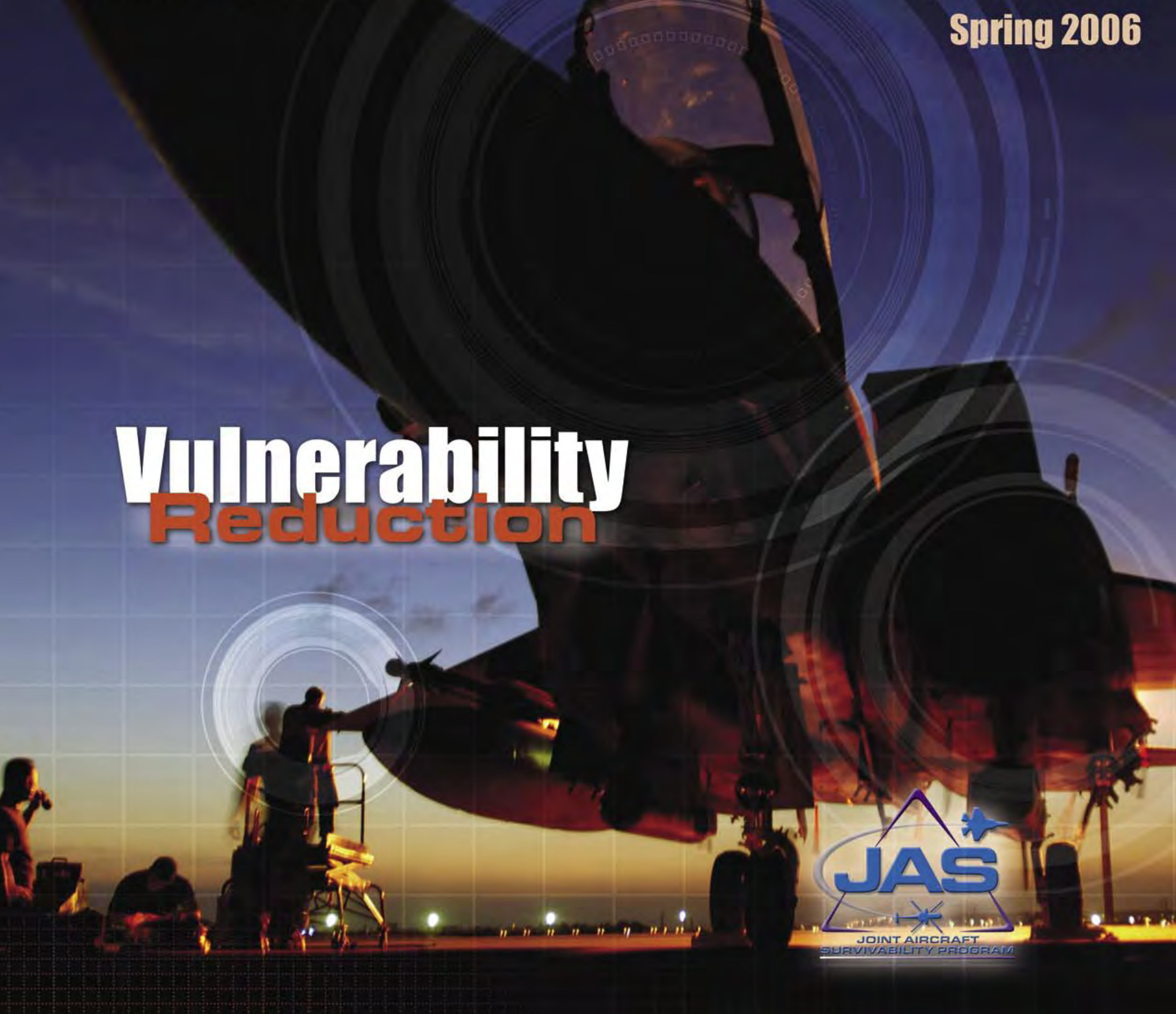
Aircraft Survivability

Published by the Joint Aircraft Survivability Program Office

Spring 2006



Vulnerability Reduction

JAS
JOINT AIRCRAFT SURVIVABILITY PROGRAM

Aircraft Survivability is published three times a year by the Joint Aircraft Survivability Program (JASPO). The JASPO is chartered by the Joint Aeronautical Commanders Group.

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Table of Contents

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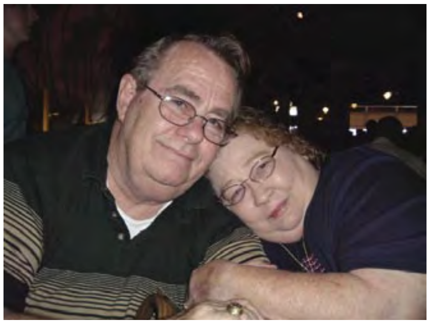
■ by Dennis Lindell



Mr. Jim Buckner and his wife Jean

Jim Buckner Retires

Jim Buckner retired on November 1, 2005. For 25 years, Mr. Buckner provided financial management, administrative, and computer database support for the Joint Aircraft Survivability Program Office (JASPO) and its predecessor, the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS). Jim joined the JTCG/AS in 1981 after a career in the Navy. He graduated from the Naval Academy in 1957 and had a long and interesting career that included service in Southeast Asia during the Vietnam War. Later in his career, Jim completed work at several computer schools and was placed in charge of all computer operations for the Pacific Cruiser-Destroyer Force Staff. He later helped consolidate all Type Commander data processing into the first Navy Data Processing Service Center in San Diego, CA, where he learned the skills he later used in support of the JTCG/AS and the JASPO.

Mr. Buckner has been a stalwart in the JTCG/AS and the JASPO, where he provided the "corporate memory," as various Directors and members came and went. At one time, the JTCG/AS had three separate program elements, one from each Service, and Jim "saved" the JTCG/AS many times with his financial knowledge, as different agencies, for various reasons, attempted to cut JTCG/AS funding. Jim also helped edit the first edition of the survivability textbook for its author, Distinguished Professor Robert E. Ball of the Naval Postgraduate School, Monterey, CA. Jim has greatly contributed to our goal of establishing survivability as a design discipline and providing more survivable aircraft. Jim's many friends in the survivability community wish him the very best. ■

Dennis Lindell is the New JASPO Program Manager

LCDR Dan Chisholm, who was the JASPO Program Manager, rotated back to the National Reconnaissance Office on 31 October 2005, and we all wish him well. On 1 November 2005, Dennis Lindell was appointed as the new JASPO Program Manager. Dennis has been a member of the JASPO staff since 2003 and had previously been Deputy Program Manager for Vulnerability Reduction. ■

Mr. Dennis Lindell, JASPO Program Manager

Rotary Wing Safety and Survivability Tiger Team

In August 2005, the Office of the Secretary of Defense (OSD) Acquisition, Technology, and Logistics (AT&L) Joint Vertical Aircraft-Task Force (JVA-TF) briefed the Deputy Secretary of Defense, Mr. Gordon England, and the Senior Readiness Oversight Council (SROC) on the need to invest in improving vertical-lift aircraft safety and survivability. The JVA-TF, highlighting the significant number of rotary-wing aircraft losses in the global war on terrorism that were caused by mishaps and direct enemy action, posed the question, "Is the rotary wing aviation capability adequate now and for the future?"

In response, the SROC tasked AT&L to (1) examine rotary wing safety and survivability issues, (2) provide a framework from which to define problems and address issues, and (3) develop alternative solutions and a plan of action with accomplishment milestones.

AT&L established the Rotary Wing Safety & Survivability Tiger Team in response to the SROC's tasking. The Joint Aircraft Survivability Program Office (JASPO) was asked to lead the survivability team, while AT&L/Installations & Environment (I&E) led the safety team. The JASPO gathered a survivability team comprised of core members from Headquarters Army Operations and Training (G-3)/Department of the Army, Military Operations-Attack Vertical (DAMO-AV); Navy requirements (N78); Headquarters, Marine Corps (HQMC); Headquarters Air Force (HAF)/Special Operations Division (XOOS) and the Director for Force Structure, Resource, and Assessment, Joint Staff (J8); and supporting members from AT&L and the Science & Technology (S&T) community. The survivability team examined the available, direct combat-loss data and the Department's rotary-wing fleet capabilities to identify causalities and make recommendations to AT&L for future S&T investments to mitigate future combat losses. ■

Instrumentation Roundtable

Dr. Torg Anderson and Dr. Joel Williamsen of the Institute for Defense Analyses (IDA) organized and led an instrumentation roundtable on 22 September 2005 at the JASPO 2005 Summer Joint Program Review at Nellis AFB, NV. The objective of this meeting was to identify ballistic range instrumentation capabilities, needs, and issues and to discuss potential funding avenues for improving range instrumentation. Particular emphasis was placed on high-frequency response pressure measurements.

The discussions attracted 24 test engineers, managers from the three service survivability labs, representatives from three manufacturers of pressure transducers, and a manager of the Director of Operational Test & Evaluation (DOT&E) Combined Test and Evaluation Improvement Program (CTEIP). IDA representatives discussed some observed measurement concerns, followed by a general brainstorming session of concerns and potential solutions collaboratively offered by range engineers and industry representatives. Jim Tedeschi, the CTEIP manager, presented funding paths through this program that may be applicable to improving test-range measurement capabilities. These funding possibilities will have to be further examined to develop a likely strategy.

Attendees from both government and industry seemed very positive about this meeting, stating that it provided opportunities to discuss their measurement issues and make useful connections. They encouraged the planning of similar discussions at future JASPO meetings to review and evaluate other instrumentation areas. ■

Joint Combat Assessment Team (JCAT)—Annual Threat Weapons and Effects Training

The 2006 annual session of the Threat Weapons and Effects Training Seminar is scheduled for 25–27 April 2006. The seminar provides practical, hands-on training in the lethality of threat air-defense systems and the damage they can inflict on friendly aircraft. Both Hurlburt Field and Eglin Air Force Base will host seminar events. Live fire demonstrations of selected small arms, rocket propelled grenades, and shoulder-fired missiles will be presented. Figure 1 and Figure 2 illustrate previous demonstrations.

The seminar is sponsored by the Joint Aircraft Survivability Program (JASP) and hosted by the Joint Combat Assessment Team (JCAT). Information gathered from

Figure1. Stinger Launcher Training

Figure 2. Stinger Live Fire Demonstration

incidents of threat exploitation, live fire testing, and combat experience will be presented to provide a complete picture on threat lethality. Hands-on experience will be provided with threat munitions and missiles, test articles, damaged-aircraft hardware, live fire demonstrations, and by videos from test and combat. Experienced instructors will offer current, relevant information on threat-system upgrades, proliferation, and lethality. Additional information is available on the JCAT Web site, https://threat-hit.wpafb.af.mil, or by contacting Maj Chuck Larson, US Air Force Reserve (USAFR), at 850/678–8333 or Charles.Larson3@wpafb.af.mil. ■

New Fast Shotline Generator (FASTGEN) and Computation of Vulnerable Area Tool (COVART) Versions Released to SURVIAC

Fast Shotline Generator (FASTGEN), Version 5.4.4, and Computation of Vulnerable Area Tool (COVART), Version 4.4.2, were released to the Survivability/Vulnerability Information Analysis Center (SURVIAC) in December 2006. Both are new releases and include code repairs and many methodology improvements.

FASTGEN 5.4.4 can support vulnerability analysis with High Explosive (HE) threats, such as High Explosive Incendiary (HEI) rounds or Man-Portable Air Defense Systems (MANPADS), and kinetic energy threats such as Armor Piercing Incendiary (API) rounds and fragments. For HE threats, FASTGEN 5.4.4 supports proximity-burst warheads and impact-fuzed threats. All threat types can be run in a system-level vulnerability analysis mode and in single or multiple burst-point or shot-line mode to support pre-test predictions and post-test analysis.

FASTGEN 5.4.4 adds a new diverging-ray option for HE threat analyses, offering many improvements over previous FASTGEN point-burst analysis methods. This Advanced Diverging Ray Mode (ADRAM) uses improved threat characterization inputs, along with threat and target velocity and orientation information, to better reproduce threat-induced, fragment-impact patterns on a target's geometry. Several new Pedigree threat characterization databases have been developed to support this new analysis option.

COVART 4.4.2 features many significant changes from earlier COVART releases. The outdated High Explosive Vulnerable Areas and Repair Times (HEVART) methodologies have been removed from the code, which results in a cleaner code that is easier to test, update, and maintain.

COVART 4.4.2 also features new capabilities such as support for the FASTGEN ADRAM option. Many code repairs are included, and a Change Log has been added to the documentation set, providing a user with the complete list of all source-code modifications that have occurred since the release of COVART 4.3.

A new version of COVART—COVART 5 is scheduled for release through SURVIAC in the second half of 2006 and comprises a major rewrite of the underlying code. COVART 5 is a product of the COVART Modularization effort funded by JASPO. The goal of this effort is to make the model easier and less expensive to maintain and modify.

The three main functions of COVART—penetration, damage, and fault-tree analysis—have been grouped together in a module-type format. This results in more understandable code and facilitates inclusion of new methodologies and modules such as new penetration equations, air-blast and hydrodynamic-ram models, such as Airblast in Cluttered Environment (ACE) 2.0, or fuel-migration models, such as Migrate.

For more information, contact SURVIAC or the FASTGEN and COVART Model Manager, Timothy D. Staley, DSN: 674–4483, 937/904–4483, or e-mail, timothy.staley@wpafb.af.mil. ■

NAVAIR Fire Team Receives Innovation Award

In January 2006, the Naval Air Systems Command (NAVAIR) Aircraft Fire Protection Team received a Naval Air Warfare Center Aircraft Division Innovation Award for their developmental work on an automatic engine-fire suppression system. The Joint Aircraft Survivability Program (JASP) sponsored this work in FY05 and continued its support for testing in FY06.

