. However, even with GIG deployment, distribution over the "last tactical mile" will remain a problem with Navy ships at sea and land forces at battalion and below most affected.

Communications represent a major subsystem for UAVs. Bandwidth is needed to support systems that control the flight of UAVs, including launch and recovery, to transmit the output of on-board sensors to both line of sight and beyond line of sight processing centers, and to interface with air traffic control centers. Equally important is the recognition of a mission area for UAVs acting as communication relays linking tactical forces, including other UAVs, and providing connection to global support centers. Current data link requirements range from a few kbps for launch and recovery to in excess of 250 Mbps for the transmission of output of sophisticated sensors. Global Hawk has a documented data rate requirement of 548 Mbps for "multi-INT" sensors in 2015 and beyond, Predator requires 44.7 Mbps.

UAVs will play an important role in future military operations. It is anticipated that DoD operations will be comprised of force capability packages with elements provided by the Services suited to the need. These will be capable of being rapidly deployed. Command and control will be accomplished using a highly networked communications system, in contrast to point-to-point circuits. In the early stages of such deployment prior to deployment of follow-on

forces, emphasis will be placed on reachback to CONUS based support centers for connection to intelligence processing centers, logistic support centers, medical centers, weather and other supporting elements. Airborne relays will be needed to link mobile forces in the field and other UAVs. This need was recognized in the ASD (C3I), (ASD (NII)), study on Unmanned Aerial Vehicles as Communications Platforms, dated 4 November 1997. Major conclusions were:

- Tactical communications needs: can be met much more responsively and effectively with Airborne Communications Nodes (ACNs) than with satellite
- ACNs can effectively augment theater satellite capabilities by addressing deficiencies in capacity and connectivity.
- Satellites are better suited than UAVs for meeting high capacity, worldwide communications needs.

Bandwidth requirements will be increasing. Currently there are roughly 100 UAVs in service covering the various mission areas. This number will be increasing with production of Global Hawk, Shadow, Predator, and potentially large numbers of UCAVs. Additionally, new sensors for Electro/Optical (EO), Infrared, Synthetic Aperture Radar and Hyperspectral (EO/IR/SAR/HSI) sensing will add to the demand.

Intelligence, operations, and support systems increasingly rely on assured communications bandwidth. In Desert Storm 99 mbps was available to support 542,000 deployed troops. In OIF, 3.2 Gigabits was available to support 350,000 deployed troops. 84% of this bandwidth was provided by commercial communications. However there were still communications problems in OIF with UAVs. There was a 30 day wait for Hunter in Kuwait for frequency allocation in congested (C band) spectrum. Frequencies were previously approved prior to deployment. Division commanders want communications relay capability with UAVs. SIPRNET and NIPRNET are required for intelligence analysis and UAV operations and soldiers use internet chat between nodes for coordination. Flat hierarchy of command (from commanders (LTC) to UAV Specialists (E-3/4)) made the Hunter UAV responsive to unit of action tasking. Ipso Facto our UAV

communication links must be properly engineered and designed for protection and responsiveness

RECOMMENDATIONS

COMMUNICATIONS

- 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, GIG-BE, Information Assurance Horizontal Fusion and Power to the Edge.

  Power to the Edge implies equipping warfighters across the entire battlespace with the ability to access needed information at the right time to make the right decisions. Power to the edge means making information available on a network that people can depend on and trust, and populating the network with new, dynamic sources of information to defeat the enemy while denying the enemy advantages and exploiting its weaknesses.

  ASD (NII) has advanced the concept of an integrated system Global Information Grid (GIG) incorporating GIG Bandwidth Expansion, newly conceived Transformation Satellites, Joint Tactical Radio System (JTRS) into a system of systems – in effect creating the backbone of a fully connected, global Internet-like communication service. A necessary component to connect the tactical forces on the move to this mega system is the existence of a relay to handle the "last mile problem" linking battlefield UHF/VHF systems and providing global connectivity.

  While the ASD (NII) leadership with Defense Information Systems Agency/National Security Agency acquisition is laudable, the difficulty in coordinating the many programs involved including the UAV relay will be a challenge over the long time period development will take place. A communication program office, or other

management mechanism, that exercises oversight over the myriad of programs and directs adjustments to program schedules and functionality is needed. JFCOM is empowered with a role to ensuring the viability of Joint operations and STRATCOM has been assigned leadership for global command and control. The Combatant Commands need to work together in concert with Joint Chiefs of Staff to put high priority on the development of the end-to-end GIG and to ensure that a central design authority is properly functioning. While substantial funds (approximately $5.5B) are currently committed, efforts need to be made to ensure the development path continues over a long time period.

The availability of the GIG is also important for another reason. Many of today's UAVs are dependent on commercial satellite communications for narrow band beyond line-of-sight and wide-band beyond line of-of-sight connection because Military Satellite Communications (MILSAT) are already overscheduled. The use of MILSAT, via GIG, will provide information security and improvements in anti-jam performance and its development will provide the increased bandwidth which is in short supply currently and likely to remain so for 10 years.

- Initiate development of a UAV communications relay program to provide the "last tactical mile" connection to and among lower echelon forces. Consider Global Hawk or Predator for near term and extreme endurance systems for long term. Build on the DARPA program base (Adaptive Joint C4ISR Node (AJCN) and others).

The Services have expressed individual relay requirements and they are in the early stages of acquisition under the Navy Broad Area Maritime Surveillance (BAMS), Army Future Combat System (FCS), and Air Force relay programs. The DARPA's AJCN airborne relay program using Global Hawk/Shadow is underway and will provide a development vehicle for relay operations. While the individual Service needs are understandable, efforts need to

be made to ensure that any high altitude relay can support the general requirements of the Combatant Commander. Combat theatre relays need to present a single point of contact to satellites for relay purposes. This is necessary since the satellites will have limited RF and laser capability and can ill afford to support multiple theatre UAVs. It also implies that UAVs will be equipped with UAV to UAV communications capability to enable a single switching center concept and that control of the communication UAV network is under central control. A concept of operations (CONOPS) and a protocol for this control process needs to be developed.

