AIRCRAFT SURVIVABILITY

Published by the Joint Aircraft Survivability Program Office

JAS
JOINT AIRCRAFT SURVIVABILITY PROGRAM

FALL 2008

UNMANNED Aircraft Systems Survivability

Aircraft Survivability is published three times a year by the Joint Aircraft Survivability Program Office (JASPO) chartered by the US Army Aviation & Missile Command, US Air Force Aeronautical Systems Center and US Navy Naval Air Systems Command.

JAS Program Office

Views and comments are welcome and may be addressed to the:

Editor
Dennis Lindell

Assistant Editor
Dale B. Atkinson

To order back issues of the ASnewsletter, please visit *http://www.bahdayton.com/surviac/inquiry.aspx*

Table of Contents

Mailing list additions, deletions, changes, and calendar items may be directed to:

SURVIAC

SURVIAC Satellite Office

Promotional Director
Christina P. McNemar

Creative Director
K. Ahnie Jenkins

Art Director
Donald Rowe

Technical Editor
Louise Price

Newsletter Design
Tammy Black

Illustrations, Cover Design, Layout
Kacy Cummings
Michelle DePrenger
Ricardo Real

Distribution Statement A:
Approved for public release; distribution unlimited, as submitted under NAVAIR Public Release Authorization 08-805.

by Dennis Lindell

Vulnerability Toolkit

A 1 February 2008, release of the Survivability/Vulnerability Information Analysis Center (SURVIAC) Vulnerability Toolkit includes updates to the Fast Shotline Generator (FASTGEN), Computation of Vulnerable Area Tool (COVART), Combat Assessment Tool (CAT), and several geometry viewers and utilities.

FASTGEN 5.5

FASTGEN 5.5 traces the path of a threat's shotline through a target composed of a three-dimensional database of objects, called components. The set of components encountered along a shotline is arranged in the sequence of encounter, called a line of sight (LOS). LOS data can be used as input to vulnerability assessment models such as COVART.

FASTGEN can process kinetic energy (KE) threats such as single fragments and projectiles, as well as high-explosive (HE) threats, including Man-Portable Air Defense System (MANPADS) and high-explosive incendiary (HEI). KE threats can be processed as single shotlines, groups of shotlines (multi-hit), or a grid of shotlines across the target. HE threats can be processed as single impacts, proximity bursts, or a grid of shotlines across the target. FASTGEN is written in FORTRAN90 and supported on PCs running Windows or Linux, and UNIX platforms running Sun Solaris and SGI Irix operating systems.

Major improvements incorporated in this release include support for multi-hit assessments and enhanced support for the CAT. The multi-hit capability enables users to assess bullet and fragment threats as a group of impacts, as could be seen from a burst of gun fire. This data is passed to COVART for analysis, taking into account multiply vulnerable failures attributed to the multiple impacts. CAT support includes an ability to provide data to COVART for computation of penetration information for use with CAT. Minor bug fixes also are included in this release. The FASTGEN users manual has been updated to reflect new features implemented in this release, includes additional descriptions and information related to several records and features, and corrects several errors present in previous versions of the documentation.

COVART 5.1

The COVART computer program is a method for determining vulnerable areas of targets damaged by impacting single KE penetrators, or HE rounds. Primary emphasis is given to fixed and rotary wing aerial targets; however, vulnerable areas of ground targets also can be determined, provided that their damage definitions and material properties are consistent with those acceptable to COVART 5.1.

COVART 5.1, which is a modularized version of COVART, contains separate modules for penetration equations (*e.g.,* HE projectiles, Joint Technical Coordinating Group (JTCG) fragments, and FATEPEN 2.5), damage (Pcdlh), and fault trees (MV). COVART is written in FORTRAN77 and supported on PCs running Windows or Linux, and UNIX platforms running Sun Solaris and SGI Irix operating systems.

In addition to the features in COVART 5.0, COVART 5.1 contains the following new features: multi-hit capability and support for the CAT. This release also includes many significant changes resulting from the COVART Critical Repairs project, which addressed several major software change requests (SCR). The COVART users manual also was updated to reflect the new features implemented in this release. The manual includes additional description and information related to several records and features, including RATIO, FIRE, and incendiary functioning.

CAT 3.0

The CAT 3.0 is a quick, easy-to-use interactive tool for visualizing potential impact locations and damage (holes) from HE and KE threats. The Joint Combat Assessment Team (JCAT) used this tool previously for helping to identify threat and visualization of encounter conditions. Other potential uses include aiding in ballistic test planning and documentation and visualization in support of vulnerability analysis.

The user selects a target model and threat file of interest and then interactively places the threat relative to the target in the viewer. Threat selection and placement is based on combat debriefing information such as threat type, estimates of threat orientation relative to the target, and threat velocity relative to ground at time of detonation; or upon test conditions and parameters. After target/threat orientation data has been input, FASTGEN and COVART can be run from the viewer to compute and display threat damage patterns on the target surface. This process can be repeated by varying threat parameters (*e.g.,* threat type, velocity, and orientation) until a suitable match is obtained between modeled damage patterns and damage patterns observed in the field, or until results match desired test conditions and results. CAT 3.0 is supported on only PCs running Microsoft Windows.

LFT&E and Aircraft Vulnerability Design Engineering Course

Engineers Andrew Kurpik and Philip Radlowski from the Aeronautical Systems Center, Engineering Directorate, Combat Effectiveness and Vulnerability Analysis Branch (ASC/ENDA), conducted a course on live fire test and evaluation (LFT&E) and vulnerability design engineering.

The course, offered as part of the April 2008 ASC Focus Week, presented ASC employees an opportunity to broaden their knowledge base. The goal of the course was to introduce attendees to LFT&E by demonstrating the impact of LFT&E on aircraft design and describing how LFT&E plays in the overall acquisition process, with a focus on vulnerability and Air Force programs. The target audience consisted of ASC program (or other acquisition center program) representatives who were or will be "covered programs" under live fire laws.

Mr. Kurpik and Mr. Radlowski presented a brief introduction and history of aircraft survivability and vulnerability. As part of the course, they described the development and scope of the live fire test laws, including the Joint Live Fire (JLF) program and Title X laws governing LFT&E. They discussed the interdependent relationship between LFT&E and survivability specification requirements to demonstrate how acquisition programs can leverage similar work and eliminate redundant efforts. They also used case studies from various Air Force acquisition programs as examples of current acquisition programs conducting LFT&E.

The 3-hour course is offered twice or three times annually during ASC Focus Weeks at Wright Patterson AFB; however, a program office or other entity may request that the course be presented. The course is open to government personnel and government contractors. For further information, please contact Philip Radlowski.

Hall Receives AIAA Survivability Award

Mr. David H. Hall received the American Institute of Aeronautics and Astronautics (AIAA) 2008 Survivability Award at the 49th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference. The conference was held 7–10 April, 2008, at the Renaissance Schaumburg Hotel and Convention Center in Schaumburg, Illinois. He received an engraved medal, certificate of citation, and rosette pin at the awards luncheon held on 9 April.

The AIAA Survivability Award is presented to an individual or a team to recognize outstanding achievement or contribution in design, analysis, implementation, and/or education of survivability in an aerospace system. Mr. Hall was recognized for exceptional contributions as a visionary and leader in developing integrated survivability assessment, modeling and simulation verification, and validation accreditation processes and practices.

Dave Hall Received the American Institute of Aeronautics and Astronautics (AIAA) Survivability Award.

Mr. Hall has been Chief Analyst of SURVICE Engineering Company and Deputy Manager of the Ridgecrest Area Office since 2002. Earlier, he served 34 years at the Naval Air Warfare Center, Weapons Division, in China Lake, California, where he held leadership positions. These positions included civil service as Chief Analyst of the Survivability Division and Chairman of the Survivability Methodology Subgroup for the Joint Aircraft Survivability Program Office.

A respected member of the survivability community for more than 30 years, Mr. Hall has had a profound influence on the Department of Defense (DoD) survivability community and its industry counterparts' ability to provide effective and survivable combat aircraft to our fighting forces. He can be credited individually as central to developing, testing, and implementing the first fully documented and proven capability to verify, validate, and credibly accredit complex models and simulations used for making acquisition decisions, planning and executing successful combat operations, assessing combat effectiveness, and enhancing the combat survivability of DoD's aviation resources.

AIAA advances the state of aerospace science, engineering, and technological leadership. Headquartered in suburban Washington, DC, the Institute serves more than 35,000 members in 65 regional sections and 79 countries. AIAA's membership draws from all levels of industry, academia, private research organizations, and government. For more information, visit *http://www.aiaa.org*.

Hugh Griffis is New JASP PMSG Chairman

The Joint Aircraft Survivability Program (JASP) Spring Principal Member Steering Group (PMSG) meeting was held 1–3 April, 2008. In accordance with the Joint Aircraft Survivability Program (JASP) standard operating procedures, the PMSG chairman position rotates every 2 years.

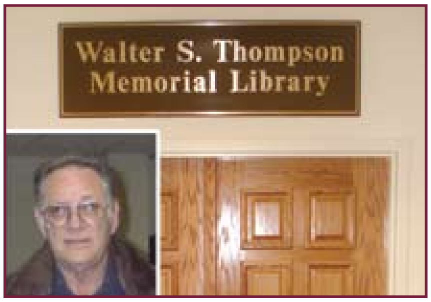
The chairman position was transferred from Mr. John Kamadulski (USA) to Mr. Hugh Griffis (USAF). Mr. Griffis is the Air Force Aeronautical System Center (ASC) Engineering (EN) Design (D), Analysis, and Simulation Division (ASC/END) Chief/Technical Director.

Hugh Griffis was Selected as the New JASP PMSG Chairman in April of 2008.

The ASC/END's mission includes advocating for the usage of enhanced modeling, simulation, and analysis (MS&A) across all phases of system acquisition and the conduct of analyses in survivability, reliability, maintainability, weapon system integrity, supportability, and the entire spectrum of combat effectiveness (engineering, one-on-one, engagement, air combat, mission, and campaign). Mr. Griffis has 27 years of system acquisition and MS&A experience. During many of these years, he was the lead vulnerability engineer for the B-2, F-22, and F-35 programs.

SURVICE Engineering Dedicates the Walter S. Thompson Memorial Library

On 25 June 2008, the SURVICE Engineering Company dedicated the technical library at its Aberdeen Area Operation to the memory of former employee and widely regarded aircraft vulnerability analyst Walt Thompson, who passed away in 2005. The ceremony and plaque unveiling was attended by SURVICE employees, personnel from



the US Army Research Laboratory (ARL)—where Mr. Thompson previously worked for more than 30 years—and Mr. Thompson's widow, Mrs. Jeanne Thompson.

In his dedicatory remarks, SURVICE CEO, Mr. Jim Foulk, spoke fondly of his four-decade relationship with Mr. Thompson and of his former colleague's important contributions to the field of air system survivability.

"In my opinion," Mr. Foulk said, "Walt was the most knowledgeable expert in the world on turbine engine vulnerability. He contributed significantly to the improvement of the survivability of most US aircraft engines developed over the past 35 years."

Of particular note is Mr. Thompson's influence on the development of the T700 engine, which is now used in the multi-service H-60 helicopter series and other aircraft. He was also a member of many propulsion committees and the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME), the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS), and the Joint Live Fire Test Program (Aircraft Systems). In addition, Mr. Thompson was an accomplished technical writer and a man who was committed to ensuring the country's vital survivability information was preserved for future analysts.

Mr. Rick Grote, the Chief of the Systems Engineering and Experimentation Branch of ARL's Survivability/Lethality Analysis Directorate, also spoke at the ceremony and reported on ARL's current efforts to implement Mr. Thompson's idea for a helicopter tilt table at Aberdeen Proving Ground. The table will allow testers and analysts to better estimate the vulnerability of the undersides of combat aircraft.

SURVICE will operate the Thompson library in coordination with the Aberdeen Satellite Office of the Survivability/Vulnerability Information Analysis Center (SURVIAC). For more information, visit *http://www.survice.com*.

JCAT Corner by CAPT Kenneth Branham, USN

2008 Threat Weapons and Effects Training Seminar

The Navy Joint Combat Assessment Team (JCAT) hosted the very successful 2008 Threat Weapons and Effects (TWE) Training Seminar at Hurlburt Field/Eglin AFB, FL 22–24 April 2008. The seminar's title was "Beyond Today: the Next Conflict" and focused on not only current threats found in Operation Iraqi Freedom/Operation Enduring Freedom (OIF/OEF) but other potential future hot spots. It was a collaborative effort between the JCAT (sponsored by the Joint Aircraft Survivability Program Office (JASPO), Aeronautical Systems Center (ASC), Naval Air Systems Command (NAVAIR), and the Army Research Laboratory), DIA (with support from the Missile and Space Intelligence Center), and other agencies. With 249 registered conference attendees for an auditorium seating 200 personnel, it was standing room only for students from some of the local commands.

The goal of the seminar is to provide not only intellectual stimulus but also practical, hands-on training on the lethality of threat air defense systems and the damage they can inflict on friendly aircraft. Information is drawn from threat exploitation, live fire testing, and combat experience to provide a complete picture on threat lethality. A hands–on experience is provided through the use of threat munitions/missiles, test articles, damaged aircraft hardware, and videos from various test activities and actual combat. The Missile and Space Intelligence Center (MSIC) brought down their MANPADS education trailer for more hands on exposure. This year's live fire demonstrations included 3 MANPAD launches from the Vehicle-Mounted Stinger currently fielded on the US Avenger and 30 mm AP shots. The Air Force Special Operations Command Dynamics of International Terrorism (DIT) team provided a small arms and anti-terrorist demonstration.

Experienced instructors provided current, relevant information briefs on threat system upgrades, proliferation and lethality. Threat briefs included a General Threat Update, and Threat Systems Briefs (SAMS, MANPADS, AAA) for China, Iran and North Korea-one for each individual country, each category. Needless to say it was a very informative and detailed analysis supported by the Missile and Space Intelligence Center (MISC) and National Ground Intelligence Center (NGIC) of the Defense Intelligence Agency. Other briefs included: JASP & JLF-Air overviews, JCAT Summary and Incident Briefs, ASDAT Summary Brief, Afghanistan and Iraq Intel Briefs, RPG and Common Missile Warning System (CMWS) Briefs. Naval Air Warfare Center, Weapons Division, China Lake presented a brief on its very successful Missile Engagement Threat Simulator (METS) Gun with a final brief presented by NAVAIR 4.1.8 on the JASP/JCAT Data Influence on Design.

The seminar is classified secret/NOFORN and is open to operations, intelligence, tactics, logistics, as well as engineering and analysis personnel. Be watching for next year's announcement for an outstanding opportunity for some in depth threat weapons training and professional development.

JCAT News…From the Front

The Joint Combat Assessment Team (JCAT) Forward has successfully entered the OEF fight in Afghanistan! After months of work with various OEF commands, LCDR Nordel received a formal invitation from CJTF-101 to train the units in Afghanistan. The JCAT Army component immediately took this request for action since CW5 Calvert and team were already in Bagram conducting an assessment. It is good to see JCAT continue to extend their influence and support the warfighter in new areas.

The May 2008 MNC-I Commander's Monthly Aviation Conference in Baghdad focused on the JCAT mission, JCAT products and support to OIF combat operations. CDR Robert Mark presented the JCAT mission; LCDR Steve "Nordo" Nordel presented the JCAT assessment process, recent threat systems analysis, and provided some demonstrative hardware; and CW5 Len "Ike" Eichhorn presented the ASDAT assessment of current US Army aviation tactics. The presentations were a big hit—several Army Combat Aviation Brigade Commanders commented that "this was the best MAC conference in the past two years."