The Innovation Award is the premier awards program in the NAVAIR Warfare Center Aircraft Division. The Command places great emphasis on innovative ideas that solve problems, cut costs for the fleet, and improve operations.

The Team recognized that the most significant drawback in the performance of any engine fire extinguishing system is the delay time between fire ignition and fire-bottle discharge. The longer a fire burns, the tougher it is to extinguish, and pilot-activated system designs, which have been the industry standard for decades, are sometimes presented with an established fire that is too challenging for the onboard extinguishing system. The Team wanted to exploit the great success shown in another fire zone on the aircraft—the dry bay. Dry-bay fire-suppression systems are automatic and can react within 10 ms of ignition—quickly enough to suppress even fires induced by ballistics. Keying in on the benefits of automation, the Team sought and gained support from the JASP to prove that a very-fast-acting system in an engine space would offer similar benefits. That testing, led from the Naval Air Warfare Center Aircraft Division (NAWCAD), Lakehurst, NJ, and conducted at NAWCAD, Pax River, MD, not only proved the Team's theory but also quantified the leap in performance. As envisioned by the Team, an automatic engine-fire extinguishing system would be lighter than systems flying today, would be more effective in putting out typical safety fires, and, as an added bonus, would offer protection against ballistic fires—a threat never before incorporated into the design of such a system. The benefits of this development are huge, as aircraft attrition caused by fires, a leading factor in most Class A mishaps, would be reduced. In addition to the lives saved by incorporating this technology innovation, the cost savings realized by reducing the number of lost aircraft could be staggering.

Team members include Gregg Hurla, Bobbie Myers, Dave Hudgins, Mike Kubina, Mike Cosgrove, Skip Bukowski, Bill Leach, Marco Tedeschi, Joe Dolinar, and Brian Berchtold

The NAVAIR Fire Protection Team would like to thank the JASP for their continued support of this very important work. ■

NAVAIR Fire Team receives the Naval Air Warfare Center Aircraft Division Innovation Award. Left to right: Gregg Hurla, Bobbie Myers, Dave Hudgins, Mike Kubina, Mike Cosgrove, Skip Bukowski, Bill Leach, RDML J. Wieringa. Not pictured: Marco Tedeschi, Joe Dolinar, and Brian Berchtold.

Vulnerability Reduction

■ by Bob Hood

Aircraft Combat Survivability (ACS) is defined as the capability of an aircraft to *avoid and/or withstand* a man made hostile environment. Within the ACS community, there are two major materiel disciplines of interest in protecting our aircrews and aircraft. *Susceptibility* is defined as the inability of an aircraft to avoid (being damaged by) a hostile environment. One could improve overall survivability by reducing a potential adversary's ability to see or hit our aircraft. *Vulnerability* is defined as the inability of an aircraft to *withstand* (the damage caused by) a hostile environment. Overall survivability could be improved by making our aircraft tough enough to continue to operate when damaged. If one were to assume that it was possible within the realm of tactics, techniques, procedures, and technology to absolutely eliminate susceptibility, vulnerability would not be an issue, since an aircraft would not be hit. On the other hand, if one were able to absolutely eliminate vulnerability, susceptibility would not be an issue from an ACS point of view, since a warfighter would not be killed. Unfortunately, in the real world, we cannot eliminate either; hence, balanced effort and investment is needed in both disciplines. This edition of Aircraft Survivability Magazine will focus on Vulnerability Reduction.

The Joint Aircraft Survivability Program (JASP) and predecessor organizations have long made targeted investments in improving overall survivability through Survivability Assessment, Susceptibility Reduction, and Vulnerability Reduction (VR). We have gone further, starting with the project cycle for FY06, by instituting focus areas within each Subgroup. By creating these Subgroups, we are attempting to ensure that we are spending our limited resources on the areas that need the most attention and/or presenting the best technical opportunities for substantial improvement. Focus areas will continue to be reviewed and updated, as necessary, to ensure that they remain relevant to our forces in the field. Our VR focus areas for FY06 are as follows:

- To develop *opaque and transparent armors* that are 33% lighter (in areal density) than current state of the art armors for an equal level of threat protection
- To develop fuel *containment technologies* for fuel tanks/cells and lines that are 50% lighter than current systems for an equal level of threat protection.

Within the JASP organization shown on the next page, the VR Subgroup, chaired by representatives of the US Army, Navy, and Air Force, is responsible for developing and executing VR programs. To that end, we have six technical committees, again chaired by representatives from each Service, who are responsible for the technologies that fall within their respective areas of expertise:

- Aircraft and Crew Protection
- Flight Systems
- Fuel Systems
- Propulsion Systems
- Structures and Materials
- Battle Damage Assessment and Repair

We hope you find this issue of Aircraft Survivability informative and useful. The VR Subgroup will continue to work toward reducing aircraft and crew vulnerability and to improve their overall survivability. ■

F-15C Eagle

About the Author

Bob Hood is the JASPO Vulnerability Reduction Subgroup Chair. He has spent most of his over 25 year career at the Aviation Applied Technology Directorate (AATD), involved with numerous aircraft and support systems development, test, and qualification programs. He is currently the team leader for Subsystems at AATD and is responsible for a wide range of technologies, primarily in the areas of crashworthiness, fuel systems, and ballistic protection, including ballistic test and qualification for both fuel and protective systems. Bob has a B.S. in Mechanical Engineering from North Carolina State University and a Masters of Engineering Administration from the George Washington University, is a member of the Army Acquisition Corps, and is retired from the US Army Reserve.

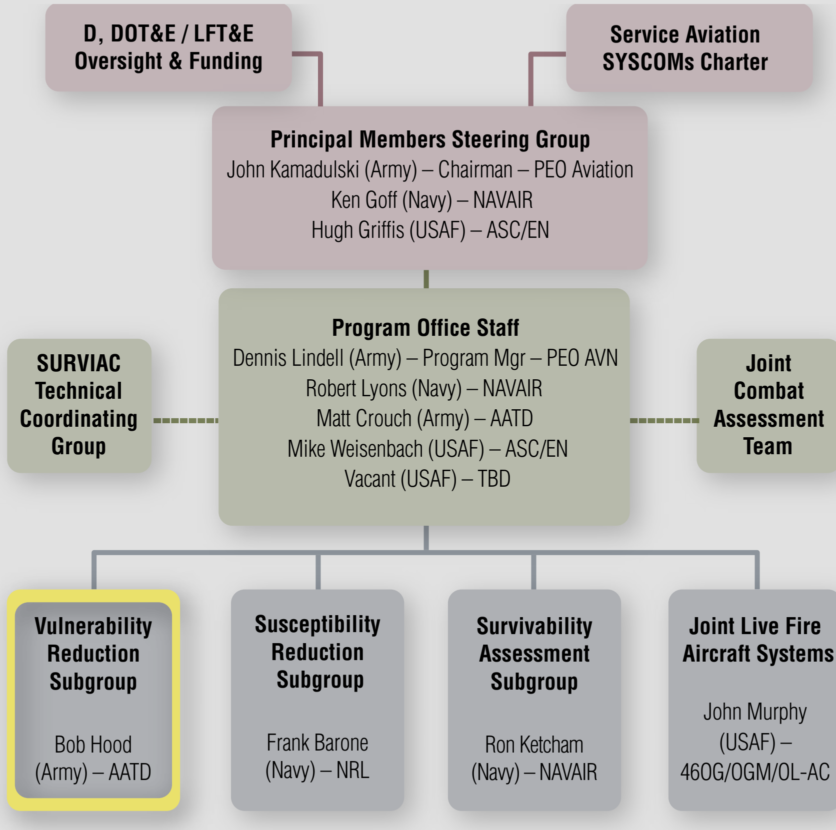


Figure 1. JASP Organization

Joint Live Fire Detailed Test Plan & Final Report Guide

■ by Jeffrey Wuich

The original Joint Live Fire (JLF) Administration Handbook, published in December 1988, contains guidance on creating a detailed test plan and final report. Since 1988, a number of lessons have been learned from both JLF and Live Fire Testing (LFT) with respect to test planning and final reporting, and these lessons needed to be documented. As a result, the Joint Aircraft Survivability Program (JASP) funded V-3-09, *Joint Live Fire Detailed Test Plan & Final Report Guide* to provide a standardized format for Joint Live Fire detailed test plans and final reports. The guide lists specific technical issues that should be considered in planning and executing tests and guidelines for reporting test results, conclusions, and recommendations. The guide is intended as a "how-to" manual for current and future testers.

This effort originated in a memo dated 24 October 03 by Mr. Tracy Sheppard, Office of the Secretary of Defense (OSD), Operational Test & Evaluation (OT&E), Live Fire Test & Evaluation LFT&E Action Officer, which provided interim guidance for JLF/Air detailed test plans. From this starting point, guidance that is still applicable today from the original JLF Administration Handbook was reviewed and incorporated. Finally, lessons learned from both JLF and LFT&E from 1988 to the present were incorporated to complete the first draft of the *Joint Live Fire Detailed Test Plan & Final Report Guide*. The first draft was made available for review and comment to the Survivability, Vulnerability & Lethality Test & Evaluation communities. On receiving and reviewing feedback on the first draft, it became clear that different stakeholders had different opinions on how much information should be contained in a detailed test plan and a final report. Because of the limited amount of funding normally associated with JLF projects, JLF personnel leaned more heavily toward a short, concise test plan and final report, whereas LFT personnel (who work with budgets that are typically magnitudes larger than JLF budgets) wanted more detail. Since JLF personnel will use this document, the final version is geared toward being short and concise, while attempting to capture the major pieces of information normally associated with LFT. (A note of caution to JLF-Sea projects: This guide focuses heavily on test-based projects, whereas many of the JLF-Sea projects focus more closely on simulation methodology and validation. A generalization to accommodate a simulation focus may be counterproductive.) Acquisition LFT&E cannot be directed to use this document, as it would impose requirements beyond those contained in the current DoDI 5000.2, *Operation of the Defense Acquisition System*; however, the LFT&E community may use it on a voluntary basis as a "best practices" example.

The author would like to recognize valuable inputs provided by the personnel listed below, whose comments were incorporated into the second draft of the guide:

The second draft was fine tuned with valuable inputs from Dr. Joel Williamsen (IDA) and Mr. Fred Marsh of the Army Research Laboratory's Survivability/Lethality Analysis Directorate (ARL/SLAD). The final version was reviewed and approved by Mr. Rick Seymour (OSD/OT&E/LFT&E Action Officer). The author is grateful to all these people for taking time out of their hectic schedules to help create a guide that will be useful to us all in the Survivability, Vulnerability & Lethality Test & Evaluation communities. This guide will be made available through SURVIAC. ■

About the Author

Mr. Jeffrey Wuich supports SURVIAC, where he has been its lead engineer for vulnerability testing conducted on Army, Navy, Air Force, and Marine Corps aircraft since 1999. He has over 16 years of professional experience evaluating new and existing aircraft to combat threats in support of a number of JLF and LFT&E programs. Previously, Mr. Wuich served as an officer and aerospace engineer in the US Air Force at Wright Patterson Air Force Base, OH. Mr. Wuich received a BS in Aerospace Engineering from Iowa State University in 1988 and an MS in Mechanical Engineering from the University of Dayton in 1992. He is a member of the National Defense Industrial Association (NDIA).

Table 1. Author extends recognition to the following personnel

JLF Air	John Murphy, Fred Marsh, Steve Polyak, Brian Smith, Rick Grote, Al Wearner, Joe Manchor, and Alex Kurtz
JLF Ground	John Polesne and Bob Wojciechowski
JLF Sea	Tom Julian
LFT&E	Rick Seymour, Tracy Sheppard, and T. R. Masino
Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME)	Erwin Atzinger and Bryan Paris
JASP	Dennis Lindell and Kelly Kennedy
SURVIAC	Kevin Crosthwaite and Steve Mascarella
Institute for Defense Analyses (IDA)	Joel Williamsen, Jerry Wallick, Larry Eusanio, Richard Fejfar, Ron Reese, Peter Filkins, Hans Mair, Dale Atkinson, and Ray Lake

Survivability and Force Protection Key Performance Parameters (KPPs):

Questions and Answers for the Test & Evaluation (T&E) Community

by Dr. Lowell Tonnessen

The National Defense Authorization Act (NDAA) for Fiscal Year 2005 contains language requiring Key Performance Parameters (KPPs) for force protection and survivability. [1] The statute does not require testing and is not linked to the statutory requirement to conduct survivability testing under Live Fire Test & Evaluation (LFT&E). [2] However, it does affect the requirements process, which may have an indirect effect on T&E. The following discussion addresses some questions the T&E community has been asking concerning the statutory requirement and its implementation.

What is the Requirement?

On 13 June 2005, General Peter Pace issued an implementing policy memo for the Joint Requirements Oversight Council (JROC) that includes the following language:

"Effective immediately, all capabilities documents will comply with the National Defense Authorization Act for Fiscal Year 2005, section 141. This language requires all manned systems and systems designed to enhance personnel survivability to identify KPPs for Force Protection and Survivability when those systems may be employed in an asymmetric threat environment." [3]

This requirement also applies to those capabilities documents in existence at the time of the memo. General Pace's memo states, "For capabilities documents that are current, submit the new KPPs as appropriate within six months or incorporate them into the appropriate capabilities document if there is a Milestone decision within one year." According to this schedule, most current capabilities documents should already have been updated to comply with the KPP requirement.