- Ensure "reachback" capabilities have the necessary bandwidth and protection to support time sensitive targeting.

  The network centric infrastructure of Remotely Piloted Aircraft (RPA) command and control and data flow have generated a worldwide "Virtual Crew" that adds tremendous capabilities and challenges to effective ISR employment. As long as UAVs have the unique attribute of being operated by virtual crews out of theater, information assurance will be paramount.

- Institute mechanisms to conserve communications bandwidth.

  Include cost of communication as part of the Total Cost of Ownership (TCO) of an UAV system and continue to search for new paradigms of use – sampling at the Nyquist rate, on-board target recognition, etc.

- Develop a common video data link between UAVs and manned ISR systems.

  For instance the Scathe View System sent Predator video images to an AC-130 gunship patrolling in Afghanistan, which then could rapidly engage the targets before they could hide again. Video from UAVs should also be sent to Joint Stars, AWACS, and MC2A etc… all using the same format and type of data link to insure we preserve this

"quick strike" capability. Likewise Hunter has successfully passed its imagery to Apache helicopters thus insuring the added survivability factor to helicopter nap of the earth operations.

- Develop a protocol for controlling UAVs in Flight

A protocol for controlling UAVs in flight is needed. It is envisioned that a method needs to accommodate group operations such as those implied with swarming to support operations such as hunter-killer, formation flying for SIGINT collection and beyond line-of-sight data relay from deep penetrating UAVs. The functions of own-ship position reporting via dependent surveillance system and collision avoidance replacing IFF and Traffic Alert and Collision Avoidance (TCAS) could be provided by this protocol with substantial cost savings.

Real progress is being made in Service collaboration with the initiation of the Distributed Common Ground System (DCGS) that provides a common system for ISR exploitation which incorporates Common Data Link standards. The relay control processes described above can be an extension of the DCGS development.

CHAPTER 5. INTEROPERABILITY AND MISSION MANAGEMENT

Most of the design focus for UAVs is on the air vehicle, including its payload, and it is this component that must be tailored for the specific mission requirements. However, as can be seen from the cost data in Table 5.1, significant costs (ranging from .5 to 3-4 times the cost of a single air vehicle/payload suite) are associated with the ground system (which includes the functions described below).

UAV Systems (in SDD or greater)
Recurring Unit Production Cost [RUPC] ($M)

UAV System	Air Vehicle $M	Comm Subsys $M	Sensor Subsys $M	Airveh w PLs $M	Grnd System $M	Basis AirSys #/yr	Basis GrndSys #/yr	Basis Year	Comm Subsys Remarks	Sensor Subsys Remarks	Performance Remarks Alt,TAS,Tot Endur,PL
Predator MQ-1A	$2.2	$0.5	$1.8	$4.5	$6.7	22		FY04	SATCOM&C LOS	MTS Ball/Hellfire	25kft,70-100kt,24hr,450#
Global Hawk RQ-4A	$16.2	$2.8	$16.7	$35.7	$22.0	8	2	FY03-04	CDL/SATCOM	EO/IR/SAR/LR-100	65kft,350kt,34hr,2000#
Shadow 200 RQ-7A	$0.3	$0.0	$0.2	$0.5	$3.8	36	9	FY03	C-Band	PoP 200 (EO/IR)	14kft,80kt,5hr,60#
Fire Scout RQ-8B	$2.2	$0.2	$0.9	$3.2	$1.9	24	8	CY-04	TCDL/UHF	EO/IR/LDRF	20kft,115kt,7hr,400#
Predator B MQ-9A	$4.7	$0.5	$4.4	$9.6	$6.7	6		FY03-04	SATCOM	MTS/Lynx SAR	30kft,225kt,20hr,700#

Source: OSD/USD (AT&L)/S&TS-AW/UAV Office with some industry supplied missing data

Notes:
1. Costs are Recurring Unit Production Cost (RUPC) based on the production quantity and year basis shown
2. Recurring Unit Production Cost [RUPC] (also called Unit Flyaway Price [UFP]) includes Manufacturing Cost (Material,Labor, ODC, G&A, Fee), Recurring Engineering, Sustaining Tooling, and Quality Control
   [RUPC does not include system/project management, engineering changes, software, system test, nonrecurring tooling,manufacturing and engineering, tech data/pubs, contractor services, support equipment, training, initial spares, ground station or RDT&E]
3. Air Vehicle cost is assumed to include a single air vehicle w/ FCS and C2 comm but not sensors or sensor data comm payload
4. [AirVeh w PLs] is total of Air Vehicle plus Sensor Data Communications and Sensor subsystems (one airborne system flyaway RUPC)
5. Ground System is assumed to include all ground communications subsystems
6. Quantity basis is the size of the current order and is the basis for the recurring unit production flyaway cost
7. Low quantity fabrication involves custom human-intensive operations and costs should decrease with automated tooling
8. Shadow 200 RQ-7A based on FY03 FRP costs for 9 systems (each with 4 Avs). Shadow Ground System includes: 2 Ground Control Stations (GCS), 2 Ground Data Terminals (GDT), 1 Launcher, 1 Portable GCS, 1 Portable GDT, 1 AV transport, 1 TALS, 1Maintenancs Section Multifunctional, 4 Remote Video Terminals. Shadow is required to simultaneously operate two air vehicles and have displaced operations at two sites.
9. Global Hawk Ground System includes 1 Mission Control Element, 1 Launch & Recovery Element plus all communications subsystems including: SATCOM (DAMA UHF, 50Mb/s Ku, INMARSAT), and LOS (CDL 274 Mb/s and UHF)
10. MQ-9 costs are GA estimates for 6 air vehicles
11. Fire Scout costs are NGC quotes based on 8 systems of 4 veh each based on order in FY03-04
12. The UAV systems shown differ considerably in performance and mission and only the basic characteristics are shown.

Figure 5.1 UAV Systems Recurring Unit Production Cost

This fact provides the rationale for the creation of common mission management systems that can control more than one type of UAV. There is also a significant benefit of reduced logistics support and enhanced operational flexibility that derives from achieving this

sought-after interoperability. Consequently, the Task Force investigated the status of DoD efforts in this area.