1stLt James Stephenson, USAF, headed home in May 2008. During his tour, James did a great job conducting thirty-three aircraft battle damage assessments. His contributions in Mosul were particularly noteworthy wherein the 4-6 Air Calvary Squadron Commanding Officer said that "James was a combat multiplier" and that due to his analysis, the squadron was able to more quickly adapt to the enemy. 1stLt Emilo "Tank" Talipan, USAF, is James' replacement in Balad.

LT Steve Bussell departed Iraq for CONUS early June 2008 after a very successful tour as JCAT Forward Training lead. He did a great job of leveraging his past experience as an enlisted marine to rejuvenate the JCAT Training for Maintainers. Steve provided this training to over one hundred deployed maintainers. His replacement, CWO3 Dave Mesa, USN, arrived in-theater 7 June.

LCDR Nordel wrapped up a solid tour as the OIF JCAT Officer-In-Charge. He focused on mentoring and administratively taking care of the team, enhancing war fighter leadership communications (through new bi-weekly Commanding General briefs), and enhanced communications with the Combat Aircraft Survivability and Threat Lethality (CASTL) community *via* the new JCAT Forward website. "Nordo" also engaged in the fight from above as he flew ten EA-6B Prowler combat missions totaling 65 flight hours covering all of Iraq. Nordo's relief, CDR Craig Black, also arrived in-theater 7 June.

LtCol Scott Matthews, USMC JCAT Lead Retires

LtCol Scott A. Matthews, the United State Marine Corps (USMC) Joint Combat Assessment Team (JCAT) lead retired on 01 June 2008 after 26 years of distinguished military service. LtCol Matthews has been involved in JCAT since its resurgence in December 2003 after the JASP brief to the Commanding General (CG) of 3D Marine Aircraft Wing (MAW) highlighted JCAT capabilities. JCAT was assigned to 3D MAW Aviation Logistics Department (ALD) and LtCol Matthews became the action officer. LtCol Matthews deployed to Iraq from February through July 2004 as the Senior Watch Officer for Aviation Logistics and JCAT Liaison Officer within the 3d MAW Tactical Air Command Center. His efforts included the planning, coordination and execution of the redeployment of Marine Aviation assets into Al Asad, Iraq; aviation logistics support for aircraft readiness for combat operations; and the employment and sustainment support of Joint Combat Assessment Team that initially served two main operating bases (Al Asad and Al Taqqadum) and numerous forward operating bases (FOBs).

Upon his return from Iraq to MCAS Miramar LtCol Matthews assumed his previous billet as the ALD Plans/Operations Officer and principal JCAT Coordinator for deploying JCAT personnel. He took it upon himself to continue to coordinate all JCAT Request For Forces (RFFs) personnel deployments for 3D MAW and 2D MAW while he remained on active duty until June 2005. Upon deactivation, LtCol Matthews became the "Marine JCAT of One" and was assigned to the 4th Marine Aircraft Wing as a drilling reservist. LtCol Matthews' primary objective was to establish permanent line numbers for a USMC JCAT within the Marine Corps' Table of Organization (T/O) which he accomplished. Prior to his retirement, LtCol Matthews was the only Marine, active or reserve, that handled JCAT matters for the US Marine Corps. A permanent USMC JCAT contingent has now been established within 4th MAW manned by Selected Marine Corps Reserves due to his efforts. He has worked closely with his JCAT counterparts in the Army, Navy, and Air Force and assisted in numerous training events for JCAT Assessor and Aircraft Survivability Programs to train Military and DoD civilian personnel. Only a small handful of USMC Officers and Senior Staff Non-Commissioned Officers have been trained to date and the objective now is to get more trained and deployed to support aviation assets currently deployed in Iraq and Afghanistan.

LtCol Matthews the USMC JCAT Lead Retired on 01 June 2008 After 26 Years of Military Service

LtCol Matthews started his Marine career being commissioned a Second Lieutenant *via* the Platoon Leaders Class Program in May of 1980 and served as an Aviation Supply Officer at Marine Corps Air Station Beaufort SC from May 1981 to February 1984. He left active duty and joined VMFA-321 at NAS Andrews as the Logistics Officer in various capacities. He also served in Marine Aviation Logistics Squadron 42 (MALS-42), out of NAS Atlanta, in various different billets and was selected as Commanding Officer in August 1998 until September 2001. He led over 1,000 Marines and Sailors both active and reserve located NAS Atlanta, NAS Norfolk, NAS Belle Chase and MCAS Miramar in all aspects of aircraft maintenance, supply, ordnance, avionics, etc at the intermediate level. His military decorations include the Bronze Star, Meritorious Service Medal (2nd Award), and the Navy and Marine Corps Achievement Medal and various other unit and personal awards.

In his civilian career, LtCol Matthews is President of Filtration Technology, Inc. a supplier of air filtration products and a turnkey clean-room contractor based out of Greensboro, NC. The company supports commercial, industrial, government and research facilities. He resides in Greensboro, NC with his wife Kimberly. They have two children; Tiffany and Ryan. LtCol Matthews' replacement will be Col Phil Harmon as the Director, USMC JCAT. Semper Fi…

Army Unmanned Aircraft Systems Survivability

by Tommy Thomas

Army unmanned aircraft systems (UAS) have become critical to the concept of operations (CONOPS) for the Army—and increasingly, the Marines—in Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF). All UAS systems are used extensively for surveillance and reconnaissance, and many of the systems are being upgraded to allow targeting or even to carry weapons. In terms of numbers and statistics, Army UAS systems (*i.e.,* Raven, Shadow, Hunter, and SkyWarrior) have flown almost 500,000 hours to date in theater.

All systems have in common an ability to provide not only a moderately high level of control and automation for flight controls, including autonomous waypoint flight, but also a line-of-sight data link back to the ground control station. Remote sites are able, within line-of-sight range, to receive the payload product on a remote video terminal (RVT). The One System Ground Control Station (GCS) and the One System RVT are keystones to the Army's enhanced interoperability, enabling one configuration of GCS and RVT to be deployed on the battlefield and operate with any of the Army UAS.

Current Army Systems

Raven

The Raven (*i.e.,* Small Unmanned Aircraft System [SUAS]) provides a man-portable small UAS capability for day and night reconnaissance and surveillance to the maneuver battalion, and it is very well suited to force protection. Battery-powered, flying at a normal altitude of about 500 feet above ground for up to 90 minutes on a lithium battery, the Raven has a roughly 10-kilometer (km) range from the controller. It carries either a front- and side-looking daytime camera (*i.e.,* electro-optical [EO]) or a side-looking night camera (*i.e.,* infrared [IR]). The aircraft has a wingspan of 4.5 feet and weighs about 4 pounds.

Shadow

The Shadow's (*i.e.,* Tactical Unmanned Aircraft System [TUAS]) mission is to provide maneuver commanders a near real-time, highly accurate, sustainable capability for over-the-horizon reconnaissance, surveillance, and target acquisition (RSTA). The Shadow aircraft, which is powered by a gasoline engine, has the following features: a 14-foot wingspan, a weight of 380 pounds, a range of 125 km, a loiter speed of 60 knots and dash speed of 105 knots, a ceiling of 14,000 feet, and a maximum endurance of more than 6 hours. The aircraft, which is launched by a trailer-mounted hydraulic catapult, is recovered on a 100-meter long-landing strip using arresting gear. Recovery flight is controlled by a ground-based automatic radar guidance system. The standard payload is a day/night (EO/IR) pod and a communications relay is being fielded and a laser designator is in development.

Hunter

First fielded in 1996, the Hunter weighs 1,950 pounds and has a wingspan of 34.5 feet, a range of more than 200 km, endurance up to 20 hours, a ceiling of 18,000 feet, and a loiter speed of 60 knots and cruise speed of 80 knots. Hunter is equipped with the Army's first heavy fuel engine for UAS. Standard payload is a day/night (EO/IR) camera pod, but many payloads have been demonstrated, including communications relay, electronics and signals intelligence, and chemical and biological detection. Hunter can carry the BAT anti-tank and VIPER laser-guided weapons.

Hunter

SkyWarrior

The Army is currently in development to begin fielding the SkyWarrior Extended Range Multi-Purpose (ERMP) UAS in FY 2009. As an interim capability, the Army deployed the smaller 2,350-pound SkyWarrior A in 2004, which has a 49-foot wingspan, a ceiling of 25,000 feet, an endurance of more than 22 hours, and a payload of 450 pounds. It is the first Army system to fly with line-of-sight and satellite data link capability.

Raven

Shadow

The SkyWarrior program of record (fielded) system provides a capability for conducting long-dwell reconnaissance, surveillance, target acquisition, communications relay, and attack missions (with Hellfire missiles). The aircraft weighs 3,200 pounds and has a 56-foot wingspan, carries 575 pounds payload internally and 500 pounds externally, has a ceiling of 25,000 feet, has an endurance of more than 30 hours, and is powered by a heavy fuel engine. The aircraft is capable of simultaneously carrying a day/night (EO/IR) camera, a synthetic aperture radar (SAR) imager, and a communications relay. It is equipped with a tactical common data link (TCDL) for line-of-sight Ku-band data link with the GCS, as well as a satellite communications link.

SkyWarrior

FCS

The Army UAS Project Office also manages the Class I and Class IV UASs for the Future Combat System (FCS). Class I is a platoon-level vehicle within the unit of action. It weighs 35 to 45 pounds, has a 8-kilometer range, has an endurance of 60 minutes, has a ceiling of 11,000 feet, and will be equipped with a day/night (EO/IR) camera with a laser designator. The Class IV (Firescout) UAS is an unmanned 3,000 pound helicopter with range and endurance for supporting the Brigade Combat Team. The Class IV UAS will provide the commander with reconnaissance, surveillance, target acquisition, and laser designation capability, and it will be able to operate from unimproved areas.

UAS Survivability Is Different

According to the Defense Acquisition University, the definition of survivability is “the capability of a system and its crew to avoid or withstand a manmade hostile environment without suffering an abortive impairment of its ability to accomplish its designated mission.” Much of the literature concerning aircraft combat survivability and much of the focus on research and development is on an ability to avoid the threat (susceptibility) and to withstand the threat (vulnerability). The threat considered is usually a hostile weapon system, and vulnerability is focused on the aircraft’s ability to not be killed.

UASs are rapidly becoming critical elements in the commander’s ability to accomplish the mission in some situations. Under these circumstances, the survivability of the UAS is not simply avoiding being killed (usually a consideration of dollars of replacement value); rather, it is a factor in overall mission success or possibly even survival of forces. Completion of the mission, often hours in duration in spite of the hostile environment, becomes a hurdle for UAS. However, the very nature of UAS presents challenges of survivability design as a result of the distributed nature of the aircraft operator from the aircraft and the need to distribute payload product to the battlefield users. These electronic, real-time functions are inherently susceptible to hostile interruption or surreption.

Identifying and Improving Enhancements

Most tools that have been developed to support aircraft combat survivability are based on analyzing the aircraft’s ability to avoid or withstand weapons engagements. To support UAS survivability analysis, these tools are still valid and valuable for supporting the UAS survivability analysis; however, additional tools involving electronic warfare and specialty tools for addressing specific payload susceptibilities also are needed. These tools would enable the analysis needed to support data link countermeasures and other electronic countermeasures. Although many of these tools exist within the specialist areas of expertise, a systematic cataloguing, configuration, documentation, and validation of the tools, similar to the other Survivability/Vulnerability Information Analysis Center (SURVIAC) supported tools, would be very beneficial.

The Army UAS Project Office, working with the Aviation and Missile Research Development and Engineering Center (AMRDEC), has begun evaluating susceptibilities of the program of record UAS. This comprehensive bottom-up analysis will help identify all vulnerabilities and susceptibilities, evaluate the probability and severity of each, and identify and evaluate mitigation approaches for implementing cost, effectiveness, and risk. The most rewarding mitigations identified will be further evaluated and implemented as funding permits. ■

About the Author

Mr. Tommy Thomas, a systems engineer at the Aviation and Missile Research Development and Engineering Center at Redstone Arsenal, AL, has been matrixed to the Unmanned Aircraft Systems Project Office since 1998. Mr. Thomas holds a Bachelor of Science in Mechanical Engineering from Texas A&M University and a Master of Science in Operations Research from the University of Alabama in Huntsville.

References

1. COL Don Hazelwood, Army AL&T, "Managing the Best Acquisition Program in the Army—This Is Where It All Happens," July–September 2007
2. Ball, Robert E. AIAA The Fundamentals of Aircraft Combat Survivability Analysis and Design, Second Edition.
3. Glossary of Defense Acquisition Acronyms and Terms, Defense Acquisition University Press, July 2005.

All photographs for this article are courtesy of Tarah Hollingsworth.

"Rapid Proto-duction" of the Apache Video From UAS for Interoperability Teaming—Level 2 (VUIT-2)

by LTC Charles S. Walls IV, USA

As we see continuous changes in how our enemies operate in various environments of the global war on terror (GWOT), we are at work constantly to embrace and seek out growing technologies. We are excited about breaking down walls of traditional acquisition processes and procurement strategies in teaming closely with our industry partners. Air and ground survivability of our forces are our priority in a peace enforcement environment of an asymmetric battlefield. The enemy's techniques to plan and operate covertly require new methods and technological improvements to increase air and ground survivability; an emerging technology to enhance manned-unmanned (MUM) teaming is evolving with video from UAS (unmanned aerial systems) for Interoperability Teaming–Level 2 (VUIT-2).

Recent developments in technology have sparked a partnership between industry and the US Army and have reinforced the strong relationships within the Army's acquisition community as program manager (PM) offices work together to streamline the acquisition process through past science and technology (S&T) experiences with MUM teaming on demonstration projects (Hunter Standoff Killer Team [HSKT] and AMUST-D) and the rapid prototyping capabilities of the Aviation Applied Technology Directorate (AATD) at Fort Eustis, Virginia. Rapid "Proto-duction" provides this capability while still ensuring that the technology is mature and applicable for providing the best product to our soldiers in harms way and to best enable them to accomplish their mission safely.

Rapid "Proto-duction" is an ability to effectively transition technology concepts through application to test article to unit fielding, yielding a new system with tactical application. This ability could effectively replace the term "streamlined acquisition" with "rapid proto-duction acquisition" (RPA). The challenges lie in—

1. Building a team from various agencies from government and industry that are focused on building the best product for the soldier,
2. Developing a plan with controlled risk based on concurrent integration, and
3. Reducing risk with design, fabrication, and installation based on a wealth of rapid prototyping experience and initiatives, combined team testing, PM acceptance of additional costs for design improvements and redesign issues, bold production decision points based on comprehensive long lead schedules, and concurrent production efforts.

From this unique partnership, the Apache VUIT-2 program evolved to get technological advances applied to US Army aircraft and out to the field in a safe, timely manner. Working as a joint PM team, PM Apache and PM UASs chartered AATD as the lead system integrator (LSI) on a proof-of-concept plan with industry partners Lockheed Martin (LM), L3 Communications, AAI, and Camber to design, develop, fabricate, integrate, and test an Apache VUIT-2 system within 6 months. Upon the success of this proof of concept, AATD, drawing on its extensive MUM teaming experience, would lead a rapidly accelerated "Proto-duction" effort. This effort would include a validation and verification of AH-64D Block I and Block II aircraft for fielding a demonstration battalion, all within a complex "window" to meet the battalion's deployment schedule and enhance CONUS training with the system before deployment.

