

# 16

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# AIRCRAFT SURVIVABILITY

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The U.S. Marine Corps KC-130J Harvest Hercules Airborne Weapon Kit (designated Harvest HAWK) provides the KC-130J tactical refueller aircraft with multi-sensor imagery reconnaissance (MIR) and close air support (CAS) capabilities. When configured, the armed KC-130J includes the addition of weapon systems, facilities, and personnel to control those weapon systems. The Harvest HAWK mission system is a response to an urgent need of the Marine Corps to provide a roll-on, roll-off (RORO) system that quickly adds MIR and CAS capabilities to an existing airframe.

## 20 GOBIGGS: THE NEW PLAYER IN EXPLOSIVE ULLAGE TREATMENT

*by Raymond (Lou) Roncase, Jr.*

The Green On-Board Inert Gas Generating System (GOBIGGS), developed by Phyre Technologies Inc., has been selected by Sikorsky Aircraft Corp. as the next-generation system to inert explosive ullage gasses. GOBIGGS was selected as a component system of the Combat Tempered Platform Demonstration (CTPD) Project awarded to Sikorsky in 2012. The CTPD project is a \$12-million demonstration program tasked to develop and integrate a suite of advanced technologies (some having previously low technology readiness levels [TRLs]) to increase the performance and survivability of U.S. military platforms.

## 23 NAWCWD COMPLETES MOST COMPLEX WEAPONS SURVIVABILITY TESTS TO DATE

by Brian Wulfekotte and Ron Schiller

On 7 April 2015, the Naval Air Warfare Center Weapons Division (NAWCWD) successfully supported the KC-46 tanker program with the most detailed, advanced weapons survivability test series ever conducted at the Weapons Survivability Lab (WSL) in China Lake, CA. The KC-46, a derivative of the commercially available Boeing 767-2C, is a refueling aircraft. An estimated 179 KC-46's will be procured to replace one third of the existing aerial refueling fleet.

## 25 CREW COMPARTMENT FIRE SURVIVABILITY

by Adam Goss

Air vehicle fatalities over the past decade have prompted defense leaders to emphasize crew protection as a focus area for survivability program initiatives. In 2014, a crew compartment fire survivability project was conducted to investigate the impact of environmental hazards on combat personnel during fire events inside medium-sized transport military aircraft. The project was based on the premise that occupants may not have sufficient time or technology to effectively suppress the fire.

## 28 EXCELLENCE IN SURVIVABILITY: SUZAN DEROSA

by Rich Hampson

The Joint Aircraft Survivability Program (JASP) is pleased to recognize Ms. Suzan (Suzi) DeRosa for her Excellence in Survivability. Suzi is currently the Survivability, Live Fire Test and Evaluation (LFT&E), and Classified Lead for the Combat Rescue Helicopter (CRH) Program at Sikorsky Aircraft Inc. in Stratford, CT. She is responsible for total survivability integration, vulnerability testing, survivability requirement compliance, and execution of the LFT&E Program for the Air Force's future HH-60W platform. She is being specifically recognized for her vulnerability reduction work on the Combat Tempered Platform Demonstrator (CTPD) program in the area of increased fire protection.

## 30 NDIA COMBAT SURVIVABILITY DIVISION PRESENTS 2015 COMBAT SURVIVABILITY AWARDS

by Robert Gierard

On 5 November 2015, the National Defense Industrial Association (NDIA) Combat Survivability Division (CSD) Awards Committee, joined by CSD founder Rear Adm. Robert Gormley, presented its Combat Survivability Awards during the group's annual Aircraft Survivability Symposium at the Naval Postgraduate School (NPS) in Monterey, CA. The awards were given in recognition of superior contributions to combat survivability in the areas of leadership, technical achievement, and lifetime achievement.

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## NAWCWD HOSTS FIRST AIRCRAFT COMBAT SURVIVABILITY SHORT COURSE

The Combat Survivability Division of the Naval Air Warfare Center Weapons Division (NAWCWD) China Lake hosted its first Aircraft Combat Survivability short course in April 2015. The three-day course was attended by 65 Navy, Army, Air Force, and Marine Corps civilians and military, as well as various industry representatives from across the United States who work in aircraft survivability fields.