On 13 December 2005, Mr. Kenneth Krieg, Under Secretary of Defense for Acquisition, Technology, and Logistics (USD-ATL) released a policy memorandum regarding the implementation of Section 141 that includes the following language:

"These requirements do not apply to systems that entered low-rate initial production (LRIP) before October 28, 2004. All other covered systems must meet the requirements of section 141, regardless of acquisition category and regardless of whether the system's requirements documents have been approved previously. With respect to programs using an evolutionary approach, section 141 applies to each increment that had not entered LRIP prior to October 28, 2004." [4]

Department of Defense Instruction (DoDI) 5000.2, *Operation of the Defense Acquisition System*, and associated policies are now being revised to comply with the statute and DoD's direction.

What Does It Mean?

The terms *force protection*, *survivability*, and *asymmetric threat environment* are central to understanding and implementing the requirement. The first two terms indicate that the statute is about protecting people and systems. General Pace's memo summarizes the meaning of these terms (italics added):

Force Protection attributes are those that contribute to protection of personnel. *Survivability* attributes are those that contribute to the survivability of manned systems. [See Joint Publication (JP) *1–02, Department of Defense Dictionary of Military and Associated Terms*, 12 April 2001 (As Amended through 31 August 2005), for Joint definitions of *Force Protection* and *Survivability*.]

Because *force protection* is defined solely in terms of personnel, a force protection KPP might address tactics, techniques, procedures, or system design features that protect the user even when a system is considered killed. For example, crashworthiness and ejection systems might be considered force protection features in addition to features that protect both an aircraft and its occupants.

The term *asymmetric threat environment* is not defined in the statute, in General Pace's memo, or in the DoD Dictionary. This permits the law's application to be crafted on a case-by-case basis. According to General Pace's memo, applicability of the requirement is determined when a capabilities document is validated, either by the JROC or by applicable Services and Agencies.

If the Statute Applies to a Program, What are the Implications for T&E?

By definition, KPPs are (1) those attributes or characteristics of a system that are considered critical or essential to developing an effective military capability and (2) those that make a significant contribution to the key characteristics, as defined in the Joint Operations Concepts (JOpsC). Therefore, these attributes must be verified by T&E.

The statute also requires "an assessment of warfighter survivability and of system suitability against asymmetric threats as part of the development of system requirements." One would expect such an assessment to have some basis in T&E. [5]

How Does the KPP Requirement Relate to the Requirement for LFT&E?

The KPP statute serves to strengthen DoD's attention to survivability by complementing the statutory requirement for

Staff Sgt. Keith Parks, USAF, marshals in an E-3 Airborne Warning and Control System.

LFT&E, rather than by direct connection. The primary emphasis of both statutes appears to be personnel survivability, whether expressed as "user casualties" or "force protection." This is apparent from the survivability provisions of both statutes, which apply only to manned systems.

The statutes have their differences, however. Most fundamentally, the KPP statute does not include a *testing requirement*. In contrast, realistic survivability testing is one of the core requirements of LFT&E.

Some other statutory differences are as follows:

- The KPP statute addresses only a subset of the expected threat—the *asymmetric threat*.

- The KPP statute is not restricted to systems of a certain cost or acquisition category. Any *manned system* would qualify, regardless of cost.

- The KPP statute more broadly addresses *personnel casualties*. "Force protection" is more inclusive than "user casualties."

- The statutes differ in their *oversight decision authority*. The Director, Operational Test and Evaluation (DOT&E), is the decision authority for LFT&E oversight (based on validated user requirements). For the KPP statute, covered systems are determined when a capabilities document is validated either by the JROC or by applicable Services and Agencies.

- The statutes also differ in their *reporting requirement*. The KPP statute requires an assessment of warfighter survivability and of system suitability against asymmetric threats, but this assessment is a component of developing system requirements and does not require reporting to the Congress.

How Can the T&E Community Help Ensure That the New Requirement Serves Its Intended Purpose and Adds Value for Particular Programs?

- Address asymmetric threats in T&E. Testing of armored ground systems is under way to establish the level of crew protection against Improvised Explosive Devices (IEDs). At least three ship programs are including scenarios based on the LFT&E damage-scenario assessments conducted after the USS Cole attack. Similarly, helicopter T&E might include asymmetric scenarios derived from real-world experiences.

- Explicitly address personnel survivability in survivability assessments. Survivability assessments should estimate both the expected number of personnel casualties and the expected loss of system hardware or mission capability. When a threat weapon downs one of our aircraft, we expect to know not only the status of the aircraft but also the status of the occupants. In the same way, our survivability assessments should

Continued on Page 31

Army Aviation Structures Science & Technology (S&T)

Technology for Rotorcraft Vulnerability Reduction (VR)

■ by David Friedmann

Of the many approaches being taken to address concerns over the survivability of the Army's helicopter fleet, the predominant approach is to retrofit aircraft with additional signature reduction devices and countermeasures in a piecemeal fashion. The majority of survivability Science & Technology (S&T) investment, in turn, follows this trend. This approach, however, only addresses the first two tenets of survivability—Don't be seen, and if seen, don't get hit.

Vulnerability Reduction (VR) features are also needed to address the third tenet—if hit, don't get killed. A common perception is that VR is only accomplished through armor or design features such as redundancy, shielding, and separation. VR can also be accomplished through component and system damage tolerance. The Army's rotorcraft structures program addresses this aspect of VR, along with crashworthiness and quick repair, which is an element of force survivability.

VR technology development is usually defined in two ways: to enable survivability against high energy threats (kinetic energy, crash, directed energy weapons, *etc.*) and to reduce the footprint penalty (weight, space, and power) associated with making a vehicle more survivable.

To improve performance and reduce weight penalty, the Army Structures Technology program focuses on the following:

■ **Modeling and Simulation**—This effort uses high fidelity, Finite Element Modeling (FEM) to understand and predict structural behavior caused by a high energy impact event.

■ **Damage Tolerance**—This effort includes fundamental physics such as fracture mechanics and strain rate effects. It also includes material systems, sizing effects, design criteria, load path integrity, and load variability.

Army CH-47 Chinook

■ **Damage Assessment and Repair**—This effort addresses the engineering of designing for repair by using diagnostic measures to sense damage and prognostic measures to alert crew and maintainers to needed actions.

■ **Crashworthiness and Energy Absorption**—This effort is a very important aspect of what is done for rotorcraft survivability. A crash survival design guide was developed in the early 70s, and the principles contained within it have been applied to two aircraft in the Army fleet, AH-64 and UH-60. Because of technology available at the time, there are limitations to the guidance and the systems. With adaptive systems and advanced structures, crashworthiness can be improved from the point design philosophy to more of an envelope design. Crashworthiness can be extended to other classes of aircraft, such as the large Joint Heavy Lift (JHL) aircraft and the small, Class III and Class IV Unmanned Aerial Vehicles (UAVs) with multi-million dollar mission equipment packages, but not without considerations of true non-linear effects of scale and operational environment.

Current Efforts

In the structures S&T program at the US Army Aviation and Missile Research Development and Engineering Center (AMRDEC), we address all these points in the ongoing (FY02 through FY06) Survivable Affordable Repairable Airframe Program (SARAP), an effort to develop and demonstrate technology. Through multiple efforts with industry, SARAP demonstrates advanced airframe structures technology that directly addresses defined technical barriers. This, in turn, leads to accomplishing S&T goals for affordability, structural efficiency, durability, sustainability, and crash and ballistic survivability.

The objectives of SARAP are twofold:

(1) to demonstrate a 25% reduction in airframe weight, a 40% reduction in manufacturing labor hours per pound of structure, and a 40% reduction in the development labor associated with advanced airframe configurations and

(2) to provide ballistic tolerance and occupant safety during crash events.

To achieve these objectives, the program is focused on validating physics based models and virtua-prototype capability through the design of experiments. Technologies will be demonstrated on highly loaded, complex, full-scale airframe structures that are representative of current fleet aircraft.

One area of emphasis in SARAP has been to improve high fidelity, large deformation FEM and virtual prototyping tools. A virtual prototype is the application of design tools, analysis tools, and methods sufficient to conduct design trade-offs and configuration management and to reduce risk in terms of system cost, form, fit, and function. Models are built in building block fashion, from coupon to element to component, and validated at each level by testing. The value of the virtual prototype is that trial and error experiments can be conducted virtually rather than physically, thus reducing cost. Testing is more efficient because either the correct test is performed (some aspect that is difficult to model), or the test successfully validates the design.

In SARAP, LS-Dyna has been the primary tool to model ballistic threats, structural response, and hydrodynamic ram. LS-Dyna and MSC-Dytran have both been used to model crash impacts. Both Arbitrary Lagrange-Euler (ALE) and Smoothed Particle Hydrodynamics (SPH) methodologies have been demonstrated. In all these cases, codes are being pushed to solve problems that have not been previously addressed. The SARAP team has worked with the software vendors to make solutions possible. A great deal of progress has been made; however, the present results do have limitations. Work needs to continue to better understand and represent the basic physics of pressure wave propagation and composite material fracture mechanics. Run times have to be reduced so that models can be used to affordably analyze effects of variations in shot lines, material properties, fragmentation, blast, environmental conditions, *etc*. Threat models that simulate coupled event physics of kinetics and blast pressure need to be validated by a recognized authority.

Durability and damage tolerance is another focus area in SARAP, where significant work has been done to characterize and model types of damage for different composite part families. This work is essential to developing true, physics based FEMs. By designing the right amount of damage tolerance into an aircraft, the aircraft can be bullet tolerant to the level desired without an excessive weight penalty.

Another SARAP focus is rapid, field level damage assessment and repair of composite structures, which has produced simple, easy composite repair methods including quick, low temperature curing materials; easy to handle pre-forms; reconfigurable tooling; reliable and portable application of heat for epoxy curing; and efficient Non-Destructive Inspection (NDI) techniques. Three successful repair demonstrations have been conducted with soldiers at the US Army Aviation Logistics School (USAALS) at Ft. Eustis, VA, to enable maintainers to return aircraft to service as quickly as possible once new composite structures are fielded.

The crash design point for current fleet helicopters (AH-64 and UH-60 only) is on hard surfaces at Structural Design Gross Weight (SDGW). Because of single-point designs, these helicopters have degraded crashworthiness at higher gross weights or different impact surfaces. Statistics show that only about 7% of Army crashes are on hard, prepared surfaces. Most of the remainder are on soft soil and water. Test data show that load paths through the structure are different for water impacts than for those on hard ground, where landing gear absorb much of the energy. Landing gear can stick in soft soil and plant an aircraft nose into the ground, which is another off design point. Metal structures, such

CH-47 Chinook

as those of the current fleet, can predictably crush and deform to provide energy absorption in a crash. Composites are brittle materials that tend to fail abruptly and catastrophically. SARAP addresses these challenges through modeling and developing energy absorbing composite structures that fail in a predictable way, absorb impact energy, and retain occupant space. External airbags are also being investigated as a means to absorb crash energy.

Future Planning

Planning for future S&T investment is ongoing. The Army has the S&T Project Reliance lead for Joint Services Vertical Takeoff and Landing (VTOL) Rotorcraft S&T. Currently, the AMRDEC is developing an Aviation Science and Technology Strategic Plan for a Joint Services VTOL Rotorcraft and Army Aerial Systems S&T program. The strategic plan will establish the Aerial System Technology Development Approach (TDA) as a roadmap for the future. At the root level, the TDA will be built on specific Technology Effort Objectives (TEOs).

Several things are considered, including the current state of the art, current and perceived future needs, past investment, and a realistic assessment of possible technologies. The proposed VR technical objectives will also be broad based to enable survivability improvement in all appropriate vehicle subsystems.

For crashworthiness, variability in aircraft weight, configuration, impact surfaces, and attitudes must be accounted for. As the gross weight of an aircraft increases over the years through new variants and upgrades, the crash performance degrades. For an aircraft the size of a JHL, the gross weight may vary up to 40% from low fuel with no cargo to full fuel with full cargo. This variability in gross weight and loading conditions presents new crashworthiness challenges. Adaptive crew seat technology already exists to optimize performance depending on occupant weight, adjusting for a ninety-fifth percentile male to a fifth percentile female. Adaptive technology can also be applied to an aircraft as a whole to provide full crashworthiness at any weight.

Typically, making an aircraft more survivable also makes it more expensive and heavier. There are trade-offs between survivability, range and payload, and maintenance. Besides new technologies, another role of VR technology development is to reduce cost, weight, space, and power penalties. Future efforts should address all VR subsystems, including fire protection, crash protection, and armor.

Army OH-58D Kiowa

Because associated threats haven't been prevalent in the battlefield (yet), certain areas haven't been fully explored: protection from chemical and biological agents; Directed Energy Weapons (DEW); electronic warfare (intercepting data streams or inserting false information into the data stream); asymmetric threats such as tampering, improvised explosive devices; and anti-helicopter mines. S&T developers must mature technologies for the next war at the same time as they solve problems for the current one.

Another way to improve survivability beyond simple damage tolerance is to develop systems that adapt to damage through self-healing or reconfiguration without losing functionality. These include self-healing flight controls, reconfigurable load paths (morphing structure), and redistribution of power. Systems that sense and assess damage, then indicate to an operator some action that should be taken, would also be helpful to pilots during, and maintainers after, missions. These go beyond diagnostics and prognostics to assessing integrity and functionality and then using decision algorithms to indicate to an operator what action is required.

When a military aircraft is damaged and removed from action, additional stress is put on remaining forces. It is imperative that aircraft be repaired as quickly as possible and returned to service. Replacing damaged components presents a tremendous logistics burden. Efforts should continue to develop structures and other systems that are simply and quickly repaired. Work should also be conducted to establish proper repair criteria so that every damaged part doesn't necessarily have to be replaced.

It is most efficient to push the repairs as close as possible to the unit level. To help facilitate this, some of the same tools that are used in the design phase—finite element analysis and vulnerability assess-

Army UH-60 Black Hawk

ments—can be combined to assess the extent of damage and level of repairs needed in near real time. Self-diagnosing airframe and subsystems will also pinpoint damage and aid quick repair. Embedded sensors, electrolytic transport, and composite self-sensing are enabling technologies for self-diagnosis that are in early development.