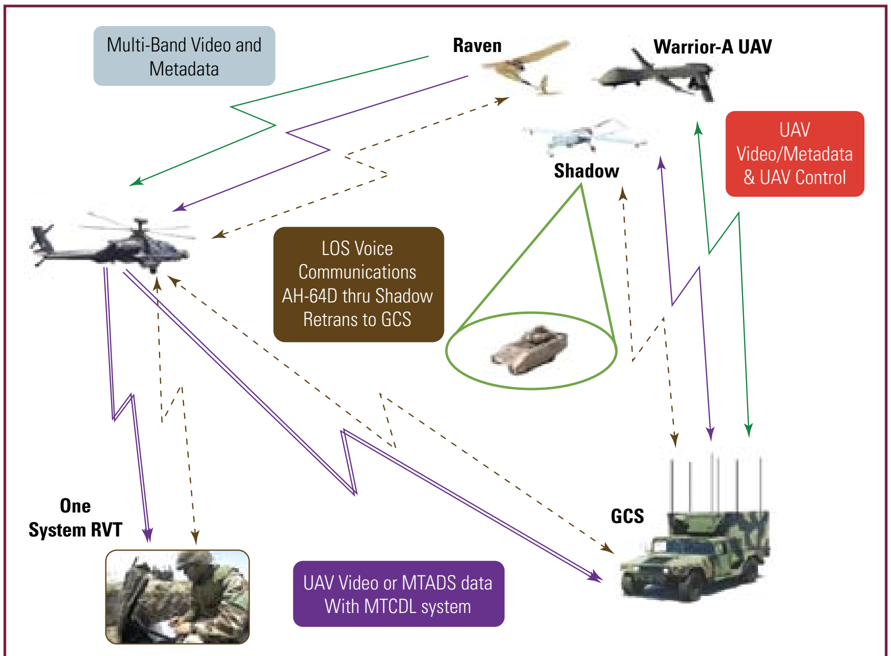


Figure 1 Apache VUIT-2 Concept

Rapid "Proto-duction" of VUIT-2

The basic concept of Apache VUIT-2 is to enable the AH-64D aircraft to receive multiband video and metadata signals transmitted from a UAV aircraft and view them in the cockpit. This concept was expanded to include enabling the AH-64D to not only send the received video and metadata from the UAS to a one source remote video terminal (OSRVT) ground station or a ground control station (GCS) but also send target acquisition designation sight (TADS) or modernized target acquisition designation sight (MTADS) video to the same ground receiving station or different ground receiving stations. Figure 1 illustrates the Apache VUIT-2 concept.

In April 2007, PM Apache (lead platform PM) and PM UAS (supporting PM) jointly established AATD as LSI for the VUIT-2 team. They chartered the team with the following threshold and objective tasks leading up to a demonstration at the end of a 6-month period.

Threshold Tasks

1. AH-64D (BLK I/II) receives UAS video and metadata (Shadow UAV)
2. Display video with metadata and map in cockpit and provide operator controls (modem control essential). Conduct flight demonstration with Shadow UAV, and demonstrate *via* simulation for Raven and Warrior A UASs.
3. Maintain two-way line-of-sight (LOS) communication between AH-64D (BLK I/II) and GCS and/or OSRVT system.
4. Develop documentation, including AMWOs, validation reports, prototype tech data package (TDP), prototype drawings, analysis, testing report, and A-kit/B-kit listing.

Objective Tasks

1. Transmission of AH-64D (BLK I/II) TADS/MTADS to GCS and OSRVT manpack systems.
2. Retransmission of UAS video/metadata to GCS and OSRVT manpack.
3. Advance pilot vehicle interface (PVI) with display that enables the selection of multiple UAS' video/metadata.

AATD's unique and diverse capabilities to incorporate S&T research from its technology divisions and rapid prototyping materiel development into one organization provides the PMs an LSI with a one-stop "concept-to-flight test" organization with the flexibility and adaptability to meet demanding quick-reaction capability (QRC) timelines in support of deploying units. For the Apache VUIT-2 system, AATD's System Integration Division supplied subject matter experts (SME) with expertise in understanding OSRVT and MTCDL systems' hardware and software and having historical experience with the HSKT. Lessons learned from the various rapid prototyping initiatives during the past 5 years of GWOT enabled the Prototyping and Integration Branch of the Rapid Prototyping Division to assemble a matrix team of engineers, experimental test pilots, and technicians for developing an optimized design. The Rapid Prototyping Division's Design and Analysis (D&A) Branch designed and analyzed mechanical and electrical components of the A-kit, allowing the design to develop from lessons learned and simultaneously be adaptable for future spiral efforts.

The Test and Instrumentation (T&I) Branch not only fabricated and installed electrical harnesses but also developed and installed the instrumentation package for testing on the prototype test aircraft. For example, the prototype aircraft was instrumented for time-synched events to record vibration data on TOMMA, transmission mounts, and left and right EFAB shelves and for thermocouples placed on all VUIT-2 LRUs in both EFABS. T&I also integrated the VUIT Interface Panel (VIP) and VUIT Power Panel (VPP), allowing for PVI for the Apache VUIT-2 system.

The Experimental Fabrication Branch fabricated all mechanical interface components and "bracketry" and provided expert mechanical installation capability. AATD's contracting division, legal office, and budget office provided direct support to Apache VUIT-2 with accelerated purchase orders and urgent contracting actions. The Aviation Support Facility (ASF) provided aircraft-specific expertise on all modifications to the install team and provided maintenance for all Apache VUIT-2 test assets in prototyping, testing, and validation and verification efforts.

Teaming with its industry partners, AATD conducted a kickoff meeting to establish the design criteria, design concept, system architecture, location of system components, system bench tests, and system integration plan. The team would have to assess OSRVT and MTCDL threshold functionality/capability, parts fabrication plan, installation plan, and AMWO development plan. A preliminary design review (PDR) and critical design review (CDR) followed this effort, with accelerated schedules that synchronized to early production decision points to minimize risk to ordering long lead items.

As the Apache VUIT-2 was conceptually evolving as a federated system, AATD was developing and evaluating three courses of action (COA) for displaying OSRVT video in the Co-Pilot Gunner (CPG) station with various LCD displays mounted at various locations. Clearly, the Apache's unique and limited cockpit geography brought challenges to design and development of a federated system. LM provided PMs and AATD with a white paper that would use a mast-mounted antenna (MMA) and LPRF chassis to house components of the OSRVT using the aircraft's installed de-rotation unit and torque tube harness as a primary means to move received signals above the rotor down to the aircraft frame. Together, AATD and LM developed a system architecture that would allow for the display of the received OSRVT video in the cockpit.

The Apache VUIT-2 system consists of three subsystems: **OSRVT system, MTCDL system,** and **VUIT-2 interface-power system,** which is composed of a thermite CPU, cockpit VIP/VPP, video splitter amp, video switch, Ethernet switch, electrical service panel (ESP), and USB-422 converter.

The **OSRVT system** provides specific components from the ground OSRVT system that are integrated on the AH-64D air craft with four primary components—

1. Multiband receiver (MBR),
2. Modem,
3. Multiband antenna, and
4. Metadata antenna (ruggedized), which are installed on the TOMMA, which uses the AH-64 flight qualified pedestal. The TOMMA (containing multiband and metadata antennas) is mounted *via* the pedestal to the top of the aircraft mast (*via* derotation unit) (Figure 2).

The MTCDL system is integrated on the AH-64D aircraft with three primary components: mini-TCDL Modem Assembly (MTMA), RFE, and bi-cone antenna. MTCDL system is located in the left EFAB, except for the

Figure 2 Tri-band OSRVT Mast Mounted Assembly (TOMMA)


Figure 3 MTCDL System Components (MTMA, RFE, Bi-Cone Antenna)

antenna. TADS/MTADS video intelligence is sent to the MTCDL system for transmission *via* a video splitter-amp located at the input side of the aircraft's video recorder, and OSRVT video intelligence is sent to the MTCDL system *via* Ethernet switch. Figure 3 shows the MTMA, RFE, and bi-cone antenna (with mount).

The VUIT-2 interface-power system contains line replaceable units (LRU) that interface and integrate the OSRVT and MTCDL systems. The thermite CPU has the OSRVT software manufactured by AAI installed to allow the OSRVT system to combine video and metadata information received *via* antennas to the MBR as well as application of information to develop a situational awareness map for display to the cockpit MPDs. LM-manufactured software is also installed on the thermite CPU, which integrates and ensures proper functioning and interfacing of OSRVT software, MTCDL software, received 1553 data bus information, and remote functioning of the VIP *via* RS422 interface. The VIP/VPP provides, *via* keypad, "hotkey" functions to the thermite CPU to interface with the MTCDL and OSRVT systems. The VPP provides on/off power to the thermite CPU, MTCDL system, and OSRVT system. The VIP and VPP are located in the CPG's station and are mounted on the left and right side of the keyboard unit (KU), respectively, as depicted in Figure 4.

The USB–422 converter allows for the translation of RS-422 protocol into universal serial bus (USB) protocol for the thermite computer. This device enables the thermite computer's software to talk with the VIP. The USB-RS422 converter is mounted on the VUIT-2 upper assembly in the left EFAB (see Figure 5). The video splitter amp and video switch are located on the aft wall of the right aft avionics bay. The video splitter-amp provides four buffered video outputs from a single video input. The video switch allows for the switching of two video sources and as applied in the VUIT-2 system, switches video between the thermite computer RS-170 output video and the RS-170 VCR video, and allows either to be sent to the display processor (DP) for display on the multipurpose display (MPD). The Ethernet switch, as applied to the VUIT-2 system, is located in the left EFAB and allows the MTMA, MBR, and thermite computer to communicate to each other *via* Ethernet (see Figure 6). The Electrical Service Panel (ESP) takes aircraft power (28V DC) and cleans (*via* filter and DC-DC power supply), has a 25A main circuit breaker and contains three sub-circuit breakers and three relays for the OSRVT system (MBR and modem), MTCDL system (MTMA and RFE), thermite, Ethernet switch, and video switch. The ESP shown in Figure 6 is mounted in the left EFAB.

Additional design factors for selecting LRU locations were driven by LRUs that were non-flight qualified and that needed to be in the conditioned air of the EFABs because of low temperature ceilings (MTMA and RFE) and by line loss limitations between specific components (RFE and MTCDL antenna). This forced a unique design in the left EFAB where because of three-dimensional space limitations, upper and lower bracket assemblies were designed. The upper assembly was built around the preexisting RFI processor and mounted the USB-422 converter, MTMA, thermite, and ESP. The lower assembly was built as a "cradle" bracket hanging down from the structural shelf and mounted the RFE and Ethernet switch. Figures 5 and 7 show the locations of Apache VUIT-2 system installed on AH-64D.

Typically, QRC programs run with great risks to schedule and cost. Apache VUIT-2 is no exception, with the complexity of concurrent actions and tasks that mutually affect each other and the critical path in limited test assets, long lead times on prototype and production parts forcing production ready decisions before completion of testing, development of training

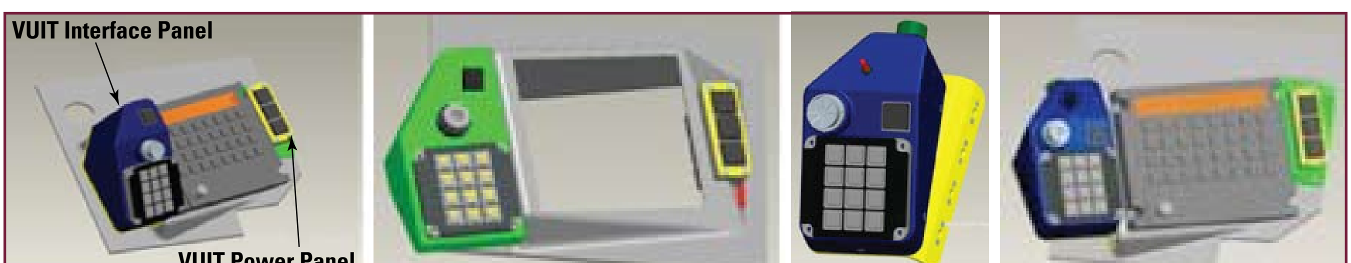


Figure 4 VIP and VPP Design Evolution

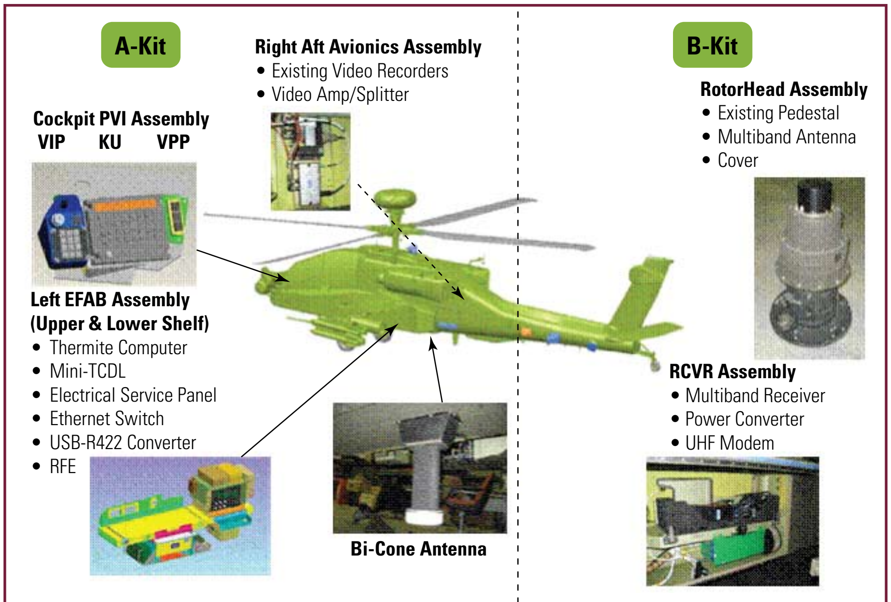


Figure 5 Apache VUIT-2 Components

Figure 6 VUIT-2 Interface Power System Components

packages to field with or before the shipsets, logistics support for installations, CONUS training, and outside the continental United States (OCONUS) deployment, sustainability plan with little to no MTBF information on first-time components, technology maturation after design-lock, and requirements creep from PMs and unit requests.

Identifying and executing risk reduction efforts is critical from the inception of the program to counter the challenges listed above. The Apache VUIT-2 team successfully planned and executed risk reduction in teaming areas in which industry partnered with government efforts from the beginning, starting with the assembling of a combined test team (CTT) that completed prototype testing and interim qualification testing to meet developmental requirements and AATD's Safety of Flight Review Board (SOFRB), as well as the Aviation Engineering Directorate's (AED) airworthiness qualification plan (AQP). Establishing two bench test locations (*i.e.*, LM in Orlando, FL; AATD at Fort Eustis, VA) enabled LM to conduct component bench testing on a prototype system with all VUIT-2 system components. The first AATD bench test allowed AATD to conduct not only hardware-in-the-loop testing (by building a bench test system around an AH-64D aircraft) but also a full system test before a prototype system was installed. The second bench test system was established at LM's location to enable the full system testing of production parts before they were shipped to AATD for kitting and government quality assurance. This action enabled LM to keep the prototype bench test system independent and free from production-line requirements. The action also allowed the VUIT-2 team to make design improvements, test these changes, and assist in troubleshooting during functionality tests and acceptance test procedures (ATP).

AATD's early delivery of prototype TDP products and draft reduced flight test data to AED for early concept awareness and design approach, coupled with synchronization of test assets such as utilization of Fort Rucker ranges and restricted area and ATTC's UAV (Shadow) assets, reduced risk to the QRC schedule. Initial planning for additional prototype systems to be used in environmental and electromagnetic interference (EMI) box-level testing at Redstone Technical Test Center (RTTC) allowed for concurrent box-level testing to enable AED to have an earlier look at box-level test data within its AWR processes. Development of an "area location-driven" installation plan for prototype integration is another risk reducer to schedule. It allows for mechanical and electrical installation teams to work in various locations on the aircraft so as not to interfere or delay the other installation team. Another effect of this plan is its flexibility. It allows mechanical and electrical teams to plan out their sequential install tasks but have alternate locations to which to move if one team experiences a delay at a specific location. A third effect of this plan is that it enables the development of sequential ordering of install instructions in a draft AMWO that optimizes manpower usage and reduces AMWO manhours.

