

## **APPENDICES**

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## **Appendix A**

### **Terms of Reference**

#### **UAV Technologies and Combat Operations**

**February 1996**

**SUMMARY:** The Chief of Staff, recognizing the importance of unmanned aerial vehicles (UAVs) to Air Force combat operations, requested the Scientific Advisory Board to investigate advancing electronic and mechanical technologies that might enable Air Force mission roles for UAVs as well as establish the related technology areas in which further advancements are needed.

**BACKGROUND:** The development, test, and use of unmanned aircraft has spanned many years with little success in integrating UAVs into the combat force. Cost and reliability have been among the chief impediments to effective use. Several developments have now made UAV operations practical: high-reliability components and subsystems, differential GPS for precision waypoint and auto-land flight, lower cost sensor suites, composite structures and skins, high-efficiency engines, etc.

The recent introduction of UAVs into combat operations (e.g., Desert Storm and Bosnia) has demonstrated the value of augmenting manned aircraft with UAVs in high threat areas and for long-endurance flights associated with reconnaissance and surveillance missions. A broader range of missions including attack, special operations, combat search and rescue, and communications must now be considered.

The rapid advancement of high-reliability, low-cost electrical and mechanical components suitable for UAVs has opened a new era, just as reduced cost of air operations has become a more critical need. This study is necessary to review the Air Force position relative to the technical capabilities and technology needs of UAVs and combat operations.

**TASKS:** The study effort will:

- Review the state-of-the-art in UAV development in the Air Force, other Services, and other Government agencies.
- Assess Air Force roles and missions for which current technologies might enable use of UAVs to accomplish combat tasks at reduced cost or lower risk of human capture or loss of life.
- Identify the new technologies significant to the development of combat UAVs capable of conducting traditional or future and nontraditional Air Force missions.

- Make recommendations for development of those technologies unique to the UAV or for which substantial risk relative to UAV applications is present, so that future UAV missions can be made possible.
- Provide recommendations for the development of UAVs and the associated technologies.

PANELS: The study effort will consist of five panels:

- Platform Panel (Airframe, Propulsion, and Flight Control Systems)
- Mission Systems Panel (Sensors, Processing, and Communications)
- Weapons Panel (Lethal and Non-Lethal Weapons and Attack Systems)
- Human Systems Panel (Ground/Airborne UAV Control, Man-Machine Interfaces, and Training)
- Operations Panel (BM/C4I, Force Integration, Roles and Missions, and New Mission Concepts)

PRODUCT: The products of the study will be a final report and a briefing.

## Appendix B

### Study Members and Organization

**Dr. Peter R. Worch**  
Study Chairman

**Maj Gen Thomas Swalm, USAF (Ret)**  
Deputy Study Chairman

**Mrs. Natalie Crawford**  
Special Assistant

#### Operations Panel

**Maj Gen Thomas Swalm**  
**USAF (Ret)**  
**Chair**

Lt Gen Robert Beckel, USAF (Ret)  
Dr. Richard Cave\*  
Maj Gen John Corder, USAF (Ret)  
Lt Gen Lincoln Faurer, USAF (Ret)  
Lt Gen Gordon Fornell, USAF (Ret)  
Mr. Jerauld Gentry  
Mr. Robert Jackson  
Mr. Michael Schoenfeld

#### Platform Panel

**Dr. William Heiser**  
**Chair**

Mr. Richard Alldredge  
Dr. Richard Bradley  
Mr. Ramon Chase  
Col Michael Francis  
Prof. Edward Greitzer  
Mr. Ira Kuhn  
Dr. James Lang  
Dr. James Mitchell  
Mr. Sherman Mullin  
Mr. Robert Patton  
Mr. Elbert Rutan  
Dr. Phillip Smith\*  
Prof. Terrence Weisshaar

#### Mission Systems Panel

**Dr. John Boriky**  
**Chair**

Mr. Geoff Butler\*  
Dr. Curtis Carlson  
Mr. Lynwood Cosby  
Dr. George Davis  
Prof. Daniel Hastings  
Dr. Stephen Iglehart  
Dr. Charles Morefield  
Dr. F. Robert Naka  
Dr. Stanley Robinson  
Dr. Gunter Stein  
Prof. Duane Stevens  
Dr. Michael Yarymovych