Proposed TEOs for VR are as follows:

- **Threat Protection Weight Reduction**—Metric: Reduction in component weight and gross weight. This technical objective is designed to address the weight penalty associated with, for example, armor, crash systems, fire protection, and chemical and biological protection.

- **Aircrew and Payload Crash Survival Envelope**—Metric: Crash Index that is a function of the crashworthiness of a system in a given condition (weight, attitude, surface) and the likelihood of crashing in that condition. This technical objective addresses platform and occupant survivability and will improve crash performance over a wide range of crash conditions rather than only allowing for point designs.

- **Non-Conventional Threat Protection**—Metric: Retained component function. The purpose is to ensure that aircraft can continue to operate after exposure to non-conventional threats such as DEW (high and low power lasers and RF), electromagnetic pulse, and chemical and biological threats; and physical and data stream tampering. This objective enhances platform, occupant, and mission survivability.

- **Post-Damage Functionality**—Metric: Retained component function. The purpose is to provide component functionality after high energy impact by conventional threat for continued aircraft operation, which improves survivability from a platform, occupant, mission, and force perspective.

Future Army rotorcraft VR programs will be built around these TEOs. Along with developing hardened and damage tolerant systems, emphasis will also continue to be placed on the analytical modeling and analysis tools for these systems. VR is an integral part of overall survivability. There has been great improvement in this area over Vietnam-era aircraft, but as old approaches and methodologies are constantly challenged, continued S&T development will ensure even more survivable aircraft. ■

About the Author

David Friedmann is an Aerospace Engineer on the Airframes Team, Platform Technology Division, Army Aviation Applied Technology Directorate (AATD). He is Technical Agent and Survivability team lead for the SARAP.

Alex G. Kurtz

Excellence in Survivability

by Dale Atkinson

The Joint Aircraft Survivability Program Office (JASPO) is pleased to recognize Alex G. Kurtz for Excellence in Survivability. Alex is the Assessment Branch Chief and a program and test engineer for Live Fire Test and Evaluation (LFT&E) for the 46th Test Wing Aerospace Survivability and Safety Flight at Wright-Patterson Air Force Base, OH.

Alex graduated in 1978 from Miami University in Oxford, OH, with a BS in Aeronautics. After graduation, he did a tour in the Marine Corps, ending as a Platoon Commander, 2nd Combat Engineer Battalion, 2nd Marine Division. While in the Marines, he was deployed for six months to Beirut, Lebanon, as part of the MultiNational Peacekeeping Force. After his tour in the Marines, he returned to school, attending Ohio State University, Columbus, OH, graduating in 1986 with a BS in Aeronautical and Astronautical Engineering. He is a Level III Certified Acquisition Professional in Systems Planning, Research, Development, and Engineering.

Alex began his career in Aircraft Survivability at the Air Force Wright Aeronautical Laboratory (AFWAL), forerunner of Wright Research Laboratory (WRL), later to be incorporated into the AF Research Laboratory (AFRL). His first job was to manage the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) Armor Analysis Methodology project and to write a 10-year Research & Development (R&D) Armor Plan for AFWAL. Alex has worked with JASPO's Aircraft and Crew Protection Subgroup (formerly the Armor Subgroup of the JTCG/AS) for most of his career.

Beginning in 1987, Alex directed and led the AC-130U Gunship-III LFT&E program, ensuring the system met the contractual armor performance specifications; complied with LFT&E, LFT&E Alternate Test Plan (ATP), and Test and Evaluation Master Plan (TEMP) issues; and met critical acquisition milestones. As the test engineer, he assisted in compiling test results and authoring briefings presented to Pentagon acquisition officials, which resulted in an armor upgrade for the AC-130U that significantly reduced the aircraft's vulnerability and increased its crew's survivability.

Before completing the AC-130U LFT&E test series, Pan Am 103 crashed in Lockerbie, Scotland, in December 1988. In 1989, Alex was assigned as the WRL representative to assist the Federal Aviation Administration (FAA) in structuring a multidiscipline program and helping to establish an organization to address commercial aircraft vulnerability to internal explosives. At that time, the FAA lacked internal personnel and an organization to address this issue. To assist the FAA, an Air Force multidiscipline team was assembled, comprised of scientists and engineers in structures, flight controls, aerodynamics, and survivability/vulnerability disciplines to address the internal explosion issue and jump-start the FAA Commercial Aircraft Hardening Program (CAHP). The CAHP addressed the issue through numerous test and analysis efforts, while the FAA managed the program and manned their new organization.

In 1993, following the successful completion of the CAHP program, Alex, along with Army and Navy engineers, was assigned to tackle another set of issues dealing with aircraft vulnerability to ballistically impacted, internally carried munitions. Very little research had been done on aircraft survivability with stowed munitions subjected to ballistic impacts. As the Joint Live Fire (JLF) and JTCG/AS lead, he spearheaded and was responsible for coordinating multiple organizations to quantify the munition reactions, identify aircraft vulnerabilities, and identify potential vulnerability mitigation techniques. These research programs and their respective results were briefed to F/A-22 and F-35 program offices and manufacturers, the Joint Aeronautical Commanders Group (JACG), the Office of the Secretary of Defense (OSD) LFT&E office, industry, and delivered at numerous conferences and symposiums. This research has lead to quantifying the problem, defining critical vulnerability parameters for F/A-22 and F-35 evaluations, developing evaluation techniques to down-select numerous protective materials, and designing and fabricating weapons bay simulators. The program recently completed a series of proof-concept protection technique series of tests, which were very successful.

In the last few years, Alex became involved in Man-Portable Air Defense Systems (MANPADS) testing and analysis, as this threat became more prominent. Analysis voids were quickly identified when he tried to predict the shotlines and quantify subsequent aircraft damage. He was instrumental in defining and managing the JASP MANPADS Methodology Program. Through the prime contractor, RHAMM Technologies LLC, this program has successfully developed MANPADS Finite Element Analysis (FEA) methodologies for aircraft threat interactions and have integrated these FEA techniques into aircraft vulnerability analysis methodology. This allows companies to analyze failure modes and to design and build aircraft that will withstand MANPADS or gracefully degrade in a controllable manner. General Electric Engines, Bell-Boeing, and the National Aeronautics and Space Administration (NASA) are using this methodology and these models to predict and measure performance and to evaluate safety of flight after a MANPADS encounter.

Currently, Alex is the 46th Test Wing Program Engineer/Manager for C-5 LFT&E. He has been involved since the early stages of the program, assisting in the development of the LFT&E inputs to the Test & Evaluation Master Plan (TEMP) and development of the LFT&E ATP. He leads a team of engineers, technicians, and analysts who are responsible for ensuring that the C-5 successfully completes the LFT&E test series. As the C-5 LFT&E program engineer/manager, he is was responsible for both overall team oversight and the evaluation of the C-5 Fire Suppression System (FSS) using a one-of-a-kind, unique oxygen sensing unit to address critical TEMP issues. He is also responsible for management oversight in a first-ever test series conducted by John Kemp, a fellow 46th Test Wing engineer, to measure C-5 fuel tank ullage oxygen concentrations in an aircraft that was fueled and defueled at the Aerospace Maintenance And Regeneration Center (AMARC), Tucson, AZ. This unique testing not only enhanced test-range hardware but also developed a unique test methodology approach to measure fuel tank ullage oxygen concentrations during de-fueling.

Throughout his career, Alex has significantly enhanced crew and platform survivability by providing leadership, direction, and as the Joint Aircraft Survivability Program (JASP) Aircraft and Crew Protection Committee Chairman. He was recently appointed as the JASP Vulnerability Subgroup Co-chair and remains the Air Force Joint Test Director for JLF. He is responsible for integrating the tri-Service, 46th Test Wing, Research Laboratories, FAA, NASA, and Department of Homeland Security (DHS) technical programs and advocating multiple collaborative Research, Development, Test, and & Evaluation (RDT&E) vulnerability reduction programs. Alex wants everyone to know that these programs are team efforts, and he appreciates everyone who has helped and supported him on these programs.

Alex also leads a four-nation international technical collaborative RDT&E group, ensuring the US maintains an international leadership role and a superior edge in aircraft vulnerability reduction technology, testing techniques, and analysis methodology. The international group has conducted research on commercial aircraft subjected to internal explosions, aircraft-MANPADS encounter methodology development, composites subjected to blast-fragment damage, and composites subjected to heat and fire. This effort gave Alex the opportunity to conduct national and international travel, and he has had the pleasure of visiting a number of different locations and organizations around the world.

Alex says his greatest joy in coming to work is mentoring new engineers, watching them grow to become program managers, and allowing them to find their niche in aircraft survivability. He also enjoys interacting and working with the very close and tightly knit national and international survivability professional community. In addition, And Alex asks, "Where else can you legally shoot US aircraft, investigate damage, and engineer fixes, knowing that success is watching pilot(s) and crew members complete their missions and come home?"

Alex has been married for 25 years to Debbie, who he says is a great wife, mom, and schoolteacher. He especially enjoys watching and participating in his children's sports and activities. When his children were in kindergarten through sixth grade, he especially enjoyed the Y-Guides and Y-Princess programs. Alex says it was a thrill to not only encourage, guide, and watch his kids, and others' children as well, conquer their fears, master various challenges, and grow in leadership capabilities.

It is with great pleasure that the JASPO honors Alex Kurtz for his Excellence in Survivability and his and contributions to the JASPO, the survivability community, and the warfighter. ■

About the Author

Mr. Dale Atkinson is a consultant on the aircraft combat survivability area. He retired from the Office of Secretary of Defense in 1992 after 34 years of government service and remains active in the survivability community. Mr. Atkinson played a major role in establishing survivability as a design discipline and was a charter member of the tri-service JTCG/AS which is now the JASPO. He was also one of the founders of DoD sponsored SURVIAC. He may be reached at jasnewsletter@jcs.mil.

Assessment of Rocket Propelled Grenades (RPGs) Damage Effects on Rotorcraft

■ by Patrick O'Connell

Rocket Propelled Grenades (RPGs), introduced in the early 1960s, were primarily designed as an infantry weapon to defeat armored vehicles—an improved bazooka. Over the years, because of their availability, ease of use, and effectiveness, they have become a weapon of convenience for attacking many other targets of opportunity, including low-flying helicopters. In fact, there have been hundreds of RPG attacks against helicopters dating back to the conflict in Southeast Asia.

Because of the RPG attacks in Iraq and Afghanistan, in 2003, the Office of the Director, Operational Test and Evaluation (DOT&E), through the Joint Live Fire (JLF) Program, initiated a joint program to characterize the damaging effects of RPGs against helicopters. Retired AH-1 aircraft were chosen for this test series because they represent, in their construction, a typical, fielded helicopter and are readily available for testing. This four-phased program is being conducted in cooperation with the US Army, Navy, and Air Force. Phases I and II were described in detail in the Spring 2004 issue of *Aircraft Survivability*.

The US Army Research Laboratory/Survivability and Lethality Analysis Directorate (ARL-SLAD), Aberdeen Proving Ground (APG), MD, conducted the first phase of the program. The objective of Phase I was to determine the fuzing sensitivity of RPGs against thin helicopter skins and to begin gathering data on helicopter vulnerability against RPG threats. The AH-1 target was static; *i.e.*, systems were not functioning, and rotors were not turning.

Phase II was conducted by Naval Air Systems Command (NAVAIR) at the Naval Air Warfare Center, China Lake Naval Air Station (NAS), CA. The objective of this phase was to characterize the lethality of an RPG warhead in a "near-miss" scenario with an operating AH-1. The AH-1 was operated in a near-hover condition while tethered to the ground. Several arena tests were also conducted to determine the sizes of warhead fragments spray distributions.

Phase III was led by the Air Force 46th Test Wing (TW) 46 Operations Group (OG)/Munitions Test Division (OGM)/Aerospace Survivability and Safety Flight's (AOL-AC), with actual testing conducted by ARL-SLAD at APG. The primary objective of this phase was to investigate the overall vulnerability of an operating helicopter to the direct impact of an RPG. A secondary objective was to explore, through static warhead tests, the vulnerability of the fuel system.

A total of six tests were completed in Phase III. Four tests involved dynamic launches of an RPG into an operating helicopter, and two consisted of static warhead detonations near the fuel cells. Shotlines were chosen to examine the vulnerability of the AH-1 in realistic scenarios that would not necessarily result in immediate loss of aircraft.

The four live-fire RPG tests were conducted using helicopters operating in-ground effect hover while secured to the test pad. (See Figures 1 and 2) The RPGs were launched using a standard, remotely operated RPG launcher. The helicopters had fully operational power and propulsion systems, and their flight controls could be remotely operated. After being struck by an RPG, the helicopter was permitted to run for up to 30 additional minutes to see if it remained operational. (See Figure 3)

For Test 5 and Test 6, a static RPG warhead was detonated adjacent to the fuel cells. (See Figure 4) The fuel cells were two-thirds filled with Jet Propulsion fuel (JP-8), and the fuel was heated to normal operating temperature. Figure 5 illustrates the "plasma jet" exiting the helicopter immediately after the RPG warhead was detonated during Test 5.

Phase IV of this program will conclude with a series of tests consisting of dynamic RPG launches into the fuel cells of operational AH-1s. This testing, scheduled to occur during FY06, is again being managed by 46OG/OGM/OL-AC and conducted by ARL-SLAD.