The single most successful risk reducer was PM Apache's directive to AATD in late April 2008 to conduct a concurrent 30-day effort to design, develop, integrate, test, and evaluate the MTCDL system installed on a Block I Apache as a proof of concept to test and evaluate TADS video being transmitted *via* MTCDL system to a ground OSRVT system. Initial range and connectivity testing on the MTCDL system with the "button" antenna also was conducted, providing a limited range and significant losses in connectivity. These testing results allowed for assessment, trade study, and planning for design modifications and improvements, which ultimately yielded an improved antenna (bi-cone antenna) that would be adapted,

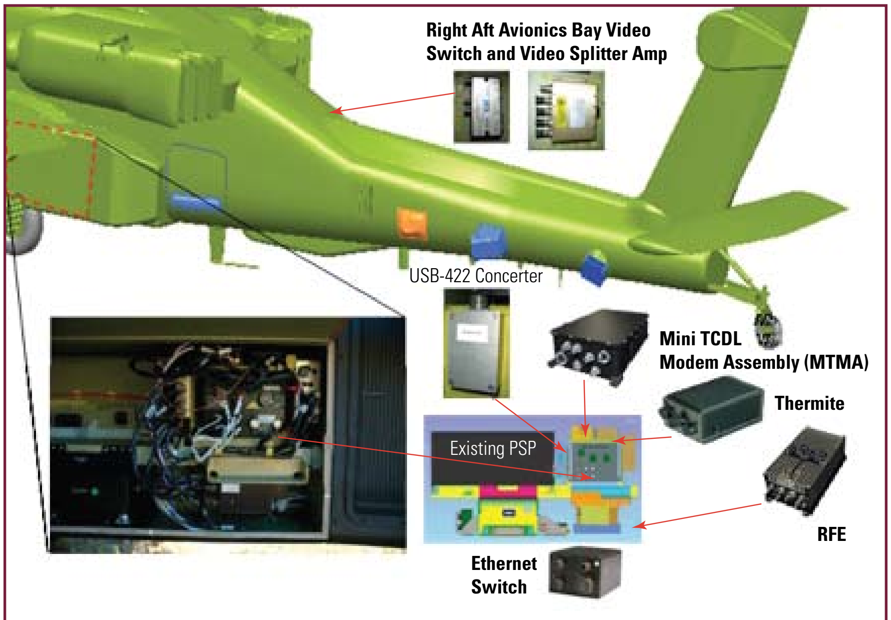


Figure 7 Apache VUIT-2 Aft Components (Left Aft EFAB and Right Aft Avionics Compartment)

developed, and tested for the fielded unit. Figure 8 presents snapshots of recorded day television video and forward-looking infrared (FLIR) imagery transmitted from the AH-64D *via* MTCDL system as displayed on a ground OSRVT notebook computer.

Although many risk reduction decisions that PM AAH made were based on recommendations from the LSI (AATD), industry partners, LM, and L3 had a significant role in risk reduction for the VUIT-2 program. After assessing the effects of configuration management conflict of the ARC-231 system with the already installed prototype VUIT-2 system, AATD and LM realized that the close proximity of the VUIT-2 metadata antenna and ARC-231 multiband antenna could have significant interference impacts on VUIT-2 system performance. LM aggressively prototyped a new antenna that would receive multiband and metadata signals evolving into the TOMMA, which we now have currently as a B kit item for VUIT-2. Furthermore, when the Government identified shortages in available LPRFs to be stripped down and built up for the VUIT-2, LM again worked concurrently to develop the Receiver Sled (RCVR). The RCVR fit mechanically the unique LPRF attachment design to the structural shelf, changing the VUIT-2 configuration to free up LPRFs. Likewise, L3 quickly responded to the poor performance reports during the "30-day effort" described in the previous paragraph with regard to the button antenna and then rapidly conducted research, provided a trade study and analysis, and recommended the bi-cone antenna. The bi-cone antenna was designed specifically with different physics of the antenna, but it provided more than twice the range and improved connectivity performance.

The testing of the Apache VUIT-2 system was executed in three phases described below.

Phase I testing involved ground-level power checks on harnesses and LRUs and then full system and limited functional checks on the system using a Shadow UAV simulator and Ground OSRVT for the end-to-end test. A Failure Modes, Effects, and Criticality Analysis (FMECA) was conducted early in the testing process at Felker Army Airfield at Fort Eustis, VA.

Phase II testing at Fort Eustis included a qualitative electromagnetic compatibility (EMC) testing on the ground and in flight, limited handling qualities evaluations attributed to installation of the OMMA and metadata antenna, the TOMMA, and the bi-cone antenna being outside the outer mold line (OML). Limited functionality testing was then conducted with the Shadow (UAV) simulator and ground OSRVT station with ground tests and flight tests, including MTCDL range and connectivity verification. Although unavailable immediately at Fort Eustis, this phase included functionality testing of the VUIT-2 system to receive Raven and Warrior A simulation and emulation as part of the threshold tasks from PM UAS. Raven simulated signals were tested at Fort Rucker during Phase III testing, and Warrior A simulated signals is planned for testing in June–August 2008. Success with these simulations will lead ultimately toward tests with actual Raven and Warrior A UASs.

Phase III testing at Fort Rucker, AL, included full functionality testing with actual Shadow UAV in flight transmitting video and metadata and with ground OSRVT stations displaying and recording TADS and OSRVT video transmitted from AH-64D VUIT-2 aircraft. The CTT conducted live fire testing for gathering vibration data and its effects on the OSRVT and MTCDL systems operating during engagements with 30-millimeter (mm) cannon and 2.75 in rockets (see Figure 9).

Figure 8 AH-64D TADS Video as Viewed and Recorded on Ground OSRVT Toughbook Computer After Transmitted *Via* MTCDL System From AH-64D Aircraft to Ground OSRVT Station

Figure 9 Live Fire Vibration Data Collection With Apache VUIT-2

Phase III testing included OSRVT range verification among AH-64D and UAV, navigation verification, and workload assessments. ATTC developed scenario-based testing that employed the AH-64D in tactical scenarios and conducted operator workload assessments on subject pilots. ATTC was the lead for conducting human factors engineering (HFE) evaluations with respect to cockpit evaluation, controls and displays analysis, control conflict and functional reach demonstration, and system safety hazard analysis. Test teaming was critically important as AATD and ATTC experimental test pilots worked together to combine AATD's research and development (R&D) experience and ATTC qualification expertise to develop a test issues/discrepancies matrix for documenting and planning for resolving test deficiencies. Test teaming was important in helping ATTC in its tasking by the PM to write a safety release recommendation (SRR) for supporting ATEC's safety confirmation report (SCR).

RTTC is now completing box-level EMI and environmental testing. In January 2008, RTTC started system-level EMC on an AH-64D Block II aircraft with the "Proto-duction" Apache VUIT-2 system installed. Follow-on testing will continue as RTTC completes interim qualification testing and continues with full qualification testing.

PM AAH identified a consolidated list of spiral proof of concept efforts that AATD will lead in the short and long term. These efforts included extended range, bidirectional link, thermite and OSRVT upgrades, tactical white board, Voice Over Internet Protocol (VoIP), and radio frequence interference (RFI) on TOMMA. The objective is to concurrently prototype and test these spiral efforts with the current Apache VUIT-2 system and then merge it with installation on follow-on attack helicopter battalions that are preparing for deployment into theater.

PM AAH and PM UAS were interested in building a joint list of spiral efforts for the VUIT-2 system above the initial six. They identified follow-on efforts as Spiral 2a (PM AAH) and Spiral 2b (PM UAS). For Spiral 2a, PM AAH directed the development of a path to Level IV while leveraging off Block III references and tests. Spiral 2b (PM UAS) enabled Level II development on other aircraft platforms such as the following—

- UH-60 A/L Medevac
- OH-58D KW
- USMC AH-1W.

Conclusions

The VUIT-2 project team clearly demonstrates that the quality application of technology to aviation platforms under extremely short QRC timelines can be accomplished between diverse and technologically specific industry organizations, and the US Army has set new milestones for streamlined acquisition. AATD's Rapid "Proto-duction" plan does just that; it has proven that partnerships between the US Army and industry not only carefully constructed to optimize the team's productivity and efficiency but also complemented each team member's capabilities during each process phase, from concept to fielding, which works to bring the best product to soldier rapidly.

Acknowledgements

This material is based on work supported, or partly supported, by the Aviation Applied Technology Directorate, PM Apache, PM UAS, AED, ATTC, RTTC, Lockheed Martin, L3 Communications, and AAI. Some portions of the material presented are considered proprietary for Lockheed Martin, L3 Communications, Camber, and AAI. Consequently, no copying, reprinting, or using any part of this article is authorized without AATD's express written consent. Any interested party must contact AATD to assess any proprietary restrictions regarding any information presented in this article.

A Rapid "Proto-duction" program of the nature of the Apache VUIT-2 cannot be successful without the dedication and commitment of all team members listed above. The cooperation level among all team members has been singularly impressive and absolutely critical for the program's success.

It is difficult to single out specific individuals or groups deserving special mention because the level of professionalism and dedication to this program was exemplary on all accounts. The effort was truly a team effort. ■

References

1. Technical Manual (TM) 1 1520 251 10, Operator's Manual for Helicopter, Attack, AH-64D Longbow Apache, 29 March 2002.
2. AED Airworthiness Qualification Plan (AQP) for the Apache Video Unmanned Aircraft System (UAS) Intelligence Teaming–Level 2 (Apache dVUIT-2), Dated 27 September 2007
3. US Naval Test Pilot School Flight Test Manual (FTM) 107, Rotary Wing Stability and Control, 31 December 1995.
4. Training Circular (TC) 1-251, Aircrew Training Manual for Attack Helicopter, AH-64D, September 2004
5. Technical Manual (TM) 1-1520-LONGBOW/APACHE, Aviation Unit and Intermediate Maintenance for Army Model AH-64D Helicopter, 21 May 2004.
6. Checklist, US Army Aviation Technical Test Center (ATTC) Qualitative EMC Checklist, AH-64D Aircraft, 2 June 2004.
7. MIL-L-85762, Lighting, Aircraft, Interior, AN/AVS-6 Aviator's Night Vision Imaging System (ANVIS) Compatible, January 1986.
8. Joint Service Specification Guide 2010-5 (JSSG-2010-5), Crew Systems, Aircraft Lighting Handbook, 30 October 1998.
9. Military Standard (MIL-STD)-3009, Lighting, Aircraft, Night Vision Imaging System (NVIS) Compatible, 2 February 2001.
10. Aeronautical Design Standard Performance Specification Handling Qualities Requirements for Military Rotorcraft (ADS-33E-PRF), 10 May 1996.
11. Natick Technical Report (TR) 91/040, 1988 Anthropometric Survey of US Army Personnel: Pilot Summary Statistics, July 1991.

About the Author

LTC Charles S. Walls IV is currently the Chief of Flight Test for the Aviation Applied Technology Directorate (AATD) at Fort Eustis, VA. He is a US Army Master Aviator and has a Commercial Pilot Certificate flying over 30 different fixed wing and rotary wing aircraft. Prior to assignment at AATD, LTC Walls graduated from the United States Naval Test Pilot School (USNTPS), as well as the Command and General Staff College in June 2002. LTC Walls received a Bachelors degree in Mechanical (Aerospace) Engineering from the United States Military Academy in 1989, and a Masters degree in Engineering Management from University of Central Florida in 2002, and a Masters degree in Computer Resources and Information Management from Webster University in 2002.

Vulnerability of Unmanned Aircraft Systems to Ballistic Threats

by Patrick O'Connell and Scott Frederick

The speed at which unmanned aerial vehicles (UAV)—or unmanned aircraft systems (UAS), as the Department of Defense now refers to them—have become an integral part of modern warfare is astounding. With the advent of the Predator A (originally known as the RQ-1), the utility and usefulness of the modern UAS became apparent very quickly. As the RQ-1 transitioned to the MQ-1 (Figure 1), which added an armed reconnaissance role, the vulnerability reduction community proposed a series of four projects through the Joint Aerospace Survivability Program (JASP) and Joint Live Fire (JLF) Program, in which the new vehicle's vulnerability characteristics would be investigated.

Figure 1 MQ-1 in Flight

The projects were accomplished by the Air Force's Aerospace Survivability and Safety Flight (780 TS/OL-AC) at Wright-Patterson Air Force Base (AFB), the Naval Air Systems Command's (NAVAIR) Survivability Division at Patuxent River Naval Air Station (NAS), and NAVAIR's Weapon Survivability Laboratory (WSL) at China Lake NAS. The projects, which took place from 2003 to 2007, examined the vulnerability of the UAS platform.

They are described as follows—

- UAV Vulnerability—Predator A Analysis. JASP funded; accomplished by 780 TS and NAVAIR-Survivability Division in 2003.
- Predator Wing Analysis. Funded by JLF and accomplished by WSL in 2004.
- UAV Hydrodynamic Ram (HRAM) Mitigation. Funded by JASP and accomplished by 780 TS and WSL between 2004 and 2005.
- UAV Systems Vulnerability. Funded by JLF in two phases and accomplished by 780 TS between 2004 and 2006.
  - Phase I—UAS Engine Vulnerability
  - Phase II—UAS Fuel Tank Vulnerability

UAV Vulnerability—Predator A Analysis

The first project, UAV Vulnerability—Predator A Analysis, primary objective was to accomplish a traditional vulnerability analysis of the MQ-1, basically a measure of the remotely piloted aircraft's ability to withstand ballistic threat effects. This was a joint program between the 780 TS and NAVAIR's Survivability Division. Because of their rather simplified system design and light construction techniques, which differ significantly from manned systems, it was believed that such a baseline would help determine how an UAS's vulnerability differs from manned aircraft. The MQ-1 was a good candidate because it was representative of a typical UAS design and was one of the larger UASs deployed at the time, making it more appropriate to accommodate vulnerability reduction techniques in future designs. The MQ-1's design also was a balance between performance and weight, with little consideration given to survivability from ballistic threats. Therefore, the analysis would provide a good baseline for a system that largely did not consider vulnerability reduction during the design phase. A secondary objective of the project was to introduce the UAS community to vulnerability reduction with very specific findings and recommendations.

Figure 2 A FASTGEN Model was Developed for the MQ-1

A Fast Shotline Generator (FASTGEN) model was developed (Figure 2) of the aircraft, and a complete vulnerability assessment was accomplished using the Computation of Vulnerable Area Tool (COVART). As part of this assessment, a damage mode and effects analysis (DMEA) of the aircraft also was developed. The vulnerability assessment identified several areas in which simple changes could be made to the aircraft design that would improve the aircraft's vulnerability.

During the DMEA development, assumptions needed to be made as to how the UAS's structure and other unique systems would react to ballistic threats. Although extensive experience and data exist for determining the vulnerability of manned systems, there was a lack of available vulnerability test data on UAS unique systems, especially for engines

Figure 3 Predator Wing Ready to be Tested at China Lake

and light composite structure. Over the next several years, the Air Force and Navy embarked on a series of ballistic test programs to further explore UAS vulnerability. The lessons learned from these test series were then used to update the assumptions and inputs used in the initial FASTGEN/COVART analysis. The analysis was conducted again using the updated inputs to determine how the knowledge gained from testing affected the vulnerability estimates.

Predator Wing Analysis

The second project in the series of UAS programs was the WSL-initiated JLF project, Predator Wing Analysis, to investigate the vulnerability of the MQ-1 wings to small arms and anti-aircraft artillery (AAA) rounds. The WSL accomplished the testing at China Lake NAS. The wings were shot upside down, and rubber mats were laid on the wings to introduce appropriate structural loading representative of a 1G flight load. As Figure 3 shows, the gun is mounted on top of the tower with the rubber mats distributed evenly along the bottom of the upside down wing. A total of nine tests were accomplished. The test program provided very valuable insight into the robustness of the wings to the various threats tested.

After testing the light MQ-1 wings, questions arose about larger size UASs that carry fuel in an integral fuel tank within the wings.