The course was designed to provide a detailed description of the various aspects of combat aircraft survivability. Instructors used actual live fire test data from the Weapons Survivability Laboratory (WSL) and modeling and simulation methodologies provided by the NAWCWD Survivability Assessment and Vulnerability branches to supplement the course content.

Dr. Sandra Ugrina, the Deputy Director for Live Fire Test and Evaluation in the Office of the Secretary of Defense (OSD), served as a guest instructor for one of the sessions. Overseeing survivability and lethality testing and evaluation of major Department of Defense (DoD) systems and munition programs, Dr. Ugrina shared with attendees some of the finer points of her office structure and operation and emphasized that the community “must think differently, be innovative.”

Although the course was the first to be held at China Lake, it has been conducted annually for more than 20 years at various locations. Lt. Col. Richard Huffman, National Range Combat Survivability (RCS) Test Facility Commander, has served as an instructor for 23 years. In talking about his involvement with the course, he said “it is a passion of mine to see our crews come home from missions.”

Ms. Brooke Corbett, of the Institute for Defense Analyses, stated that the course “was a thorough and tangible introduction to issues the survivability community encounters that was well supported with real world applications.”

In addition, Ms. Sharon Gee, a radiation and information warfare designer from Northrup Grumman, added that because she now understands the mindset that goes into building an aircraft, she can apply that thinking to what she designs and “think outside the box.” [ASJ](#)

## AIRCRAFT CBR CONTAMINATION SURVIVABILITY WORKSHOP

On 30 April 2015, the National Defense Industrial Association (NDIA) Combat Survivability Division (CSD) sponsored its annual workshop, titled “Aircraft Chemical, Biological, and Radiological (CBR) Contamination Survivability (CS).” More than 35 professionals from Government, industry, and academia attended the event, which was held at the Institute for Defense Analyses in Alexandria, VA.

The workshop was led by Ms. Helen Means, from the Department of Defense (DoD) Joint Chemical, Biological, Radiological, and Nuclear (CBRN) Defense Program Analysis and Integration Office. Ms. Means provided attendees with insight into ongoing



**Figure 1** Dr. Sandra Ugrina Speaks to Students at the First Aircraft Combat Survivability Short Course Hosted by the Combat Survivability Division of NAWCWD, China Lake (U. S. Navy Photo by Ron Rodriguez)

programs as well as operational perspectives to improve capabilities to harden and decontaminate aircraft and protect pilots, aircrew, and ground maintenance personnel.

In the opening session, Mr. Monty Pugh from the Naval Air Systems Command discussed lessons learned from the 2011 Operation Tomodachi and described the extensive procedures that were followed after aircraft from two carrier battle groups were exposed to potentially hazardous radiation levels as they supported the rescue and recovery operations after the earthquake and tsunami in Japan. The incident served to

illustrate the complexity and time-consuming aspects of thoroughly decontaminating aircraft and of the resultant potential operational impacts.

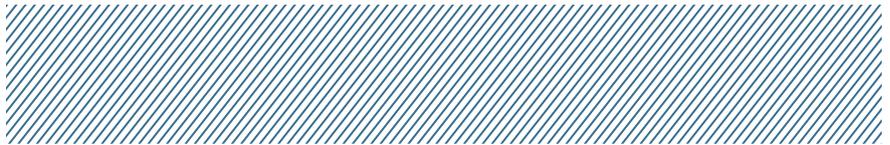
Other workshop briefings discussed the CBR CS requirements for aircraft in general (and the Joint Strike Fighter in particular), the ongoing development program for the Joint Service Aircrew Mask-Joint Strike Fighter variant, the status of the Joint Biological Aircraft Decontamination System, and perspectives and trends from the Defense Threat Reduction Agency Joint Science and Technology Office and the U.S. Strategic Command.