This tri-service program has greatly increased the understanding of an RPG's damage mechanics on a typical helicopter, the type of damage that can be expected, and the overall vulnerability of a helicopter against this threat. ■

Figure 1. RPG launcher and helicopter set-up

Figure 2. RPG heading towards the target

Figure 3. RPG blast

Figure 4. RPG warhead setup for fuel ullage test

Figure 5. RPG "plasma jet" exiting out the helicopter

About the Author

Mr. Patrick O'Connell is currently a Project Test Engineer at the Air Force's Aerospace Survivability and Safety Flight at Wright-Patterson Air Force Base. He has 20 years experience working in aircraft survivability and Aircraft Battle Damage Repair (ABDR), 11 years of which he spent as an Air Force officer. 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.

The Joint Aircraft Survivability Program (JASP)

■ by Dennis Lindell

Introduction

The Joint Aircraft Survivability Program (JASP) mission is to increase the affordability, readiness, and effectiveness of tri-service aircraft through the joint coordination and development of survivability (susceptibility and vulnerability reduction) technologies and assessment methodologies. This article provides a synopsis of JASP technology projects in Fiscal Year (FY) 2006 and is a reference for those interested in aircraft survivability research. The JASP and the projects as presented in this article are organized by JASP technology subgroups: Survivability Assessment, Susceptibility Reduction, and Vulnerability Reduction. The JASP subgroups and their committees incorporate the technical expertise of the Department of Defense (DoD) aircraft survivability community. Additional information or answers to questions may be found by contacting the Joint Aircraft Survivability Program Office (JASPO).

Focus Areas

Beginning with the FY 2006 program build, the JASP defined a limited number of focus areas in which to concentrate its efforts. The intent is to make significant progress on a few defined aircraft survivability requirements within three to five years. In this first attempt, the focus areas were brought forward from the three subgroups: Survivability Assessment, Susceptibility Reduction, and Vulnerability Reduction. The JASP is working to refine the focus-area development process to incorporate warfighter and acquisition community input and to create roadmaps to define the survivability gaps and the plans to fill them. Following are the six focus areas for the FY 2006 program build.

■ **Survivability Assessment**—This focus area will identify and address deficiencies in the current JASP vulnerability and endgame Modeling and Simulation (M&S) environment that limit the application of the Integrated Survivability Assessment methodology. This effort supports a goal of reducing Developmental Test, Operational Test & Evaluation (OT&E), and Live Fire Test & Evaluation (LFT&E) cost by 20% through the use of M&S. It will also plan, execute, and document sufficient verification and validation to confirm the credibility of the JASP M&S toolset. Acceptance of the toolset by the Developmental Test, OT&E, and LFT&E communities will also support the goal of reducing test costs by 20%.

■ **Susceptibility Reduction**—This focus area will explore technologies and techniques and demonstrate capability to meet Directed Energy Infrared Countermeasures (IRCM) requirements at 25% of current costs and/or that are as effective against next-generation threats as against current threats. It will also explore manned (stand-off, escort) and unmanned [stand-in Unmanned Aerial Vehicle (UAV)] jamming platform technologies to meet requirements against advanced, coherent, parameter-agile Integrated Air Defense System threats, while also jamming all legacy deployed radars, seekers, and data links.

Global Hawk

■ **Vulnerability Reduction**—This focus area will develop opaque and transparent armors that are 33% lighter (in areal density) than state-of-the-art armors for an equal level of threat protection. It will also develop fuel containment technologies for fuel tanks, cells, and lines that are 50% lighter than current systems for an equal level of threat protection.

FY06 Program

Survivability Assessment

M-97-03 Survivability/Vulnerability Information Analysis Center (SURVIAC) M&S Accreditation Support Information Development—The objective of this project is to prepare the JASP Fire Prediction Model (FPM) for accreditation. The principal tasks are to document the code development, establish the criteria and data for code verification and validation, and prepare an accreditation support package for the baseline model. By establishing the model's foundation, this effort will increase the community's confidence in—and use of—the model in aircraft survivability analyses.

Project Engineer—Michelle Killikauskus, United States Navy (USN), Naval Air Systems Command (NAVAIR)

M-98-01 SURVIAC Model Manager Support—This project provides model manager support for the JASP models in SURVIAC, including monitoring Software Change Requests for each model and planning, hosting, and documenting two JASP Model User Meetings (JMUMs) per year. These efforts contribute to improving key aircraft survivability models and their configuration management, which results in more capable and credible tools for survivability analyses.

Stinger Missile Testing

Project Engineer—Mike Weisenbach (JASPO)

M-00-04 Dry Bay Fire Model/ WINFIRE Enhancements—This task further develops a standard, physics-based dry bay fire model for use by the survivability analysis, LFT&E, and system evaluation community. By improving the model analytical capability and configuration management, this effort supports all Department of Defense (DoD) services, program offices, and industry partners with a credible fire and explosion prediction capability. Products include changes approved by the Configuration Control Board (CCB) to the stand-alone computer code, the graphical user interface, and analyst and user manuals.

Project Engineer—Marty Lentz, US Air Force (USAF), 46th Test Wing (TW)

M-04-04 Integrated Survivability Assessment (ISA) Demonstration—This task applies the JASP Integrated Survivability Assessment (ISA) process to the Multi-Mission Maritime Aircraft (MMA) program to demonstrate and further refine the ISA process. The project will thoroughly test the ISA process and supporting models and identify key areas for future improvements. Integrating susceptibility, vulnerability, and mission-level modeling will allow credible assessment of survivability enhancements on aircraft mission effectiveness.

Project Engineer—Ron Ketcham, USN, NAVAIR

M-05-01 Accelerator for Reticle Processing—This project will provide accelerated reticle processing for use in all-digital and Hardware-In-The-Loop (HITL) simulation of infrared (IR) threat missile systems. The application of Commercial-Off-The-Shelf (COTS) Focal Plane Gated Array (FPGA) technology will result in greater capability, smaller form factor, and less expense than current approaches. These enhancements will improve IR threat missile simulations and their application toward improving aircraft survivability through susceptibility reduction, countermeasures development, and tactics' generation.

Project Engineer—Billy Parsons Defense Modeling and Simulation Office (DMSO), Threat Simulator Management Office (TSMO)

M-06-01 Vulnerability Endgame—Develop a long-term plan for vulnerability endgame modeling and simulation based on documented acquisition community requirements. The plan will focus future JASP efforts to fully support the acquisition community with capable and credible vulnerability endgame M&S tools.

Project Engineer—Kelly Kennedy USAF, Advanced Simulation and Computing Aeronautical Systems Center / Engineering Directorate (ASC/EN)(ASC)

M-06-02 Structural Response to Internal Blast—Enhance and standardize methodologies used to evaluate the effects of internal blast effects on aircraft structures in aircraft vulnerability analysis models. This project will allow accurate assessment of aircraft vulnerability to explosive effects inside the aircraft body.

Project Engineer—David Lynch, US Army (USA), Army Research Laboratory (ARL)

M-06-03 Enhanced Surface-To-Air Missile Simulation (ESAMS) Validation—Validate eight critical model functions for Russian Radio Frequency (RF) threats in ESAMS. A functional element validation report will be provided for each threat. This project will improve the credibility of ESAMS and allow its use in systems evaluations and other assessments that require threat-engagement analysis.

Project Engineers—Ralph Mattis, USN, NAVAIR and Jim Begovitch, USAF, ASC

M-06-04 Fuel Bladder Survivability for Fire Prediction Model—Develop penetration algorithms for ballistics threats vs. fuel bladders and bladder materials. This project will further extend the applicability of the Fire Prediction Model to helicopter fuel subsystems and support the verification and validation of the model.

Project Engineer—Linda Moss, USA, ARL

AH-1 Cobra and UH-1 Huey

M-06-06 JCAT Data Correlation to Vulnerability/Survivability (V/S) Analyses—To compare Joint Combat Assessment Team (JCAT) damage reports on AH-1Ws and UH-1s involved in Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) to Navy maintenance data and vulnerability analysis M&S input development and output results. This effort will further improve the JCAT damage-assessment process and support Verification and Validation (V&V) of conventional aircraft vulnerability analysis tools and procedures.

Project Engineer—James Young, USN, NAVAIR

M-06-07 Probability of Kill Methodology Workshops—This project will host a workshop at which analysts and test engineers from all services can discuss Probability of Damage Given a Hit (Pd/h) methodologies and develop Pd/h standards. The workshop will produce a standardized methodology document for a select class of aircraft components. The workshop focus in 2006 will be determined based on tri-service model-user input through JASP model-user meeting participants. If this workshop proves successful, additional topics will be addressed at future workshops.

Project Engineer—Kelly Kennedy, USAF, Aeronautical Systems Center/ Engineering Directorate (ASC/EN)

M-06-08 Man-Portable Air Defense System (MANPADS) Damage Effects Models—This project will generate standardized finite element models (FEM) of the SA-16/18 and SA-24 MANPADS threats in LSDYNA. These models will add to the existing JASP library of validated MANPADS and high-explosive projectile threat models that engineers can use to develop more survivable aircraft.

Project Engineer—Alex Kurtz (USAF, 46th TW)

M-06-09 HEI Damage Effects Models—Develop validated, physics-based (LSDYNA) models of 23mm High-Explosive Incendiary (HEI), 30mm HEI, and blast-fragmentation RPG projectiles that include fragment and blast effects for use in hydraulic ram analyses. This project will provide validated models that can be used with confidence to evaluate the damage tolerance of aircraft the blast and fragmentation threats.

Project Engineer—Alex Kurtz (USAF, 46th TW)

M-06-10 Passive Covert Radar Countermeasures—Develop and assess a passive covert radar (PCR) evaluation tool for few-on-few simulations, construct PCR test bed, develop and assess electronic attack techniques, and demonstrate PCR countermeasures. The capability to assess PCR countermeasures does not exist currently; this project will fill the gap.

Project Engineer—Richard Smith (USAF, AFRL)

Susceptibility Reduction

S-03-01 Special Material Urban Decoy (SMAUD)—In it's third and final year, the SMAUD project is developing a variant of Special Materials Decoy that improves countermeasures effectiveness against counter-counter measure (CCM) threats for protection of fixed wing aircraft in the departure and approach phases of a mission. In FY06 the developmental flare will be flight tested to assess it's performance.

Project Engineers—William Taylor, Engineer—and Mike Pershing (USAF, AFRL)

S-04-01 Common Service Exciter—Develop and demonstrate a common architecture radio frequency exciter based on field programmable gate array (FPGA) technology that has 800 MHz of instantaneous bandwidth (IBW) and signal fidelity (>6 bits processing) to effectively jam agile radars. The FPGA technology being developed under this project can provide power efficient wide band exciters capable of coping with current and emerging agile radars.

Project Engineers—Chris Moss (USN, NRL) and George Gonzy (USAF, AFRL)

S-04-02 Countermeasures Susceptibility of Several New Foreign Threat IR Seekers—This project, in its final year, is measuring the countermeasure susceptibility of several new infrared air-to-air and surface-to-air threats that represent a serious threat to US aircraft. The knowledge gained will enable development of the countermeasures required to protect US aircraft from these threats.

Project Engineer—Rick Moore (USN, NRL)

S-04-03 Reactive IR Suppressor—This project is developing an Advanced Reactive IR suppressor system applicable to multiple helicopter platforms that provides a significant reduction in IR signature on demand while eliminating engine performance penalties during non-threat operations. The project has completed developmental ground testing on a ground stand and will conduct flight tests using the fully articulated IR suppressor in FY06.

MH53-J Pave Low

Project Engineers—Kellie Unsworth and Revis Napier (USA, AATD)

S-04-04 Impact of Electronic Limiting on Imaging Seeker Countermeasures—This project is investigating the laser power, pulse repetition frequency and pulse width that will consistently saturate infrared focal plane arrays (FPA) made of known and widely available technologies. Understanding the phenomenology of the laser-FPA interaction will enable the design of more effective laser countermeasures against imaging infrared seekers.

Project Engineers—Rick Moore (USN, NRL) and John Keat (USA, RDECOM)

S-04-05 Low Cost Helicopter IRCM Components for Advanced Threat—To decrease the cost of directed energy IRCM systems, this project is exploring the use of commercial off the shelf laser beam scanning technologies as a limited field of view IRCM laser pointer tracker (P/T). Two potential approaches were identified, one based on the AIM-9X seeker and the other investigating a distributed aperture fiber bundle system. In FY06 key components will be engineered to demonstrate the technology in a field environment.

Project Engineers—Allan Chan and Mike Scott (USA, CERDEC)

S-04-06 Affordable Visible Missile Warning System—This project is developing an affordable visible missile warning system that will detect the launch of portable shoulder-fired missiles at a system cost an order of magnitude less than current IR/UV systems. The final design specifications of the lab prototype missile warning sensor optics and filters were completed in FY05. The FY06 effort will focus on development, evaluation and optical integration of the missile warning system algorithms.

Project Engineer—John McCalmont (USAF, AFRL/SNJT)

S-04-09 Millimeter Wave Electronic Warfare Receiver for Stand-in Jammer—This project is designing, developing and demonstrating a brass board coherent channelized fast-tuning millimeter wave (18-40 GHz) electronic warfare receiver. The receiver will be used in Electronic Attack payload for a UAV/drone Stand-in-Jammer (SIJ)/ Escort Jammer. This broadband MMW receiver is a key enabling technology supporting the requirements of the 2010 Navy and Marine Corp Network-Centric Suppression of Enemy Air Defenses (SEAD) mission.

Project Engineer—Christian Hochuli (USN, NRL)

S-04-10 Millimeter Wave Radar Warning Receiver (RWR) for UAVs—This project is developing millimeter wave hardware that is suitable for use in unmanned aerial vehicles. The project will integrate prototype hardware with existing receiver hardware and demonstrate functionality with flight tests on a UAV. This project fills a gap of small UAV RWRs and pushes the frequency range coverage into the MMW region where many advanced threats operate.