#### Weapons Panel

**Mr. Theodore Wong**  
**Chair**

Mr. Milton Finger  
Dr. O'Dean Judd  
Maj Gen Donald Lamberson, USAF (Ret)  
Prof. Digby Macdonald  
Dr. Joseph Mayersak  
Mr. Robert Millet  
Mr. Gregory Shelton  
Mr. Darryl Spreen

#### Human Systems Panel

**Dr. Richard Gabriel**  
**Chair**

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Mr. David Hoagland  
Mr. Douglas Hosmer  
Dr. John Howe, III  
Dr. John Retelle, Jr.  
Dr. Henry Taylor  
Mr. Richard Weeks\*  
Dr. Harry Wolbers

\* Members of the UK Defence Research Agency, a Division of DERA

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Maj M. Reagan, SAB  
Lead Executive Officer

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## Appendix C

### Abstracts of Panel Reports

#### Operations Panel Report Abstract

The task of the Operations Panel was to use the range of future Air Force operations to generate a description of the contribution provided by UAVs. Future operations were divided into three groups, representing near-term (1996 to 2005), mid-term (2005 to 2015), and far-term (2015 to 2025). The first step was to generate a list of potential UAV operations. This incorporated 22 different operational mission concepts and tasks, covering a wide range, including attack of fixed and moving targets, cargo transport, humanitarian, and others. All of the operations, including those beyond the 9 published in Volume I are described in Volume II.

In most of the operational concepts, UAVs have applications in the near-term for performing mission-specific ISR. Non-ISR functions begin to be available in most cases in the mid-term (initial operational demonstrations could occur in the near-term). Possible near-term initial operational demonstrations of non-ISR functions include fixed target attack, moving target attack, communications-navigation support, TMD, SEAD, airborne communications node, jamming, and air-to-air. The technological requirements for concepts are discussed for each operation.

It is recommended that development of UAV-based operational concepts be evolutionary, ensuring reliable operational utility before incorporation into the Air Force structure. A phased approach should be utilized to demonstrate UAV flight characteristics and weapon integration before the more complex concepts and missions are started.

#### Panel Membership

##### **Maj Gen Thomas Swalm, USAF (Ret) Chair**

Lt Gen Robert Beckel, USAF (Ret)

Dr. Richard Cave, UK Defence Research Agency

Maj Gen John Corder, USAF (Ret)

Lt Gen Lincoln Faurer, USAF (Ret)

Lt Gen Gordon Fornell, USAF (Ret)

Mr. Jerauld Gentry

Mr. Robert Jackson

Mr. Michael Schoenfeld

Maj Kermit Neal, Executive Officer

Maj Earl McKinney, Technical Editor

## **Platform Panel Report Abstract**

The objective of the Platform Panel was to identify and specify the air vehicle system and subsystem technology investments most essential or beneficial to the future development of UAVs. To achieve its purpose, the Platform Panel carried out several interrelated activities, some of which are described as follows.

First, the opinions and ideas of insightful experts from inside and outside the UAV community were gathered during a series of field trips and meetings. Second, the most compelling UAV mission tasks and the minimum number of candidate air vehicle concepts needed to accomplish these tasks were identified, starting from the national military needs. Third, vehicle point designs were generated so that sensitivities to proposed technology advances could be determined. Fourth, conclusions were summarized in the form of roadmaps for critical enabling technologies and for UAV systems development and deployment. Throughout, the work was closely coordinated with the Operations, Human Systems, Mission Systems, and Weapons Panels to ensure that the study results were integrated to maximize the chances of success for UAVs.

The report concludes with a short but comprehensive list of final recommendations that includes precise descriptions of the next steps to be performed in order to capitalize on the great promise of UAVs to perform vital missions of the Air Force.

### Panel Membership

#### **Dr. William Heiser, Chair**

Mr. Richard Alldredge

Dr. Richard Bradley, Jr.