As with previous workshops, recommendations from the workshop were provided to the DoD to enhance the state of aircraft survivability. [ASJ](#)



## JCAT CORNER

by CW5 Mike Apple, Capt. David Storr, and Maj. Ron Pendleton



The mission of the Joint Combat Assessment Team (JCAT) mission has not changed in the past year, but we have adapted our processes considerably. The JCAT was pulled out of theater in late 2014 and has had to rely on alternate means to collect battle damage in both Afghanistan and Iraq. Since 2003, forward deployed JCAT assessors have responded to more than 1,400 battle damage events and have supported aviation commanders in reporting aircraft battle damage. With the help of the intelligence community, these assessors have also used the collected data to capture friendly trends and enemy tactics to reduce future events. Additionally, they have documented damage in the Combat Damage Incident Reporting System

(CDIRS) to support lessons learned and improve aircraft survivability design.

The Army JCAT has had to use an alternate method to collect this vital information, relying on the Army Tactical Operations (TACOPS) officers that were already supporting the JCAT program embedded in their Brigades. Fortunately, a few years ago, the Army JCAT began training the TACOPS officers and Maintenance Test Pilots (MTPs) to collect aircraft battle damage information while these personnel were in their formal training schools. It was found that the best time to train TACOPS officers and MTPs was while they were in their training courses at Fort Rucker, AL. The Army JCAT trained TACOPS officers and MTPs to photograph

aircraft battle damage and to send all relevant information to the Army JCAT at Fort Rucker. The Army JCAT also established procedures to support deployed TACOPS officers by producing a final assessment for TACOPS officers to brief commanders and air crews and uploading the report into CDIRS, thus completing the process. The Army JCAT's deployment mission also hasn't changed, and the team will continue to deploy for catastrophic events.

The Navy JCAT has created a Rapid Response capability to support U.S. Navy (USN) and U.S. Marine Corps (USMC) aviation. The Navy JCAT mission resides in the U.S. Navy Reserve Program that supports the U.S. Naval Air Systems Command



**Figure 1** The 2016 JCAT Class



**Figure 2** 2015 TWE MANPADS Demonstration

(NAVAIRSYSCOM). The Navy JCAT maintains a team of U.S. Naval Reserve Officers who are ready to respond worldwide to an aircraft battle damage event.

In addition to changing our processes for collecting aircraft battle damage this year, the JCAT has hosted effective training events. JCAT phase 1 training was hosted by the Army JCAT and was a huge success. During this event, 33 personnel from Army, Navy, and Air Force JCAT programs came to Fort Rucker to begin their training in aircraft battle damage collection. In addition to training military personnel on collecting battle damage information, Phase 1 JCAT training included an introduction to threat weapon systems and detailed instruction on aircraft survivability systems. For the final part of the Phase 1 course, personnel were tasked to collect aircraft battle damage information and assess numerous damaged aircraft in

the Army JCAT's "boneyard." The assessors used the information they collected to produce executive summaries of aircraft battle damage. Phase 1 JCAT training prepared the personnel who attended for the next phase of their training at China Lake Naval Air Station (NAS), which will be conducted by the Navy JCAT. Of note, the Army personnel who completed JCAT Phase 1 training deployed soon afterward and are now using the skills they learned in support of deployed units.

Once again, Navy Reserve In-Service Engineering and Logistics (ISEL) Detachment Bravo, based at Naval Air Weapons Station, China Lake, CA, will play host to Phase 2 for 20 personnel from the Army, Navy, and Air Force. Students will be taught the art and skill of assessing and reporting battle damaged aircraft. Upon completion of this training, these new assessors will be prepared for deployment and will be

capable of conducting detailed forensic assessments on battle damaged aircraft and professionally debriefing their findings. The Naval Air Warfare Center Weapons Division (NAWCWD) command has played host to Phase 2 for more than a decade. This site offers students a number of unique advantages, including a vast on-site inventory of weapons effects showcasing a majority of enemy threats; accessibility to technical experts, acquisition professionals, and survivability engineers; and exposure to a 330-acre training range that simulates two different downed aircraft scenarios, giving students a greater degree of preparedness for real-world situations. The week will be highlighted by a night-time field exercise, a survey of a real crash site, and socials designed to strengthen interservice collaboration and partnerships.

