United States Air Force

Scientific Advisory Board

Report on

Unmanned Aerial Vehicles in Perspective:
Effects, Capabilities, and Technologies

Volume 0: Executive Summary and Annotated Briefing

SAB-TR-03-01
July, 2003

Cleared for open publication

This report is a product of the United States Air Force Scientific Advisory Board Committee on *Unmanned Aerial Vehicles in Perspective: Effects, Capabilities, and Technologies*. Statements, opinions, recommendations, and conclusions contained in this report are those of the committee and do not necessarily represent the official position of the U.S. Air Force or the Department of Defense.

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U.S. AIR FORCE

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Executive Summary

Introduction

Unmanned aerial vehicles (UAVs) are not new to aviation, the military, or the Air Force (AF). The first UAV was developed and operated by Samuel Pierpont Langley, in 1896. During World War I, two separate efforts were conducted to develop UAVs for surface attack. While neither effort was finished in time to see combat, the Sperry Torpedo and Kettering Bug both flew in 1918 as unmanned, automatically controlled bombers. UAV development stalled until World War II, when development was again too late to contribute to the war. The BQM-34 was developed in the 1950s and used operationally as a photoreconnaissance platform. More recently, UAVs have developed along two very distinct paths. Vehicles like Helios and Global Hawk have been engineered for extreme range and altitude, making them large. In contrast, the Black Widow, which has a wingspan of only six inches, was developed to be portable and travel to places where humans cannot go. The UAV is not new, and past experience can be used to chart the course for future development. Today the revolution in technologies such as signal and image processing and sensors can be leveraged to permit UAVs to assume a larger role in Air Force missions.

The Air Force is off to a good start as an operational user of UAVs. Ten types of UAVs were used in OPERATION IRAQI FREEDOM. These UAVs performed traditional intelligence, surveillance, and reconnaissance functions as well as a range of more novel missions. One of the UAV's most used and desired attributes was persistence. The marriage of Predator to the Hellfire missile resulted in an unprecedented capability to hold targets at risk, with a level of endurance that made it difficult for the adversary to hide. Special Forces used portable UAVs to scan their areas of operations, enabling them to achieve tactical surprise.

This diversity of UAV sizes provides a wide spectrum of potential uses. Understanding the range of missions in which UAVs can contribute, or providing perspective regarding the utility of UAVs, was the purpose of this study. To accomplish this task, the Study addressed the following three focus areas:

1. *Provide notional mission concepts, to include innovative missions, for UAV employment in combat and non-combat roles*
2. *Delineate the evolution of roles and the appropriate synthesis of tasks for manned and unmanned aircraft over a spectrum of possible applications*
3. *Recommend air vehicle software technology and system capabilities for development and demonstration*

The Air Force is off to a Good Start

The Air Force has already studied the applications of UAVs, gained valuable experience in combat operations, integrated UAVs in networked operations, and identified key issues facing future UAV evolution. The Air Force has emerged as a knowledgeable proponent of UAV applications and appears prepared to leverage more UAV applications that support a range of Air Force missions.

Operations in both Afghanistan and Iraq demonstrated the value of UAVs in both ISR and combat roles. UAVs were integrated into the operational force and became valuable contributors to the total force. The integration of weapons on the Predator provided significant armed reconnaissance benefits, especially in the case of persistent response to time-critical targets. The benefit of Predator as ISR support for the C-130 gunship underscores the positive synergy between manned and unmanned systems.

The AF has acted upon previous SAB studies, which identified the need for persistent ISR and time-urgent threat response. UAVs have both designated targets for off-board weapons and engaged targets directly, which relates to the SEAD/DEAD mission area identified in the 1996 SAB study. This study was also a catalyst for the recent USAF/DARPA development of the UCAV, which may help transform the military aerospace landscape in both persistent battlespace presence and unmanned systems' integration with manned systems.

Other transformational concepts like Net-Centric Operations can be tapped to maximize the effectiveness of UAVs while saving significant costs. The characteristics of UAVs as platforms, which can run the gamut of onboard sophistication, suggest that they may be more flexible than manned systems in allowing the network to achieve greater system-level functionality. In fact, the idea of remoting the pilot function, as with Predator, demonstrates a degree of flexibility in the network that allows it to assume control of any UAV function by ensuring the development of an onboard processing package and validated flight software.

Despite this progress, the study identified several remaining issues associated with UAV systems. These include cost, flight safety, operator qualification, mission management technology, and the development of an integrated manned/unmanned architecture. The cost picture is unclear, primarily because of limited UAV experience and because procurement numbers are so low that per unit costs have remained high. Safety concerns regarding UAVs flying in the battlespace may force significant flight constraints that could curtail operational effectiveness, pending resolution of policy issues with FAA and ICAO. A key technical area is mission management software, which Includes autonomy and human-system interfaces. Finally, UAVs should not be considered independent systems in the battlespace. They must be integrated into the overall architecture (operational, technical and system) containing manned and unmanned systems.

Do Things Differently

To get the most from UAV platforms the AF should make changes in the way it procures and operates UAV systems.

Net-Centric Operations (NCO)

Among the insights gained during this study is the realization that limited-capability UAVs can accomplish complex tasks by leveraging other systems in an integrated network. Similarly, manned systems benefit greatly from the data provided by UAVs. Unmanned vehicles must be a part of NCO, which involves integrating the vehicle communications into the command and control network and transmitting data and intelligence gathered from the UAV to the broader network to enhance situational awareness on the part of all other operators in the battlespace. The creation of a net-centric constellation of manned and unmanned assets will be a step toward the realization of Predictive Battlespace Awareness, the topic of last year's SAB study and an important AF organizational goal. Through this increased awareness and sharing of data, systems with limited capabilities will be able to perform complex tasks by leveraging the network.

Acquisition Strategy and Cost

The study concluded that both different acquisition concepts and cost-reducing measures must be implemented for UAVs to be procured in large numbers and escape the low-density/ high-demand space they currently occupy.

Current UAVs are being procured in small numbers, and this fact has resulted in high per-unit costs. Going forward, the number of systems procured will be highly dependent on their planned missions. To control life cycle costs, "requirements creep" must be controlled. The data show that UAVs manufactured to manned-aircraft standards of mission accomplishment, performance, survivability, and reliability will have procurement costs that are very similar to those of manned systems.

While procurement cost savings may be limited, substantial savings appear to be possible in operations and support costs. Since UAVs are operated remotely, the operator's role in a mission can be completely replicated in a simulator without the need for training sorties. While some sorties for maintenance proficiency and interoperability with other platforms will still be required, substantial savings can be made by cutting actual flight operations. Deployment packages for similar mission capabilities can be substantially smaller for UAV systems, since in many instances, only launch and recovery teams need to be sent forward. UAV employment concepts may also reduce requirements for combat search and rescue, jamming escort, etc.

Do New Things

There are several new things that must be accomplished for the AF to realize the full potential that UAVs can bring to the battlespace.

The AF needs to invest in mission management technologies. While flight control and basic vehicle technologies are already well developed, the technologies to actually manage the mission (such as automation, human-systems interface and dynamic replanning algorithms) are the key limiting factors to increasing both the performance of UAVs and the vehicle-to-operator ratio. Although supporting work in mission management technologies was a recommendation of the 1996 SAB UAV Study, little work has been done in this area, and it remains a key area for focused investment.

The AF should procure the set of three present and planned systems (Predator, Global Hawk, and UCAV) as part of a family-of-systems concept. To realize the wide set of capabilities sought across the AF Task Force CONOPS, three new family members must be developed. The new systems are a survivable deep penetrating ISR, a survivable deep penetrating strike, and a set of small UAVs.

By analyzing the various CONOPS for needed capabilities and then comparing those capabilities to currently programmed systems, the study discovered that this limited set of vehicles is capable of achieving a diverse set of effects. Predator, Global Hawk, and UCAV are able to add value to five of the ten key missions identified for UAVs. Additionally, they are capable of accomplishing or enhancing 14 of the 27 missions. The recommended family of multi-functional UAV platforms, with modular payloads, can enhance the AF capability to achieve effects in 26 of the 27 mission areas. Procuring UAVs as a small family of fully interoperable systems will result in purchase numbers being sufficient to drive down costs, while supporting a broad range of capabilities.

Recommendations

The UAV Study is supportive of improved UAV capabilities and strongly encourages the acceleration of Air Force acquisition activities. UAVs have already emerged as working elements of the Aerospace Force. The study recommends that the Air Force:

1. Continue to procure Global Hawk, Predator, and UCAV, incorporating new capabilities through spiral development using open system architectures and modular payloads.

2. Begin research and Analysis of Alternatives on the Survivable High Altitude Endurance and Survivable Large systems.

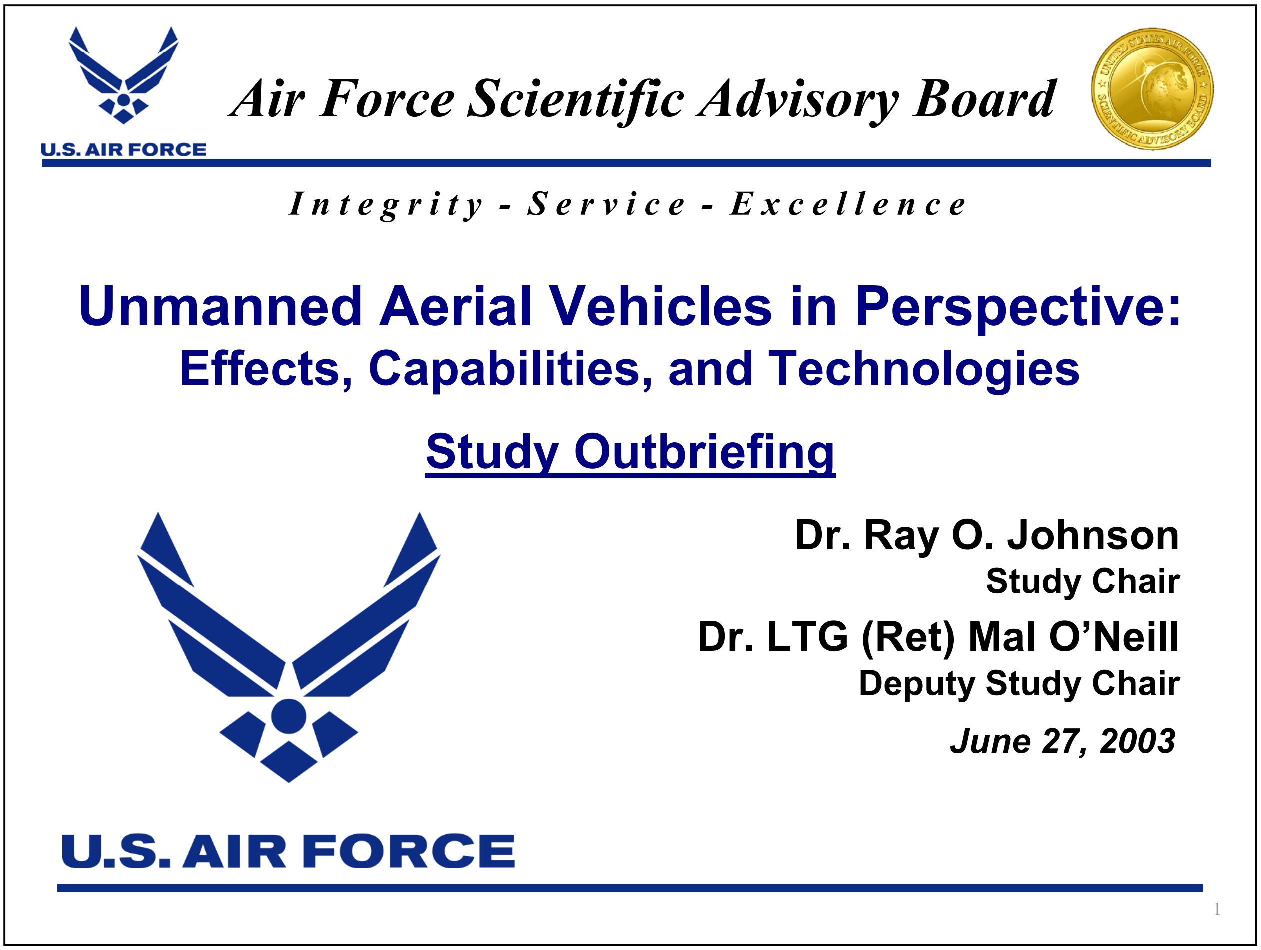
3. Develop a cross-cutting research initiative in Autonomy and Human-System Integration mission management technologies; integrate using a testbed environment.

4. Develop an architecture and the associated standards that enable the integration of UAVs with manned and space systems.

5. Initiate innovative research into small UAV platforms and the enabling technologies.

6. Conduct near- and mid-term demonstrations of specific capabilities to integrate unmanned systems into the force structure.

Slide 1



This report summarizes the conclusions of the AF Scientific Advisory Board Summer Study titled *Unmanned Aerial Vehicles in Perspective*.

Slide 2

U.S. AIR FORCE

On War

"In the past war, the nature of the weapons, the brilliance of our sources, and the mistakes of our enemies all weighed the balance in our favor. It may well not remain so in the future."

R. V. Jones
Assistant Director of Intelligence, Science
Ministry of Defence, UK
1939-1945
The Wizard War

Integrity - Service - Excellence 2

Reginald Victor Jones, PhD was born in 1911. He studied physics at Oxford, and was awarded his doctorate from the Clarendon Laboratory. Shortly after getting his PhD, Dr. Jones was asked by the U.K. Air Ministry to work on an airborne infrared detector that could be mounted on aircraft. Shortly after the infrared detector project was completed, Dr. Jones was attached to the intelligence services to investigate the German use of science in the war. Jones assembled a small staff at the Air Ministry in 1940 and rapidly developed a method of jamming the navigational beacons that German pilots were using to guide bombers to their targets. This success led to his appointment as the Assistant Director for Intelligence – Science. In this capacity, he continued to make vital contributions to the Allied war effort. Among his accomplishments were the development of "window," the first chaff, and important contributions to the allied understanding of the German V-1 and V-2 rocket programs.

The quote from Jones was made shortly after WWII, but is equally valid today. We have come to rely on a technical advantage over our opponents, and we have historically leveraged this to our smaller forces to defeat adversaries with larger numbers. Jones warns that without continued efforts to stay ahead, this advantage may someday be lost. This study believes that the field of unmanned vehicles is an area where we must continue to work to maintain our advantage.