Project Engineer—Pete Bartolomeo (USN, NAVAIR)NAWCAD)

S-05-01 IR Hollow Core Photonic Bandgap Fibers—This project, in its second of three years, is designing and fabricating hollow core photonic band gap (HC-PBG) glass fibers for the transmission and distribution of multi-spectral IR high-power laser energy to various IRCM apertures at the aircraft surface. Using HC-PBG fibers will reduce the weight and cost of directed energy IRCM systems and therefore make them available to more aircraft.

Project Engineer—Dr. Ishwar D. Aggarwal (USN, NRL)

S-06-01 False Alarm Reduction Technology—This two year project will characterize the RF signatures of certain potential false alarm sources identified in the System Specification for Advanced Threat Infrared Countermeasure System / Common Missile Warning System (ATIRCM / CMWS). The data from this effort will help establish requirements for correlation discrimination that can be incorporated in future radar warning receiver upgrade programs.

Project Engineer—Owen O'Neill (USA, I2WD)

S-06-02 Affordable Laser IRCM Survivability System (ALISS)—The ALISS project, over two years, will develop and test a prototype affordable laser IRCM architecture that is lightweight, reliable and affordable. The prototype will be suitable for all modes of testing including limited flight test on operational aircraft.

Project Engineer—William Taylor, Engineer—Lt. Aaron Boesch (USAF, AFRL)

S-06-03 Ground Fire Detection, Classification, and Location—This three year project will develop algorithms for existing sensor systems that enable detection of ground fire events and then extend the algorithms to include ground fire identification friend or foe, classification and location.

Project Engineer—Vince Cassella (USN, NRL)

Vulnerability Reduction

V-04-02 Automatic Engine Fire Suppression System—This project is developing an automatic engine fire suppression system capable of immediately extinguishing fire/explosion allowing continued controlled operation of the affected engine. The project has conducted research and assessed available technologies, developed a prototype system and in 2006 will test its effectiveness against ballistically induced fires. The project is endorsed by the JSF, J-UCAS, and MH-60R programs.

F15-E Strike Eagle

Project Engineer—William Leach (USN, NAVAIR)

V-04-03 RPG Damage Effects Modeling—This project is developing a hydrocode model of a Rocket Propelled Grenade for use in predicting and evaluating the kinetic energy and warhead damage effects against aircraft systems. The project is collecting characterization data on RPG properties and damage effects, developing a model that will be verified and validated with test in 2006.

Project Engineer—Larry Lukens (USA, ATEC)

V-04-07 MANPADS Damage Effects on Large Aircraft Engine—This project will predict MANPADS damage effects on a CF-6 engine using LS Dyna 3D modeling techniques developed with prior years JASP funding. The effort will validate the accuracy of the prediction model and process through correlation with JLF-Air tests in 2006. General Electric and NASA endorse the project.

Project Engineer—Greg Czarnecki (USAF, 46th Test Wing)

V-05-01 RPG Characterization Testing and Model Support—This project is conducting tests to collect previously unavailable data to support development of finite element (LS-DYNA) Rocket Propelled Grenade threat models for application to high-fidelity dynamic structural modeling of threat and aircraft structure interaction.

Project Engineer—Karen McNab (USA, ARL)

V-05-02 Joint Service BDAR Capability Improvement Program (JBCIP)—This project is assessing current tri-service Battle Damage Assessment and Repair (BDAR) capabilities with the objective

Army OH-58D Kiowa

of developing a JASP BDAR roadmap for R&D requirements. The Aviation Ground Support Equipment (AGSE) program endorses the project.

Project Engineer—Doug Carter (USAF, AFRL)

V-05-03 UAV Wing Hydrodynamic Ram Mitigation—This project is investigating, developing, and through test validating hydrodynamic ram mitigation techniques for a light, composite UAV wing structures with integral fuel tanks. The project is providing new insight into the vulnerability of UAV structures and successful mitigation strategies.

Project Engineer—Neil Hamilton (USN, NAVAIR)

V-06-01 Multifunctional Structures for Ballistic Protection—This project will demonstrate an affordable multi-functional integral armor solution for a helicopter floor that provides improved ballistic protection and significant weight reduction, as compared to current parasitic approaches. The project is endorsed by TAPO and SIMO.

Project Engineer—Dr. Mark Robeson (USA, AATD)

V-06-02 Fuel Inerting and Hydrodynamic Ram Attenuation—This one-year project will evaluate the viability of an experimental fuel system that through the introduction of ullage gases or nitrogen and a surfactant is capable of mitigating fire ignition, flame spread, and attenuating the pressure from hydrodynamic ram, thereby minimizing the effect on surrounding aircraft structure.

Project Engineer—Fred Marsh (USA, ARL)

V-06-03 Spaced Armor for Rotorcraft—This two-year project will design, model, fabricate and demonstrate a spaced armor system for rotorcraft that will yield, at a minimum, a 30% weight reduction compared to appliqué steel systems for a given armor-piercing projectile threat. The project is endorsed by TAPO and SIMO.

Project Engineer—John Crocco (USA, AATD)

V-06-04 Hydrodynamic Ram Mitigation through Pressure Wave Interaction—This three-year project will investigate a proof-of-concept strategy for a HRAM mitigation system using pressure wave interaction with a goal of producing a 60 - 80% reduction in overpressure and provide a significant reduction in associated fuel tank failures.

Project Engineer—Dr. Pete Disimile (USAF, 46th Test Wing)

V-06-05 Intumescent Coatings "Instant Firewall" for Passive Dry Bay Fire Protection—This two-year project will demonstrate and optimize intumescent technology to form an "Instant Firewall" in both mid and small wing dry bays to mitigate, extinguish and/or contain a ballistically initiated fire.

Project Engineer—Peggy Wagner (USAF, 46th Test Wing) ■

About the Author

Dennis Lindell is the Joint Aircraft Survivability Program Office (JASPO) Manager. Mr. Lindell has been a member of the JASPO Staff since 2003. Prior to his current position, Mr. Lindell was the Deputy Program Manager for Vulnerability Reduction. He may be reached via phone at 703/604-1104 or via e-mail at jasnewsletter@jcs.mil.

Annual Survivability Awards Presented by the Combat Survivability Division

■ by Dr. Mike Mikel

The National Defense Industrial Association's (NDIA) Combat Survivability Award for Leadership was presented jointly to Jesse T. McMahan and Philip L. Soucy. The Combat Survivability Award for Technical Achievement was presented to Carl S. Carter. These awards were presented at the Aircraft Survivability 2005 Symposium held 1–3 November 2005, at the Naval Postgraduate School (NPS), Monterey, CA. The NDIA Combat Survivability Awards, presented annually at the NDIA Combat Survivability Division's Aircraft Survivability Symposium, are intended to recognize individuals or teams that demonstrate superior performance across the entire spectrum of survivability, including susceptibility reduction, vulnerability reduction, and related modeling and simulation.

Combat Survivability Award for Leadership

The NDIA Combat Survivability Award for Leadership is presented to a person who has made major contributions to enhancing combat survivability. The individual selected must have demonstrated outstanding leadership in enhancing the overall discipline of combat survivability or have played a significant role in a major aspect of survivability design, program management, research and development, modeling and simulation, test and evaluation, education, or standards development. The emphasis of this award is on demonstrated superior leadership of a continuing nature.

Jesse T. McMahan was recognized for outstanding leadership in aircraft combat survivability. During his several years in key Air Force special-program management positions and then as Co-president of Modern Technology Solutions, Mr. McMahan's leadership has been particularly impressive in maturing stealth technology, developing the potential of air-vehicle survivability modeling simulation and analysis, and integrating multiple technical elements into survivability analysis. Mr. McMahan exhibited exceptional leadership in survivability technology, including balancing the stealth, speed, and electronic-combat design elements of advanced aircraft. Through his leadership, air-vehicle survivability requirements, simulation, and testing have become significantly more robust, with increased coordination among the stealth, electronic combat and high-speed communities.

Philip L. Soucy was likewise recognized for outstanding leadership in aircraft combat survivability. As Co-president of Modern Technology Solutions, Mr. Soucy's leadership has been particularly impressive in maturing stealth technology, establishing Low Observables (LO) testing standards, developing the potential of air-vehicle survivability Red Teams, and integrating multiple technical elements into survivability analysis. During a time when LO testing of operational vehicles was just being invented, Mr. Soucy was among the first to realize that it was critical to establish "groundtruth" standards. Through his leadership, air-vehicle survivability testing has become significantly more standardized, with attendant increased confidence.

Mr. McMahan and Mr. Soucy also recognized the need to capture within one company the ability to integrate signature prediction, modeling and simulation, survivability testing, and analysis, all linked by feedback. This vision has contributed substantially to the quality of many of this country's frontline LO weapons systems and their recent performance on the battlefield.

Combat Survivability Award for Technical Achievement

The NDIA Combat Survivability Award for Technical Achievement is presented to a person or team that has made a significant technical contribution to any aspect of survivability. It may be presented for a specific act or contribution or for exceptional technical performance over a prolonged period. Individuals at any level of experience are eligible for this award.

Carl S. Carter was recognized for exceptional technical achievement in aircraft combat survivability. For over 25 years, Mr. Carter has pioneered the development of stealth technologies and their integration into survivable weapons systems at the Lockheed Martin Skunk Works. Over the last 10 years, he has been Lockheed Martin's Chief Engineer for Low Observables Technology. His initial efforts in aircraft signature-management design occurred during the F-117A design phase, for which he was awarded the prestigious Robert E. Gross award in 1982. Mr. Carter also contributed significantly to the F/A-22 Raptor program, enabling the achievement of all signature goals without penalizing aircraft performance. He was a member of a National Science Foundation committee assessing the adequacy and completeness of the US Navy's investments in military aircraft technologies. In signature testing, He energized a combined government and industry team to review government Radar Cross-Section (RCS) test facilities and recommend future investments to advance RCS testing across the industry. Mr. Carter is also currently the Co-Chairman of the F-35 Low Observables Greybeard Review Team.

Best Poster Paper Awards

Three awards were also presented for the best poster papers displayed as part of the symposium's Exhibits and Poster Papers feature. First place went to Paul Wang and Matthew Orr, ITT Industries Avionics Division, for their paper, *New Algorithm Development for Agile Threat Processing*. Second place went to Jeremy Dusina, Skyward Ltd., for his paper, *Enhanced Powder Panel Design Validation and Optimization*. Third place went to Dr. Ron Hinrichsen, RHAMM Technologies, LLC, for his paper entitled, *MANPADS Modeling Methodology Development*. ■

About the Author

Dr. T.N. (Mike) Mikel is the Chief Engineer for Unmanned Aircraft Systems at Bell Helicopter. He has 25 years of experience in the rotary wing aircraft design and survivability disciplines at Bell. He is a former US Army Aviator and Infantry Officer. He holds a BS and two MS degrees from Texas A&M University and a PhD from the University of Texas at Arlington. Dr. Mikel has been a member of the NDIA CSD Executive Board since 2000 and currently serves as the Communications and Publicity Committee Chair.

Left to right: Roland P. Marquis, Chairman, Awards Committee, Combat Survivability Division; Jesse T. McMahan and Philip L. Soucy, Leadership Award recipients; Carl S. Carter, Technical Achievement Award recipient; and Maj Gen John W. Hawley (USAF Ret.), Chairman, NDIA Combat Survivability Division.

Left to right: Dr. Ron Hinrichsen, Paul Wang, and Jeremy Dusina, Poster Paper Award Recipients.

Enhanced Powder Panel Validation

by Jeremy Dusina and Daniel Cyphers

Over the past few years and with the assistance of Joint Aircraft Survivability Program (JASP) funding, investigations have been conducted into upgrading an existing lightweight, passive, fire protection device for aircraft dry bays called a *powder panel*. These investigations were triggered by the recognized needs for effective fire extinguishing agent substitutes for halon and for alternatives to the often heavy, complex, active fire extinguishing systems that frequently get first consideration. Powder panels for ballistic-induced fire protection have been around for years but until recently have not been improved to increase fire protection effectiveness. As a result, they have rarely received serious consideration as a vulnerability reduction design alternative.

Powder panels lining an aircraft dry bay provide fire protection by releasing a fire extinguishing agent on ballistic impact, thereby effectively inerting the volume before combustible liquids that spill into it can be ignited by incendiaries. Powder panels are primarily composed of two thin walls separated by an internal rib or core structure. Current commercial powder panels used for ballistic-induced fire protection contain a lightweight honeycomb core and two thin, composite walls. The void spaces of the core are filled with a fire extinguishing agent in the form of a dry chemical powder. In a military vehicle, powder panels are arranged adjacent to, or on the walls of, a flammable fluid container (fuel tank, fuel line, hydraulic fluid reservoir, *etc.*).

Through the combined efforts of a number of programs, Skyward, Ltd. in Dayton, OH, has been developing an Enhanced Powder Panel (EPP), now patented, that incorporates unique materials and a completely different structural design to increase the effectiveness of the powder panel concept. This development, which began with a clean sheet of paper and some fresh ideas derived from other recent work, shows real potential for a commercial product for vulnerability reduction.

Experimental testing with EPPs began in the fall of 2001 through the Next Generation Fire Suppression Technology Program (NGP). A dry bay/fuel tank simulator was designed and fabricated to directly compare powder panel materials and designs and to examine both pre-existing and improved concepts. This testing was conducted in Range A of the Aerospace Vehicle Survivability Facility at Wright-Patterson Air Force Base (WPAFB), OH. This facility is operated by the US Air Force 46th Test Wing's 46 Operations Group/Munitions Test Division/Aerospace Survivability and Safety Flight (46 OG/OGM/OL-AC). Design efforts focused on material variations and on modifying the honeycomb core design to increase powder panel face fracture on the side exposed to the dry bay, thereby increasing powder release. The honeycomb design isolates the fire extinguishing powder within the cells and tends to permit only those cells penetrated by the projectile to release powder into the void space. New designs permitted the powder to flow freely from the entire panel volume and thus enhanced powder dispersion. This test and evaluation program demonstrated that major performance benefits were achievable with some enhanced design concepts compared with standard powder panel designs. This finding indicated that new powder panel concepts have the potential to significantly enhance the fire extinguishing effectiveness of this vulnerability reduction method.