UAV Hydrodynamic Ram Mitigation

In 2004, NAVAIR's WSL and the 780 TS jointly initiated a JASP project to investigate the effects of hydrodynamic ram on a typical UAS light composite wing structure with an integral fuel tank. The project also investigated the fuzing and incendiary functioning of high explosive incendiary (HEI) and armor piercing incendiary (API) projectiles of panels and spar sections representative of the integral wing structure of a UAS.

The two wing-box test articles used for the HRAM testing, which was also conducted at the WSL facility, consisted of an inboard and an outboard left composite wing section (Figure 4). The fuel tanks were filled with water for this test program and shot with mostly smaller caliber and some AAA rounds. Instrumentation consisted of pressure and strain gauges along with high-speed video. Seven tests were accomplished (Figure 5): four with no airflow, and three with 200 knots of airflow across the wing section.

The coupon and spar testing accomplished by 780 TS at the Aerospace Vehicle Survivability Facility (AVSF) at Wright-Patterson AFB provided comprehensive data on how various structural components reacted when APIs and HEIs impacted them. This data was incorporated into the vulnerability analysis for the Predator and provided input for the next project accomplished in the series.

UAV Systems Vulnerability

The fourth project examining UAS vulnerability was the JLF project, "UAV Systems Vulnerability," which consisted of two different phases: I, Engine Vulnerability Testing; and II, Fuel Systems Vulnerability Testing. Phase I focused on testing UAS engine systems, and Phase II focused on the probability of ballistic-induced fire in and around the wing and fuselage fuel tanks. The 780 TS led this program, and the AVSF conducted all testing.

Figure 4 UAS Wing-box Used for HRAM Testing (Pictured Upside-down)

Figure 5 High-speed Video Capture Just After Impact of Water Filled UAS Wing Box

The primary objective of Phase I was to characterize the damaging effects of various ballistic threats against representative medium-altitude UAS engines. Little or no ballistic test data existed on small engines, such as those used on UAS. Three operational Rotax 912 engines were tested, which are representative of the Rotax 914 found on the MQ-1, and a nonoperational Centurion engine, which is the engine type used on the Army's Warrior UAS. Dynamic and static ballistic tests were accomplished. The three operational Rotax 912s were tested under realistic conditions until they were rendered inoperable. Then, static testing was accomplished on both engine types. More than 30 total ballistic tests were accomplished. Figure 6 shows damage caused to a piston in a typical ballistic test conducted in this JLF program.

The primary objective of Phase II was to determine the effect that ballistic impacts have on the UAS's primary fuel tanks and the likelihood of starting a fire. In the past, many JLF and live fire test and evaluation (LFT&E) programs have been performed to determine the fire probabilities of manned aircraft; however, because of the unique physical properties of the UAS (*e.g.,* small composite structure, fuel cell liners), additional testing was required to characterize the fire threat for these types of aircraft. Eleven tests were accomplished with APIs, simulated missile fragments, and an HEI. Figure 8 shows typical damage incurred during testing of the fuselage test article.

As mentioned, the results from all the test projects described above were incorporated into the original vulnerability analysis conducted on the MQ-1, and the analysis was performed once again. Several interesting results came out of the updated study. A few single point failures were identified that were a result of designing the aircraft for weight and performance. Although it would be possible to easily modify the system to add redundancy to those systems, the result would be increased weight to the aircraft. The analysis identified other areas in the aircraft's design, in which redundant systems were grouped together for convenience. Simple changes could be made to modify the

Continued on page 19

Excellence in Survivability—Greg Fuchs

by CW5 Leonard J. Eichhorn, USA

In March 2003, it began to rain helicopters in Iraq. LTG Richard Cody, Army G-3, decided it was time to determine exactly how and why this was happening. He directed that a team of experts be formed and deployed to Iraq to assess the type of weapon that the enemy was using so successfully against our helicopters. The original US Army Aircraft Shoot Down Assessment Team (ASDAT) was then formed, and CW5 Greg Fuchs was one of its dozen team members.

CW5 Fuchs in Iraq

The First "ASDAT"

CW5 Fuchs, with more than 28 years in the Army, was a perfect choice for the mission. When the ASDAT was formed, he was the Chief of the Tactical Operations (TACOPS) Officer Course at Fort Rucker, AL. The TACOPS course is where the Army trains aviation officers in the art and science of electronic warfare and enemy threat weapons systems. CW5 Fuchs was not only Chief of this school, he also was instrumental in building the entire TACOPS career track for Army Aviation Warrant Officers. He was one of a few subject matter experts (SME) in Army aircraft survivability equipment (ASE) and threat systems being used in Iraq and Afghanistan.

When the ASDAT deployed to Iraq in December 2003, the team immediately began to see indications that what was being considered a threat was incorrect. Evidence collected by the team indicated the type of weapon being used. Other organizations then analyzed this evidence to verify the weapon type, resulting in a confirmation of the cause. The ASDAT's ability to correctly identify the weapons and characterize the threat enabled commanders and Army senior leadership to develop tactical and material solutions for reducing or mitigating the threat in future combat operations. This success led to the permanent formation of the ASDAT and its role as the Army component of the Joint Combat Assessment Team (JCAT).

Building the Team

After his return from Iraq, CW5 Fuchs began building an enduring combat damage assessment capability for the Army. The original team had consisted of personnel from many organizations, but they now needed to return to their regular duties. CW5 Fuchs began identifying and recruiting the right people for permanent positions, and the team began to grow.

By 2005, the ASDAT had grown to three full-time assessors, and CW5 Fuchs began writing the documentation for formalizing the ASDAT within the Tactics Division of the Directorate of Training and Doctrine at the US Army Aviation Center of Excellence at Fort Rucker, AL.

The process required more than 2 years. By December 2007, the Department of the Army approved the Table of Distributions and Authorizations (TDA) for ASDAT. The ASDAT now consists of six US Army active duty Aviation Combat Forensics Officers (ACFO). ASDAT also includes two full-time civilian positions to cover operations and intelligence and to provide backside support for the deployed team. The approval of the ASDAT TDA as an enduring capability will be CW5 Fuchs' legacy as a soldier and aviator in the US Army.

CW5 Fuchs' work in ASDAT has been essential in developing and fielding new aircraft survivability equipment systems for Army aviation. The data collected from shoot-down assessments has been captured and is being used to help our material developers understand thoroughly what weapons and threats our aviators are facing in Iraq and Afghanistan. Working closely with the acquisition and test communities, CW5

CW5 Fuchs in Afghanistan

Left to Right: CW4 Calvert, CW5 Fuchs, and CW4 Chance During Assessment of Easy 40, Iraq

Fuchs has ensured that the systems we have procured and fielded are capable of defeating the current and future threat.

CW5 Fuchs' work in ASDAT and the team's recommendations resulted in the rapid fielding of the Common Missile Warning System for all Army tactical aircraft. This system has dramatically reduced the lethality of the Man-Portable Air Defense System (MANPADS) threat for all who fly on Army aircraft in harm's way. CW5 Fuchs also was involved in developing and testing five sensor configurations for CMWS and new expendable infrared countermeasures. All his recommendations on survivability and vulnerability reduction have been or are being implemented. CW5 Fuchs is the SME to whom senior Army leadership turns for survivability advice.

Since his retirement in June 2007, CW5 Fuchs has continued to serve the Army as a survivability specialist for ASDAT. His civilian duties include the training and development of Army TACOPS officers and aviators attending professional courses at Fort Rucker. As a highly experienced combat damage assessor and aircraft survivability expert, he is one of the primary instructors for the JCAT Phase I training conducted annually at Fort Rucker.

CW5 Fuchs is the ASDAT primary reach-back person when teams deploy, providing additional research and coordination capability for the deployed members. His experience and expertise will remain with the team and will continue to be a strong asset to the US Army and the survivability community for years to come. It is with great pleasure and pride in our military that the JASP honors Chief Greg Fuchs for his Excellence in Survivability contributions to the Army, the JASP, and the warfighters in Iraq and Afghanistan. ■

About the Author

CW5 Leonard Eichhorn (USA) is Chief of the ASDAT. He replaced Greg Fuchs in 7 Feb when Chief Fuchs retired. Chief Eichhorn is an Apache longbow pilot with 27 years in the Army and two tours in Iraq. He has deployed with ASDAT on 4 separate occasions for 7 combat loss assessments.

Vulnerability of Unmanned Aircraft Systems to Ballistic Threats

Continued from page 17

Figure 6 Crack in Side of Piston

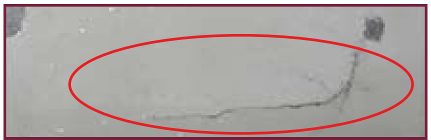


Figure 7 Damage to UAS Fuselage Section

system layout to separate the redundant components and increase the survivability of the UAS. The results of the program were provided to the Program Office and manufacturer for consideration on subsequent models of the Predator series, and several of the vulnerability reduction axioms of separation, redundancy, and shielding have found their way onto more recent models of the aircraft.

As with any aircraft design, tradeoffs among the various performance requirements drive the final configuration of the aircraft. Because UAS differ dramatically in size, capability, and expense, their requirements for tolerance to ballistic threats also differ. For UAS that are expected to operate in combat zones, vulnerability requirements should be established during the design of the system. During the design process, the biggest improvements in vulnerability can be made with the smallest associated weight penalty. By establishing a clear set of requirements upfront, vulnerability reduction can be traded off against other design requirements, and the appropriate level of survivability can be built into the aircraft. ■

About the Authors

Mr. Patrick O'Connell is currently a project test engineer at the Air Force's Aerospace Survivability 780TS/OL-AC, and Safety Flight at Wright-Patterson AFB. He received a BS in Aerospace Engineering from Parks College of Saint Louis University and an MS in Mechanical Engineering from the University of Dayton. He has more than 20 years of experience working in aircraft survivability and aircraft battle damage repair, 11 years of which he spent as an Air Force Officer. He was the government test engineer for the UAS Vulnerability program.

Mr. Scott Frederick is a senior analyst at Skyward, Ltd. He received a BA in Mathematics from the University of Cincinnati. His professional experience includes more than 17 years involved in aircraft survivability/vulnerability analysis and testing and evaluation. His technical experience also includes aircraft battle damage repair analysis. Mr. Frederick led Skyward's efforts during the UAS Vulnerability program.

For further information on the Predator A Vulnerability Analysis project, please contact Ms. LeAnn McKay, the Deputy Manager at the SURVICE Engineering Company, Dayton Area Operation.

Unmanned Aircraft System (UAS) Survivability and Safety

by Dave Hall, Mike Ray, Ray Terry, and Ron Dexter

Up until now, survivability has not been a significant design driver of unmanned aircraft systems (UAS). Partly because current inventory UAS were originally advanced technology demonstrators and/or not acquisition programs of record, other considerations such as performance have dominated the system's design issues. Currently, issues such as airspace coordination, command and control, and reliability are driving UAS use and design. Based on our experience with manned aircraft, however, history shows that sooner rather than later, survivability will become a driver for UAS utility. UAS survivability is no longer a "nice-to-have" feature, especially for larger, longer duration systems and armed UAS, because battlefield commanders are increasingly depending on them for mission accomplishment.

UAS costs also are climbing, with ever-increasing capabilities in sensor packages and weapons employment, which means that the loss of UAS can be detrimental to the battlefield commanders' ability to prosecute their missions. The threats to UAS are similar to threats to manned aircraft, including infrared (IR) and radio frequency (RF) guided missiles, air defense artillery systems, and directed energy systems. Lower and slower flying UAS are more susceptible to small arms fire, rocket-propelled grenades (RPG), and anti-helicopter mines. UASs also have susceptibilities in their uplink/downlink communications systems, and those relying on Global Positioning System (GPS) capabilities are susceptible to GPS jamming.

Even very low attrition rates have a devastating effect on warfighting capability after a surprisingly short time period. Figure 1 illustrates the effects of attrition on the percentage of UAS remaining, as a function of attrition rate and number of sorties flown. For example, with as little as 0.2% attrition, only half of the force remains after 350 missions; with 0.4% attrition, half the force remains after only 175 missions.

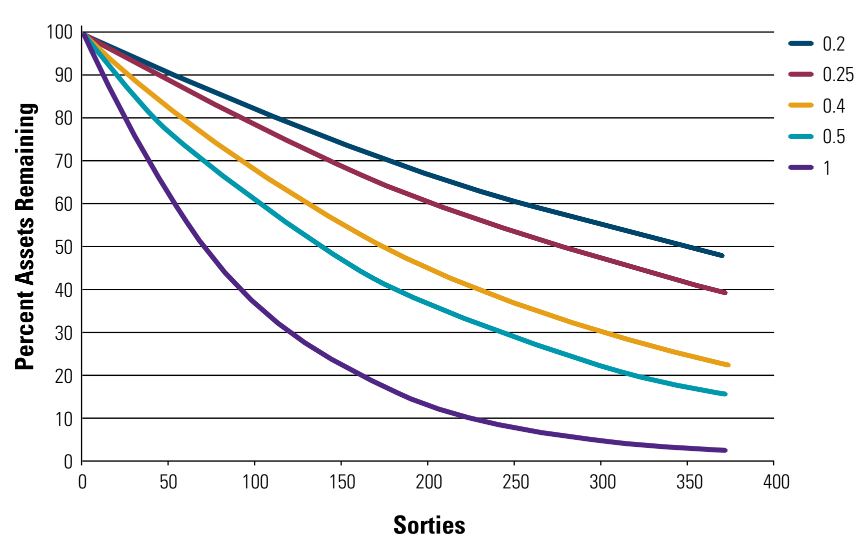


Figure 1 Effects of Attrition

It is difficult to estimate attrition rates for unmanned systems based on historical data because they have been in use for only a relatively short time, but some suggestive data are available for fixed-wing aircraft in Vietnam (before survivability features were an institutional factor in aircraft design). Between April 1965 and March 1973, the hit rate for US Navy aircraft was 5.23 hits per 1,000 sorties, and the kill rate was 1.05 aircraft lost per 1,000 sorties. Equivalent figures for US Marine Corps aircraft were 6.32 hits and 0.54 aircraft lost per 1,000 sorties. Therefore, attrition rates were roughly 0.1%, and hit rates were about 0.5%. These rates are averaged over all missions conducted during that period, ranging from benign environments to high threat environments. Considering that current day UASs have not implemented vulnerability reduction features in their design, it should be expected that the attrition rates for UAS will be on the same order as their hit rates. A UAS attrition rate of 0.4% would not be inconsistent with the fixed-wing aircraft experience in Southeast Asia.

What does this mean for UAS survivability programs? If we "turn Figure 1 upside down" and consider what the effect would be of halving that assumed UAS attrition rate of 0.4%, we get Figure 2. Figure 2 shows what percentage of UAS assets would be saved as a function of the number of missions flown if we somehow were able to reduce the attrition rate from 0.4% to 0.2%. As

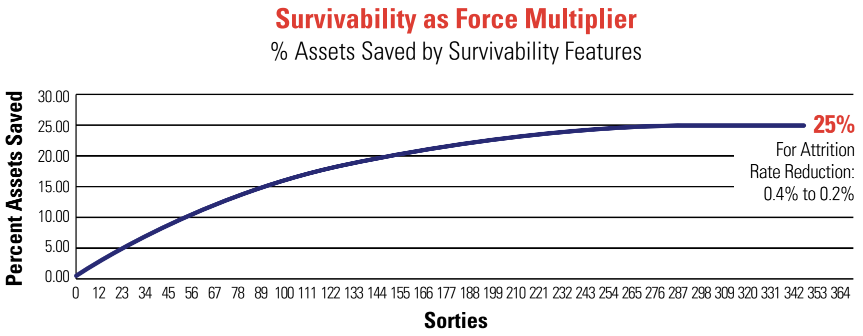


Figure 2 Survivability as Force Multiplier

also can be seen from Figure 2, the percentage of assets saved approaches 25%. This is true regardless of the beginning attrition rate: the percent of assets saved approaches 25% for halving any attrition rate—that value is just reached at different numbers of sorties for different starting rates. In the case of halving 0.4% attrition, the 25% savings is reached at roughly 350 missions flown. That means that a UAS program could afford to spend up to 25% of its system cost on survivability enhancement features, if that would result in halving the attrition rate over the system's life.