The principal programs reviewed were the Navy-led Tactical Control System (TCS) and an Army initiative to require a common mission management system for small UAVs by building off the Shadow control system. TCS is a joint program, managed by the Naval Air Systems Command, to provide both command and control and direct data download for a joint family of UAVs. The Block II configuration currently is compatible with Pioneer, while the plans for Block III call for support of Predator and Fire Scout. The DoD UAV Planning Task Force has defined a Common Mission Planning Architecture (CMPA) [3] that provides a technical framework to guide all future UAV mission-planning developments. Also, NATO created a similar standard for mission planning documented in STANAG 4586.[4]

Because of the wide range of capabilities and missions, no single mission management system will fit all UAV categories, types and classes. The fact that mission management may include all or part of the functions of route planning, air vehicle management and control, communications, sensor tasking, and data dissemination and exploitation is a source of confusion that complicates interoperability discussions. For example, the Global Hawk Common Ground Segment focuses on mission planning and vehicle control with a clear separation from the sensor data download, exploitation and dissemination functions. In many smaller UAV platforms, management/control and exploitation are more integrated. Broad adoption of a standard functional breakdown, such as the DoD UAV Planning Task Force's CMPA (see Figure 5.2), would clarify some of the confusion and provide a foundation for enhanced interoperability and lower operating costs.

[3] NOTE: Add Reference to the CMPA report
[4] NOTE: Add Reference to STANAG

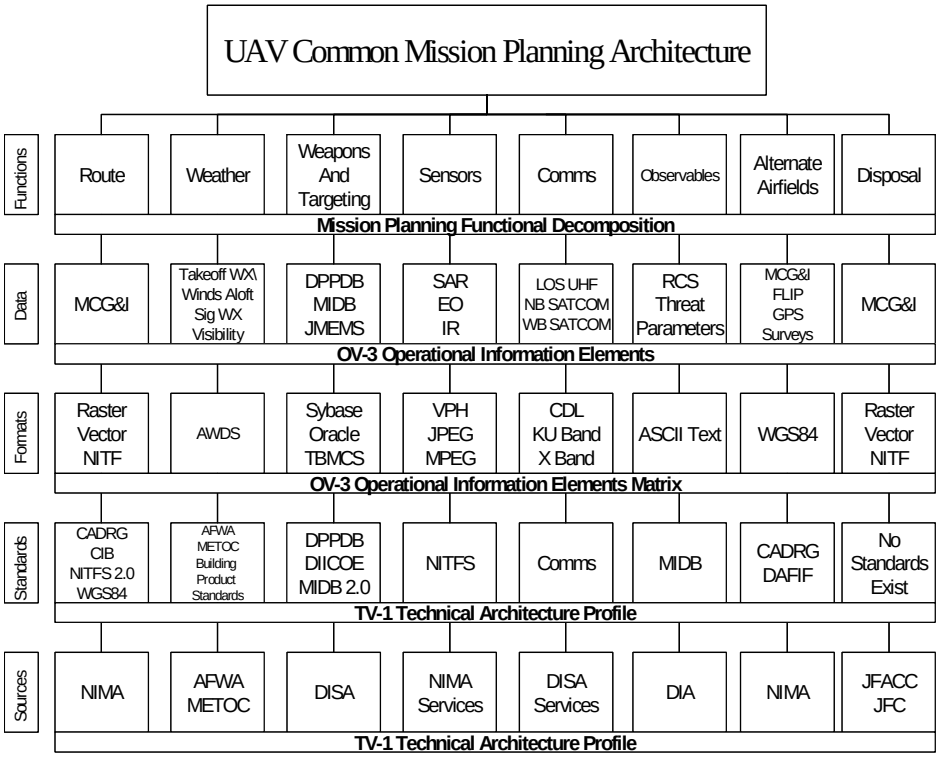

Figure 5.2. Overview of the UAV Common Mission Planning Architecture.

To date, individual Services have been reluctant to adopt common mission management systems or other interoperability approaches within similar types or classes of UAVs. At least 100 UAVs of 10 different types were used in OIF yet none of them allowed integrated direct data receipt. Each Service has tended to initiate its own separate development program specifically tailored to its requirements rather than adopting an existing capability within another Service. For example, the Navy is proceeding with the Broad Area Maritime Surveillance (BAMS) development rather than using Global Hawk. There have been no exercises or demonstrations that would stimulate cross-Service interchange of vehicle performance or mission management approaches. The Navy plans to use a few Global Hawks

in the BAMS mission, but only to valid concepts of operations, not to assess air vehicle or mission management suitability.

Current acquisition practices allow for vehicle-specific mission management stovepipe solutions rather than vehicle management and control across UAV systems. Most of the programs are structured to include the full system capability – air vehicle and ground segment. However, the focus is on the air vehicle and the mission management system is an afterthought. Frequently, it is a variant of some prior capability within the development prime contractor rather than a specific design for the UAV mission requirements.

Those few programs that have separately addressed common mission management, such as the Tactical Control System (TCS), were either not connected to air vehicles and/or were delayed such that the air vehicle projects had to develop their own capability. Once a standalone mission management system has been developed, there is significant resistance to the effort and expense to transition to a common system. Currently, there are so many different UAV systems in various stages of development that they are outstripping the ability of evolving standards and common mission management development efforts to keep up. A new approach to the structuring of UAV acquisition programs is required to address this challenge.

Current mission management systems require multiple operators to control a single UAV platform. Even for the smaller classes of UAVs, the current capability is no better than one operator per air vehicle. This staffing level adds significant operational costs. For certain small unit operation, one-to-one may be acceptable. However, the one-to-many command and control concept, integral to UCAV and swarms of micro-UAVs, is still an objective not reality. To achieve this objective, significantly higher levels of autonomous operation are required.