The 2015 Threat Weapons Effects (TWE) training was a great success, with much positive feedback from the attendees. Training was conducted by the Army JCAT at both Hurlburt Field and Eglin AFB, FL, in late April. Briefings were conducted in the Hurlburt Theater, and live fire events were conducted at Eglin AFB ranges. Attendees included JCAT and TACOPS officers, intelligence communities, survivability experts, and aircrews from all of the Services. The live fire event at the 2015 TWE took all participants out to the range, where rockets and missiles were fired at various rotary-wing aircraft to assess the weapons effects. Participants were also able to build relationships through the cross-talk of all of the Services during the discussions and scheduled breaks. The 2016 TWE will be run by the Air Force JCAT.

In addition to developing new processes for collecting aircraft battle damage

information and participating in training events, the JCAT worked to improve the accuracy and availability of aircraft battle damage information. To do this, the Army, Navy, and Air Force JCATs came together to improve the CDIRS database. Standardized drop-down menus were implemented, and instructions for inputting data were added. These changes were crucial to improving the CDIRS database, but they will require the Services to go back into all of the events and to make the changes. There is still a lot of work ahead, but it will be worth the effort.

In addition, in September 2015, the JCAT program supported a Joint Live Fire (JLF) Warhead Effects project (T-14-02), providing subject-matter experts (SMEs) from each of the Services to the 96 Test Group (TG). Specifically, the JCAT, with NAWC and 96 TG assistance, opened the aircraft (F-16C) and scored internal damage created by Blue and Red missile tests. The aircraft collection project benefited the Joint Aircraft Survivability Program (JASP) project as well as provided valuable experience to all the JCAT assessors involved.

This year, the Army JCAT also began working with the U.S. Army Aeromedical Research Laboratory (USAARL) and Joint Trauma Analysis and Prevention of Injury in Combat (JTAPIC) in the assessment of aircraft combat losses. However, the current assessment process for aircraft combat losses includes neither formal analyses of the injuries or deaths of the occupants nor performance of personal protective equipment (PPE), the vulnerability of occupants, or survivability considerations. JTAPIC has agreed to examine the CDIRS database and to research occupant injuries using medical databases. It will then compare the entries to establish or discount links

between combat aircraft losses and specific injuries. Like the standardization of CDIRS entries described previously, this will be tedious work, but it could provide great insight into improvements in current and future aircraft.

The JCAT's Army Component underwent a chain-of-command realignment that will place the team under the Army Aviation Center's Capabilities and

Requirements Division (CRD), aligning the team with Army Aviation's requirements managers and combat developers. This move will better integrate the data collected during combat assessments into both modifications to current platforms to enhance survivability and support the combat development community as they determine the path ahead to the Army's next generation rotorcraft.