Mr. Ramon Chase

Col Michael Francis

Prof. Edward Greitzer

Mr. Ira Kuhn

Dr. James Lang

Dr. James Mitchell

Mr. Sherman Mullin

Mr. Robert Patton

Mr. Elbert Rutan

Dr. Phillip Smith, UK Defence Research Agency

Prof. Terrence Weisshaar

Maj W. Lance Harwell, Executive Officer

Capt Mark Cherry, Executive Officer

Maj Alice Chen, Technical Editor

## **Mission Systems Panel Report Abstract**

The Mission Systems Panel evaluated the electronics required onboard UAVs to perform the operational tasks that are the basics of this study and assessed the availability of technologies to implement the selected system concepts. The Panel charter covers sensors of all types—communications, navigation and geolocation, electronic warfare, fire control, and information processing. The report deals first with the mission systems of each operational task and then with summaries of the key technology areas.

In general, the Panel found that enabling technologies for basic UAV operational concepts are available or in advanced stages of development. Thus, UAV systems that add significant operational capability can be demonstrated and fielded in the near-term. For the mid- and far-terms, specific high-leverage technologies that will make feasible UAVs with greatly enhanced performance and availability have been identified and recommended for focused technology development efforts. In particular, the technologies forming the mathematical and computing basis for higher levels of autonomous payload operation, including automated evaluation of sensor inputs, have great potential.

The Panel developed the avionics content of a point design for a UAV SEAD platform, which is a major outcome of the study as a whole. The Panel's recommendations highlight the importance of an improved BM/C<sup>4</sup>I architecture to allow UAVs to be used with maximum effectiveness. Other recommendations include near-term demonstration of UAV platforms to deal with shortfalls in communications and navigation in the battlespace, with urgent operational needs to replace manned jamming platforms and with high-precision target location to support weapons such as JDAM and JSOW. Technology recommendations deal with critical components and with technologies that enhance affordability.

### Panel Membership

#### **Dr. John Borky, Chair**

Mr. Geoff Butler, UK Defence Research Agency

Dr. Curtis Carlson

Mr. Lynnwood Cosby

Dr. George Davis

Prof. Daniel Hastings

Dr. Stephen Iglehart

Dr. Charles Morefield

Dr. F. Robert Naka

Dr. Stanley Robinson

Dr. Gunter Stein

Prof. Duane Stevens

Dr. Michael Yarymovych

Maj Thomas Pauly, Executive Officer  
Capt Brian Mork, Technical Editor

## **Weapons Panel Report Abstract**

UAVs are under consideration for a number of Air Force missions and tasks. Some will require weapons to effectively kill difficult targets. Long endurance and other unique attributes of the UAV enable it to deliver weapons more effectively in some of these tasks. These include CW/BW neutralization, SEAD, boost phase intercept of tactical ballistic missiles, and interdiction of some hard targets.

Analysis of elements of these tasks, evaluation of the threat, examination of parametric design data, and review of available technology led to the selection of a family of three small weapons capable of employing a family of new modular warheads. One of the weapons is on the shelf. The others employ some existing subsystems. The family of weapons/warheads provides UAVs with near-term capability to very effectively conduct the spectrum of mission/tasks identified above, as well as some collateral air-to-air missions. In addition, the weapons are candidate for delivery by manned aircraft.

The technology necessary to develop these weapons is basically in hand. To facilitate their development, it is recommended that advanced flying plate and incendiary warhead technology—the enabler of high lethality in a very small volume—be quantified (hydrocode analysis and tests) beyond the demonstrations that have already taken place.

### Panel Membership

#### **Mr. Theodore Wong, Chair**

Mr. Milton Finger

Dr. O’Dean Judd

Maj Gen Donald Lamberson, USAF (Ret)

Prof. Digby D. Macdonald

Dr. Joseph Mayersak

Mr. Robert Millett

Mr. Gregory Shelton

Mr. Darryl Spreen

Maj John Foley II, Executive Officer

Capt Thomas Bailey, Technical Editor

## **Human Systems Panel Report Abstract**

The task of the Human Systems Panel was to identify significant human-system issues in the development and deployment of UAVs for various missions identified by the Operations Panel and to recommend technical requirements, research needs, or process changes necessary to assure effective integration of the human. The role of the human, human systems interface technology, command and control, and maintenance and personnel training issues are addressed.

Determining the degree of autonomy and functions of the human is a vital front end concern that drives design. Simulations of various types, including man-in-the-loop “gaming” simulation, are effective methods of supporting function allocation and these simulations should be performed early in concept development. Research in how to promote situation awareness is required. Designing methods to keep the human in the loop will be a challenge to display format designers if the system is relatively autonomous.