The task force found little evidence of demonstrations/exercises and tactics development that would stimulate Service adoption of UAVs let alone the use of common UAV elements or cross-Service cooperation/interoperability. In fact, the vast majority of the experience with UAVs has accumulated from taking developing

systems directly to war and discovering their value in the heat of battle. Significantly more effort is needed on the integration and evaluation of UAV operations and mission management systems. This effort will accelerate the development of doctrine and tactics to integrate UAVs more fully into the force structure. It will also provide the environment to generate and validate requirements for common, interoperable mission management systems.

RECOMMENDATIONS

INTEROPERABILITY AND MISSION MANAGEMENT

To address the challenges of enhancing UAV interoperability and to achieve the benefits of common mission management systems for classes of similar UAVs, DoD should take the following actions:

- The SecDef should designate USD (AT&L) the Deputy, UAV Planning Task Force as the DoD advocate for UAV interoperability.

  As part of the DAB review for each new UAV system, the Deputy, UAV Planning Task Force should advise the USD(AT&L) about the potential for an existing UAV system from another Service to satisfy the new requirements. The acquisition strategy review at the DAB should explicitly assess the approach to mission management with the goal of reducing proliferation of unique, stove-pipe ground system components. An early focus for this function should be the Navy Broad Area Maritime Surveillance (BAMS) program where the existing Global Hawk system or at least its Common Ground Segment are attractive alternatives to an entirely new development.

- Task JFCOM in concert with STRATCOM to more aggressively develop UAV doctrine and tactics.

  Both JFCOM and STRATCOM have equities for Global ISR missions and for transition from a platform based garrison force to a capabilities-based expeditionary force. As part of its new ISR mission, JFCOM must be more

aggressive in the development of doctrine and tactics to integrate UAVs more fully into the force structure. JFCOM should supervise the Service UAV Battle Laboratories in experimentation programs to define doctrine and tactics for the use of UAVs. A high priority task should be to develop a CONOPS to allow UAV flight control and payload tasking by one Service with acquisition, basing, maintenance and launch by another Service. DoD should provide $50M/yr additional funding for JFCOM experimentation, and tactics and doctrine development. This effort should be funded independently from platform/payload development.

Special Operation Forces and general purpose forces use UAVs in a completely different manner. Training syllabuses for each community of interest needs to be developed. Likewise closer cooperation with interagency organizations needs to be better defined and coordinated.

- Evaluate a separate procurement of a common mission management system for all UCAV variants.

UCAV, as it goes forward as a joint program, is a prime example of how a common mission management/vehicle control system could be derived for a UAV type that features differing platforms. A Joint Program Office (JPO) was stood up on 1 October 2003 to address Air Force and Navy UCAV issues. Its goal is to create standards that will allow UCAVs to be built along common lines in hopes of decreasing costs while retaining interoperability. This new UCAV JPO should structure its acquisition with separate mission management procurement for a system to be used with all air vehicle variants.

- Fund the UAV Planning Task Force at $10M per year.

The DoD UAV Planning Task Force should be given a budget to support requirements, architecture and standards trades and related analyses required to provide better advice to USD(AT&L) relative to UAV issues. In addition to providing the resources to support the Deputy, UAV Planning Task Force in advocating UAV interoperability,

the organization should expand its standards development efforts to examine systematically the interactions/roles among mission management, infrastructure, level of autonomy and operator skill level. The DoD UAV Planning Task Force could also harmonize the UAV/UCAV efforts at the various service battle labs and technology centers if better staffed.

- The Joint Staff should develop a Deployable UAV Operations Cell (DUOC). This initiative will develop new CONOPS and technologies for use in operation centers/cells to monitor multiple UAVs and limit the number of personnel required for supporting multiple UAV operations.
- Develop a joint mission rehearsal and training system for UAVs. This system could help visualize the mission execution needs of both manned and unmanned systems. Train and familiarize commanders (Bn, Bde, Div) with UAV/UCAR/UCAV capabilities. This could be accomplished by strengthening UAV operations training in Officer Advanced, Command and General Staff College, Pre-Command Courses. Battle Command Training Programs (BCTPs) must include UAV play (currently an option)
- Insure the Joint Operations Concepts or JOCs recently developed by the Joint Staff include UAV and UCAV capabilities in the four outlined JOCs areas: Major Combat Operations, Stability Operations, Homeland Security and Strategic Deterrence.
- Given the potentially high reliance and cost impact of UAV systems on geospatial intelligence support, Service UAV and UCAV development organizations and program offices should ensure the National Geospatial Intelligence Agency (NGA) is an early participant in the definition of geospatial intelligence requirements for UAV and UCAV systems.

In addition to these specific recommendations, technology development should be sponsored to permit enhancement of the level of autonomy in UAV mission operations so that the goal of multiple vehicles controlled by a single operator can become a reality. This objective will require "intelligent" autonomy in both the vehicle and the mission control element, including more status sensing and control onboard the platform and intelligent decision aiding for operators. Ultimately, this will require a mindset of designing for unmanned operation rather than evolving manned platform system design practices.

CHAPTER 6. INTEGRATE UAVS INTO NATIONAL AIRSPACE

The DoD has an urgent need to allow UAVs unencumbered access to the National Airspace System (NAS) outside of restricted areas (airbases and military operating areas), here in the United States and around the world. The need stems from the requirement to transit to/from combat areas of operations and perform time-sensitive training. Access is most needed for medium/high altitude, long endurance UAVs, which must fly great distances for mission accomplishment. It is not unreasonable that Predators, Global Hawks and someday UCAVs and high altitude airships will require rapid access to the airspace to fly from the U.S. to/from overseas locations. This access is critical to optimized force structure allocation during conflict. OSD recognizes this issue as a high priority and describes it in detail in the DoD UAV Planning Task Force UAV Roadmap.

Although not officially briefed to this DSB, we also concur with recent AF Scientific Advisory Board recommendations, which addressed extending UAV operations into international and mix-aircraft environments. In addition to facilitating "file and fly" flexibility for UAVs in the NAS, the military must develop the capability to operate increasing numbers of unmanned air systems in combat theaters where hosts of manned aircraft must also fly. This will require reliable Detect, See and Avoid (DSA) conflict avoidance systems on board most UAVs and adapting mission planning and C3 systems to accommodate high intensity mixed fleet operations of manned and unmanned aircraft. Current initiatives to integrate UAVs into the NAS should be expanded to include international airspace since large UAVs may have to transit long distances to reach combat theaters, and both large and small UAVs may have occasion to conduct training flights in airspace outside the United States.