**Figure 3** 2105 TWE Weapons Effects Demonstrations

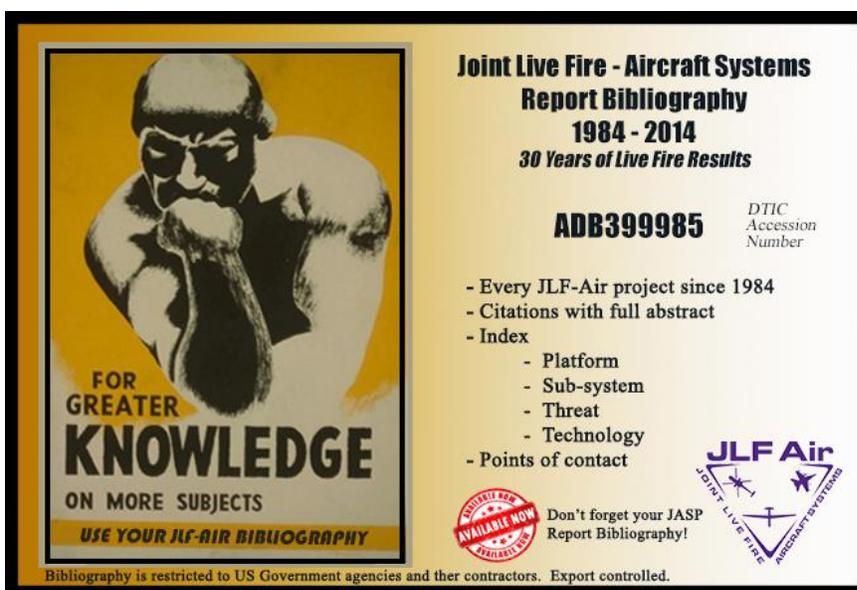
The Army JCAT is also undergoing significant personnel changes this past year. CW3 Brian Bartee, retired after 23 years of service, and CW3 Nels Bergmark is transferring back to a flying assignment with the 4th Combat Aviation Brigade at Fort Carson, CO. As they depart, the team is adding CW4 Mitch Villafania, who is coming from the 101st Combat Aviation Brigade; CW4 Bart Schmidt, who is coming from an assignment in Germany; and CW3 Chris Crawford, who was an instructor for the TACOPS course. All of these Army JCAT teammates were recruited as SMEs in the TACOPS field, and they bring a wealth of experience based on their deployments. Last but not least, Mr. Warren ("Jeff") Whitmire was hired to fill our vacant Intelligence Specialist position. Jeff is a retired Army Intelligence officer with experience supporting aviation units.

The Air Force JCAT also had some changes in personnel in 2015. The long-time first-level supervisor of the Air Force JCAT, Mr. Larry Taranto, moved to a different position within the organization. His replacement has yet to be announced. Also, the Deputy Director of the Engineering Directorate, Col. Michael Meyer, has changed assignments and will be replaced by Col. Russell Kurtz.

The Air Force JCAT continues to work with the Air Force Reserve Command, Life Cycle Management Center, and Air Force Materiel Command on ensuring long-term sustainability of the Air Force JCAT program. Restoring a sufficient level of personnel is a top priority, and recent developments in DoD-level guidance have helped tremendously. Two highly qualified candidates have been identified as new additions. Their transfer is pending approval in the assignments process.

Finally, the Air Force JCAT is leading the preparations for TWE 2016, which will take place at Hurlburt Field and Eglin AFB, FL, 26–28 April. The training draws information from threat exploitation, live fire testing, and combat experience to provide a complete picture on threat lethality. Hands-on experience is provided with threat munitions/missiles, test articles, and damaged aircraft hardware. The live-fire demonstration will simulate weapons effects for personnel that assess combat damage to aviation

platforms. This year's demonstrations will include firing of an Avenger, static warhead detonations, unguided weapons, small arms, antiaircraft artillery cannons, and rocket-propelled grenades. For more information and registration, visit <https://www.dsiac.org/resources/events/2016-threat-weapon-and-effects-training>. **ASJ**



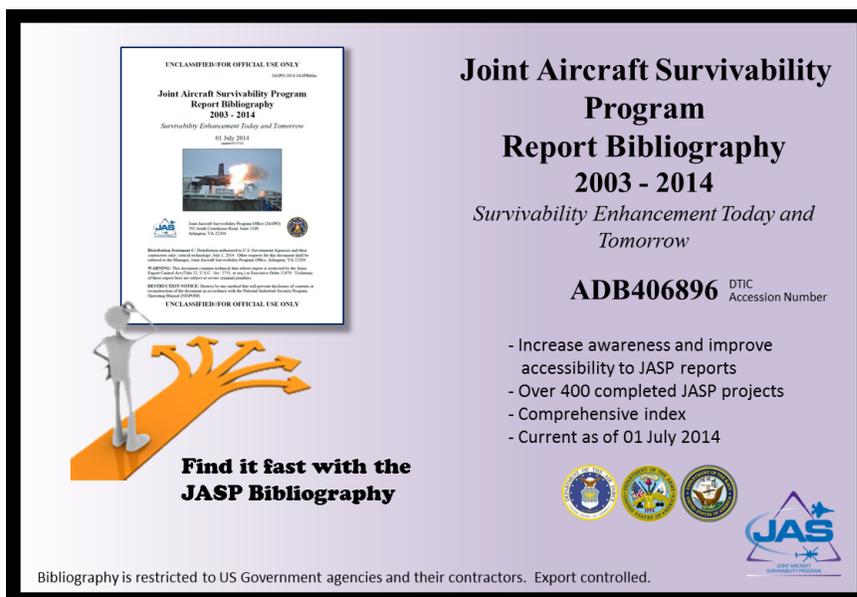
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# THE DEFENSE SYSTEMS INFORMATION ANALYSIS CENTER: TRANSFORMING INFORMATION INTO KNOWLEDGE