UAS survivability programs have not been universally successful in the past. For example, the Dark Star program's concentration on designing for low observables led to an expensive, lower performance system and contributed to the program's cancellation. However, some relatively simple things can be done with little cost to the program, such as fuel line and electrical system placement, redundancy, and low IR paint. The survivability program for any UAS should take a balanced approach to survivability design rather than having the UAS design depend on enhancing only one element of survivability. Various designs will be required for various UASs, depending on the overall system cost, their intended mission, and their perceived value to the battlefield commander.

Some unique survivability issues concern UASs. Current systems usually do not have built-in redundancy for critical components; they also have single engines, making them vulnerable to a single projectile hitting them. The long-mission duration for many UASs makes the effects of even small fuel leaks far more critical than for tactical aircraft, which have considerably shorter duration flights. The weight and volume constraints of most UASs make it more difficult to design in fire and explosion suppression systems. Because there is no operator in the cockpit, the system operator (where there is one) has no direct feedback of damage events, and the software controlling most UASs is not able to react to damage. The acoustic signature of small UAS can be a problem, and the size and weight of countermeasures systems currently make them problematic for all but the largest UAS.

However, through smart design conducted early in the development cycle, many of the traditional manned aircraft survivability technologies can be customized and integrated into the UAS. The results are obvious; minimized attrition rates and greater mission capabilities. This benefit can be shown through integrated survivability assessments.

Survivability Assessment

There is an established process for assessing the survivability of air systems, documented most recently in a report describing Integrated Survivability Assessment (ISA) as envisioned by the JASP. This process combines the use of models and simulations with test and evaluation results to provide assessments of system survivability for requirements development, systems design, testing, and evaluation. The process builds up from the basic vulnerability and susceptibility features of the system to an assessment of its survivability while performing its mission in a multi-threat environment.

Figure 3 shows the first element of the analysis process: vulnerability assessment. Typical metrics for vulnerability are probability of kill given a hit ($P_{k/h}$) by various threat types, and "vulnerable area," which is defined as presented area multiplied by $P_{k/h}$. The vulnerability analysis can provide valuable information about the relative merits of various technologies, without conducting a full-up mission assessment. Other measures of merit include a "vulnagram," shown in the lower right of the figure. The color scheme illustrates vulnerable "hot spots" on the vehicle as illustration. (Note that a releasable vulnagram of the Predator was unavailable; a tank was substituted to illustrate the process.)

Figure 4 illustrates typical results of the susceptibility analysis process. This figure shows an "intercept envelope" for a representative surface-to-air missile system, located in the center of the grid. The envelope, produced by ESAMS in this example, represents locations in which the missile system can intercept the UAS effectively as it passes by on parallel straight and level flight paths over and near the threat. The color scheme within the envelope can be used to show high and low areas of probability of killing the UAS. The figure on the left represents the "dry" case in which no electronic countermeasures (ECM) are available to the UAS, whereas the figure on the right shows the "wet" case where an ECM system is assumed to be employed. If these were actual results, we could see the obvious value of the ECM system in terms of its performance against the particular threat missile system.

Figure 5 illustrates a different sort of metric for IR-guided missile systems. In that figure, the picture on the left (produced by CHAMP) represents the apparent IR contrast between a small aircraft and the sky background, when the aircraft is painted with typical high-gloss commercial paint. The aircraft stands out rather clearly against the background. The picture on the right shows the apparent contrast when the aircraft is painted with a military low-IR paint scheme. The contrast between the aircraft and the sky background is much less in that case: the implication is that it would be more difficult for an IR guided threat system to detect and track the air vehicle with low-IR coatings than with the commercial paint.

The true value of survivability enhancement features for UAS cannot be assessed actually without putting these effects into the context of the missions that it will be expected to execute and the threats that it is likely to encounter. Figure 6 shows an example of overall results of evaluating the effects of various IR jamming systems on the cost effectiveness of the UAS over various missions and scenarios. These results are only representative, but they illustrate the

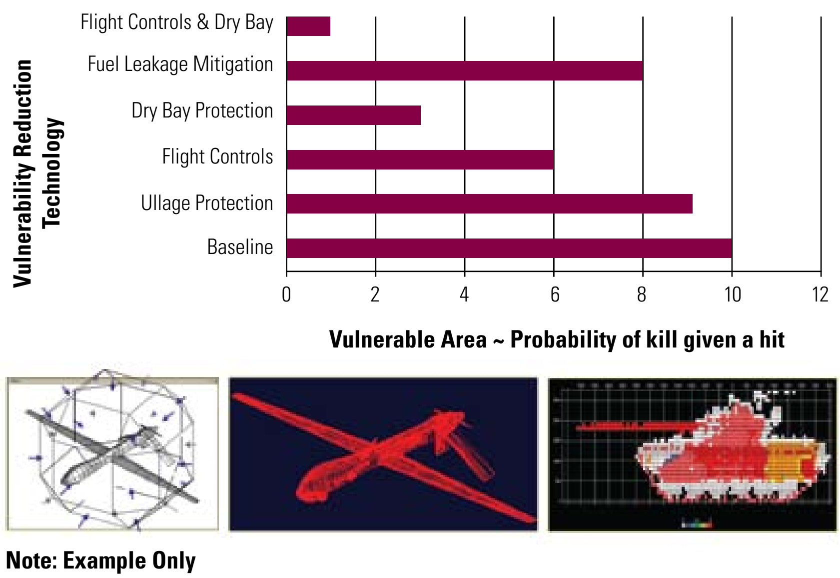


Figure 3 Vulnerability Assessment

process. (Note that these results may come from numerous mission-level simulations, such as SUPPRESSOR, JIMM, or EADSIM; this particular example was generated using a simplified spreadsheet approach.) Figure 6 shows that a hypothetical "directed energy countermeasure" results in the fewest UAS losses but has the highest unit cost. Consequently, the "advanced conventional jammer," even though it results in higher losses, ends up having the lowest life cycle cost, even after considering the cost of more lost vehicles.

Survivability Testing

Testing is an important part of the survivability program for any system, including UASs. All military services employ ballistic test facilities to evaluate the effectiveness of vulnerability reduction technologies under simulated flight conditions. Open air range facilities are used to assess the effectiveness of signature reduction and countermeasures systems; hardware-in-the-loop facilities can supplement open air range testing with more controlled assessments of system effectiveness against various threat systems.

The approach taken for survivability testing is a "model-test-model" process, whereby modeling and simulation results support test plan development and help explain in some instances why test results came out the way they did. The test results are used to support model validation and improvement, and the validated model is then used to support follow-on testing throughout the design and operational testing of the system.

SURVICE Engineering has implemented a unique approach to field test data collection for manned and unmanned systems to support vulnerability testing and analysis. As Figure 7 illustrates, the system uses advanced metrology equipment to collect, in the field (x, y, z), data points from the UAS under consideration. That "data cloud" is then post-processed to develop geometric models of the UAS skin, structure, and components. These geometric models are used primarily for vulnerability assessment, but they also can be used for signature modeling and for antenna location optimization. The metrology system also is used to develop detailed computer representations of damage to system components after the tests are conducted.

This process was exercised during the Joint Live Fire (JLF) program on the Predator, in support of the Air Force's 780th Test Squadron. The JLF program, funded by the Office of the Secretary of Defense, conducts vulnerability assessments of fielded aircraft systems and for lethality assessments of weapon systems. A geometric model of the Predator was developed from field measurements and used to support pre-test predictions and develop detailed test plans for JLF. The vulnerability codes were executed to evaluate vulnerability reduction technologies, and model predictions were correlated to the test results.

Survivability Lessons Learned

Experience with manned aircraft programs indicates that some survivability features must be applied early in the design process if they are to be implemented cost effectively. RF signature reduction and ballistic vulnerability reduction are two examples of those kinds of features. In the aircraft design world, RF signature reduction often gets considerable attention, but vulnerability reduction is too often forgotten until it is too late in the program's development to be most effective.

UAS can be protected against many ballistic threats through various means. High-priority items include fire and explosion protection systems (for "dry bays" adjacent to fuel cells, and for the fuel cells themselves). Some structures

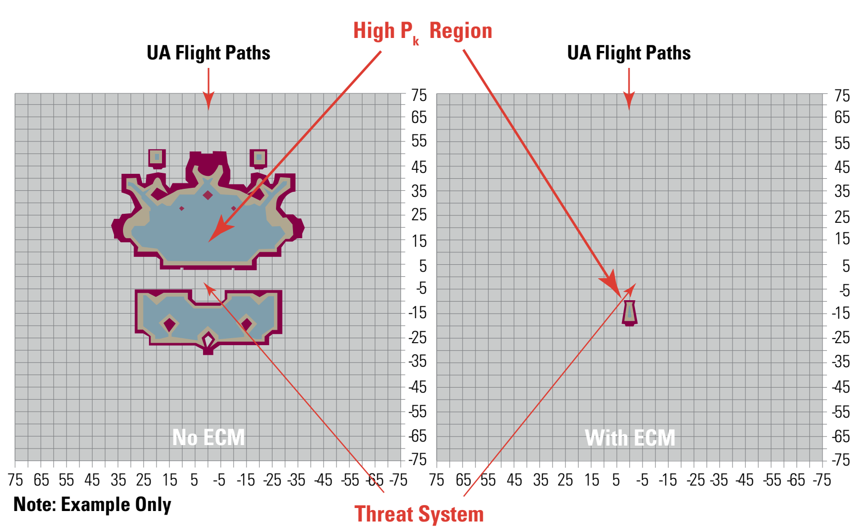
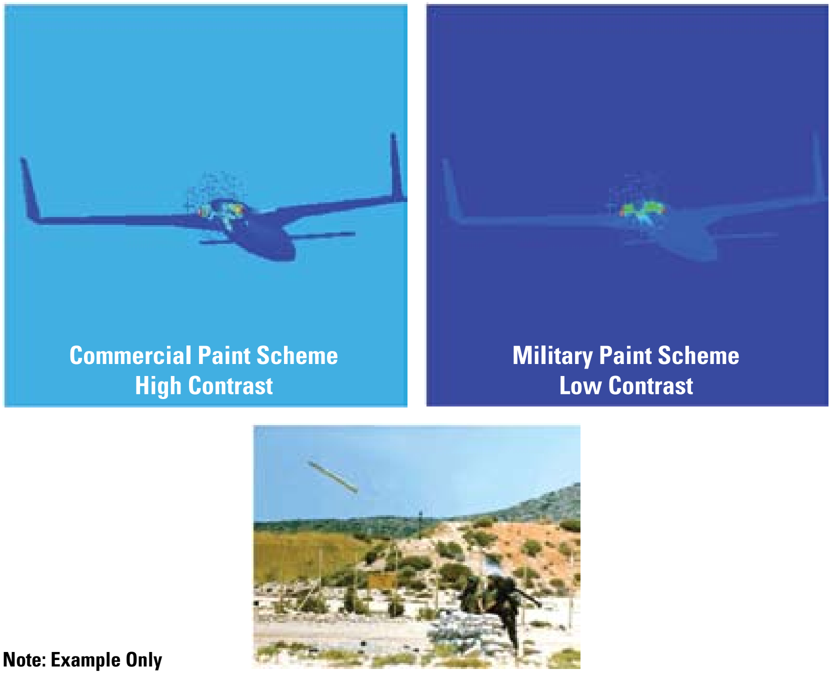
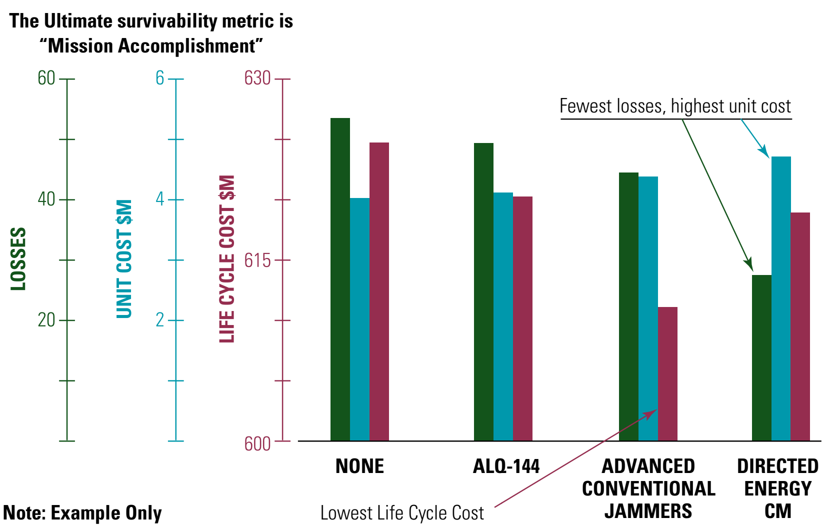


Figure 4 RF Susceptibility Assessment



Note: Example Only

Figure 5 IR Susceptibility Assessment



Note: Example Only

Figure 6 Mission Survivability Assessment and Life Cycle Cost

can be designed to withstand single threat impacts by designing in multiple load paths, without unduly increasing cost or weight.

Susceptibility reduction does not need to have an overly high cost. Simple items such as low-IR paint can be important and effective against various IR threat systems. Composite structures and small size may be effective against some RF threats. Survivability can be enhanced simply by making effective use of the information available from a network of systems.

The ability to develop detailed information on fielded systems using the advanced metrology system has shown to be of value for survivability assessment and testing. The availability of data in the absence of detailed CAD models promotes the model-test-model paradigm for survivability testing.

Survivability, Reliability, and System Safety

Survivability enhancement features for air vehicles have been demonstrated to improve not only survivability but also reliability and safety. Figure 8 shows relationships among survivability, reliability, and system safety. The UAS must operate in its environment, part of which is the normal operating environment and part hostile environment. The hostile environment consists of abnormal factors (*e.g.*, turbulence, lightning, mishaps), as well as man-made hostile acts. Combat survivability deals with man-made hostile acts. System safety is the primary factor in abnormal hostile environments, and reliability is the primary factor in normal operating environments.

However, vulnerability reduction features in particular can improve system reliability and safety. For instance, component redundancy improves survivability and reliability. Alternative structural load paths may affect survivability; safety; and to some extent, reliability. Fire and explosion suppression systems are safety features, as well as vulnerability reduction technologies. Flight control system improvements also enhance reliability and survivability.

At some point, armed UASs will become involved in the weapons systems safety review process. The Department of Defense (DoD) UAS Systems Safety Guide is a good general system safety primer for manned and unmanned systems. The guide provides programmatic, operational, and design safety precepts for unmanned systems.

One particular issue that armed UAS may be required to address is weapon safe escape/safe arm. Safe escape analysis determines whether the launching platform is far enough out of the weapon's debris hazard zone when the warhead is armed, or whether the launcher will be required to execute a "safe escape maneuver" to evade its own weapon after launch or at target intercept. Figure 9 illustrates the safe escape/safe arm consideration.

Safe escape requirements have not been established for unmanned systems, even though UASs are being armed at a steadily increasing pace and their value on the battlefield is increasing. Manned aircraft safe-escape requirements are based on established tri-service agreements for maximum probability of hit (P_h) and probability of kill (P_k) of the launching aircraft by its own weapon (P_h or P_k less than 1/10,000). The P_k calculations are made with the same vulnerability models used in the survivability assessment process. The recommendation for UAS is that these same probabilities be used as guidelines for armed UAS systems in conducting an assessment of the risk to the launching UAS from its own weapon. Requiring armed UAS programs to perform these safe escape risk assessments is consistent with current requirements laid on UAS programs to assess other risk factors to their system.