The ACTD process has largely ignored manpower, personnel, and training requirements and a systematic and timely method of addressing these needs must be implemented.

### Panel Membership

#### **Dr. Richard Gabriel, Chair**

Mr. Jeff Erickson

Mr. Dave Hoagland

Mr. Doug Hosmer

Dr. John Howe, III

Dr. John Retelle, Jr.

Dr. Henry Taylor

Mr. Richard Weeks, UK Defence Research Agency

Dr. Harry Wolbers

Ms. Roxanne Constable, Executive Officer

Capt Sandra Eisenhut, Technical Editor

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## Appendix D

### Distribution List

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AF/CVA	1	Assistant Vice Chief of Staff
AF/ST	1	Chief Scientist
AF/TE	1	Test and Evaluation
AF/LRP	1	Long Range Planning
AF/HO	1	Historian
Assistant Secretary for Acquisition		
SAF/AQ	3	ASAF, Acquisition
AQX	1	Management Policy and Program Integration
AQL	1	Special Programs
AQI	1	Information Dominance
AQP	1	Global Power
AQQ	1	Global Reach
AQS	1	Space and Nuclear Deterrence
AQR	1	Science, Technology and Engineering
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AF/IN	1	ACS, Intelligence
INX	1	Plans and Policy
INR	1	Resource Management
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AF/XO	1	DCS, Plans and Operations
XOO	2	Operations
XOR	2	Operational Requirements
XOF	2	Forces
XOX	2	Plans
XOM	2	Modeling, Simulation, and Analysis

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AF/LG	2	DCS, Logistics
Deputy Chief of Staff, Command, Control, Communications, Computers		
AF/SC	1	DCS, C4
SCM	1	C4 Mission Systems
SCT	1	C4 Architectures, Technology and Interoperability
SCX	1	Plans, Policy and Resources
Directorate of Programs and Evaluation		
AF/PE	1	
AFPEO/AT	1	Airlift and Trainers
AFPEO/SP	1	Space Programs
AFPEO/FB	1	Fighter and Bomber Programs
AFPEO/C3	2	C3 Programs
AFPEO/BA	2	Battle Management
AFPEO/WP	2	Weapons
AFPEO/JL	2	Joint Logistics Systems
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USD (A)/DSB	1	Defense Science Board
DDR&E	3	Director, Defense Research & Engineering
ASD/C3I	1	Assistant Secretary of Defense for C3I
OUSD (AT)	1	Deputy Under Secretary for Advanced Technology
BMDO	1	Ballistic Missile Defense Organization
DARO	5	Defense Airborne Reconnaissance Office
DARPA	5	Defense Advanced Research Projects Agency

Other Air Force		
AFMC	1	Air Force Materiel Command
ST	2	Section
WL, AL, PL, RL, OSR	5 ea.	Science and Technology
ESC, ASC, HSC, SMC	1	Labs and AFOSR Product Centers
ACC	3	Air Combat Command
AMC	1	Air Mobility Command
AFSPC	1	Air Force Space Command
PACAF	3	Pacific Air Forces
USAFE	3	US Air Forces Europe
AFOTEC	1	Test and Evaluation Center
AFSOC	1	Air Force Special Operations Command
AIA	2	Air Intelligence Agency
NAIC	1	National Air Intelligence Center
USAFA	1	Air Force Academy
AU	1	Air University
AFIWC	1	Information Warfare Center
AFIT	1	Air Force Institute of Technology
NGB/CF	1	National Guard Bureau
AFSAA	5	Air Force Studies and Analysis Agency
Army		
ASA (RD&A)	1	Assistant Secretary of the Army for Research, Development and Acquisition
ASB	3	Army Science Board
Navy		
ASN (RD&A)	1	Assistant Secretary of the Navy for Research, Development and Acquisition
NRAC	1	Naval Research Advisory Committee
NAWC	3	Naval Air Warfare Center
NRL	3	Naval Research Laboratory
ONR	2	Office of Naval Research

Joint Staff		
JCS	1	Office of the Vice Chairman
J2	1	Intelligence
J3	1	Operations
J5	1	Strategic Plans and Policies
J6	1	C3 Systems
Other		
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Aerospace Corporation	2	
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Naval Studies Board	1	

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