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Study Focus Areas

1. **Notional mission concepts, including innovative missions, for UAV employment in combat and non-combat roles**
2. **The evolution of roles and the appropriate allocation of tasks for manned and unmanned aircraft over a spectrum of possible applications**
3. **Air vehicle platform and software technologies; system capabilities development and demonstration**

Our Vision for UAVs

UAVs will complement the manned and space forces by incorporating the advantages of unmanned systems to make the 21st Century Aerospace Force more capable

Integrity - Service - Excellence 3

These three focus areas of the study were derived from the Terms of Reference, which follow:

- Provide notional concepts of operation that support the operational capabilities addressed in the study and address issues that may affect management processes or technology design and development.
- Consider innovative missions for unmanned aerial vehicles that are not just a replication of manned missions and the features that make unmanned aircraft superior to manned aircraft for specific missions.
- Consider the evolution of roles and the appropriate division of tasks for manned and unmanned aircraft over a spectrum of possible applications – from fighters and bombers to transports and reconnaissance aircraft in the near-, mid-, and far-term.
- Survey and recommend air vehicle platform and software technology needs and availability – such as avionics, propulsion, flight control, and stealth. Consider the flight management technologies and processes that are needed when unmanned aircraft are used in close proximity to manned aircraft.
- Consider how the Air Force measures the contribution of unmanned aircraft to warfighting capabilities including the development of the test and demonstration metrics.
- Recommend technology and system capabilities development and demonstration plans. The Study Vision for UAVs envisions UAVs complementing the manned and space forces.

Slide 4

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Study Membership

Mission Concepts Panel
Dr. Pete Worch, Panel Chair
VADM (ret) Lyle Bien
Dr. Jim Lang
Mr. William Lawler
Col Rhys MacBeth
Mr. Steve May
Dr. Chris Mitchell
Mr. Phil Pearson
Mr. Ken Pedersen
LCDR Dave Seagle
Ms. Heidi Shyu
Mr. Phil Soucy
Dr. Mike Yarymovych
Capt Frank Gaillard (Panel Exec)
Lt Jim Patrey (Panel Tech)
Mr. Rob Ripperger (Study Exec)

Mission Management Panel
Dr. Greg Zacharias, Panel Chair
Dr. Stephen Cross
Dr. Mica Endsley
Mr. Jeffery Erickson
Dr. Matthew Ganz
Ms. Teresa Lunt
Dr. Robin Murphy
Dr. Shankar Sastry
Dr. Michael Shatz
Col Steven Suddarth
Capt Raymond Bernier (Panel Exec)
Maj Heather Pringle (Panel Tech)

Executive Panel
Dr. Ray Johnson, Study Chair
Dr. LTG (ret) Mal O'Neill, Deputy Chair
Col John Bedford
Mr. Ed Brady
Mr. John Entzminger
Lt Col John Geis
Mr. William Hewitt
BGen Mike Hostage
Maj Jay Lowell
Maj René Noel (Panel Tech)
Maj Dwight Pavek (Study Exec)
Maj David Quick (Panel Exec)

Vehicles Panel
Dr. Brian Hunt, Panel Chair
Dr. Brian Argrow
Mr. Harry Berman
Lt Col David Bossert
Dr. Robert Byer
Dr. Claude Canizares
Dr. Armand Chaput
Dr. Tom Cruse
Dr. Gary Denman
Dr. Hamish Fraser
Mr. Wally Hoff
Dr. Don Kenney
Mr. Steve Kracinovich
Prof. Robert MacCormack
Dr. Richard Murray
Lt Col (Sel) Christina Morris (Panel Exec)
Maj Scott Nowlin (Panel Tech)

Integrity - Service - Excellence 4

The Study is organized into three Operational Panels and an Executive Panel. The Vehicles panel defined the vehicle concepts and design needs, identified vulnerabilities and limitations unique to UAVs, identified vehicle cost savings opportunities, identified vehicle technology limitations, and developed an integrated plan for near-, mid-, and far-term UAV system capabilities and demonstration. The Mission Concepts and Demonstrations panel analyzed the AF's needed capabilities and effects and developed measures for determining the value of manned and unmanned platforms in achieving these effects. From these measures, the panel established a long-term vision for roles in which UAVs would enhance the capabilities of the AF and suggested a series of demonstrations that could be the basis for system maturation and fielding. The Mission Management Panel examined UAV human-systems interface and autonomous operating technologies related to command and control, platform operation, and payload employment. This panel then identified key operational constraints associated with current levels of technology and defined a framework for understanding future needs, future trends, and potential solutions.

The Executive panel oversaw and integrated the efforts of the other three panels in the study.

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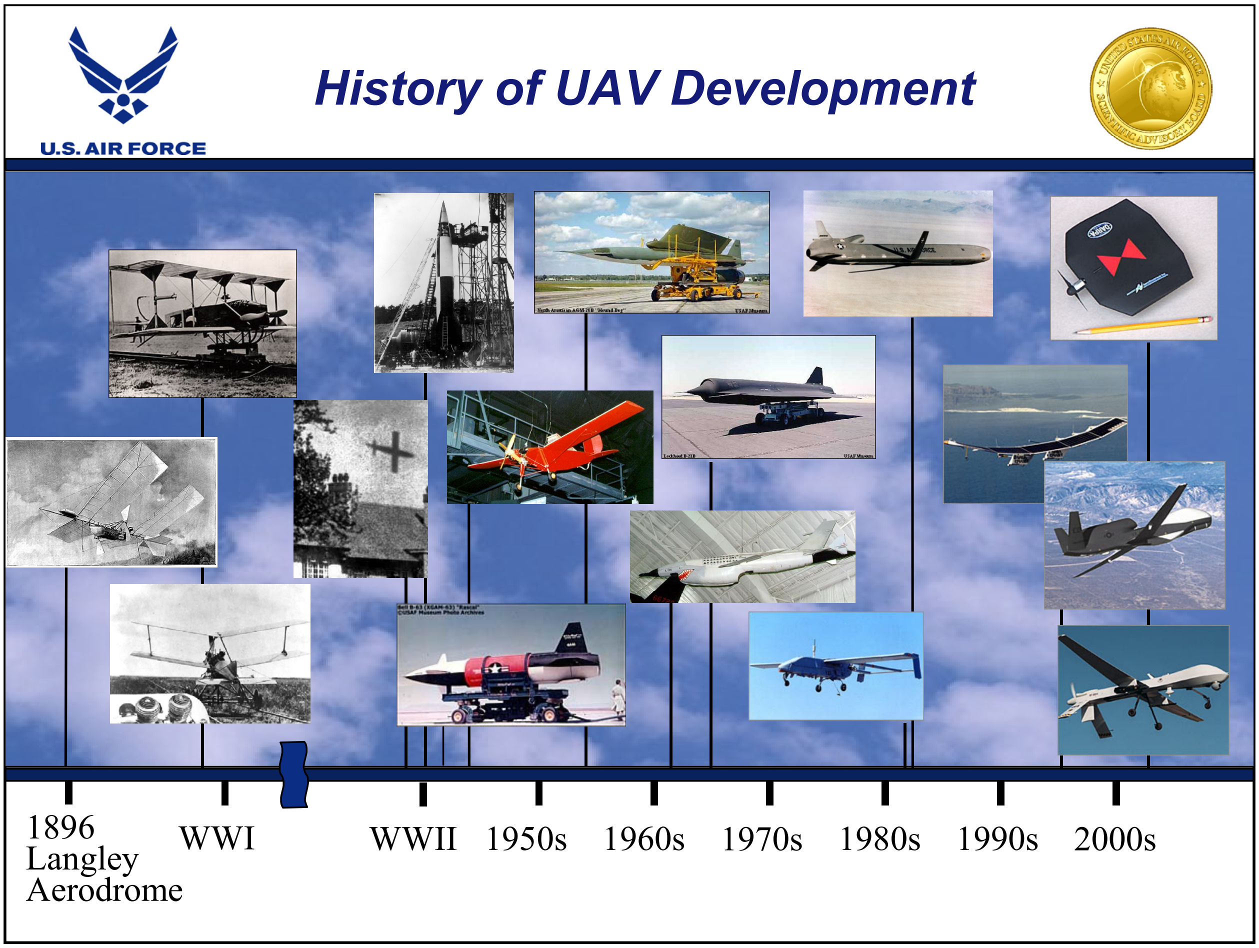
Visits and Briefings

- ACC
- Air Staff (XO, XOIR, XOR)
- AFAWC
- AFC2ISR
- AFMC
- AFRL (HE, VA, PR, MN)
- AFSOC
- Allison Advanced Development Co.
- Alphatech
- Army
- ASC
- AWFC
- BAI Systems
- Bluefin Robotics
- Boeing
- C2TIG
- CIA
- DAPR-EDI
- DARPA (IPTO, IXO, TTO)
- Draper Labs
- DSB UAV Study
- General Atomics
- General Electric
- Geneva Aerospace
- JCS/J8
- Honeywell
- Lockheed Martin
- NASA ARC
- NAVAIR
- Northrop Grumman
- NRAC
- NSA
- ONR
- OSD-ISR
- SOCOM
- UAV Battlelab
- UCAV SPO
- OUSD (AT&L)
- Pratt & Whitney
- RAND
- Raytheon
- Rolls-Royce
- SAF/AQL
- Scaled Composites
- Sippican Systems
- Williams
- Woods Hole Oceanographic Institute
- 12th RS, Beale AFB

Integrity - Service - Excellence 5

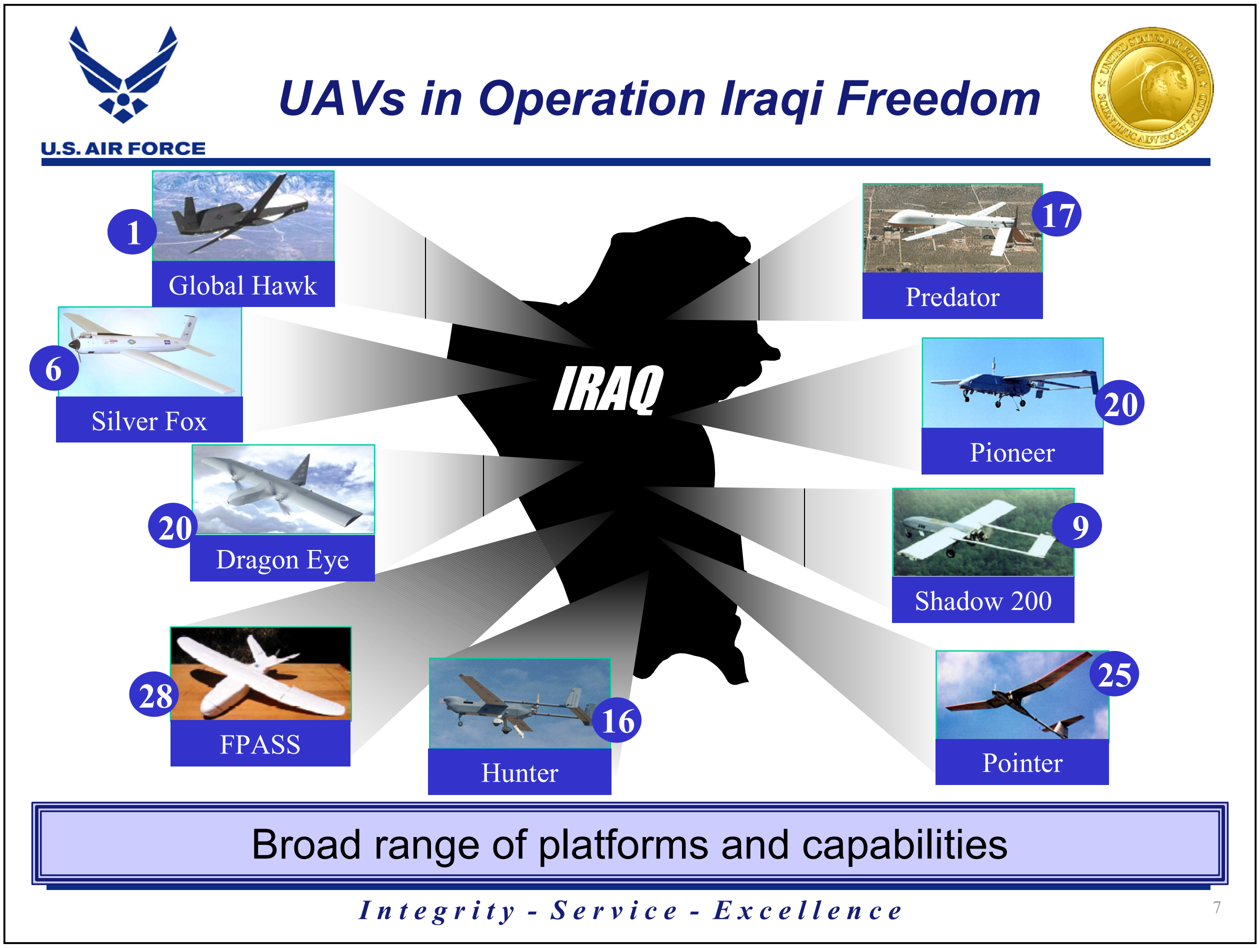
Study participants traveled widely around the United States in an effort to gather the data necessary to put UAV operations and future capabilities into perspective. The study consulted a broad range of government, industry, and academic institutions.

Slide 6



The development of UAVs dates back to the late 19th Century when Samuel Pierpont Langley developed an unpiloted heavier-than-air vehicle, which flew in May 1896 over the Potomac River. In World War I, the development of unmanned vehicles continued with the development by Lawrence Sperry of an unmanned bomb called the "Sperry Torpedo." Development began in 1916, and the first flight was in March 1918. This was followed shortly thereafter by the "Kettering Bug" which first flew in October 1918. Due to the ending of World War I, neither of these vehicles saw mass production. World War II saw the development of a new set of unmanned weapons. Beginning in June 1944, Germany used the V-1 rocket to attack and terrorize the people of Great Britain. The V-1 was followed in September by the first use of the V-2. The German use of these devices prompted U.S. research efforts, which again came to fruition only after the end of the war. The Bell B-63 guided missile and the OQ-A Radioplane were both developed in 1946 and were never produced in mass quantity. Development of unmanned systems continues to this day. Thus far, over 1,500 separate types of UAVs have been developed, a small fraction of which appear here. In recent years, UAVs have exhibited two disparate trends. Some UAVs have shown remarkable range and payload capacity, such as the Global Hawk. Others have become very small, like the Black Widow, which is only around six inches long.

Slide 7



In Operation Iraqi Freedom, over 10 types of UAVs were used. In addition to the nine depicted above, ground forces used several small UAVs that directly supported maneuver commanders. In general, the UAVs performed very well. Reachback for UAV operations enabled a reduced forward logistics footprint, which enabled more efficient deployment. UAVs provided persistent ISR over areas of interest throughout the battlespace and were synchronized with manned strike systems. This combination enabled the attack of time-critical targets at several points during the operation. Even though UAVs were preferred to manned systems in medium- and high-threat environments, losses were lower than expected, with only one Predator lost in combat.