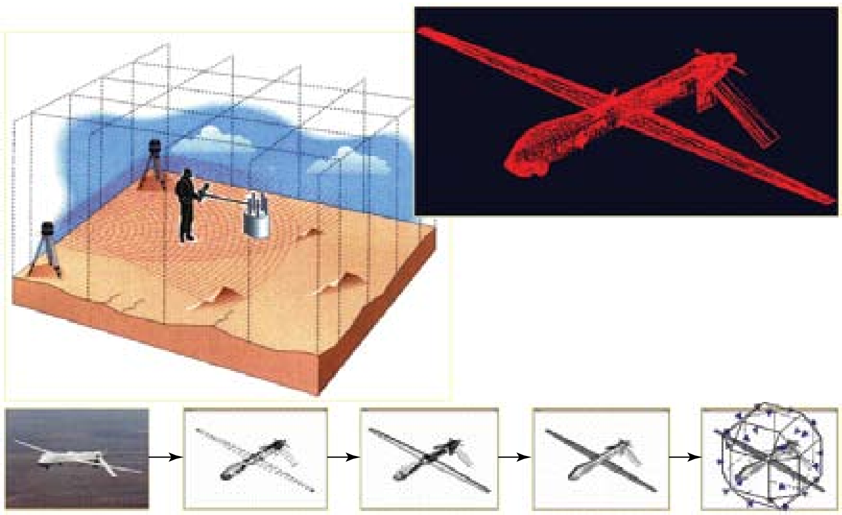


Figure 7 UAS Data Collection and Modeling

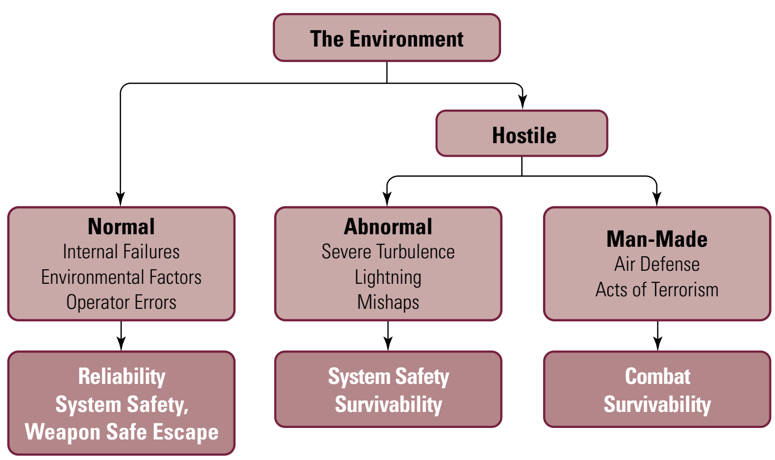


Figure 8 Combat Survivability, Reliability and System Safety

Figure 9 Safe Escape/Safe Arm

Summary

Survivability issues apply equally to manned and unmanned aircraft. UASs can leverage manned aircraft technologies, analysis methodologies, and experience in defeating the threat "kill chain": detection, tracking, launch, intercept, and kill. UAS should be effective especially at using available networked assets for improved situational awareness.

Unique UAS survivability requirements are related to long mission durations and system size and cost. Smaller, less expensive UASs may be expendable, whereas larger and more expensive UAS will require survivability cost-benefit trades in their design.

UAS safety programs should leverage the experiences of safety programs for manned systems. Guidelines should be established for weapon release safe escape, and requirements should be established for safe escape/safe arm risk assessments to be accomplished for armed UAS.

Survivability of UAS must be a balanced design between vulnerability and susceptibility reduction features, balanced with other design considerations (*e.g.*, performance, payload, reliability). But survivability can help enhance some of those other design elements, such as reliability and system safety. Survivability is most effective when considered early in the system's design. ■

About the Authors

David H. Hall is Chief Analyst of SURVICE Engineering Company and Deputy Manager of the Ridgecrest Area Office. He retired after 34 years civil service as Chief Analyst of the NAWCWD Survivability Division and Chairman of the Survivability Methodology Subgroup for the Joint Aircraft Survivability Program Office (JASPO). Mr. Hall holds a BS and an MA in Mathematics from California State University, Long Beach.

Michael S. Ray is the Manager of the SURVICE Engineering Huntsville, AL and is the lead for SURVICE's IR/RF Susceptibility efforts. He has over 20 years of survivability test & evaluation and systems analysis experience on both aircraft and ground vehicles obtained while working at US Army Materiel Systems Analysis Activity and SURVICE. Mr. Ray is current president of the

Continued on page 31

JASP 2008 Survivability Short Course

by Dr. Mark Couch

The 2008 Joint Aircraft Survivability Program Survivability Short Course was held 14–17 April at the Naval Postgraduate School in Monterey, CA. Seventy-two students attended the course, including military, civilian, and contract employees working for Department of Defense (DoD, industry, and academia. The lead instructors were CDR Chris Adams, Director of the Center for Survivability and Lethality at the Naval Postgraduate School (NPS), and Dr. Mark Couch, Research Staff Member at the Institute for Defense Analyses.

Figure 1 JASP Short Course Instructors RADM Robert Gormley (bottom left), CDR Chris Adams (middle left), Dr. Robert Ball (center), Mr. Kevin Crosthwaite (center right), and Dr. Mark Couch (right)

The course was designed to introduce students to the aircraft survivability discipline building on the pioneering work of Distinguished Professor Emeritus Robert Ball, who founded the first and only graduate-level course on aircraft combat survivability at NPS in the 1970s. What remained unique about Dr. Ball's course was that it included both susceptibility and vulnerability aspects, whereas other courses tended to focus on only one area or part of one.

Attendees received a copy of the textbook, *The Fundamentals of Aircraft Combat Survivability Analysis and Design, 2nd Edition,* and a CD containing the lessons and presentations. Selected chapters from the "Threat Effects" video, developed by Mr. Robert Ball, Jr., under Joint Aircraft Survivability Program (JASP) sponsorship, highlighted current threats to aircraft and techniques used to reduce vulnerability to these threats. Footage from interviews with experienced combat pilots in Iraq and Afghanistan also was included to present the pilot's perspective to the students.

In his keynote address, RADM Robert Gormley, USN (Retired), discussed the changing character of survivability. During the post-Vietnam era, reaction to the loss of more than 5,000 aircraft spurred the development of damage-tolerant structures and components, reduced signatures, advanced radio frequency and infrared (RF/IR) countermeasures, and mission planning systems. During the Gulf War, precision-guided and standoff weapons came into maturity. Today, further advances along the Net-Centric path are influencing some survivability requirements, but heightened interest in survivability of rotorcraft and airlifters at low altitudes is becoming more pronounced as a result of the ubiquitous nature of today's threats. Further reductions in vulnerability and IR signatures are receiving special attention along with improved IR countermeasures. He concluded his remarks by challenging students to tackle deficiencies in the survivability discipline and understand what senior commanders really want.

Following the keynote address, Dr. Ball presented an introductory lesson on aircraft survivability. Students thoroughly enjoyed not only learning about survivability from the author of the world's only textbook on the subject but also listening to his recounting of how the discipline originated and why it is still needed today. He remained available throughout the duration of the course to sign copies of his text and answer students' questions.

The remainder of the course covered material such as introductory concepts, threats and threat effects, susceptibility

Figure 2 RADM Gormley enjoys a conversation with Dr. Robert Ball and Mr. Robert Ball, Jr.

and susceptibility reduction, vulnerability and vulnerability reduction, modeling and simulation, and live fire testing. Practical application was shown with presentations that described specific aspects of survivability design for fighters, large transports, and helicopters. Classified sessions were held to discuss current threats to aircraft and recent combat incidents from OIF/OEF.

CDR Adams and Dr. Couch taught many of the lessons providing the educational foundation for the course.

Figure 3 Dr. Mark Couch and CDR Chris Adams welcome students at the JASP Short Course

Figure 4 Dr. Robert Ball prepares to answer a student's question at the JASP Short Course

Figure 5 RADM Robert Gormley presents the keynote address at the JASP Short Course

Figure 6 Students listen to Dr. Robert Ball at the JASP Short Course

These lessons walked students through Dr. Ball's text, highlighting key aspects of survivability to give the students an overview of the material. However, as a result of the breadth of the survivability discipline, subject matter experts (SME) also were invited to share their knowledge of specific areas to enhance the learning experience. The following SMEs provided material for the course—

- Mr. Kevin Crosthwaite, Director Survivability/Vulnerability Information Analysis Center (SURVIAC), taught lessons about using historical combat data and about modeling and simulation; he also provided an overview of the SURVIAC organization.
- Dr. Lowell Tonnessen, Institute for Defense Analyses, discussed the assessment of personnel casualties in aircraft programs.
- Ms. Kris Dennie-Young, Naval Air Systems Command, presented a classified briefing on current threats to aircraft.
- Mr. Martin Welch, 412th Electronic Warfare Group, Air Force Flight Test Center, taught radar fundamentals and electronic warfare.
- Dr. Knox Millsaps, Mechanical and Astronautical Engineering Department, Naval Postgraduate School, taught fundamentals of infrared signatures.
- Maj Bryan Forney, student at the Naval Postgraduate School, discussed his thesis research on USMC rotary wing infrared countermeasures.
- Mr. Tracy Sheppard, Live Fire Test and Evaluation Office of the Director of Operational Test and Evaluation, discussed the Live Fire Test and Joint Live Fire programs.
- Mr. Dennis Lindell, Program Manager, Joint Aircraft Survivability Program (JASP), discussed the current projects and initiatives that JASP is investigating.
- LCDR Michael Erickson, student at the Naval Postgraduate School, discussed his thesis on vulnerability analyses of helicopters in Iraq.
- Mr. Greg Fuchs, Army Shootdown Assessment Team (ASDAT), presented a classified briefing about recent aircraft combat incidents and an overview of the Joint Combat Assessment Team (JCAT).
- Mr. William Dooley, Joint Strike Fighter Office, discussed fighter-specific aspects of survivability.
- Mr. David Legg, Multi-mission Maritime Aircraft Office at Naval Air Systems Command, discussed large transport specific aspects of survivability.
- Mr. Ron Dexter, SURVICE Engineering, discussed helicopter-specific aspects of survivability.

As part of the course and to foster closer working relationships, attendees were treated to dinner Tuesday night at A Taste of Monterey on Cannery Row. The guest speaker for the event was Mr. Alan Brown, first F-117 Program Manager for Lockheed. He discussed his involvement in the design of the F-117 and provided several anecdotes on the challenges his team had to overcome.

Overall, the aircraft survivability short course provided a good mix of academic fundamentals and practical application. In the past 6 years that JASPO has sponsored this course, this year's course was judged as best by JASP leadership. If you are relatively new to the aircraft survivability community or simply want to refresh your knowledge, plan to visit Monterey next April for next year's course. ■

About the Author

Dr. Mark Couch is a Research Staff Member in the Operational Evaluation Division at the Institute for Defense Analyses (IDA). He supports projects in live fire test & evaluation and operational testing. Prior to joining IDA, he served in the Navy for 23 years as a helicopter pilot flying the MH-53E Sea Stallion conducting mine countermeasures missions. He also had tours on several Fleet and Wing staffs and as military faculty at the Naval Postgraduate School and University of Illinois. He has worked in the survivability discipline since 2000. He earned his doctorate in Aeronautical and Astronautical Engineering from the Naval Postgraduate School in 2003.

Warfighters Need a Joint Survivability Library

by Maj Trenton Alexander, USAF

Recent air campaigns focused on complete and permanent air dominance. Air planners sought to destroy all targets capable of hindering our control of the air battlespace. To gain this effect, much work was put into creating aircraft and munitions that could defeat anti-air threats.

As an analogy, in the past we created hammers to destroy a bowl of eggs. As our technology improved, we created munitions and specialized aircraft to target key threats or interests. Now, we can pick and choose which particular eggs we want to destroy in the bowl. The future of air campaigns is being able to reach one's entire hand into the bowl and pluck out a desired egg without marring or cracking the other eggs.

These future operations will require the Department of Defense to maintain localized or surgical air-ground dominance. We will want to control the battlespace within a small radius or corridor, minimizing our target sets and footprint. We also will want to execute quickly with available assets. Last, we might be constrained by national policies. Initiatives such as the small diameter bomb increase our options but do not achieve surgical air ground dominance.

Mission success in these future air operations is dependent on lethality and survivability. To that end, we must pursue a common joint aircraft survivability database or library. A single repository of aircraft survivability information would help planners and air mission commanders choose which targets must be engaged to complete their missions successfully.

Assumptions

A true discussion of comparable capabilities and survivability requires a classified medium. In addition, the library should focus primarily on the electronic countermeasures and operating environments. The ability of aircraft to sustain damage from a certain munition is also important, but secondary in this situation.

Background

Air Force combat search and rescue (CSAR) pilots commonly interact and operate in a mixed aircraft task force. We operate with available fixed wing and rotor wing aircraft to affect the return of isolated personnel in denied territory. The pinnacle of our mission is to use this task force to penetrate an integrated air defense to affect personnel return. Analogous missions reside in special operations.

In special operations and CSAR, the mission indicators to execute occur with little or no lead time. In CSAR, the assets available are dependent on availability and not necessarily capability. Couple this scenario with national policy that seeks a reduced footprint or reduced collateral damage, and the challenge arises. How does the task force determine and prioritize the minimum number of threats to be neutralized for gaining surgical air-ground dominance and completing the mission?

With ample lead time, planners specifically tailor the task force to meet national and tactical goals. Without lead time, planners need some type of standardized capability list for the participating airframes. The Joint Technical Coordinating Group (JTCG) for munitions effectiveness (JTCG/ME) provides the Joint Munitions Effectiveness Manual (J-MEM) with an excellent source of weaponeering data. Weaponeering data enables the planners to determine which airframes and munitions can strike which threats. However, a CSAR or special operations task force does not require lengthy or prolonged airspace dominance. Mission success also is not dependent on the destruction of all the threats. Success is dependent on neutralizing threats that have a higher than acceptable probability of infringing on the desired area of air ground dominance. In addition to weaponeering, planners need survivability information on all players.

Figure 1 illustrates this point. The stick figure represents isolated personnel within an unfriendly integrated air defense. The defenses are an active SA-2 site, a SA-6 site, and a possible rifle company. Red rings represent the weapons' engagement zone. The task force is composed of HH-60Gs and OA-10s alert launched at night to respond. Using altitude to prioritize the threats, each flight lead would develop his or her threat priority.

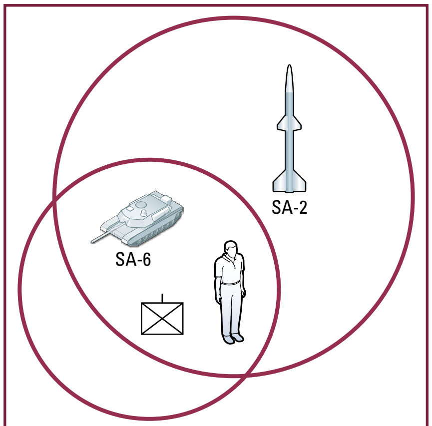


Figure 1 Threat Overlay

According to Janes, the minimum altitudes for the SA-6 and SA-2 are 100 meters (328 feet) and 400 meters (1,312 feet), respectively. According to Air Force Link, the A-10 can operate under 1,000-foot ceilings. Thus, the threat priority for A-10s is likely the SA-6; the SA-2; and last, the rifle company. To complete the mission, A-10s would require the SA-6 to be neutralized before escorting the HH-60s forward. However, helicopters

Continued on page 31

Preliminary Evaluation of Damage to Composite Wing and Fuselage Structures by Ballistic Impacts

by Terry Manuszak

Ever since the earliest aircraft were fabricated from wood and cloth, designers and engineers have struggled to reduce aircraft weight while increasing structural strength. For years, the aviation industry relied on various aluminum alloys for the best strength-to-weight ratios, but during the latter half of the 20th Century, composite materials were introduced as an aircraft structural material. Design and fabrication techniques have evolved to the point at which composites exceed the structural strength of steel at only a fraction of its weight.