The DoD relies upon FAA Order 7610.4, Special Military Operations to obtain approval to fly UAVs in the NAS. The regulation provides a process to obtain permission via a Certificate of Authorization (COA) to fly UAVs according to stringent planning and safety factors. It can take up to two months to obtain a COA for a

particular UAV mission. The COA process has served the nation well, but should be modified/revised to enable more rapid access to the NAS, especially for wartime missions.

According to the DoD UAV Roadmap, the DOD seeks to "coordinate revising FAA Order 7610.4 to replace the requirement for using the Certificate of Authorization process for all UAVs with one using the DD form 175 for qualifying UAVs." The U.S. Air Force has the action to complete the task in FY 2004. This Task Force concurs with this approach, but the effort should be extended into international airspace through the International Civil Aviation Organization (ICAO) using the traditional DD form 1801, international flight plans. This will require the DoD to become fully involved with not only FAA, but also international regulatory bodies working this issue. Results from international negotiations on this subject should be captured formally in the DoD plan and updated in the next DoD UAV Roadmap.

As an interim step to streamline Global Hawk operations, the Air Force petitioned the FAA and got approval for a Global Hawk National COA (NCOA). This COA shortens the approval time to fly to no more than five days, but applies only to domestic operations involving take offs and landings in restricted areas, such as Beale AFB. The NCOA is a very appropriate movement in the right direction towards true "file and fly" capability similar to approvals for manned aircraft today. However, other DoD UAVs are not captured in this NCOA. This may require the DoD to seek case-by-case COAs, which will require substantial FAA coordination.

Conflict avoidance, especially in a fully autonomous, lost-link situation will be the "Achilles Heel" challenge for the FAA to approve. Inherent in revising FAA Order 7610.4 is the need to fully satisfy the FAA that the DoD can build and operate UAVs in a manner that provides an "equivalent level of safety" (ELOS) to manned aircraft. We applaud the DoD for recognizing the magnitude of this problem and instituting integrated product teams to establish requirements and potential solutions. For true "file and fly" capability (using DD175 and DD1801 flight plans) this may be a very difficult task involving issues concerning UAV reliability/airworthiness, operator qualifications, levels of autonomy, and most importantly, the ability

for the UAV to avoid conflicts with other aircraft. Both cooperative (e.g., Traffic Collision Avoidance System and Automatic Dependent Surveillance-B) and non-cooperative DSA situational awareness/collision avoidance systems may be required in each UAV to satisfy the FAA. It is highly unlikely the DoD will be able to self-certify this capability.

In parallel to these DoD initiatives, the high altitude, long endurance (HALE) aerospace industry has formed an alliance called UAV National Industry Team (UNITE) (www.unitealliance.com) to gain full access to the NAS for civil and commercial purposes. UNITE has joined with NASA in partnership called Access 5 (www.access5.org). Access 5 seeks, within five years, to develop solutions for all barriers to flight in the NAS initially for HALE UAVs by systematically addressing all necessary technology, policy, regulatory and infrastructure issues satisfactory to the FAA.

DoD has joined Access 5 partnership to insure joint cooperation and sharing of information/technology to achieve mutually advantageous results and minimize duplication of efforts, real or perceived. DoD has accepted a formal seat on the Access 5 Steering Committee, which is represented by UNITE, NASA and the FAA. The DoD has worked closely with Access 5 to jointly develop a detailed plan to access the NAS. Success in this planning effort will lead to program initiation in February 2004. The FAA fully supports Access 5 in an advisory capacity and is carefully reviewing how to proceed with "file and fly" to insure uniform safety is maintained in the airspace for all participants.

In addition to facilitating "file and fly" flexibility for UAVs in the U.S. NAS, the military must develop the capability to operate increasing numbers of unmanned air systems in combat theaters where hosts of manned aircraft must also fly. This will require reliable DSA systems on board most UAVs, and adapting mission planning and C3 systems to accommodate high intensity mixed fleet operations of manned and unmanned aircraft.

Current initiatives to integrate UAVs into the U.S. NAS should be expanded to include international airspace since large UAVs may have

to transit long distances to reach combat theaters, and both large and small UAVs may have occasion to conduct training flights in airspace outside the United States.

Other nations of the world are also investigating ways to integrate their UAV systems into their airspace. Both DoD and Access 5 initiatives could lend support and leadership to global airspace integration and standardization, which in the long run, will be of benefit to all operators.

A major distinction between DoD and Access 5 programs is that DoD can self-certify aircraft, whereas industry must certify civil aircraft independently. Currently, there are no rules or regulations that permit commercial or military UAV systems certification. While the DoD is developing internal UAV systems certification practices for FAA concurrence, Access 5 seeks to develop civil rules and regulations and obtain approval from the FAA; which will allow industry to proceed with the civil certification process. Without acceptable certification rules and regulations no commercial HALE UAV markets will evolve and insurance rates will remain be prohibitively expensive. DoD self-insures their aircraft. Access 5 could be a major enabler for companies to produce HALE UAVs in volume, thus enabling future cost reductions for DoD procurements. There is direct commercial and industrial linkage to economies of scale for the DoD.

RECOMMENDATIONS

INTEGRATE UAVS INTO NATIONAL AIRSPACE

- DoD should become an active participant in NASA, FAA and industry efforts to accelerate "file and fly" capability for all classes of UAVs for operation in U.S. and international civil airspace as well as provide better integration of UAVs in military airspace during peace time training and in combat zones.