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We're Off to a Good Start

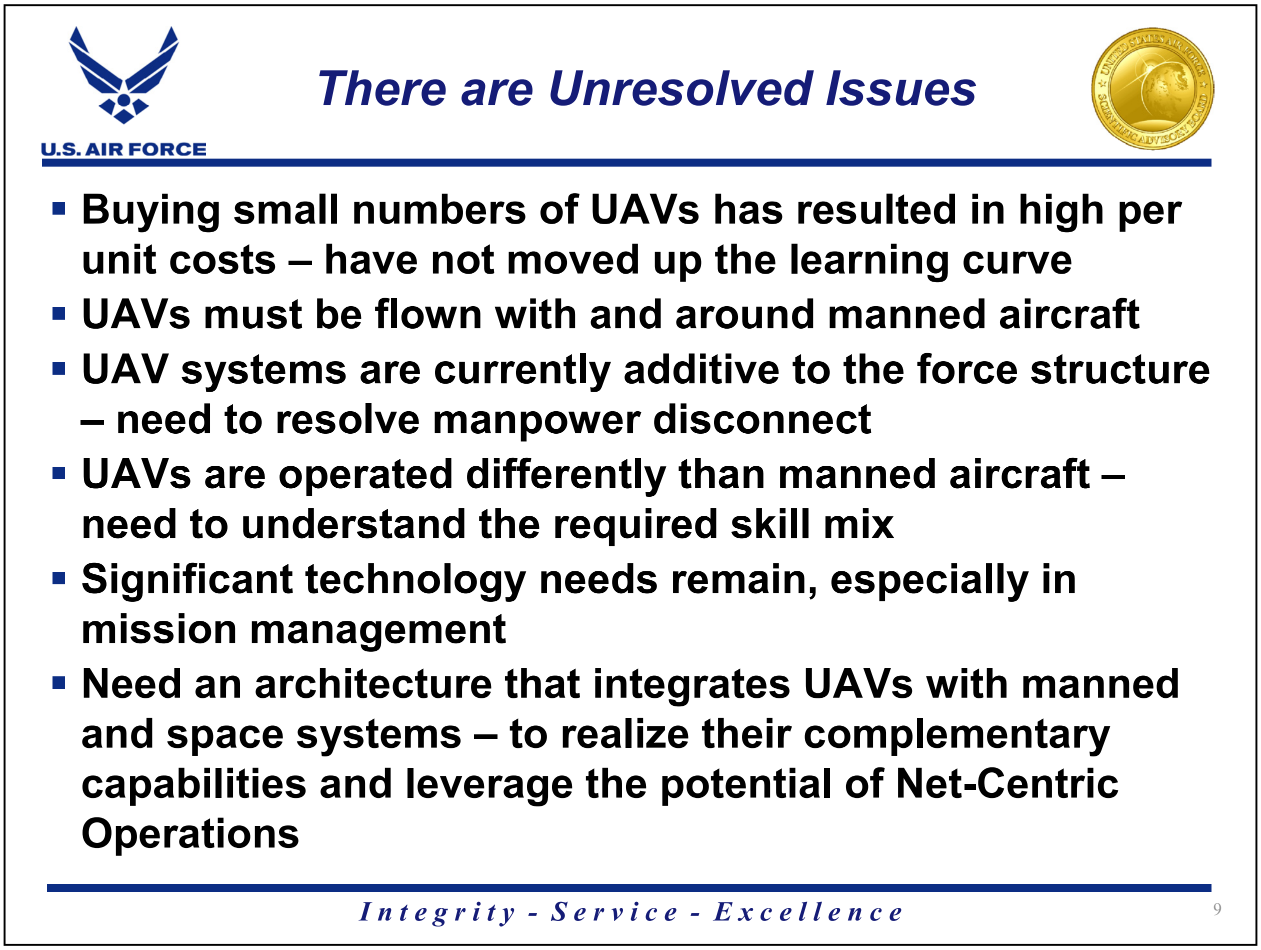
- Previous and current studies identified specific needs
  - *UAV Technologies and Combat Operations*
  - *Sensors for Difficult Targets* and *PBA*
  - *Machine-to-Machine* and *Long Range Strike*
- AF has started to take advantage of UAV system attributes
  - Persistence, precision, survivability, flexibility, lethality
- AF Transformational Flight Plan fully integrates UAVs
- There are excellent examples of Air Force ingenuity in the application of UAVs to military roles
- Less expensive, limited capability UAVs have been able to leverage the power of networked operations to accomplish complex and demanding missions

Integrity - Service - Excellence 8

The Air Force is well on its way to defining future requirements for UAV systems. Several AF Scientific Advisory Board (SAB) studies contribute to this discussion, including the 1996 study on *UAV Technologies and Combat Operations*, the 2001 *Sensors for Difficult Targets* study, the 2002 *Predictive Battlespace Awareness* study, and the 2003 ad hoc studies on *Technology for Machine-to-Machine ISR Integration* and *CONOPS and Technologies to Support Long Range Strike Operations*. The AF has also fully integrated UAVs into its Transformational Flight Plan.

Additionally, the AF has made considerable progress over the past ten years in UAV employment and research. In Iraq, the AF leveraged UAV attributes of persistence, precision, survivability, flexibility, and lethality to strike time-sensitive targets and create desired battlefield effects. The use of Global Hawk to provide mensurated coordinates to F-16CJs for precision weapon employment and rapid target destruction in Operation Iraqi Freedom, and the use of Predator-A as an airborne forward air controller in Operation Enduring Freedom point both to the resourcefulness of Air Force professionals and to the innovative ways UAVs can complement manned aircraft in the battlespace. These operations demonstrate that less expensive, limited-capability UAVs have been able to leverage the power of Net-Centric Operations to accomplish complex and demanding missions.

Slide 9

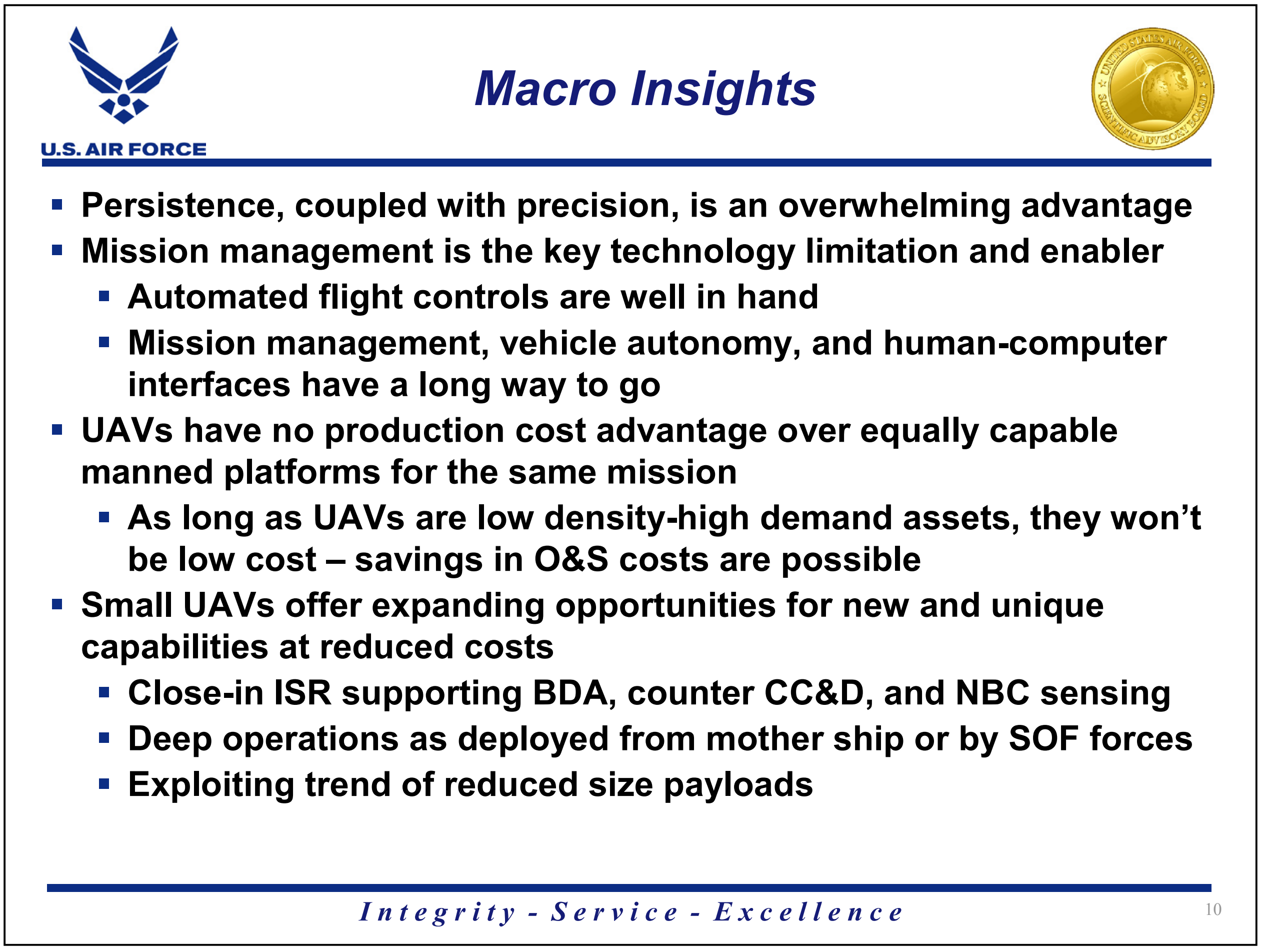


While the AF is off to a good start, a number of unresolved issues remain. Among these are cost, flight safety and airspace concerns, force structure challenges, and technology needs.

Today, UAVs are expensive to develop, acquire, and operate due, in part, to the relatively small numbers of systems produced. If UAVs are to be used in large numbers, then different design and procurement models are needed.

UAVs must be flown with and around manned aircraft, as operations over Iraq and Afghanistan have demonstrated. A key challenge is getting people and machines to work together. While *ad hoc* arrangements worked in Iraq, more permanent concepts for airspace integration and deconfliction need to be developed. There is, however, a second aspect of this problem. The civilian air traffic controlling agencies (FAA and ICAO) continue to place restrictions on UAV operations, which can significantly constrain training, and operations. Like the interoperability problem, this issue also needs to be resolved. To do this, an architecture that integrates UAVs with manned systems to realize complementary capabilities and leverage net-centric operations is needed. This architecture should also include space systems.

Slide 10



In determining what these different or new things were, the study came across some macro-level insights. To begin with, persistence is an overwhelming advantage, particularly when coupled with precision. This was the key to UAV performance in Iraq and Afghanistan, and the study believes this will continue in the future.

UAVs are not a one-for-one replacement for manned platforms. There is no production cost advantage if a UAV is designed to the same standards (performance, reliability, survivability) as manned platforms. Furthermore, as long as UAVs remain low-density assets, they will continue to be expensive. There may, however, be some operations and support cost savings in using UAVs.

Small UAVs offer allow the achievement of a new set of battlefield effects. Small UAVs are capable of going to places manned platforms cannot reach. As such, even with inexpensive sensors, small systems can produce high-resolution imagery of targets from very close range. Close-in battle damage assessment, counter-camouflage, concealment and deception, sensing of chemical, biological, and radiological elements and location of tanks under trees are all possible missions for small UAVs. To deploy these systems deep into an adversary's territory, a hen-and-chick concept of operations or SOF deployment will be required to aid the small UAVs in reaching the target.

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Macro Conclusions

- **UAVs can make significant contributions to AF capabilities – and have already done so!**
- **A limited number of multifunctional UAV platforms with modular payloads will be adaptable to a wide range of missions**
- **With UAVs, like with manned platforms, the optimum solution is people and machines working together**
- **Significant advancements need to be made in mission management technologies**
- **To realize the potential power of UAVs**
  - **Some things must be done differently**
  - **Some new things must be done**

Integrity - Service - Excellence 11

A number of "truths" are evident as UAV operations to date are examined. UAVs have made considerable contributions to AF capabilities, as operations in the Balkans, Afghanistan, and Iraq have demonstrated. These contributions have provided the greatest value when people and machines worked in concert with each other.

Properly configured with modular payloads, a small family of UAV systems operating in concert with manned platforms can accomplish a wide range of missions and achieve a wide range of effects. To achieve this end, mission management technologies will need to advance significantly. Furthermore, the AF will need to do some things differently and do some new things to realize the potential of UAVs.

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Understanding the Mission Space

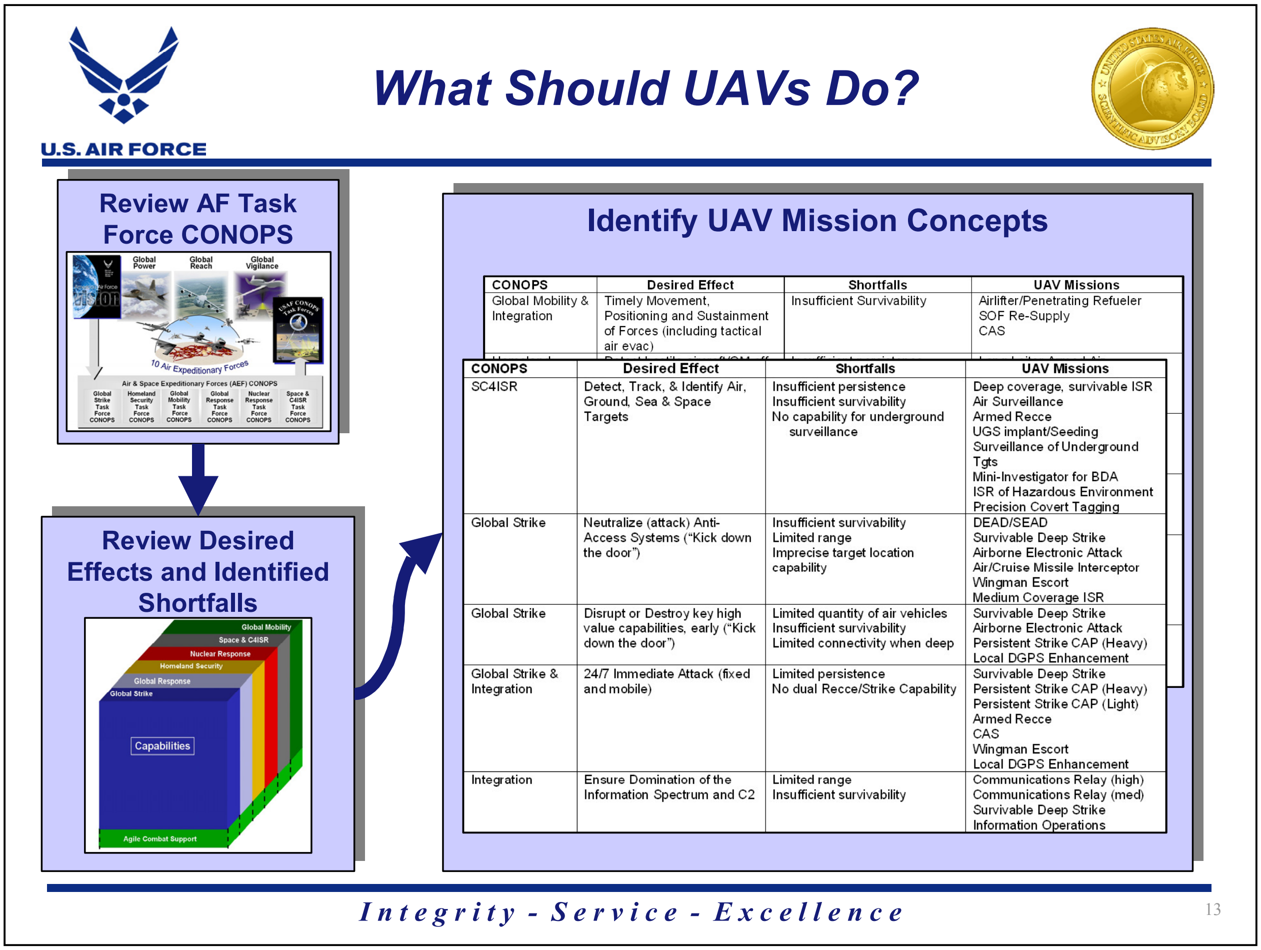
Began to parse the mission space…

- **Recognized that all missions contain**
  - **Some elements that machines do better than people**
  - **Some elements that people do better than machines**
- **For example…**
  - **Machines**
    - Provide persistence and handle large volumes of data
    - Take advantage of trend of increasing processing power with correspondingly decreasing costs, size, and weight
  - **People**
    - Rapidly make robust cognitive decisions
    - Infer from, interpret, and synthesize images and contextual information
- **The challenge is to optimally integrate human and machine abilities**