Figure 1 Beech Starship

Predictions were that the future of aviation would likely see the replacement of aluminum aircraft with all-composite aircraft. Well, the future is here. Composites have evolved to the point at which many military and business aircraft are now constructed of high-tech, high-strength skins and resins. The Beech Starship (Figure 1) is one example of a commercial aircraft constructed largely of composite material. The Starship's fuselage and wing were constructed of Nomex honeycomb composite because of its excellent strength-to-weight ratio.

Although composites have been proven as aircraft structural materials, the study of the survivability and vulnerability of composite materials remains in its infancy. The 46th Test Wing, 780th Test Squadron, Aircraft Survivability and Safety Flight (780 TS/OL-AC) at Wright Patterson Air Force Base (WPAFB) was challenged to determine the survivability of late 20th Century composite structures to various ballistic impacts. The test results will be used to help construct a baseline for future survivability testing of future Nomex honeycomb composite.

Two dismantled Beech Starships were acquired as test articles. The objectives were to determine—

1. if airflow over the aircraft structure increased the potential for skin delamination after ballistic impact,
2. the potential strength retained in the wing after a ballistic impact, and
3. the effect of a detonation of a 23 millimeter (mm) high-explosive/incendiary (HEI) projectile within the aircraft fuselage.

Figure 2 Overpressure and Frag

Testing consisted of one 1.25 inch diameter steel sphere (to represent foreign object debris) and various 5.56, 7.62, 12.7, and 23mm projectiles threats. In the first test, the steel sphere and one round of 23mm HEI were shot at the underside of the fuselage. The steel sphere produced limited localized damage to the outer skin of the fuselage, with no apparent delamination. The 23mm HEI projectile entered the fuselage and detonated, with the fragments exiting the top and sides of the fuselage. To duplicate a worst-case scenario, the cockpit was pressurized to 8.4 psi, and the aircraft overpressure valve was closed; the overpressure from the detonation blew out a cockpit window and deformed a passenger window (Figure 2).

In a second test, two 23mm HEI projectiles were fired into the underside of the left wing with the wing under a loading of 1g and 330 knots airflow. One shot to an empty fuel tank ("dry bay") resulted in considerable localized damage to the top of the wing including a substantial skin fracture along the line of the main wing spar, a major structural element (Figure 3). However,

Figure 3 HEI Dry Bay Damage

Figure 4 Damage to Top of Exterior Wing

Figure 5 HEI Wet Bay Top Damage

Figure 6 12.7-mm Wet Bay Damage

post-test loading of the wing to loads of 2g produced no new visible damage, and it was determined that the wing suffered only a 13.7% loss of overall strength.

The second 23mm HEI projectile was fired into a wet bay (fuel tank filled with water), resulting in extensive hydrodynamic ram damage to the top and bottom of the wing. Post-test loading of the wing to 2g loads revealed a 32.4% loss in overall strength (Table 1, Figures 4 and 5).

In the third test, three projectiles—5.56, 7.62, and 12.7mm—were fired into and from below, using no wing loading or airflow, into a dry bay in the right wing, with the only apparent damage being three entrance holes of the appropriate and expected size. A second 12.7mm projectile was fired into a wet bay in the right wing (fuel tank filled with water), and this damage was limited to an entrance hole, minor localized damage, and a 6% overall loss of strength (Figure 6).

Composites have evolved to the point at which many military and business aircraft are constructed of high-tech, high-strength skins and resins. The intent of testing a commercial aircraft fabricated from composite material was to provide preliminary data on how historical design and fabrication techniques react to ballistic impacts. The results of various ballistic impacts, representing foreign object debris and three common smallarms ammunition, seem to indicate promising ballistic tolerance to smallarms threats. Composite design and fabrication was in its infancy more than 20 years ago, and ballistic tolerance was not a requirement; however, it seems that with good design and material selection, ballistic protection follows. The scope of these tests was to study how this aircraft fabricated from composite material responded to small-arms impacts. No concrete conclusion can be drawn from this brief preliminary look at Nomex honeycomb composite. These tests encourage inventors, designer, fabricators, and material scientist to continue using composites for future ballistic applications. ■

About the Author

Mr. Terry Manuszak is a senior test manager for the 780 TS/OL-AC at Wright Patterson Air Force Base in Ohio. Mr. Manuszak holds a Bachelor of Science in Mechanical Engineering from the University of Toledo and a Masters of Engineering Management from the University of Dayton.

Table 1 Structural Strength Losses

Ammunition		Target	Structural Strength Loss			
			Wing			Overall
Size	Type		Root	Midspan	Tip	
23 mm	HEI	Dry bay	19.0%	12.6%	13.6%	13.7%
		Wet bay	33.3%	33.2%	32.2%	32.4%
7.62 mm	API	Dry bay	7.4%	5.71%	6.0%	6.0%

Note: The wet bay shot for the 23mm HEI was conducted on a separate fuel tank within the same wing as the dry bay shot at a location closer to the wing root. The overall structural strength lost considers the wing to have been undamaged previously. This actually represents a 41.6% loss in overall structural strength when compared with the original wing before the 23mm HEI projectile was fired into the dry bay.

'There's No Such Thing as an Autonomous System'

T&E Professionals Discuss the Unique Challenges of Unmanned Vehicles

by Eric Edwards

How appropriate that on the 10th anniversary of the very first flight of the Global Hawk unmanned aerial vehicle (UAV), more than 300 defense test and evaluation (T&E) leaders were meeting to discuss the unique challenges that autonomous vehicles pose to the T&E community. The group gathered in Palm Springs, CA, 25–28 February for the 24th National Test and Evaluation Conference of the National Defense Industrial Association's (NDIA) T&E Division.

Figure 1 The Global Hawk Unmanned Aerial Vehicle

This theme of this year's conference was twofold: the T&E of unmanned/autonomous systems and the T&E community's role in the requirements process. The 4-day event included more than 70 speakers and a dozen display exhibitors. The Honorable Charles McQueary, Director of Operational Test and Evaluation (OT&E), OSD, and Gen Larry Welch (Ret), former Air Force Chief of Staff and President of the Institute for Defense Analyses, presented keynote addresses.

Conference sessions included several roundtable/panel discussions and a town hall meeting, as well as detailed focus sessions on subject areas such as T&E requirements; T&E policy; OT&E challenges; T&E analytical approaches; and test instrumentation, data collection, and architecture issues. Several pre-conference tutorials were also conducted, including one about unmanned system vulnerability that Dr. Albert Moussa from BlazeTech, Inc., presented.

Other unmanned system discussions focused on unique test design requirements and technologies, data fusion, data latency, training, life cycle costs, modeling and simulation, survivability and sustainability, data collection and archiving, airspace management, ground robotics, relevant government reports, and combat lessons learned.

Likewise, requirements-related talks focused on improving the requirements-generation process (by including the T&E community); "recalibrating" requirements post-RFP; dealing with rapid fielding issues and changing requirements; and providing feedback to improve requirements, programming T&E, and acquisition.

Figure 2 One of 70 Speakers Addressing T&E Attendees

The conference featured several award ceremonies and guest speakers during the week. Dr. Paul Deitz, US Army Research Laboratory, was recognized at the Honors Banquet as the 2008 Walter W. Hollis award recipient for outstanding lifetime achievement in defense T&E. Following the presentation, guest speaker Dick Rutan, former Air Force fighter pilot and world-record holder, shared his experiences planning and conducting the first nonstop, nonrefueled flight worldwide.

A Tester-of-the-Year Awards Luncheon honored numerous outstanding civilian, military, and contractor testers from across the services. Another luncheon featured guest speaker Marco Ciavolino, from Enktesis, LLC, who spoke to attendees about motivating young Americans to pursue robotics technology through the several regional and national robotics clubs and competitions."

Finally, at the end of the conference, a synthesis panel was convened to discuss and record some notable findings and themes that had emerged during the week. These themes included the following—

- Testers need to remember that there is no such thing as an autonomous system. There is always a human in the loop somewhere.
- Although unmanned systems have typically been considered expendable, at the cost of today's systems, that view is no longer valid.
- Developmental testing is about discovery; operational testing is about confirmation.

Figure 3 24th Annual NDIA T&E Conference

- T&E is not about passing or failing a system. It is not about saying, "I gotcha." It is about learning and sharing knowledge with the acquisition and user communities.
- Too often requirements documents are written as specifications, not as capabilities.
- More coordination and consistency are needed between DT and OT.
- In developing autonomous systems, we need requirements, not desirements.
- We do not do well at predicting far in advance what the most relevant capabilities of a system should be.
- The T&E community has not only a unique responsibility for setting realistic expectations and requirements but also the unique qualifications to do it.
- We must move from an attitude of ownership of information to stewardship of information if we are ever going to support the warfighter.
- We should be testing for tasks, not technologies.
- Most military systems are part of an SoS, regardless of whether they are explicitly recognized. Addressing SoS is not simply a scale issue.
- The more testing on a system we can do in theatre, the better it will perform in theatre.

Many of these themes are planned to be used as a basis for a white paper and overview article to be published in the NDIA's National Defense Magazine later this year. The next conference, the T&E Division's Silver Anniversary conference, is scheduled to be held in Atlantic City, NJ, on 2–5 March 2009. For more information, contact Britt Bommelje. ■

About the Author

Eric Edwards is technical writer and editor at the SURVICE Engineering Company in Belcamp, MD. He has supported ARL and other defense organizations for nearly 20 years, editing numerous technical publications, including Ballisticians in War and Peace, Volume III; Lessons Learned From Live Fire Testing; *and* Fundamentals of Ground Combat System Ballistic Vulnerability/Lethality. *Mr. Edwards holds a BA in print journalism from Bob Jones University and an MS in professional writing from Towson University.*

UAS Survivability and Safety

Continued from page 24

AUVSI Pathfinder Chapter and past chairperson for the Pathfinder Annual Symposium.

Dr. Ray C. Terry is the lead for System Safety at SURVICE and in an expert for safety risk management, safety risk assessments, and system safety engineering policies for aircraft and weapons systems, unmanned aerial vehicles and aviation support systems, including air launch and recovery equipment. He has been a member of INCOSE for last 11 years and is a former chapter president. Mr. Terry was a Johns Hopkins University adjunct faculty member where he instructed MS courses on Systems Engineering and Technical Management.

Ronald M. Dexter is the Manager of the SURVICE Engineering Dayton, OH and Ridgecrest CA Operations, and is the lead for the SURVICE Fire Works group. He has over 19 years of ballistic vulnerability design, assessment, and test experience on both rotary and fixed wing aircraft obtained while working at Sikorsky Aircraft and SURVICE. Mr. Dexter is currently the Chairperson for the AIAA Survivability Technical Committee and is an active member of the NDIA Combat Survivability Division executive board.

Joint Survivability Library

Continued from page 27

operate in a lower altitude environment and have a different threat priority. The threat priority for the HH-60s would be the possible rifle company; the SA-6; and last, the SA-2. In this instance, the HH-60 would probably not require close escort. The flight leads could work these details real time as the mission occurs, but a single survivability library would reduce the in-mission dialogue among the players.

In this example, the mission commander could access a joint survivability database or library and would recognize the various threat priorities. Without a joint survivability library, the mission commander must build his airframe versus threat understanding from scratch, which could cost time and opportunity.

Conclusion

Current weaponeering libraries enhance the joint warfighter's ability to use the appropriate type of weapon for the target. However, a joint aircraft survivability library completes the air-ground dominance picture. In operations in which national policy or available assets preclude the destruction of all threats, a mutual understanding of survivability increases the chances of mission success. A joint aircraft survivability library brings into focus and targets the obstacles to gaining a surgical air-ground dominance. ■

References

1. Janes. Jane's Information Group. 3 January 2008 *http://search.janes.com*
2. Air Force Link. Air Combat Command, Public Affairs Office, 23 January 2008 *http://www.af.mil/factsheets/factsheet.asp?id=70>*

About the Author

Major Trenton Alexander is a senior pilot in the United States Air Force. He holds a BS from the United States Air Force Academy and an MS in systems engineering from Southern Methodist University in Texas. Major Alexander has flown the UH-1N and HH-60G, totaling 2,000 hrs. He has deployed numerous times in support of Operation Enduring Freedom and Operation Iraqi Freedom.

Calendar of Events

NOV

AFCEA TechNet Asia-Pacific 2008 Conference & Expo
3 November 2008
Honolulu, HI
http://www.afcea.org/calendar

Principles of Modern Radar
3 November 2008
Atlanta, GA
http://www.defense.gatech.edu/courses

AAAA Aircraft Survivability Equipment Symposium
3 November 2008
Nashville, TN
http://www.quad-a.org

NDIA Aircraft Survivability 2008
4–7 November 2008
Monterey, CA
http://www.ndia.org

Introduction to Radar and EW Course
4–7 November 2008
Alexandria, VA
https://www.myaoc.org

Modeling & Simulation in Electro-Optical and Infrared Systems
11–14 November 2008
Atlanta, GA
http://www.defense.gatech.edu/courses

AFA Symposium on Space
16 November 2008
Beverly Hills, CA
http://www.afa.org/events

AFCEA & IEEE: MilCom 2008
16 November 2008
San Diego, CA

Missile Sciences Conference
18 November 2008
Monterey, CA
http://www.aiaa.org/events

Aircraft Fire and Explosion
18–21 November 2008
Cambridge, MA
http://www.blazetech.com/firecourse.html

DEC

26th Army Science Conference
1 December 2008
Orlando, FL
http://www.asc2008.com/overview.htm

Infrared Countermeasures
2 December 2008
Atlanta, GA
http://www.defense.gatech.edu/courses

Military Laser Principles and Applications
2 December 2008
Atlanta, GA
http://www.defense.gatech.edu/courses

AAAA UAS Symposium
8 December 2008
Arlington, VA
http://www.quad-a.org

JAN

AUSA's ILW Aviation Symposium & Expo
7 January 2009
Arlington, VA
http://www.ausa.org/webpub/DeptIndustry.nsf/byid/DeptIndustry.nsfhome

Annual AFCEA Conference & Expo
19 January 2009
Camp Lejeune, NC
http://www.afcea.org/calendar

Network Centric Warfare 2009
26 January 2009
Washington, DC
http://www.iqpc.com/ShowEvent.aspx?id=85586

FEB

JASP OAG
9 February 2009
Crystal City, VA
Invite only

AFCEA West 2009
10 February 2009
San Diego, CA
http://www.afcea.org/calendar

AFA Air Warfare Symposium
10 February 2009
Orlando, FL
Call 703/247-5800

U.S. Air Force T&E Days 2009
10 February 2009
Albuquerque, NM
http://www.aiaa.org/content.cfm?pageid=230&lumeetingid=2104

Heli-Expo 2009
22 February 2009
Anaheim, CA

MAR

NDIA 25th Annual National Test and Evaluation Conference
2 March 2009
Atlantic City, NJ
http://www.ndia.org/Template.cfm?Section=91901&Template=/ContentManagement/ContentDisplay.cfm&ContentID=24095

Spring Simulation Multi-Conference 2009
22 March 2009
San Diego, CA

Information for inclusion in the Calendar of Events may be sent to:

SURVIAC, Washington Satellite Office
Attn: Christina McNemar
13200 Woodland Park Road, Suite 6047
Herndon, VA 20171

COMMANDER
NAVAL AIR SYSTEMS COMMAND (4.1.8J)
47123 BUSE ROAD
PATUXENT RIVER, MD 20670-1547

Official Business

PRSRT STD
U.S. POSTAGE
PAID
PAX RIVER MD
Permit No. 22