  It is absolutely critical that the DoD develop DSA requirements for all classes of UAVs that they intend to deploy in the NAS and overseas. Once these requirements

are validated, then technology solutions should be developed and tested to DoD and FAA satisfaction. The FAA has established an office that will interface with DSA development with Access 5. DoD is encouraged to integrate DSA development and testing activities with Access 5 planning to insure rapid decision-making and efficient use of federal resources. The FAA will require DoD to demonstrate military DSA systems operating in the NAS with civil traffic (cooperating and non-cooperating) to meet ELOS standards that civil UAV's will be expected to meet. The great debate will be whether the FAA will accept simple passive (e.g., electro-optical/IR cameras) DSA systems or more complex all weather active (e.g., radar) solutions, which could drive cost and complexity. A balance between safety, cost and operational performance must be struck. DoD should collaborate with Access 5 on DSA to the maximum extent possible consistent with funding and schedules.

- DoD should evaluate all types of OTH communications to insure compliance with FAA requirements. This may include dual redundant SATCOM links.
- Accelerate advanced research on autonomous vehicle operation, specifically focused on airspace situation awareness. This research would include speech recognition for Air Traffic Control (ATC), DSA compatibility with TCAS/ADS-B and new approaches for lost-link recovery.
- Direct accelerated development of DSA and other technologies so as to permit safe flight of UAVs in mixed manned/unmanned aircraft environments.
- Direct Commander Joint Forces Command to develop tactics, techniques and procedures that will assure safe, yet combat-effective flight of mixed forces of manned and unmanned aircraft in combat theaters.

CHAPTER 7. FOCUS TECHNOLOGY INVESTMENTS

The Task Force received briefings from many government and commercial entities developing or improving technologies that will in turn increase the capability and usefulness of UAVs to the war fighter. UAVs in service with our military today span small vehicles like the Dragon Eye which carries just a few pounds of payload to the Global Hawk which carries several thousand pounds. Because of the large range of UAV sizes and the fact that many technologies are involved with any given vehicle, there are literally hundreds of technologies that enable UAVs to do their job.

Despite the large number of technologies related to UAVs, the Task Force found that there is sufficient DoD investment in technology. In addition some DoD technology advancement is also being driven by the demands of commercial products, relative to which, any DoD investment would be small. For instance, the light-weight batteries being used in small UAVs were developed by the lap-top computer and cellular phone industry.

The following general trends in UAV related technology were observed:

- Computing and sensor technology is allowing flight control systems to fit in much smaller packages and enabling more automation.
- EO and IR sensor systems and other sensing technologies are becoming smaller and more capable
- Battery and other energy storage systems are getting better and smaller.

Generally the above trends will allow the size of a UAV designed to do a given mission to be smaller and cheaper. Or alternatively a UAV of a given size and cost will be able collect more information and be more autonomous in the future.

The following are a few cautions related to technology that the Task Force felt needed acknowledgement:

- Faster computers and sensor technology advancements can lead to requirements creep and/or quick technology obsolescence.
- The attraction of advanced technologies can lead us to overlook the continued development of basic building blocks like propulsion systems and structures.
- All UAVs rely on GPS and geospatial intelligence resources for basic navigation, georectification, and targeting. Efforts to install jam-resistant GPS on UAV's and other DoD equipment must continue to be a high-priority.

Several current development programs are underway to implement lightweight Laser Detection and Ranging (LADAR) systems for integration into UAVs. The Urban Reconnaissance Advanced Concept Technology Demonstration (ACTD), for example, is developing a LADAR package that will be under 100 lbs. and can be deployed in a variety of UAVs.

The LADAR systems will collect sub-meter resolution, precise 3-dimentional data for development of Geospatial Intelligence in the urban environment, and will detect activity under foliage and camouflage. LADAR sensors will provide a significantly increased resolution data set that can provide a superb foundation for the Common Operational Picture. These capabilities will support numerous data and intelligence requirements as stated by the Army, Air Force, and SOCOM. Once the technology is demonstrated, every effort should be made to implement the technology into operational UAV platforms (e.g., Predator and Global Hawk) and the mission applications they support.

The utility of low frequency (UHF and VHF) radar systems for the detection of targets is critical in the counter camouflage, concealment, and deception targeting problem. The development of such a radar capability for Global Hawk was the recommendation of the Time Critical and Time Sensitive Targets DSB. The Global Hawk ORD has

this specific requirement. However, the requirement is not funded in the Air Force POM. The NGA Interferometric Synthetic Aperture Radar (IFSAR) Mapping ACTD has the development of this sensor as part of its funded baseline. However, the Air Force has not yet fully supported the use of a Global Hawk for this mission.

Systems such as the UCAV are planned to carry an excellent radar system. The radar data from that system has the potential capability to be used to generate precise terrain elevation and target location data onboard the jet, without the need for interoperation with the NGA-produced, data intensive Digital Point Positioning Data Base (DPPDB). NGA and the UCAV System Program Office have initiated a technology effort – funded by the UCAV SPO – to develop this capability. The technology is relatively low risk, with high application to UCAVs and to other aircraft/systems applications (e.g., F/A-22, Joint Strike Fighter) with "next generation", highly precise radar systems and fairly robust onboard computing power).

Current Service precise positioning tools may be unable to support the growing volume and expanded performance capabilities of the Precision Guided Munitions (PGMs) entering the inventory. These tools and the processes to apply them will be an impediment toward satisfying the warfighter's requirements for engaging time sensitive targets. The current generation of operational tactical sensor systems was not designed to meet stringent requirements for measuring sensor state information in order to support point positioning and precision targeting at the required levels of accuracy. Metadata generated by current tactical sensors is not adequate to generate a high success rate of auto-correlation of tactical images to reference imagery.

UAV's have historically run into trouble with requirements creep and/or the insertion of new technologies into operational systems before they have been matured in the lab. The Task Force does not advocate a new, large technology investment program. Quite to the contrary, with the exception of a few recommendations below to focus existing technology investments, we feel that additional funding is better spent in other areas addressed in this report.