Integrity - Service - Excellence 12

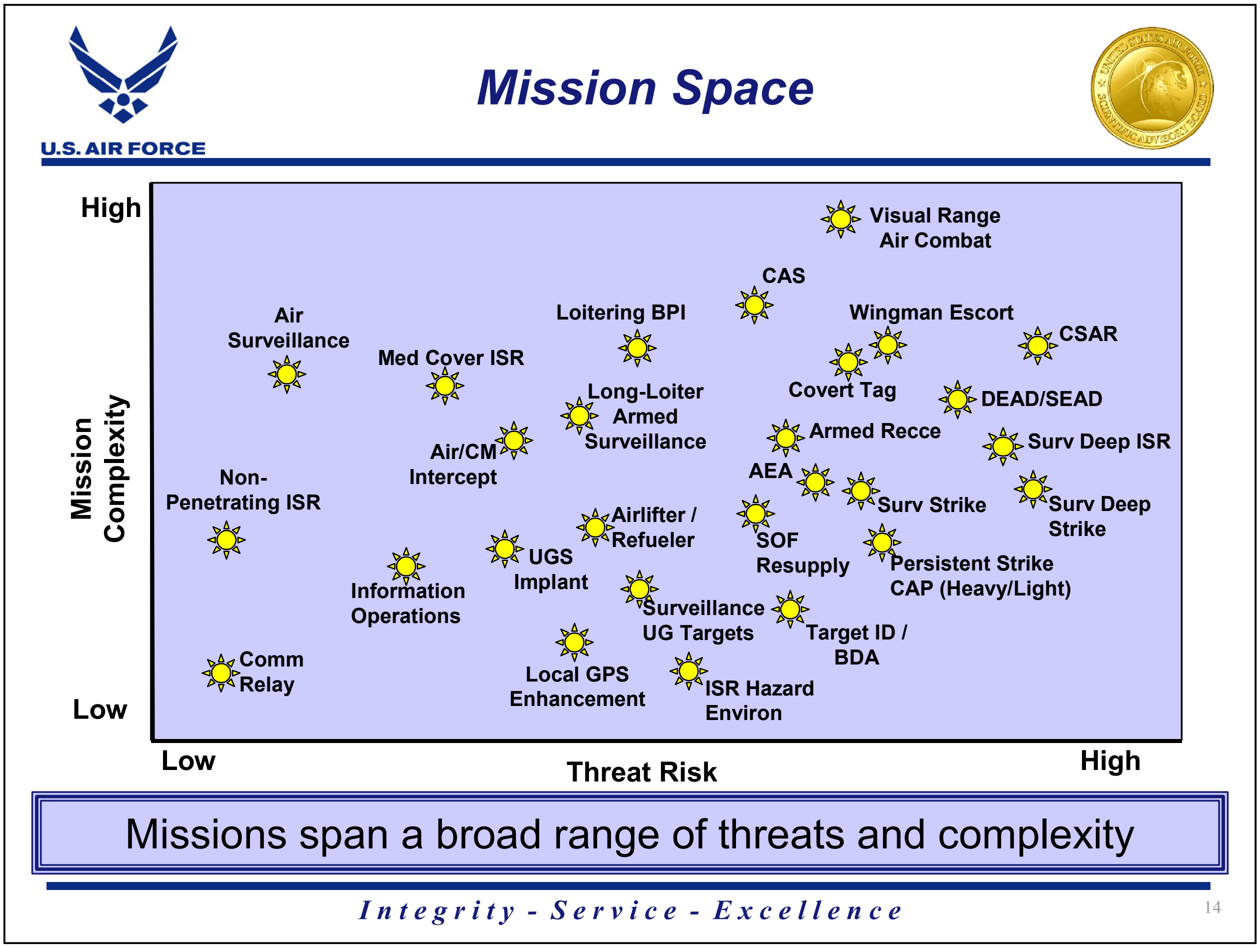
At the beginning of the study, the board began by critically analyzing the mission space. It became evident that each mission contained some elements that machines do better than people did, and some that people do better than machines. For example, machines have the advantage of long endurance and are able to efficiently handle large volumes of data. People, on the other hand, are better able to make complex cognitive decisions rapidly and are able to infer, interpret, and synthesize contextual information. The challenge is therefore the optimal integration of human and machine abilities to leverage the full potential of UAV capabilities.

Slide 13



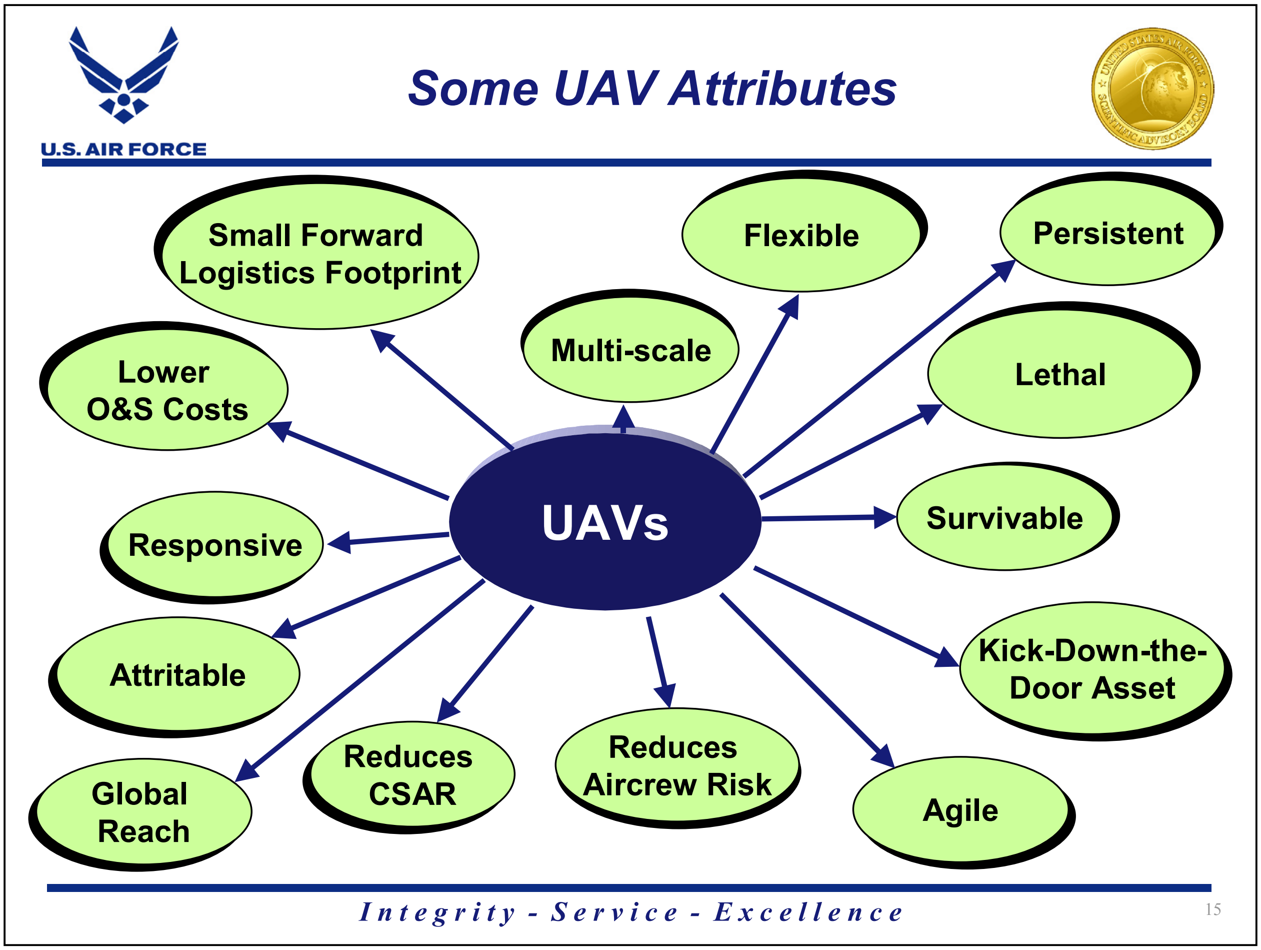
The study conducted an analysis of the seven AF Task Force CONOPS. From these a set of desired effects and needed capabilities was derived. These effects and needed capabilities were compared to existing systems to produce a list of shortfalls. These shortfalls were then compared to potential UAV missions to determine what roles UAVs might be able to perform in the future.

Slide 14



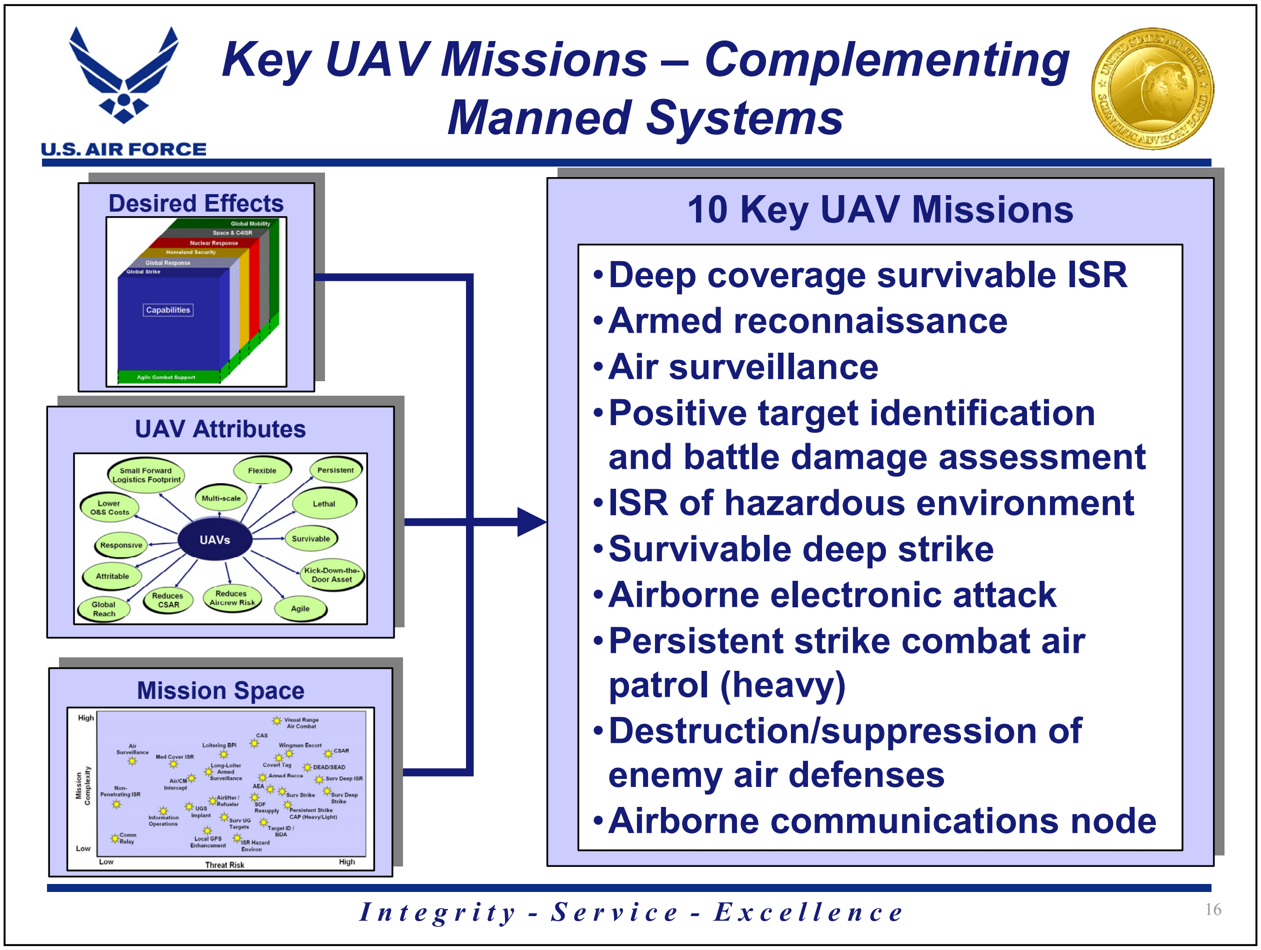
These UAV roles and missions were then plotted in a two-dimensional space. The bottom axis, threat risk, delineates the level of danger to the system (manned or unmanned) performing the mission. The vertical axis, mission complexity, describes the relative level of difficulty associated with accomplishment of the described mission. This difficulty can come from the number of other systems with which the mission vehicle must communicate, the complexity of the task itself, or the detail of cognitive thought required to perform the task. While some minor disagreement is possible in the specific location of any individual item, the plot above represents the consensus of the study members.

Slide 15



The study then examined the key attributes of unmanned vehicles. Among these are: a small forward logistics footprint, lower operations and support costs, the ability to be responsive, attritability, global reach, reducing the need for combat search and rescue, agility, and the ability to kick down the door in anti-access environments. Still, the most important attributes were defined as persistence, precision, flexibility, lethality, and risk mitigation. The study viewed these attributes as being complementary to capabilities and attributes of manned systems.