The EPPs rapidly evolved from concept development to demonstration in the summer of 2002. The EPPs' ability to prevent fire ignition was first demonstrated in a piggy-back test sponsored by the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS), now incorporated into JASP. Tests were conducted in a simulated aircraft dry bay at the Naval Air Warfare Center Weapons Division Weapons Survivability Laboratory (WSL) in China Lake, CA. A second demonstration was conducted in a Federal Aviation Administration (FAA) test program, also at China Lake. This test examined the feasibility of powder panels in preventing fuselage fires in commercial aircraft from the impact of an uncontained engine rotor blade with flammable fluid lines. Both test programs successfully demonstrated the ability of the EPPs to disperse and suspend fire extinguishing powder to a much greater degree than current commercial powder panels. The data also demonstrated that EPPs significantly improve fire extinguishing effectiveness over standard powder panel designs. Enhanced powder panels prevented ignition in all five tests, four JTCG/AS and one FAA. Conversely, fires resulted in all four commercial powder panel tests, two JTCG/AS and two FAA.

Following feasibility demonstration testing, Skyward continued to conduct research on impact dynamics in the NGP project, with a focus on optimizing the EPPs and parametrically examining design variations. Optimization testing indicated that weights were achievable up to 30% below commercial powder panels of the same length and width, with better powder release. Thicknesses as much as 35% thinner than commercial panels were also evaluated. Powder release was an important measurable factor in the testing, because the greater the amount of powder dispersed in the dry bay—particularly along the shotline—the lower the chance of an ignited fire. The percentage of powder loss and front-face area removal was also used as a performance measurement. In one example, the data showed that an EPP can be as much as 19% lighter and 39% thinner than a commercial powder panel, yet release over 10 times more powder mass—30 times greater a percentage of powder originally contained within the panel—and sustain 32% greater front-face area removal. (See Figure 1) Optimization work concluded with documenting examples of how EPPs could be used in a production design at a weight comparable to active fire extinguishing systems.

In the summer of 2003, NGP live fire demonstration tests were conducted of the optimized EPPs and a commercial panel in a dry bay/fuel tank simulator test fixture. The test fixture was composed of a fuel tank (14.0 in W x 2.0 ft H x 1.0 ft along the shotline) and a dry bay area (2.0 ft W x 2.0 ft H x 4.0 ft along the shotline). The fuel tank was filled with 13.5 gallons of Jet Propellent (JP-8) fuel, sufficient to evaluate hydrodynamic ram effects. The dry bay was bolted to the upstream face of the fuel tank. One side of the dry bay was Lexan, allowing observation of the events *via* standard and high-speed video cameras. An access hole on the side was cut in the dry bay to introduce more oxygen into the system, thus creating a more realistic test environment. A striker plate was used to induce a fully functioning round and was placed 1.0 ft upstream from the fuel tank. In every test, the powder panel (commercial and EPP) was placed directly onto the fuel tank wall. These tests revealed that the EPP designs were highly successful at preventing fire (five of six tests), while the commercial panel failed to prevent fire in the only commercial panel test. Although the EPPs were as much as 26% lighter and 29% thinner, the EPPs released at least 87% more powder than the commercial powder panel and the size of the front-face area removed was typically at least 34% better for the EPPs compared with the commercial powder panel. In addition to the aforementioned improvements over the commercial panels, the powder cloud that was produced by the EPPs remains suspended in the dry bay for well over 5.0 min. (See Figure 2)

Although the feasibility of optimized EPPs had been demonstrated, technology was still required for transitioning EPPs into production form for implementation into aircraft. This led to an effort, funded by JASP and sponsored by the 46 OG/OGM/OL-AC, to assist in this goal. This effort provided further examination of the more promising EPP designs and their potential for improving fire protection, while being producible in a practical form and able to survive in a typical aircraft environment. Despite significant increases in powder release for EPPs, it was recognized that there were necessary design balances among weight and thickness, robustness, and fire mitigation effectiveness. Manufacturing and assembly concepts were also conceived and developed during this program to optimize these processes for production application.

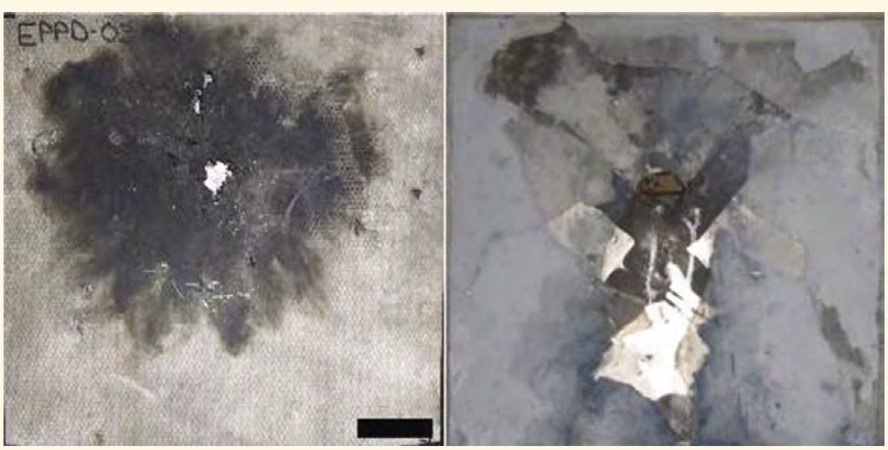


Figure 1. Post-Test Comparison of Commercial (Left) and Enhanced (Right) Powder Panels

Beyond the design effort, a number of additional ballistic tests were also conducted at the AVSF in the dry bay/fuel tank simulator used in previous NGP testing. These tests were designed to ensure that EPP effectiveness was maintained for producibility despite minor design changes. During the JASP test program, commercial powder panels were tested in addition to various EPP designs. Through this test program to refine a production panel, several different EPP designs were evaluated with varying degrees of success. The front-face material and the fire extinguishing powder within the panel were the two most scrutinized variables. In total, 38 EPP tests were conducted in this series, 36 with a 12.7mm Armor Piercing Incendiary (API) threat and the final two with a 23mm API threat. Testing demonstrated the ability of refined EPPs to continue to prevent fire ignition and sustainment even with a varying dry-bay environment, including the introduction of additional oxygen through increased ventilation. One design was even able to prevent ignition during a fully functioning 23mm API test. This was significant in that previous powder panel testing had focused on threats no larger than a 12.7mm API, and the weight of the EPP tested was commensurate with current commercial panels. The two commercial tests, using a 12.7mm API threat, both resulted in a sustained pool fire.

The end result of testing was the selection of three viable EPP designs that could be recommended for integration evaluation, depending on application design requirements. Each design had a unique characteristic that made it ideal for a specific application. One primary design would fit the majority of aircraft applications. A second design is more robust, using material variations, but weighs more. A third design uses a back face that can self-seal the penetration hole produced by a ballistic threat, which mitigates the flow of fuel into the void space of the aircraft and still releases the fire extinguishing agent. All

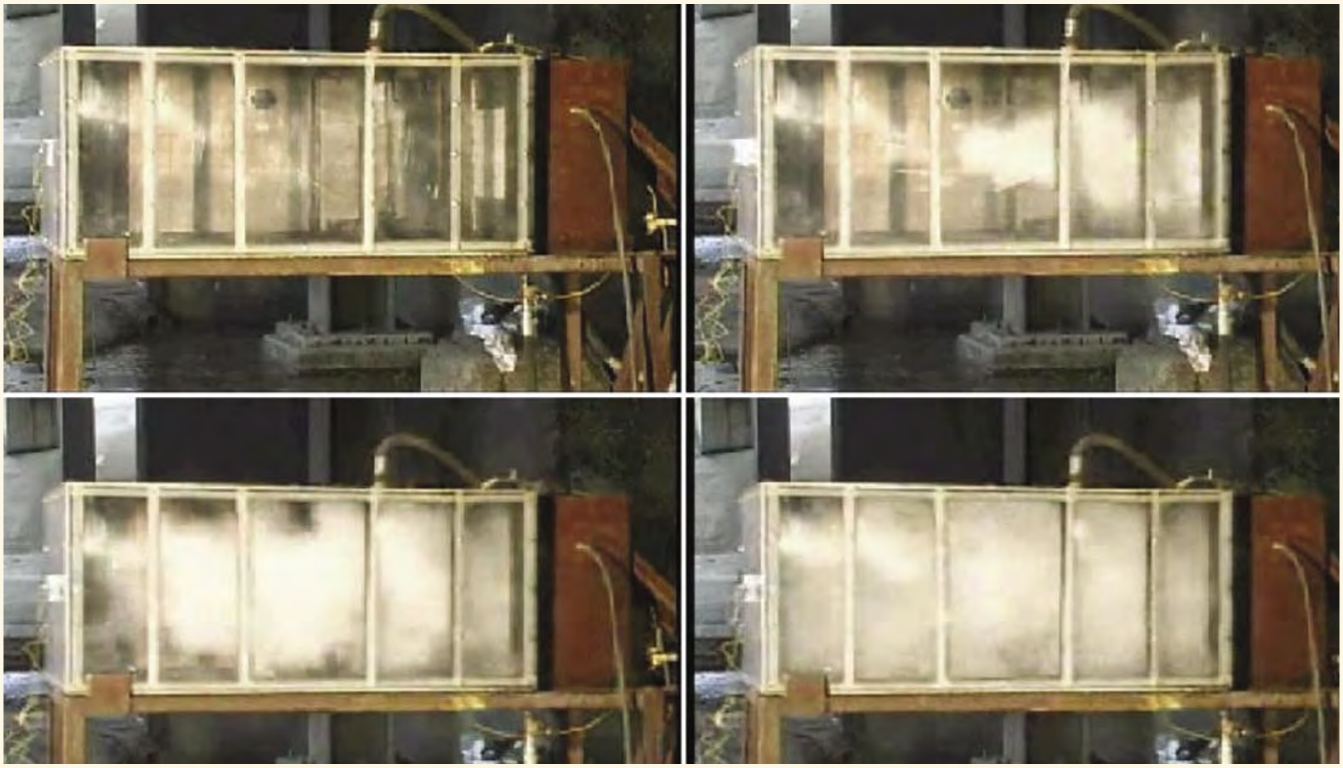


Figure 2. EPP Powder Cloud Expansion

three designs were proven to be successful in preventing ignition in the aforementioned dry bay simulator but have design variations that make them more suitable for certain application requirements.

EPP superiority is clear in a comparison of the three EPP designs and the commercial panel. The EPPs are thinner (less than 0.1 in) and as light or lighter (175–200 g for 1.0 sq ft); yet they produce greater front-face breakup, produce more powder dispersion and improved suspension, and—most importantly—are more effective at preventing fire ignition and sustainment.

Current work focuses on demonstrating EPPs in production or replicated production dry bays. Tests have already been conducted with EPPs in a V-22 aircraft dry bay. A current Joint Live Fire (JLF) program plans to extend these demonstrations to production or replica helicopter and fixed wing aircraft dry bays. Further work will also be done to ready the EPPs for production application, including investigating additional techniques for installing the EPPs, even in difficult dry bay arrangements. This work will also include further investigation of potential requirements for qualification tests.

Although additional work is necessary to ensure EPPs meet the requirements of individual aircraft programs, they are now in a position to be considered seriously as an alternative solution in future fire protection evaluations. The success of EPP investigations continues to generate interest among a number of aircraft programs seeking alternative fire protection methods, including lightweight, passive means. Efforts will continue to address their concerns in preparation for the imminent commercialization of EPPs, and investigations will continue into other applications for these fire protection devices.

Of particular interest to the survivability community as a whole, the evolving EPP story demonstrates the potential for combining the relatively modest resources of JASP and other survivability programs with some ingenuity to advance an effective vulnerability reduction technique from a research concept to the brink of commercialization. ■

About the Authors

Mr. Jeremy Dusina received a BS degree in Mechanical Engineering from Ohio Northern University and is nearing completion of an MS degree in Combustion and Fluids from the University of Cincinnati. He works for Skyward, Ltd., supporting the 46th Test Wing Aerospace Survivability and Safety Flight at WPAFB. Mr. Dusina specializes in aircraft survivability, concentrating on ballistic, threat-induced fire ignition and live fire test analysis. He may be reached by e-mail at jdusina@skywardltd.com or at 937/252–2710, ext 106.

Mr. Dan Cyphers is a Senior Engineer and Manager for Skyward, Ltd. He received a BS degree in Mechanical Engineering and an MS degree in Aerospace Engineering, both from the University of Dayton. Mr. Cyphers has been involved in aircraft survivability/vulnerability testing and analysis for over 15 years, including ballistic live fire test and evaluation and vulnerability reduction concept evaluation. His technical experience also includes aircraft battle damage repair, space environmental effects on advanced materials, and technology transfer. He may be reached via e-mail at dcyphers@skywardltd.com or via phone at 937/252–2710, ext 102.

Continued from Page 11

F-15 Eagle and P-51 Mustang.

make explicit accounting of both equipment and personnel. We need to be able to track progress toward increasing the survival of people, even when an aircraft is downed—whether through improved crashworthiness, ejection systems, or some other means.

- Include approved force protection and survivability KPPs in Test and Evaluation Master Plans (TEMPs), and show how the T&E will address the KPPs.

- In constructing LFT&E strategies, draw on planned T&E to verify compliance with KPPs that are related to asymmetric threats, personnel survivability, and system survivability.