RECOMMENDATIONS

FOCUS TECHNOLOGY INVESTMENTS

Despite our general opinion that there is sufficient investment in DoD technology, we did identify a few areas that are not getting sufficient investment. The following recommendations address these few, under-funded, high-payoff technologies:

- Expedite the development of specifications, RDT&E and fielding of heavy-fuel engines suitable for UAVs. This is a technology area that will not be addressed by commercial efforts and will benefit: Predator, Army TUAV, Hunter, Navy VTUAV, Pioneer and others.
- Push technology to drive down the cost and weight, while maintaining performance, of all categories of sensors to maximize their utility on UAVs, as well as on manned and unmanned ground systems.
- Develop the new technologies necessary to allow integration of UAVs into the national and international airspace
- Implement auto-land and auto-takeoff technology for all UAVs with a gross weight of greater than 100 pounds. This will benefit Predator, Hunter, Pioneer and others.
- Develop "next generation" tactical sensor metric performance and cost parameters critical for support to precise geopositioning and targeting.

In addition to the above specific recommendations, technologies that address the bandwidth constraint that is a limiting factor for all UAVs need continued investment.

CHAPTER 8. REDUCE UAV COMBAT VULNERABILITY

Most of the UAVs in the inventory today are quite vulnerable to a variety of different air defense systems. Anti aircraft artillery (AAA), shoulder-fired man portable systems, and radar directed low medium and high altitude surface to air missile systems can all be quite lethal to UAVs within their range.

In an effort to keep costs in check, UAVs have not typically been equipped with either sophisticated radar warning systems or electronic countermeasure suites. UAV designs have also not incorporated much stealth technology, although for some of the short range varieties their small size and quiet engines do a reasonable job of reducing the probability of detection.

Vulnerability to air defenses has led to concept of operations employing UAVs in regions where the air defense threats have already been largely eliminated. However, there are (at least) two scenarios of interest where UAVs would be quite useful where the defenses had not been suppressed.

- Scenario 1. Providing extended surveillance in denied areas prior to conflict. Long endurance UAVs that could provide persistent coverage of an area, in all weather, while remaining covert would be a very useful capability to have. To do so would require the UAV to be immune from detection, tracking and/or targeting by modern air defenses.
- Scenario 2. Operating early in a conflict in a tactical reconnaissance role. UAVs or UCAVs would be very useful for obtaining updates on the location or status of specific targets or threats early in a conflict prior to defenses being suppressed. This mission is similar to the RF-4 tactical reconnaissance mission, with quick ingress and egress. It does not require the persistence of the first mission, nor the covertness, but does require an enhanced degree of survivability over current UAVs.

The panel did not have access to current special access initiatives in these areas but many of the members have been fully accessed to various similar programs during the last 10-15 years. Many of those programs did not succeed for technical, cost and/or conops reasons. It is from that experience that we make the following observations and recommendations.

OBSERVATIONS

- The goal of stealthy ISR capability, able to survive while providing persistent observation of a battle space, is unquestionably attractive. This "holy grail" has been pursued in many different, classified programs over the past 25 years and, for one reason or another, each program has been terminated. High altitude, long endurance, deep penetration, stealthy ISR is the most difficult of all possible UAV missions.
- Recommending development of a VLO, high altitude, endurance UAV would be easy for a DSB that is unconstrained by costs. This approach is consistent with the desires expressed by senior personnel in OSD and USAF so there is a receptive audience. However, there are a number of issues which must be considered in formulating a recommendation in this area. These include (1) mission requirements and trades, (2) survivability trade space, (3) technical and operational feasibility, (4) unit and opportunity costs.
- Achieving high altitude, long endurance, persistent all weather coverage while maintaining a low observability signature is a demanding task of the highest order. The degree to which these goals can be met is quite unclear. In previous programs we have let these goals "float," selected the most glitzy airframe proposal and as the program progressed thought little about hard things like sensors, communications, software, stealth details and real cost analysis. That is obviously not the right path to follow.

- Designing a UAV or UCAV for the RF-4 like tac recce mission is not as difficult. Operating at lower altitude, without persistence over a given area, with rapid ingress to predesignated points and rapid egress makes the stealth design significantly less stressing.

RECOMMENDATIONS

REDUCE UAV COMBAT VULNERABILITY

- Compile "lessons" from past programs in this overall area – with full security access to each. Make these lessons available to the ongoing/future efforts and implement actions to guard against making the same mistakes.
- Establish an independent Red Team to review all aspects of the pre-conflict persistent mission vehicle. Develop a clear understanding of the intended threat sophistication, mission requirements, and concepts for survivability. Presence, persistence, operability, sensing, reporting and survival must be achieved essentially simultaneously and the analyses cannot deal with them one at a time.

APPENDIX I. TERMS OF REFERENCE

ACQUISITION, TECHNOLOGY AND LOGISTICS

THE UNDER SECRETARY OF DEFENSE

3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

15 JUL 2002

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

Subject: Defense Science Board Task Force on Unmanned Aerial Vehicles (UAVs) and Uninhabited Combat Aerial Vehicles (UCAVs)

You are requested to form a Defense Science Board (DSB) Task Force to conduct a comprehensive review of the Department's plans for development and fielding of UAV and UCAV systems. For purposes of this study, UAVs and UCAVs are as defined in Joint Publication 1-02 and include both lethal and non-lethal systems.

Transforming the U.S. military requires rebalancing existing forces and capabilities. Global situation awareness and the global war on terrorism mandate responsive worldwide airborne intelligence, surveillance and reconnaissance. Over the last decade we have seen a substantial increase in the employment of UAVs in Desert Storm, Operation Allied Force and Operation Enduring Freedom. UAVs have complemented other airborne and terrestrial Intelligence, Surveillance and Reconnaissance (ISR) systems as well as our National Technical Means. We have also witnessed the weaponization of UAVs.

However, the Defense Department and Services have been slow to fund the needed investments to field a robust UAV and/or UCAV capability in the near term. Concerns continue to be raised regarding affordability and increasing costs, interoperability disconnects, communications architectures to include bandwidth and redundancy, accident rates, operational control in both FAA airspace and military restricted airspace, survivability, military utility analysis, and management approaches. I would like the Task Force to place special emphasis on the aforementioned concerns, identifying the principal impediments to full and rapid exploitation of the joint warfighting potential of UAV and UCAV systems and, further, recommending how these constraints might be mitigated or removed.