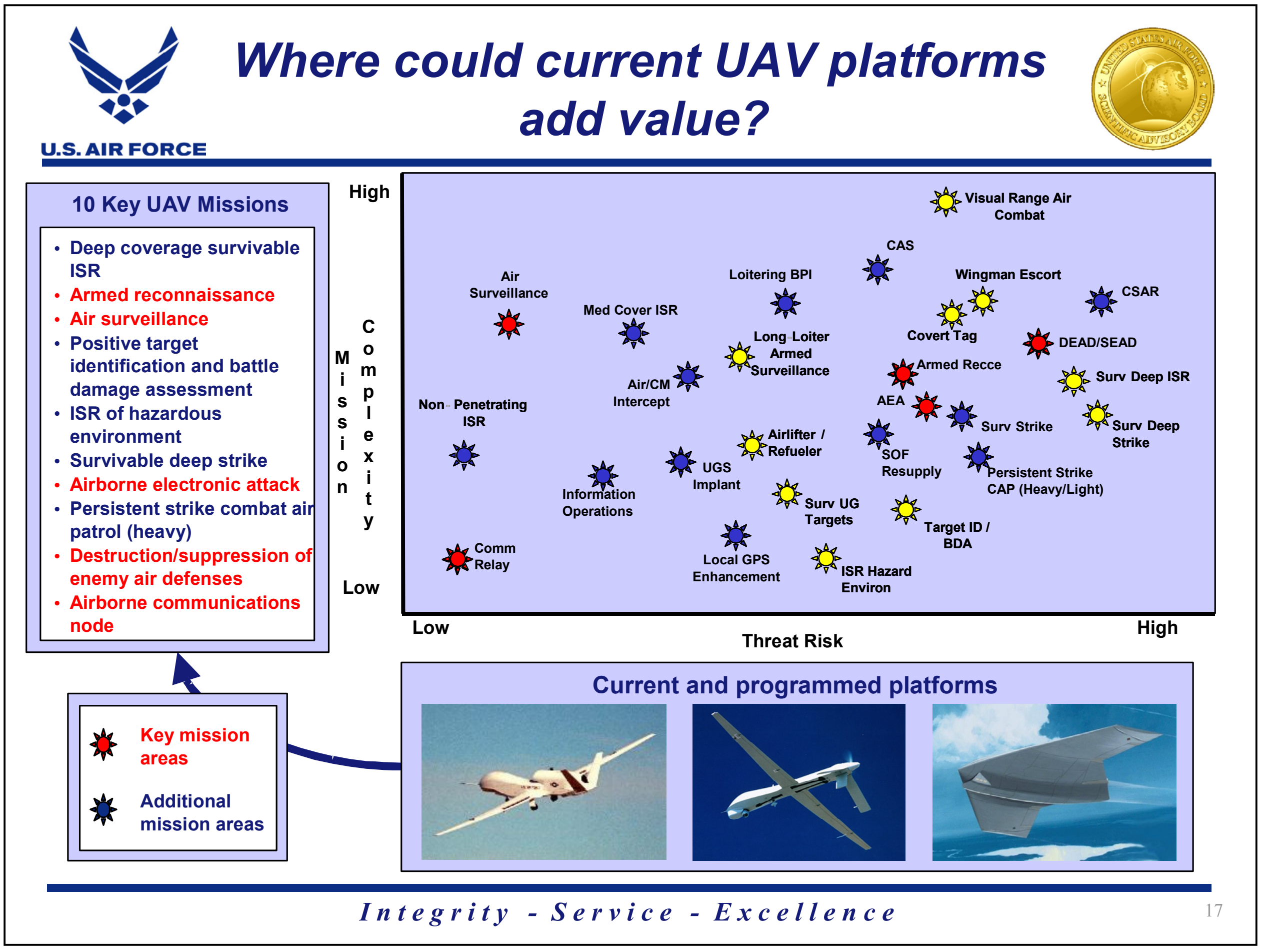
Slide 16



The study then took the desired effects and the identified shortfalls, compared them to UAV attributes, and analyzed this combination in conjunction with the above mission space. This revealed a set of ten key UAV missions that the study believed were the most important and of the highest value to the AF. These ten missions are:

- Deep coverage survivable ISR
- Armed reconnaissance
- Air surveillance
- Positive target identification and bomb damage assessment
- ISR of hazardous environments
- Survivable deep strike
- Airborne electronic attack
- Persistent strike combat air patrol (heavy)
- Destruction/suppression of enemy air defenses
- Airborne communications node

Slide 17



The three current and programmed platforms – Predator, Global Hawk, and UCAV – are able to conduct the following five missions: armed reconnaissance, air surveillance, airborne electronic attack, destruction/suppression of enemy air defenses, and service as an airborne communications node. The study analyzed potential modular, mission-specific payloads appropriate to this set of UAVs to determine what other effects are possible with these three systems. An important finding of the study was that with these modular payloads, the three currently programmed UAVs would be able to accomplish missions and achieve effects across a wide range of the mission space. In fact, 17 of the 27 missions identified can be enhanced with the programmed set of UAVs. Additional missions that can be accomplished or enhanced with these vehicles include medium coverage ISR, loitering boost-phase intercept of missiles, local GPS enhancement, close air support, combat search and rescue, survivable strike, persistent strike (light), and special operations resupply. It is important to emphasize that UAVs cannot totally accomplish all of these missions, but to each of these missions UAVs have attributes that add value and enhance the achievement of desired effects.

The study then examined the missions that were not accomplished or enhanced by the three programmed systems. Among the ten key missions not met by the existing programs were the following: deep coverage survivable ISR, positive target identification and bomb damage assessment, ISR in hazardous environments, survivable deep strike, and persistent strike combat air patrol (heavy).

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Technology Shortfalls

PLATFORM	MISSIONS	REQUIRED ATTRIBUTES	TECHNOLOGIES
UCAV X 	**Airborne Electronic Attack** **DEAD/SEAD** **Armed Reconnaissance** Survivable Strike, Wingman Escort Medium Coverage ISR Close Air Support SOF Re-Supply UGS Implant/Seeding	Cost Survivability Modular Payload Capacity Combat Range Selectable Autonomy Cooperative Operations	Low Observables Low Specific Fuel Consumption (SFC) Engines Low Probability of Intercept Communications Aerial Refueling On-board autonomy Human-autonomous software integration Operator Situation Awareness HPM Weapons
GLOBAL HAWK X 	**Communications Relay (High)** **Air Surveillance** Non-Penetrating ISR Loitering BPI/PLI	Cost (airframe and sensors) Prime Power Endurance Modular Payload Capacity	Low SFC Engines Passive / LPI Sensors High-output generators High Power Extraction Engines Multi-function RF systems Integrated multispectral systems Automatic target cueing and recognition On-board autonomy Human-autonomous software integration Operator Situation Awareness
PREDATOR X 	**Armed Reconnaissance** **Airborne Electronic Attack** Air/Cruise Missile Interceptor Close Air Support Communications Relay (med) Persistent Strike CAP (Light) Information Operations	Speed (target to target) Communications Data Rate Weapons (Survivability) Modular Payload Capacity	HPM Weapons Miniature communications On-board autonomy Human-autonomous software integration Operator Situation Awareness

Integrity - Service - Excellence 18

The study then compared the three programmed platforms to the missions that they can enhance or enable. From that the desired attributes of the system and payload, needed technologies were derived.

These needed technologies listed above span the areas of propulsion, low observable technologies, energy storage, and smaller sensors and weapons.

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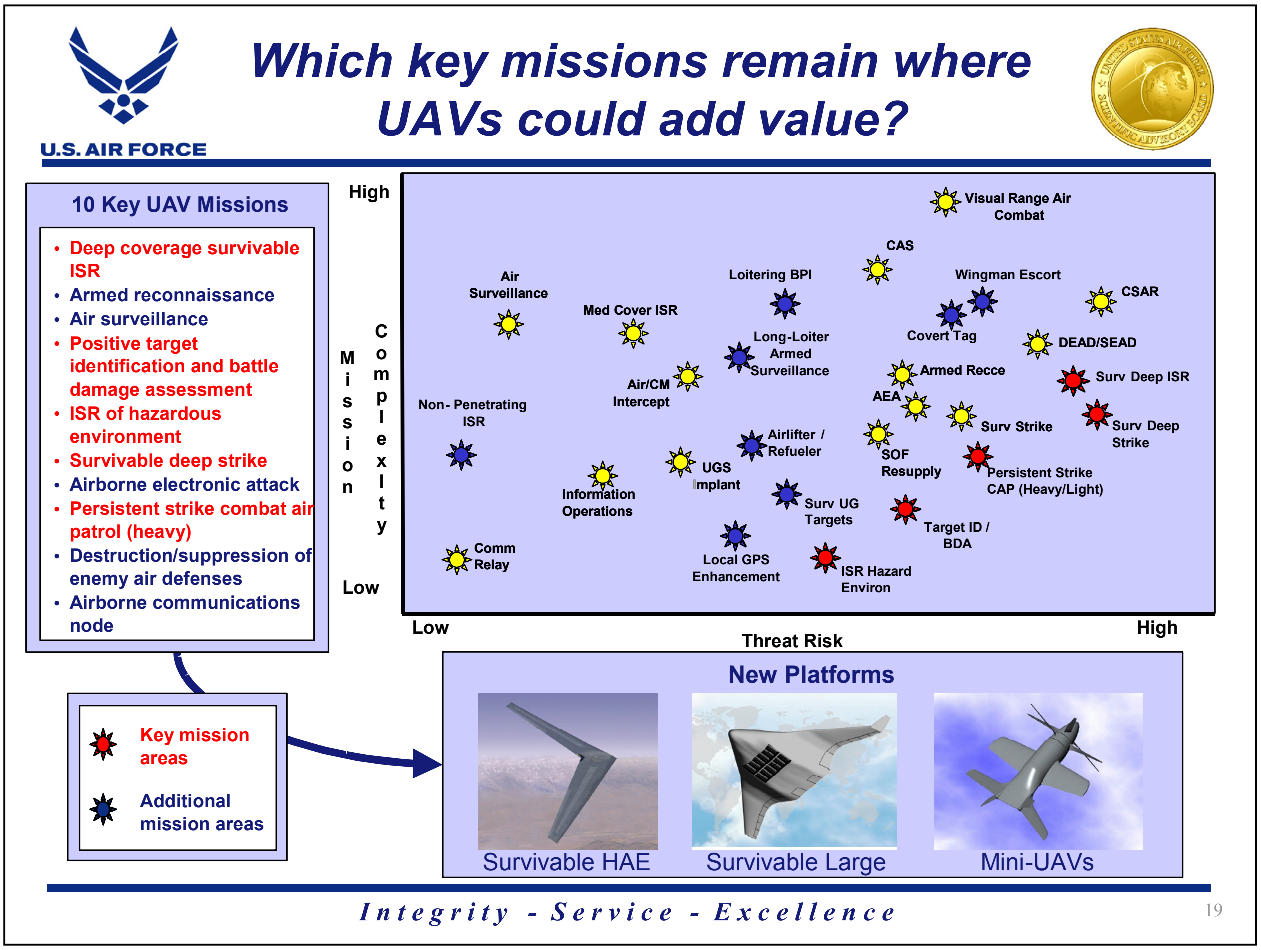


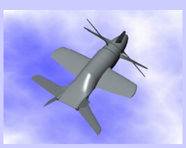
To accomplish these key missions, the study determined that three new UAV systems could cover the five new mission areas not currently addressed by unmanned systems. These systems are:

- Survivable High-Altitude Endurance UAV that brings reliable, persistent ISR into denied areas.
- Survivable Large Payload Endurance UAV that serves as a persistent CAP weapons delivery platform able to dispense from a wide variety of munitions upon demand.
- Miniature UAVs that are released either by larger airborne systems or by Special Forces to perform positive target ID, BDA and/or characterization of hazardous environments.

This study views these three systems as a set of additions to Predator, Global Hawk, and UCAV-X to complete the family of systems. Each of these systems would be equipped with modular payloads and integrated into the transformational communications architecture.

Slide 20

New UAV Family Members

PLATFORMS	MISSIONS	REQUIRED ATTRIBUTES	CHARACTERISTICS		ENABLING TECHNOLOGIES
SURVIVABLE HIGH ALTITUDE ENDURANCE 	**Deep Coverage Survivable ISR**	Endurance Survivability Multiple Communications Links Cost Mission Flexibility Selectable Autonomy Precision Target Location	Radius (to AO) Persistence (in AO) Payload Altitude TOGW	2000 nm 18 hrs 4000 lbs >50,000 ft 45,000 lb	Low SFC Engines LO HBPR Engine Installation Low Observables Low Probability of Intercept (LPI) Communications LPI or Passive Sensors High dynamic-range digital receivers On-board autonomy Human-System Integration Operator Situation Awareness
SURVIVABLE LARGE 	**Survivable Deep Strike** **Persistent Strike CAP (Heavy)** Long Loiter Armed Air Surveillance Loitering Boost-Phase Intercept and Post Launch Intercept Airlift / Penetrating Refueler	Endurance Survivability Cost Weapons / Flyout Time Multiple Communications Links Mission Flexibility Selectable Autonomy	Radius (to AO) Persistence (in AO) Payload Altitude TOGW	400 nm 10 hrs 20,000 lbs 25-45,000 ft 94,000 lb	Low SFC Engines Low Observables Low Probability of Intercept Communications Aerial Refueling On-board autonomy Human-System Integration Operator Situation Awareness High Mach Weapons
MINI-UAVs 	**Mini-Investigators for Positive ID/ Battle Damage Assessment** **ISR of Hazardous Environment** Local DGPS Enhancement Surveillance of Underground Targets Precision Covert Tagging	Cost Quiet Operations Connectivity Selectable Autonomy	Radius (to AO) Persistence (in AO) Altitude TOGW	100 nm 4 hrs 100 -10,000 ft 550 lb	Miniaturization of Sensors Heavy Fuel IC Engines Sensor Stabilization Quiet Propulsion Miniaturized Communications High Power Density On-board autonomy Human-System Integration Operator Situation Awareness