- Assist program offices by providing examples of survivability and force protection KPPs that have been used for similar programs, or propose candidate measures for consideration as KPPs. These measures should help implement the intent of the KPP statute (*i.e.*, focus on reducing attrition and casualties). They should also be objective and capable of evaluation by analysis and/or testing.

- Initiate closer dialog and cooperation between and among the survivability, safety, logistics support, and user communities to strengthen force protection at all levels.

In summary, the KPP statute serves to strengthen DoD's attention to survivability. It is not a T&E statute, but it complements current requirements for survivability T&E. This article identifies possible implications for T&E and possible improvements we can make to ensure the intent of the KPP statute is achieved. ■

About the Author

Dr. Lowell Tonnessen is Assistant Director, Operational Evaluation Division, at the Institute for Defense Analyses (IDA). He looks forward to comment, feedback, and continued discussion of the issues discussed in this article and may be reached by telephone at 703/845–6921 or by e-mail at ltonness@ida.org.

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1. Section 141, "Development of Deployable Systems to Include Consideration of Force Protection in Asymmetric Threat Environments", was implemented as Public Law 108-375. This requirement was quoted in full in Aircraft Survivability, Spring 2005, under the heading "New Requirement for Survivability" (p. 5).

2. Title 10, United States Code, Section 2366 (10USC2366): "Major systems and munitions programs: survivability testing and lethality testing required before full-scale production."

3. JROC Memo, Subject "Policy for Updating Capabilities Documents to Incorporate Force Protection and Survivability Key Performance Parameters (KPP)", 13 June 2005.

4. USD-ATL Memo, Subject "Implementation of Section 141, Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005", 13 December 2005.

5. Chairman Joint Chiefs of Staff Instruction (CJCSI) 3170.01E, 11 May 2005.

Unmanned Aircraft Systems (UAS) Vulnerability Reduction Guide

by Mathias L. Kolleck

The Joint Aircraft Survivability Program Office (JASPO) recently funded the Survivability/Vulnerability Information Analysis Center (SURVIAC) to assess the vulnerability of current fleet Unmanned Aircraft (UA). JASPO's focus on UA survivability derives from the traditional perspective that survivability in general and vulnerability in particular were not given much consideration in Unmanned Aircraft System (UAS) designs. The common mind-set in the UAS design community has been that UA were attritable because there were no humans on board and they were "inexpensive."

To the extent that UASs possess low or reduced observable attributes— seamless composite skins, fewer windows and hatches, and/or smaller sizes— they are inherently optimized for some level of survivability. Beyond that level, however, trading performance and/or cost for survivability ran counter to the prevailing perception that, to justify their acquisition, UASs had to be cheaper, more attritable versions of manned aircraft. Losses were to be expected and tolerated.

This mind-set is currently being reexamined. UAS costs are escalating significantly. The cost of only the Global Hawk aircraft is approximately $20M (FY02$). The Global Hawk system, including payload and sensors, is estimated at $57M (FY02$). [1] This significant increase in cost has forced the Air Force to notify Congress that the average Global Hawk unit cost has increased by 18%, which violates the Nunn–McCurdy Amendment. [2] In addition, the technologies currently being placed on the UA are such that the Department of Defense (DoD) does not want these technologies falling into enemy hands.

This change in system design philosophy is reflected in the new Unmanned Aircraft Systems Roadmap 2005–2030, which was released by the Office of the Secretary of Defense (OSD) in August 2005. This updated roadmap contains an appendix dedicated to UA survivability. The appendix states that it is imperative that the survivability of a UA be a key consideration during the system design process, and it emphasizes that survivability design features should be considered with respect to the UA's size, required mission, and the potential threat environment. Potential survivability design features are presented covering vulnerability and susceptibility reduction. "These potential design features should be considered in the systems engineering design process to develop the most effective UA for the lowest life-cycle cost." [3]

This document also introduces some terms specific to UA survivability:

- **Expendable**—the UA is minimally survivable.
- **Attritable**—the UA is somewhat survivable.
- **Survivable**—the UA is highly survivable.

The survivability of a UA can be enhanced by either reducing its likelihood of being detected (susceptibility) or reducing its likelihood of being destroyed if it is hit (vulnerability). Vulnerability reduction is most effectively accomplished early

Global Hawk

in the design process, when component sizes, locations, materials, construction, and redundancies are evaluated and analyzed. It is during this early stage that the vulnerability of the aircraft should be reduced to its lowest level possible, within the constraints of cost, flight performance, weight, maintainability, and other important attributes that contribute to overall effectiveness. Analysis tools used for vulnerability assessments of manned aircraft are also available and applicable to UA, as are vulnerability reduction technologies, many of which can be retrofitted to current UA.

Background

The US military has a long and continuous history of involvement with UA. UA have been used in combat since 1944 when the TDR-1 assault drone, guided by a pilot-in-the-loop using television, was used to drop bombs on Japanese positions in the Pacific. UA have also had active roles in the Vietnam, Persian Gulf, and Balkans conflicts. Furthermore, as the Global War on Terrorism (GWOT) enters its fourth year, the contributions of UA in sorties, hours, and expanded roles continue to increase. As of September 2004, coalition UA have flown over 100,000 total flight hours in support of Operation Enduring Freedom and Operation Iraqi Freedom. Furthermore, with recent technology improvements that permit more capability per pound, today's UA are more sophisticated and capable than ever. As the military's operational tempo has increased, so too has the use of UA, including performing an expanding range of missions, *e.g.*, Intelligence, Surveillance, and Reconnaissance (ISR), Suppression of Enemy Air Defense (SEAD), Destruction of Enemy Air Defense (DEAD), Electronic Attack (EA), anti-surface ship warfare, anti-submarine warfare, mine warfare, ship to objective maneuver, and communications relay. With this expanded role, UA have helped reduce the complexity and time lag in the sensor-to-shooter chain for acting on "actionable intelligence."

The advantages offered by UA to military commanders are numerous, most notably in mission areas commonly categorized as "the dull, the dirty, and the dangerous":

The Dull—During the Kosovo conflict in 1999, B-2 crews flew 30-hr roundtrip missions from Missouri to Serbia for 34 days. The normal two-man crews were augmented with a third pilot, but fatigue management was still the dominant concern of unit commanders. The post-Kosovo RAND Corporation assessment determined that:

- increasing crew ratios to address this issue would require increasing the number of training hours and sorties flown by the Air Force's limited B-2 inventory, or
- reducing the number of training sorties and flying hours available to each crew member would unacceptably compromise his or her operational proficiency and expertise.

This situation should be contrasted with the nearly continuous string of day-long Predator missions over Afghanistan and Iraq that have been flown by stateside crews operating on a four-hour duty cycle for almost two years. The UA is preferable to a manned aircraft in providing better sustained machine alertness over that of a human being.

The Dirty—The Air Force and Navy used unmanned B-17s and F-6Fs from 1946 to 1948 to fly into nuclear clouds within minutes after bomb detonation to collect radioactive samples. Returning UA were washed down by hoses, and samples were removed by cherry-picker-type mechanical arms to minimize the exposure of the ground crew to radioactivity. In 1948, the Air Force decided the risk to aircrews was "manageable" and replaced the UA with manned F-84s whose pilots wore 60-lb lead suits. Some pilots later died because they were trapped by their lead suits after crashing or by the long-term effects of radiation. Manned missions to sample nuclear fallout continued into the 1990s. Reduced costs in the loss of fewer human lives by radiation exposure makes the UA the platform of choice for these types of dirty missions.

Predator

Global Hawk

The Dangerous—Reconnaissance has historically been a dangerous mission; 25% of the 3rd Reconnaissance Group's pilots were lost in North Africa during World War II compared with 5% of bomber crews flying over Germany. When the Soviet Union shot down a US U-2 and captured its pilot on May 1, 1960, manned reconnaissance flights over the USSR ceased. This incident and other losses drove the Air Force to develop UA for this mission—the AQM-34 Firebee and the Lockheed D-21. The loss of seven of these UA over China between 1965 and 1971 went virtually unnoticed. Thirty years later, the loss of a Navy EP-3 and the capture of its crew of 24 showed that manned peacetime reconnaissance missions remained dangerous and politically sensitive. Lower political costs, lower human costs if the mission is lost, and greater probability that a mission will succeed are strong reasons for selecting UA for these types of dangerous missions. [4]

The increased use of UASs in these types of missions will result in potential exposure to extremely high concentrations of enemy ground fire. This intense ballistic threat will pose a formidable hazard to UA. Accordingly, future UA will need to use protection techniques that can defeat these increased threat levels.

Vulnerability Reduction Guide

To address these issues, the JASPO tasked SURVIAC with developing a UAS Vulnerability Reduction Guide. This completed document provides UAS designers with proven techniques to decrease UA vulnerability to combat damage and explains these techniques to the UA community. Results of this effort will benefit all future UAS design work or upgrades to current UA by focusing the design engineers on relatively easy and cost-effective options for reducing the vulnerability of their platforms. Six concepts can be used to reduce the UA vulnerability:

- **Component Redundancy, with Separation**—In *component redundancy*, redundant components must be effectively separated to minimize the probability that both components can be killed by the same hit.

- **Component Location**—*Component location* requires the positioning of a component to minimize the probability and extent of damage.

- **Passive Damage Suppression and Active Damage Suppression**—the *passive damage-suppression* concept uses no damage sensing capabilities, while an *active damage-suppression* concept uses a sensor or other device. This device senses when a hit occurs and activates a function that either contains the subsequent damage or reduces the effects of damage.

- **Component Shielding**—*Component shielding* places ballistically resistant materials; *e.g.*, armor, in front of a critical component to prevent it from being hit.

- **Component Elimination or Replacement**—Critical *component elimination or replacement* either removes a critical component; *e.g.*, the pilot, or replaces a critical component with a less vulnerable one.

Each vulnerability reduction concept has numerous techniques associated with it. A vulnerability reduction technique is the use of any design technique or piece of equipment that controls or reduces the amount or the consequence of damage to the aircraft when it is hit.

To serve as a baseline for the Guide, seven current fleet UA were assessed to determine which vulnerability reduction techniques were incorporated: Global Hawk, Predator, Pioneer, Hunter, Fire Scout, Eagle Eye, and Shadow 200. The assessments determined that each platform had multiple vulnerability reduction techniques, the most common being redundant, adequately separated components. Also, it was evident from the assessments that no design consideration was given to protecting the UA from fire and explosion by using active fire-suppression systems, self-sealing fuel tanks and lines, or ullage inerting. More detailed results are presented in the Guide. It must be emphasized that these assessments were based on limited data obtained from various sources.

To further assist UAS designers in developing less vulnerable platforms, the Guide also includes a summary table of vulnerability reduction techniques. These techniques are presented on a systems basis, and each is identified as one that could either be retrofit on existing platforms or would have to be incorporated in a new platform design. The various aircraft systems that were considered include the fuel, structures, propulsion, flight-control, avionics, and electrical systems. ■

About the Author

Mr. Kolleck has 21 years of experience in the area of survivability/vulnerability with the Aeronautical Systems Center, Wright Patterson Air Force Base, OH,. He has extensive experience in the area of fire suppression technology, having supported the Joint DoD/FAA Halon Replacement Program for Aviation and the National Institute of Standards and Technology (NIST) Next Generation Fire Suppression Technology Program (NGP). He has also served as an Adjunct Instructor at the Air Force Institute of Technology where he taught the aircraft survivability course. Mr Kolleck earned his BS in Aerospace Engineering from the University of Cincinnati and his MBA in Finance and MS in Economics from Wright State University. He may be reached at Mathias.Kolleck@wpafb.af.mil.

References

1. Unmanned Aerial Vehicles Roadmap 2002–2027, December 2002, pg 32.
2. As part of the Defense Authorization Act for Fiscal Year 1982, Senator Sam Nunn (D-GA) and Representative David McCurdy (D-OK) included language intended to limit cost growth in major weapons programs, known as the Nunn–McCurdy amendment.
3. Unmanned Aircraft Systems Roadmap 2005–2030, August 2005, pg K-5.
4. Unmanned Aircraft Systems Roadmap 2005–2030, August 2005, pg 2.

Calendar of Events

MAY

1–4, Newport, RI
47th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 14th AIAA/ASME/AHS Adaptive Structures Conference, 7th AIAA Gossamer Spacecraft Forum, 2nd AIAA Multidisciplinary Design Optimization Specialist Conference, 8th AIAA Non-Deterministic Approaches Conference
https://www.aiaa.org/content.cfm?pageid=230&viewcon=register&lumeetingid=1172

1–5, Reno, NV
American Society for Photogrammetry & Remote Sensing Annual Conf 2006
Conference Rate: http://www.caesars.com/reservations/main.aspx?hotelid=06&specialgroupcode=ASPRS / Government Rate: http://www.caesars.com/reservations/main.aspx?hotelid=06&specialgroupcode=ASPGNT

2–5, London, United Kingdom
Sixth EW/IO Conference and Expo
https://www.myaoc.org/EWEB/dynamicpage.aspx?webcode=06_London_Home

JUN

5-8, San Francisco, CA
36th AIAA Fluid Dynamics Conference and Exhibit, 24th AIAA Aerodynamic Measurement Technology and Ground Testing Conference, 25th Applied Aerodynamics Conference, 37th AIAA Plasmadynamics and Lasers Conference, 3rd AIAA Flow Control Conference, 9th AIAA/ASME Joint Thermophysics and Heat Transfer Conference
http://www.aiaa.org/content.cfm?pageid=230&lumeetingid=1188

19–23, Colorado Springs, CO
JMUM 2006
jeng_paul@bah.com

JUL

9-12, Sacramento, CA
42nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit
http://www.aiaa.org/content.cfm?pageid=230&lumeetingid=1178

11-13, Boeing Kent Space Center, Kent, Washington
Aircraft Combat Survivability Short Course
http://jas.jcte.jcs.mil/

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

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