For these reasons, I ask the DSB to undertake a comprehensive review of UAV and UCAV systems immediately and to provide a briefing on interim findings and recommendations by October 15, 2002 and a final report and briefing by January 2003. The Task Force should leverage the work of the Joint UAV Planning Task Force and its FY02 update of the Department's UAV roadmap.

Study recommendations should be explicit and presented in three categories, with operational benefit and rough estimates of costs included: (1) items for immediate, quick-reaction implementation; (2) those that can be fielded by end of the FYDP period if accorded priority; and (3) technologies and systems for long term development.

The study will be sponsored by me as the Under Secretary of Defense (Acquisition, Technology and Logistics), the Assistant Secretary of Defense (Command, Control, Communications, and Intelligence), and the Director, Strategic and Tactical Systems. Major General (Retired) Ken Israel and Mr. Bob Nesbitt will serve as co-chairmen. Mr. Dyke Weatherington, OSD Strategic and Tactical Systems will serve as Executive Secretary and Commander Brian Hughes, USN, will serve as the Defense Science Board Secretariat Representative.

The Task Force will operate in accordance with the provisions of P.L. 92-463, the "Federal Advisory Committee Act," and DoD Directive 5105.4, the "DoD Federal Advisory Committee Management Program." It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of Section 208 of Title 18, U.S. Code, nor will it cause any member to be placed in the position of acting as a procurement official.

E. C. Aldridge, Jr.

APPENDIX II. TASK FORCE MEMBERSHIP

CO-CHAIRMEN

Mr. Robert Nesbit	MITRE Corporation
MajGen Kenneth Israel, USAF (Ret)	Lockheed Martin

TASK FORCE MEMBERS

Mr. Harry Berman	SRS Technologies
Mr. Bob Curtin	Aerovironment
Mr. Vic DeMarines	MITRE Corporation
Mr. John Entzminger	Private Consultant
RADM Bob Gormley, USN (ret)	Oceanus Company
Ms. Barbara Lindauer	General Dynamics
Mr. Larry Lynn	Private Consultant
Dr. Joe Markowitz	Private Consultant
Mr. Jim Shields	Draper Labs
Mr. Dale Tietz	Aerovironment

EXECUTIVE SECRETARY

Mr. Dyke Weatherington	OUSD(AT&L) Defense Systems - Air Warfare

DSB REPRESENTATIVE

CDR David Waugh, USN	Defense Science Board

GOVERNMENT ADVISORS

Mr. Kevin Meiners,	USD (I)
Maj. Jim McCormick,	USD (I)
Maj. Ken Myers	J-6
CDR Mike Pease	USN/J-8

Mr. Eric Bradbury	CIA
Mr. Mark Spivey	NGA
Mr. Ron Smetek	NGA
Mr. Steve Thompson	DUSD/IP

SUPPORT STAFF

Mr. David Greinke	Strategic Analysis Inc.

APPENDIX III. ACRONYMS

AAA	Anti aircraft artillery
ACN	Airborne Communications Node
ACTD	Advanced Concept Technology Demonstration
AJCN	Adaptive Joint C4ISR Node
ASD (NII)	Assistant Secretary of Defense for Networks and Information Integration
ATC	Air Traffic Control
ATD	Advanced Technology Development
AWACS	Airborne Warning And Control System
BAMS	Broad Area Maritime Surveillance
BCTP	Battle Command Training Program
C3	Command, Control, and Communications
CMPA	Common Mission Planning Architecture
COA	Certificate of Authorization
CONOPS	Concept of Operations
CONUS	Continental United States
CRW	
DAB	Defense Acquisition Board
DARPA	Defense Advanced Research Projects Agency
DCGS	Distributed Common Ground System
DoD	Department of Defense
DPPDB	Digital Point Positioning Data Base
DSA	Detect, See and Avoid
DSB	Defense Science Board
DUOC	Deployable UAV Operations Cell
ELOS	Equivalent level of safety
EO	Electro/Optical
FAA	Federal Aviation Administration
FCS	Future Combat System
GIG	Global Information Grid

GIG-BE	Global Information Grid Bandwidth Expansion
HAE	High Altitude Endurance
HALE	High altitude, long endurance
HSI	Hyperspectral
ICAO	International Civil Aviation Organization
IFF	Identification, Friend or Foe
IFSAR	Interferometric Synthetic Aperture Radar
IOC	Initial Operational Capability
IR	Infrared
ISR	Intelligence, Surveillance and Reconnaissance
JCS	Joint Chiefs of Staff
JFCOM	Joint Forces Command
JOC	Joint Operations Concepts
JPO	Joint Program Office
JTRS	Joint Tactical Radio System
J-UCAS	Joint Unmanned Combat Air System
LADAR	Laser Detection and Ranging
MC2A	Multi-Sensor Command and Control Aircraft
MILSAT	Military Satellite Communications
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NCOA	National Certificate of Authorization
NGA	National Geospatial-Intelligence Agency (Formerly National Imagery and Mapping Agency (NIMA)
NIPRNET	Government Restricted Unclassified Internet
OIF	Operation Iraqi Freedom
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OASD/C3I	Office of the Assistant Secretary of Defense (Command, Control, Communications and Intelligence)
OTH	Over The Horizon

PGM	Precision Guided Munitions
RDT&E	Research, Development, Test, and Evaluation
RF	Radio Frequency
RPA	Remotely Piloted Aircraft
SAM	Surface to Air Missile
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communication (Commercial)
SIGINT	Signals Intelligence
SIPRNET	Classified Government Internet
SPO	System Program Office
STOM	Ship to Objective Maneuver
STRATCOM	Strategic Command
TCAS	Traffic Alert and Collision Avoidance
TCO	Total Cost of Ownership
TCS	Transformational Communication System
TUAV	Tactical UAV Program
UAV	Unmanned Aerial Vehicle
UCAR	Unmanned Combat Armed Rotorcraft
UCAV	Uninhabited Combat Aerial Vehicle
UNITE	UAV National Industry Team
USAF	United States Air Force
USD(AT&L)	Undersecretary of Defense (Acquisition, Technology and Logistics)
VLO	Very Low Observable
VTOL	Vertical Take-off and Landing
VTUAV	Vertical Take-off UAV