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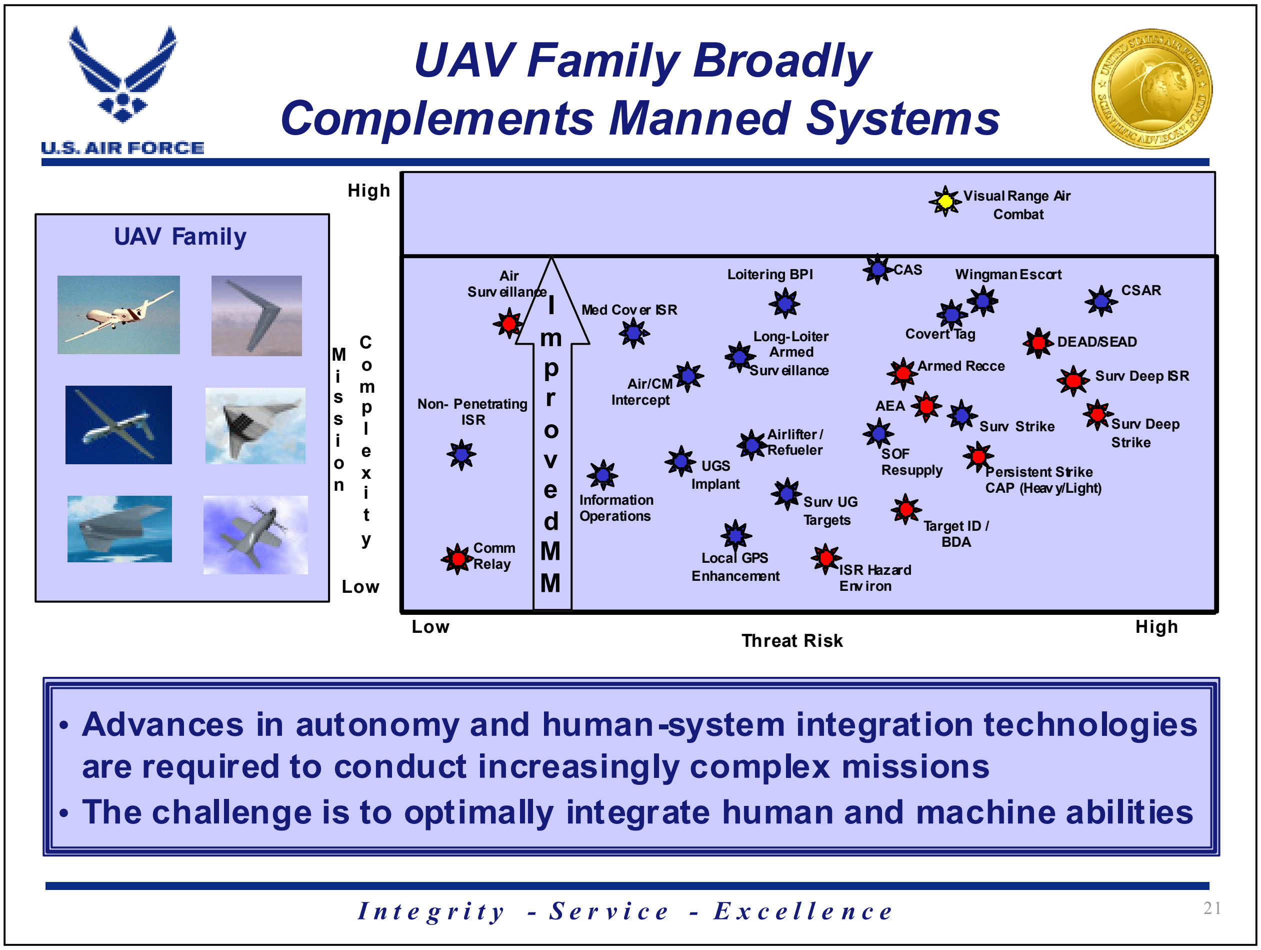
The description above specifies the capabilities and key technologies that will need to be developed for each of the new UAV systems. The technology requirements are discussed in detail in the following slides.

Slide 21



The study then looked at the impact on the mission space, assuming Predator, Global Hawk, UCAV, and the three proposed systems were procured with modular payloads appropriate to the desired missions and effects. As depicted below, this family of six UAV systems brings benefit to 26 of the 27 missions in the mission space.

Slide 22

While we are off to a good start employing UAVs, we have identified several areas where the Air Force would benefit from doing things differently. The first of these areas is cost reduction. In order to realize the true benefits of UAVs and to employ them efficiently and effectively, we must realize economies of scale by reducing their costs. Another area where we need to do things differently is in our systems architecture. Rather than continuing with our current paradigm of independent and stove-piped manned, unmanned, and space systems, we need to integrate all systems into a single architecture: a veritable system-of-systems. Finally, we must strive to improve the communications capabilities of UAVs by optimizing the mix between data transfer and on-board processing.

Slide 23

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Vision for Cost Reduction
Development and Acquisition

- **Development**
  - **Move from point designs to a family of platforms**
  - **Tailor design criteria and associated testing for unmanned platforms**
  - **Develop a plug-and-play architecture that supports affordable modular payload integration**
  - **Design mission-independent subsystems (e.g., avionics, some sensors)**
- **Acquisition or Production Costs**
  - **Increase production of modular payloads and common airframes to move beyond Low Density – High Demand assets**
  - **Take advantage of the modular architecture and Moore's Law**

Integrity - Service - Excellence 23

Although there are limited data to support precise cost estimates, and the AF is early on the UAV learning curve, there are acquisition areas that should be explored for cost reduction.

Air vehicle cost drivers are payload weight, power, speed, altitude, maneuverability, endurance, and survivability. Under current UAV low-density/high demand (LD/HD) production practices, manned and unmanned vehicles cost about the same, given the same design requirements. Deleting typical "pilot" support and human system requirements saves approximately five to ten percent, or approximately $1,800 per pound.

Sensor payloads for ISR UAVs have become approximately 50 percent of the total system cost. These payloads, due to their very specialized nature and limited quantity production result in costs of roughly $8,000 per pound.

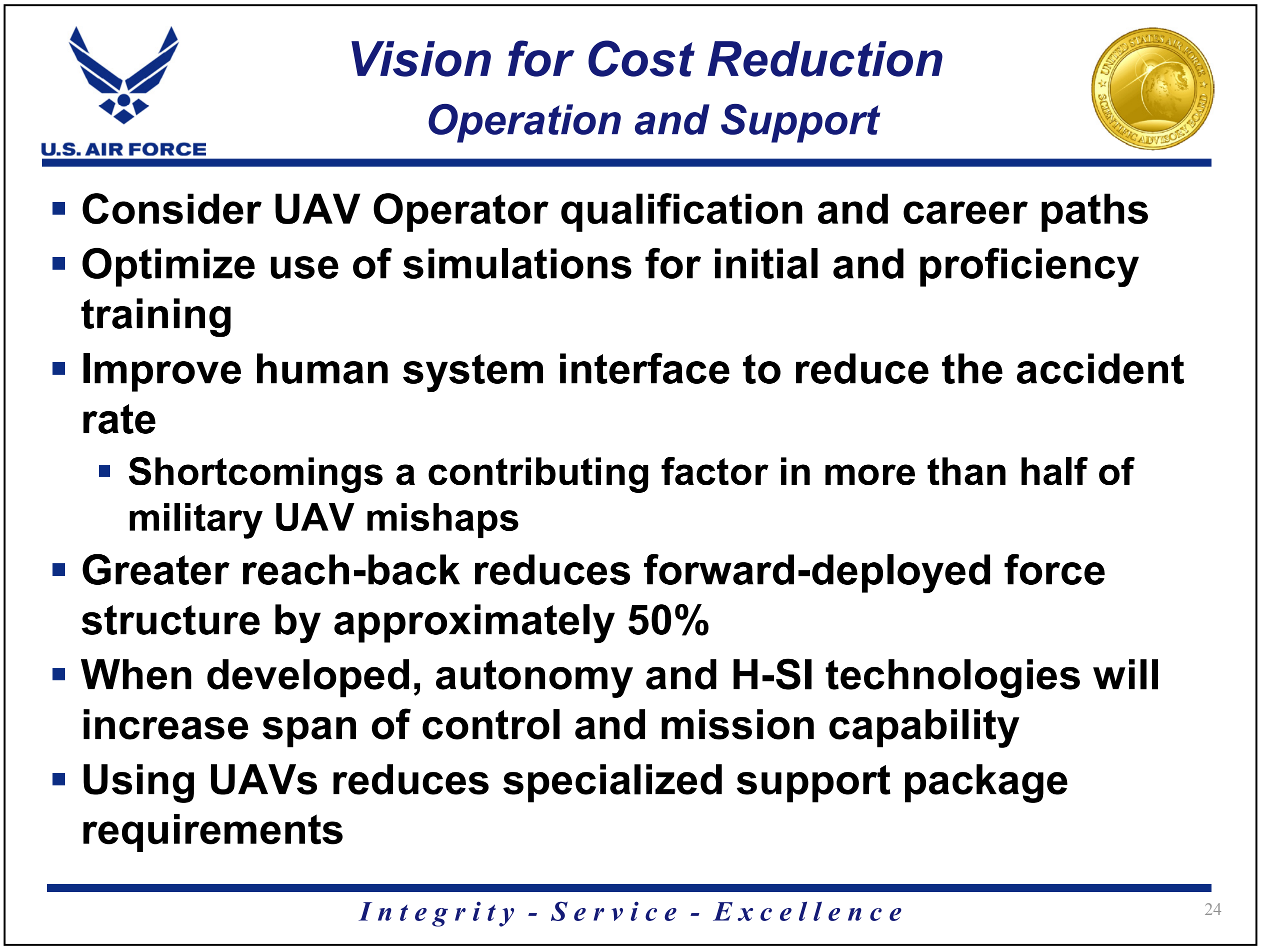
Since operations and support traditionally comprise over 50 percent of the life-cycle costs, there may be savings in this area, especially since aircrew training with UAVs may involve greater simulation and fewer actual flying sorties.

There is an opportunity to reduce UAV acquisition costs through savings in both development and procurement.

Movement from a point design for individual mission designs to families of systems should reduce development costs. Furthermore, UAV designs can eliminate traditional manned aircraft requirements in such areas as canopy resistance to bird strike, fan blade containment, and maneuvering margins. Additional savings may be possible in testing by possibly eliminating or reducing live fire testing, and reducing static and handling qualities testing.

Ideally, payloads can be inserted rather than built as part of the system, achieving economies of scale. A plug-and-play architecture can gain great leverage across the family of platforms and can take advantage of spiral development in the design of mission independent subsystems to keep pace with advances such as those due to Moore's Law.

Slide 24



While there are limited data to support precise cost estimates, and because we are still near the origin of the learning curve, this study concluded that some savings are probably achievable in operations and mission support costs over the life cycle of the system. Different training and operator proficiency requirements offer the greatest opportunity for cost savings. High fidelity simulation trainers can be used much more extensively in UAV crew training than in manned systems training, thereby reducing vehicle use costs. While there would be a need to participate in exercises and mixed-use training for other systems, vehicles would be used less, and as a result, the maintenance costs would be lower than those for manned systems.

One challenge to achieving reductions in operations costs is the need for improved human-systems interfaces to reduce the accident rate of UAVs. Current data shows that up to 75 percent of Predator accidents are attributed, at least in part, to human-systems interface-related issues. Improvement in mission management technologies will allow for better operator situational awareness and rapid evolution toward multi-platform control. The increased vehicle-to-operator ratio afforded by well-designed autonomy and human-system interface technologies means fewer operators and lower costs. When combined with reachback, which reduces the logistics costs of deployment, this evolution has the potential for further savings in O&S costs over the life of the family of systems.

UAVs also require reduced support packages. The fact that these are uninhabited vehicles means there is no need for CSAR or escort packages. As a result, UAV missions may be less expensive than those conducted by manned aircraft.

Slide 25

UAV System-of-Systems Architecture Needs

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- UAV architecture consistent with ongoing architectures including Command and Control Constellation
  - Supports interoperability, operational and tactical control
- Integrated open systems and interfaces for both payloads and mission management
  - Consistent with a reference architecture
  - Common mission management across platforms
- Rapid communication network re-configuration
  - Must be integrated with the data communications architecture and the Transformational Communications System
- Common mission control station architecture
  - Consistent human-machine interface across UAV systems
  - Dynamic assignment of autonomy levels

In order to achieve the most efficient employment of all vehicle systems (manned, unmanned, and space), we must ensure all are incorporated into a single, integrated architecture: a system – of systems. To achieve this, the UAV architecture must be consistent with existing and developing architecture roadmaps; this will support interoperability among systems, as well as tactical and operational control. In addition, integration of open systems and interfaces for both payloads and mission management will achieve common mission management across all platforms, while retaining consistency with reference architectures. The UAV communication network must be integrated with the data communications architecture and the Transformational Communications System (TCS) so that a rapid communication network configuration can be realized. Finally, a common mission management framework is needed which includes consistent human-machine interfaces across all systems while optimizing the assignment of UAV autonomy levels. A common architecture for UAVs, manned aircraft, and space systems will ensure the AF realizes their complementary capabilities while simultaneously leveraging the potential of Net-Centric Operations.

Slide 26

Communications – Still an Issue

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- Vehicle command and control is a small portion of the system bandwidth
- The degree of autonomy and automation affects data rate needs
  - On-board decision making may require substantial off-board data to build situation awareness
  - Off-board decision making may require transfer of on-board data
  - Other users may also need the on-board data somewhat negating on-board processing benefits

Type of Vehicle Control	Bandwidth (Mb/sec)	
Remote Pilot	1	
Autopilot Assisted	0.1	
Scripted Waypoints	0.01	
Autonomous Flight	0.001	
Sensor Data	**EO/IR**	**GMTI**
Raw Sensor Data	100	100
Signal Process 2003	20	1
Signal Process 2010	10	0.1
Auto Target Cueing and Clipping	1	0.01
Auto Target Recognition (1 False Alarm/100 Square km)	0.001	0.001

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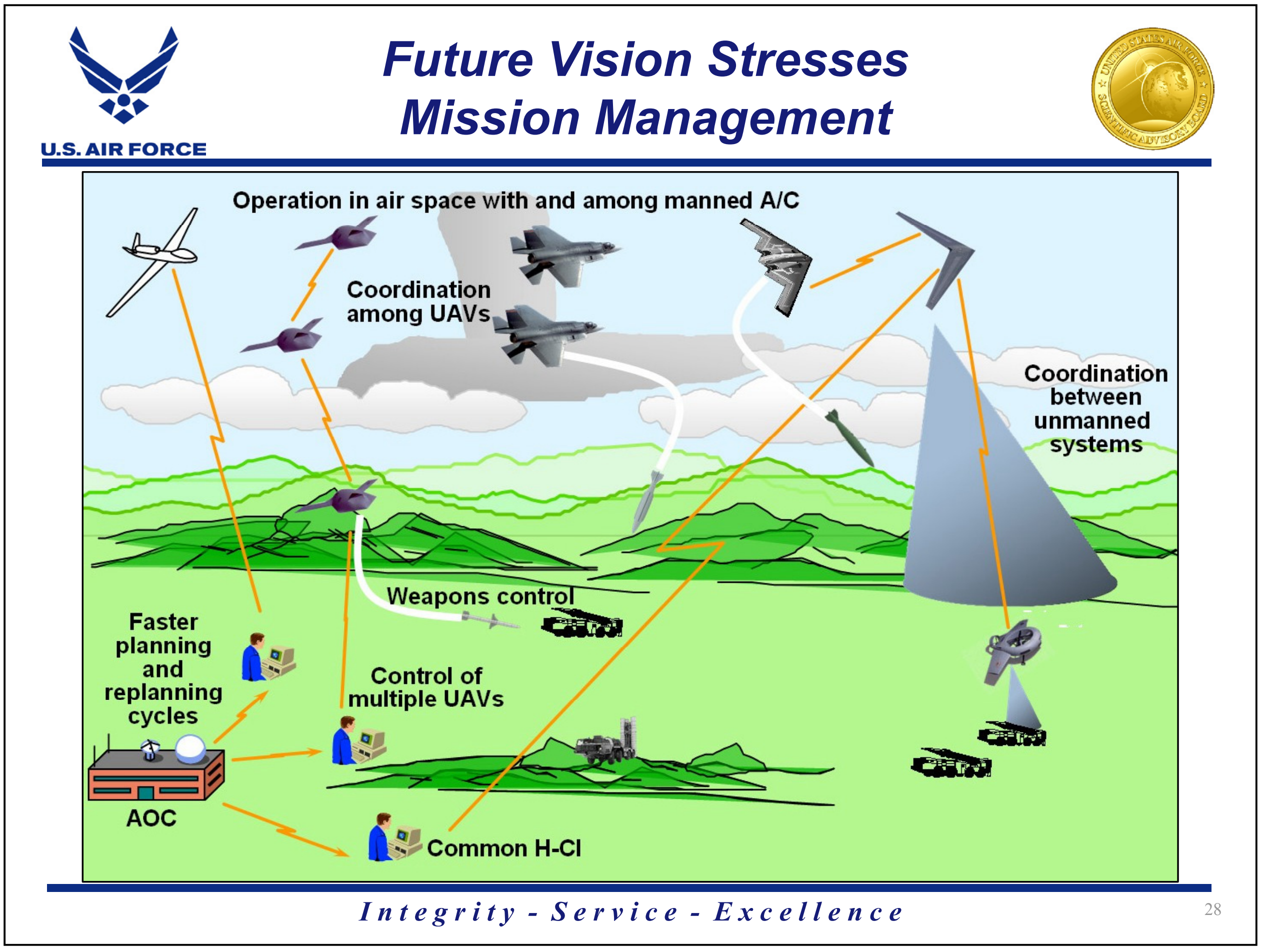
Communications became a major concern during operational use of Global Hawk, since it appeared the data rate (~100 Mbps) required for accomplishment of a single aircraft sortie could saturate most of the available operational communications links. The bulk of this bandwidth requirement is needed to pass all raw ISR data back to the intelligence infrastructure. The UAV vehicle command and control takes a very small portion of the required data rate – in the case of Global Hawk, less than one percent.

Providing UAVs with on-board processing capability, as would likely be required for weapons employment missions, would reduce the data rates significantly. However, in order to maintain situational awareness with on-board processing, data must be communicated to and processed by the UAV and the UAV must transmit its status and environment to an off-board control station. Additionally, off-board users may need the on-board data, thus negating some on-board processing benefits. Further analysis is still required to determine the optimum mix of on-board and off-board processing.

Slide 27

In addition to doing things differently, the AF will need to do some new things. Mission Management, vehicle, and payload technologies must be developed and new concepts must also be developed.

Slide 28



The vision of multiple UAVs operating in the battlespace alongside aircraft and in conjunction with space assets places great stress on mission management-related technologies. These technologies are the human-systems interface enabling operator control and operator situational awareness and the suite of technologies that enable autonomous operations. Additional research will be required to develop the interfaces and autonomous systems to enable safer flight in close proximity to manned systems, avoid crashes, and communicate with all other members in the net-centric operations space.

As systems develop greater autonomy, dynamic planning and replanning cycles will speed up and operators will need to understand the vehicle's level of autonomy, trust it appropriately, and dynamically shift their control of the vehicle to respond to these faster cycles. Further, methods of positive control of weapons will need to be determined.

Slide 29

To achieve effective mission management for future operations several key technology enablers must be addressed. Operator situational awareness needs enhancement. To obtain it, displays to support better awareness of the state of the vehicle within the context of its environment and mission need to be developed. These displays will need to compensate for losses in sensory information and the communications lag times associated with UAVs, especially in conjunction with reachback operations. As the operator-to-vehicle ratio increases, providing greater autonomy, display technologies to support "global" situational awareness for multiple vehicles and across a larger segment of the battlespace will be needed to help operators allocate attention and solve problems across the system constellation.

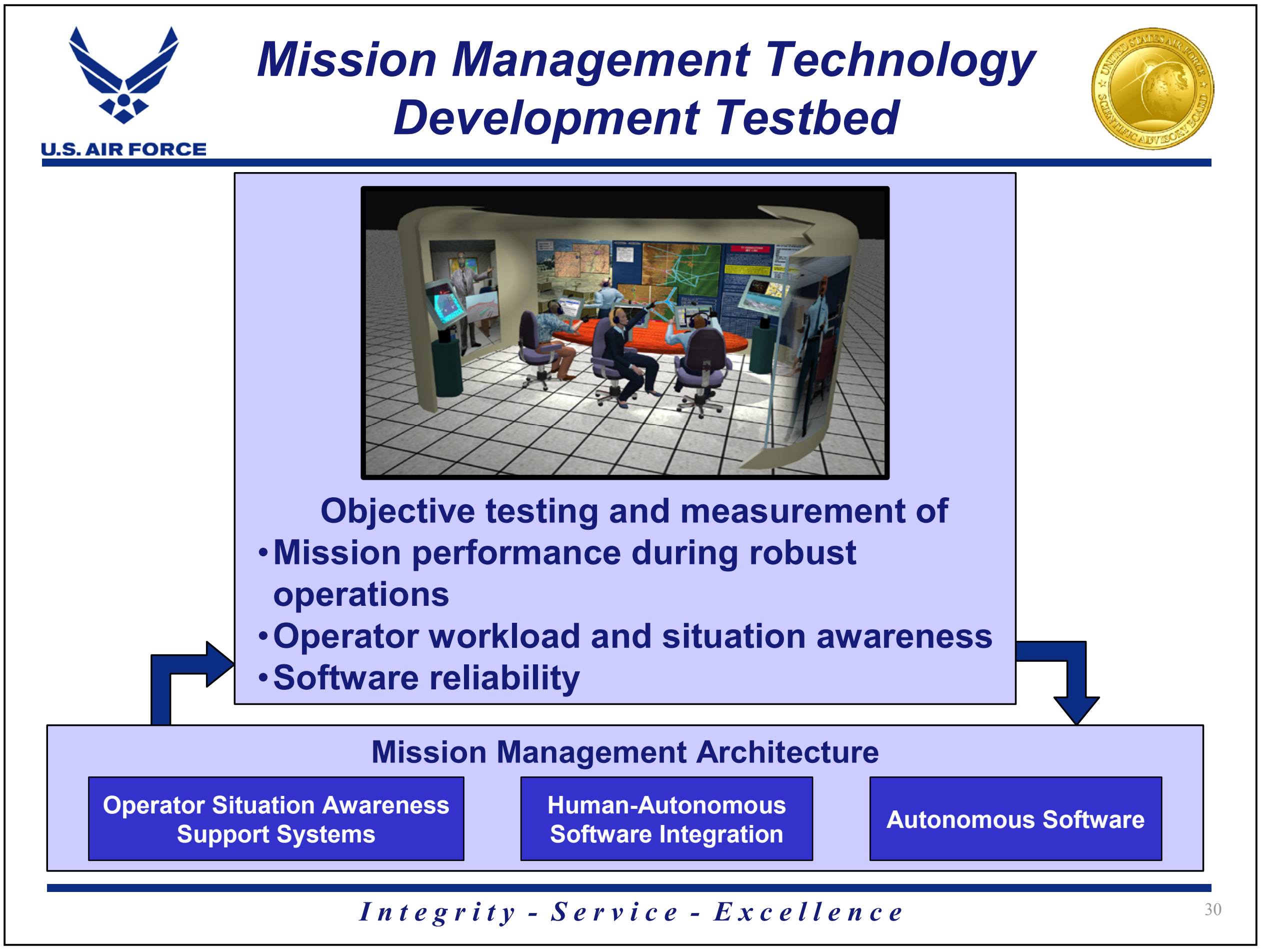
The Air Force must improve the integration of human operators with autonomous systems. The current practice of automating what you can and leaving the rest to the human does not work, and there is thirty years' worth of research to prove it. The appropriate levels of task automation to keep the operator in the loop and provide effective human/system performance need to be developed. We must evolve methods for supporting human understanding in the face of rapid shifts in the level of automation, as little research exists on methods for varying the degree of operator control and automation. Methods also need to be developed to help operators understand and predict the reactions of automated systems under operational circumstances.

Emphasis must be placed on increasing autonomy to enable lower operator-to-vehicle ratios and reducing bandwidth requirements to support larger numbers of UAVs. Among the necessary key technology developments are: machine-based perception and integration to form machine situational awareness, dynamic replanning and handling of situation uncertainties to replace the tightly scripted methods used today, vehicle health management (to include diagnoses of multiple concurrent faults), and multi-vehicle coordination and cooperation.

Addressing these key issues in mission management will not only allow for the vision of using UAVs for a much wider variety of missions, but will have the added benefit of providing better support for the wider battlespace management problem. In doing this, methods to integrate UAVs with manned aircraft and the air operations centers need to be addressed. To accomplish this goal, a better understanding of how to combine manned and unmanned assets to accomplish varying mission objectives is needed.

All of these issues still require substantial developmental research.

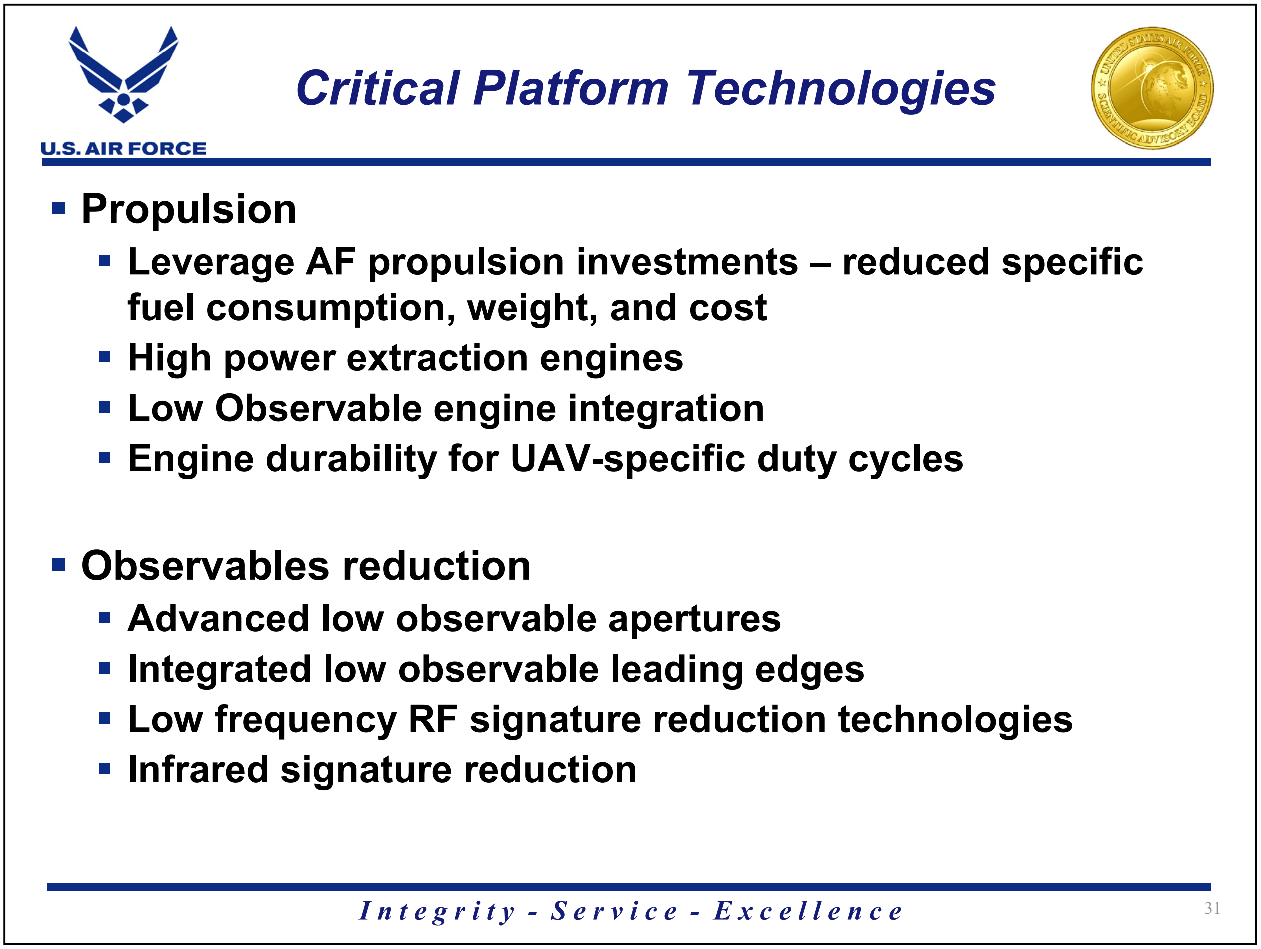
Slide 30



To conduct this research in mission management technology the creation of a dedicated UAV mission management test bed is essential. This test bed would allow for the objective evaluation of the effectiveness of new technologies and concepts and integration of those concepts to form a mission management system that can support operations in a wide variety of situations and missions.

A feature of the test bed will be connections and interoperability with lab facilities within AFRL, the AF Battlelabs and industry. This will allow for rapid development and prototyping of independent mission management technologies that can then feed and transition to UAV programs. This test bed may be able to serve as part of a Distributed Missions Operation Center to enable the evolution of CONOPS for mixed manned-unmanned system operations.

Slide 31



There are several new platform technologies needed to enable new UAV systems development.

To develop propulsion technologies to support new UAV systems, the advancements made in the Air Force Research Laboratory program on Versatile Affordable Advanced Turbine Engines (VAATE) need to be leveraged. Specifically, future UAV systems need less expensive engines with reduced specific fuel consumption and reduced weight. High power extraction engines and systems for electrical energy storage also must be developed. These engines also need to be designed for durability when operated in UAV-specific duty cycles — long duration missions with relatively few shutdown cycles.

Several additional advancements are needed to enable the development of survivable UAV systems that can travel deep into an adversary's territory. Among these advancements is the ability to integrate a low-observable high-bypass-ratio engine into a UAV design. Additionally, new developments are needed in advanced low observable apertures, integrated low observable leading edges, low frequency RF signature reduction technologies, and infrared signature reduction methods.

Slide 32

Critical Small UAV Technologies Investments

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- Propulsion
  - Efficient, lightweight, heavy fuel engines
  - Quiet propulsion
- High energy density materials
  - Energy storage and power extraction to extend platform range and endurance
- Miniaturized avionics, sensors, and communications
- Flight stability and control
  - Platform control in dynamic environments and in the low Reynolds number regime
  - Sensor stabilization to enhance image quality
- Multi-functional structures to reduce weight and volume
- Command, control, and communications for urban operations

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Several technologies specifically apply to fielding a class of small UAV systems. The study determined that additional developments are needed in several areas listed below:

- Efficient, heavy fuel internal combustion and turbine engines
- Low pressure blades for low Reynolds number efficiency
- Quiet propulsion
- High energy density storage and power extraction to extend platform range and endurance
- Microelectronics to include miniaturized avionics, sensors, and miniature wide-band data links
- Flight stability and control for flight in dynamic environments and sensor stabilization for image quality
- Multi-functional structures to reduce vehicle weight and volume
- Systems for command, control, and communications, especially for operation in urban areas

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Critical Payload Technologies

- Sensor suites
  - Lower cost, size, weight, and power
  - Multifunction RF systems and integrated multispectral capabilities
  - Low probability of intercept and detection waveforms
- Communications that support net-centric operations
  - IP-based network architecture
  - Low cost miniaturized terminals
  - Standardized communications relay packages
- Weapons that meet range and time-to-target requirements
  - High speed missile to attack time-critical targets
  - Long range missile for self protection
  - Longer-range standoff precision munitions
  - Directed energy weapon options

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To enable the envisioned family of UAV systems to enhance or cover the missions discussed above, several advances must be made to make modular payloads appropriate to this larger UAV mission set feasible. These developments span sensors, communications, and weapons.

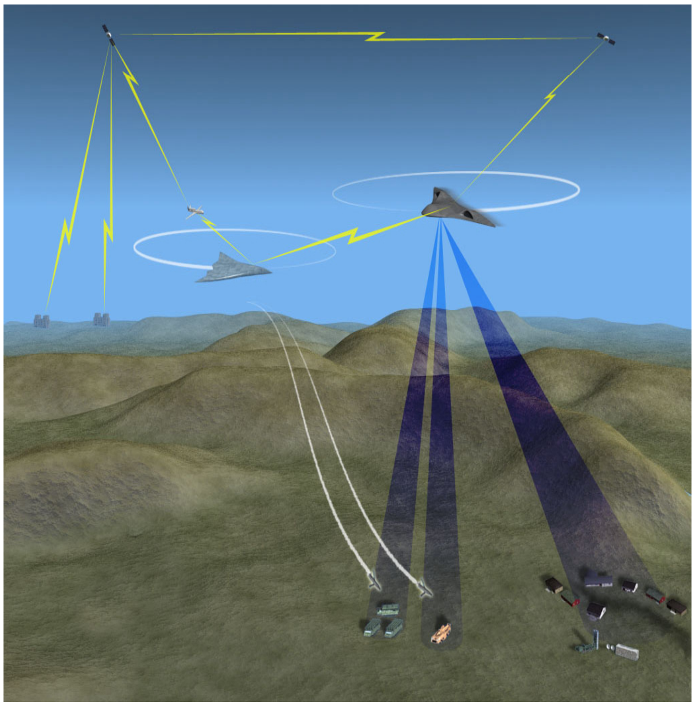
New sensor suites that are substantially lower in cost, size, weight, and power need to be developed. The study specifically concluded that multi-function RF sensors including synthetic aperture radar with moving target indicators and sensors to conduct electronic surveillance are needed. Multispectral sensors to include medium wave and long wave infrared are also needed. Furthermore, advancements in laser technologies to include lightweight LADAR and laser range finding systems are also required.

Advancements are also needed in communications that support net-centric operations. These include establishment of an IP-based network architecture, low-cost miniaturized terminals for connectivity to the new transformational communications architecture, and standardized communications relay packages for use on the UAV systems.

Finally, new developments are also needed for system weapons payloads. Multifunctional systems for electronic attack are needed. Additionally, winged glide bombs with GPS accuracy and ranges that approach 100 miles would be useful to compliment the Small Diameter Bomb. New air-to-air missiles that travel 130 miles beyond visual range are also necessary. High-speed (~Mach 4) missiles to attack time critical targets at ranges of up to 200 miles are needed. Directed energy weapons also need to be developed with higher-power output in smaller packages.

Slide 34

Persistent Deep ISR Supporting Rapid Strike



Deep Survivable ISR
- Continuous surveillance and target detection
- Precise target location and identification
- Reach back C3
- Image server in the sky

Persistent Strike CAP
- Remotely taskable
- Mixed weapons load
- Weapons delivery inside move-stop-move timeline
- Reach back C3
- Weapons server in the sky

Integrity - Service - Excellence 34

The study examined two novel applications for the proposed family of UAV systems. The first of these applications deals with the synergy attained by the two proposed new UAVs. In this concept, the two UAV systems operate together to produce devastating effects in an anti-access environment.

A Deep Survivable ISR UAV can loiter in the heart of enemy airspace, using a variety of sensors to find, fix, and track targets and act as an image server, making its ISR data being available to the net-centric architecture, even at reachback distances from the AOR. This system provides a level of persistence that enables the combatant commander to observe and target mobile targets while they are temporarily stationary.

Data from the Deep Survivable ISR system are shared directly with the Persistent Strike CAP UAV, a heavy system that plays the role of a flying "arsenal ship." This system carries a variety of weapons, which enable the operators to tailor the weapons selected to achieve precise effects on demand either through remote tasking or from controllers in the AOR.

The combination of both platforms allows operators to strike targets well within the enemy move-stop-move reaction time.

Slide 35

Mini-Investigator for Positive Target ID and BDA

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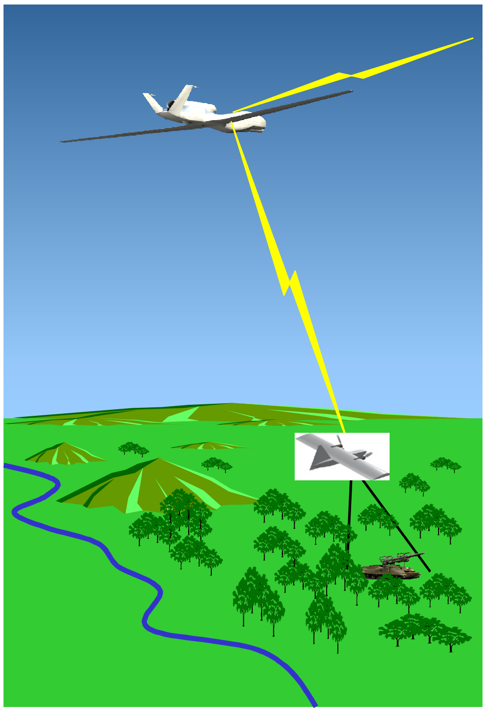

<u>"Mother-hen" UAV provides</u>
- Persistent, all weather sensing
- Wide area surveillance
- Wide band communications with reach back
- Positive Target ID is the problem

<u>"Chick" Mini UAV provides</u>
- Air delivered – possibly by the Mother hen
- 1-hour endurance
- Quiet, hard to see
- High resolution sensors EO and LADAR
- GPS guidance to target
- Fly, hover, perch, or crawl
- Provides Positive Target ID and BDA!

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The second novel application involves use of large-scale UAV to deploy smaller systems to provide positive target identification and/or battle damage assessment. Among the potential missions that small UAV systems with appropriate modular payloads can enhance are the location of targets under forest canopy or camouflage, positive identification of adversary or friendly troops, and detection of hazardous materials or plumes. This concept exploits the ability of very small UAVs, because of their size and scale, to fly where manned platforms cannot go and see what high-altitude ISR systems cannot see.

Slide 36

Getting UAVs to the Fight

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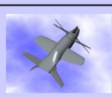
Vehicle	Basing Concepts	Air Vehicle Deployment Concepts	Technology Needs
	In-Region Flight Operations, Reach-back C2	Self-Deploy	Detect and Avoid
	In-Theater Flight Operations, Reach-back C2	Self-Deploy	Aerial Refueling, Detect and Avoid, Robust Low Observables
	In-Theater Flight Operations, Reach-back C2	Pre-positioned Boxed Transport	Detect and Avoid
	In-Theater Flight Operations, Reach-back C2	Self-Deploy	Detect and Avoid, Robust Low Observables
	In-Region Flight Operations, Reach-back C2	Self-Deploy	Aerial Refueling, Detect and Avoid, Robust Low Observables
	Local Launch, Air Dispense	Pre-positioned/ Boxed Transport	Heavy Fuel, Batteries, Fuel Cells

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This slide provides the basing and air vehicle deployment concept for the family of UAV systems. As can be seen, most of the envisioned family of systems would be capable of self-deployment to the theater, which may save substantially on logistics requirements. However, to achieve this vision, several technology enablers are required, and significant work remains to be done in the areas identified above.

The ability to "detect, see, and avoid" (DSA) is key to the use of UAVs in civil airspace. Finding a solution acceptable to the FAA and ICAO would give commanders the flexibility to self-deploy larger UAVs, and would allow pre-positioned UAVs to transit friendly airspace and share battlespace more smoothly.

Aircraft that dwell in combat areas will clearly benefit from the Air Force's robust low-observables program.

Finally, small UAVs will become more useful as range and endurance increase. Very high efficiency turbines, heavy fuel engines, high-density batteries and fuel cells all offer the potential to give the small UAV the ability to get to the fight, loiter, and come home.

Slide 37

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UAV Demonstrations

- **Near Term – Flexible ISR**
  - **Internet-protocol based command, control, and communications and dynamic image serving**
  - **Dynamic flight-path re-planning and sensor re-tasking**
  - **Modular communications and sensor payload integration**
- **Near Term – Multiple Target Engagement**
  - **Improved ground station human-computer interface**
  - **Automatic target cueing and tracking**
  - **Autonomous tasking of mini-UAVs for close engagement**
- **Mid-Term – Deep DEAD/SEAD**
  - **Next-generation survivability enhancement integration**
  - **Manned / unmanned cooperative mission execution**
  - **Air refueling of UAV**
  - **Directed energy weapon integration**

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In conducting this study, it became clear that UAV capability demonstrations have played a significant role in convincing the warfighter of the value of these systems. To continue this progress, this study recommends two near-term demonstrations and one mid-term demonstration of UAV systems capability.

The Flexible ISR near-term demonstration will integrate IP-based command, control, and communications and dynamic image serving. The UAV system will demonstrate dynamic flight path re-planning and sensor re-tasking along with modular communications and sensor payload integration.

The Multiple Target Engagement near-term demonstration will demonstrate the UAV system's ability to automatically cue and track targets and autonomously task mini-UAVs for close engagement of the multiple-target set. This demonstration will also highlight an improved ground station human-computer interface.

The Deep SEAD mid-term demonstration will display next-generation survivability enhancements integrated into the system and platform. The UAV will demonstrate manned-unmanned cooperative mission execution to include air refueling of the UAV and directed energy weapons integration.

Slide 38

Recommendations

U.S. AIR FORCE

1. **Continue to procure Global Hawk and Predator and develop UCAV incorporating new capabilities through spiral development using open system architectures and modular payloads**
2. **Begin Analysis of Alternatives and design trades on the Survivable High Altitude Endurance and Survivable Large systems**
3. **Develop a cross cutting mission management research initiative and establish a testbed to transition capabilities into operational concepts and systems**
4. **Develop an architecture and the associated standards that enable the integration of UAVs with manned and space systems**
5. **Continue innovative research into small UAV platforms and the enabling technologies**
6. **Conduct near- and mid-term demonstrations of specific capabilities to integrate unmanned systems into the force structure**

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The AF is off to a good start. Three members of the family of six systems are the current programs of Global Hawk, Predator, and UCAV. These systems should be continued in spiral development and should be developed using open architectures and modular payloads

The AF should begin research on an analysis of alternatives and design trades on the two large members of the family of systems. This study did not do an in-depth analysis of the cost of these programs, nor did it attempt to analyze the trade space between a UAV family of systems and manned and space assets. These analyses need to be done.

Mission management, autonomy, and human-systems integration remain the “long poles in the tent.” These are key areas that require the establishment of a test bed to transition capabilities and they need additional technological investment.

The AF should develop an architecture and set of standards to enable UAVs, manned aircraft, and space systems to work together. Small UAVs can do things manned platforms cannot, and can go places manned platforms cannot. The study believes some of the most innovative payoffs may be in this category, which will likely be relatively inexpensive.

The AF needs to continue to conduct capability demonstrations to integrate UAVs into the force structure. These dividends will increase operator familiarity and comfort with new technologies, and this will continue to pay dividends well into the future.

Slide 39

Per R.V. Jones, we looked into the distant future and found that man and machine are still working together.

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USD (A&T)/DSB	Defense Science Board
DARPA	Defense Advanced Research Projects Agency
DIA	Defense Intelligence Agency
DISA	Defense Information Systems Agency
MDA	Missile Defense Agency

Other Air Force Organizations

AC2ISRC	Aerospace Command, Control, Intelligence, Surveillance, and Reconnaissance Center
ACC	Air Combat Command
– CC	- Commander, Air Combat Command
– 366th Wing	- 366th Wing at Mountain Home Air Force Base
AETC	Air Education and Training Command
– AU	- Air University
AFMC	Air Force Materiel Command
– CC	- Commander, Air Force Materiel Command
– EN	- Directorate of Engineering and Technical Management
– AFRL	- Air Force Research Laboratory
– SMC	- Space and Missile Systems Center
– ESC	- Electronic Systems Center
– ASC	- Aeronautics Systems Center
– HSC	- Human Systems Center
– AFOSR	- Air Force Office of Scientific Research
AFOTEC	Air Force Operational Test and Evaluation Center
AFSAA	Air Force Studies and Analyses Agency
AFSOC	Air Force Special Operations Command
AFSPC	Air Force Space Command
AIA	Air Intelligence Agency
AMC	Air Mobility Command
NAIC	National Air Intelligence Center
NGB/CF	National Guard Bureau

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USAFA	U.S. Air Force Academy
USAFE	U.S. Air Forces in Europe

U.S. Army

ASB	Army Science Board

U.S. Navy

NRAC	Naval Research Advisory Committee
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ABSTRACT (Maximum 200 Words) The report discusses the future of UAV employment in the USAF. It suggests a range of potential missions for future UAV employment, as well as a set of systems that could be constructed to accomplish these missions. The report examines the current state of mission management technologies and maps out a plan of development for mission management and UAV CONOPS. This report summarizes the findings to be discussed in detail in subsequent volumes.				
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