By Thomas Moore



To comply with a number of federal government initiatives to reduce duplication, the Defense Technical Information Center (DTIC) completed the most transformative change in the 65-year history of the Department of Defense (DoD) Information Analysis Center (IAC) program, streamlining 10 distinct IAC contracts into 3 consolidated basic centers of operation. The establishment of the Defense Systems Information Analysis Center (DSIAC) in January 2014 consolidated six of these legacy IACs, including the Survivability/Vulnerability Information Analysis Center (SURVIAC), which had served the community for nearly three decades. The SURVICE Engineering Company, which supported SURVIAC in a subcontractor role, became the operator of the new DSIAC as the result of an Air Force

small business competitive acquisition. Although DSIAC's main offices are located in Belcamp, MD, satellite operations are maintained in the former SURVIAC space at Wright-Patterson Air Force Base, OH, to conduct classified operations and distribute survivability and vulnerability (S&V) models for the DoD. In addition to supporting S&V, DSIAC now also supports eight other communities of practice, as shown in Figure 1.

DSIAC's primary objective is to facilitate access to scientific and technical information (STI) and provide cost-effective technical analysis and research and

development support for the U.S. defense systems community. To help researchers, engineers, scientists, and program managers use and exploit STI to support problem solutions and maximize return on DoD investments, DSIAC maintains an extensive knowledge base, which includes subject-matter experts (SMEs) as well as a supporting repository of historical, technical, and scientific data and information. The primary source of STI is the controlled access DTIC Research and Engineering (R&E) Gateway, which contains more than 4 million defense-related technical reports and full-text documents. Approximately one-third of the DTIC



**Figure 1** DSIAC's Nine Communities of Practice

collection is full-text searchable and available for electronic download. The remaining reports are discoverable by metadata search and can typically be acquired by specific request from DSIAC or DTIC. As a value-added resource for DoD researchers, DSIAC also has access to other DoD and non-DoD STI repositories for maximum penetration of subject areas.

In addition to identifying and disseminating STI to qualified recipients, DSIAC also researches and answers technical questions—referred to as “technical inquiries” or “TIs”—from the community. TIs are a signature service of the IAC program, often representing DSIAC’s first contact with a customer. These inquiries can range from a simple document request to a structured literature search to a detailed question on a system or technology. DSIAC researches and answers most TIs using its core staff, supplemented as needed by a larger network of SMEs to provide additional technical bench strength. DSIAC’s basic TI service is free; however, it is limited to 4 hours of staff research per customer inquiry. In addition, customers must meet eligibility and need-to-know requirements for access to DoD limited distribution, export-controlled, and/or classified information.

For more extensive technical support, Government customers can use DSIAC’s pre-competed Core Analysis Task (CAT) indefinite delivery, indefinite quantity (IDIQ) contract vehicle. For example, the Joint Aircraft Survivability Program (JASP) leveraged a CAT delivery order for SURVICE and DSIAC to expand their support of the JASP and S&V community. This support now includes the administration of the JASP Model Users Meeting (JMUM), publication and distribution of the *Aircraft Survivability*

journal, maintenance of the JASP website, and the publication of the next edition of the *JASP Specialist Directory*, which is scheduled to come out this summer. Each DSIAC CAT delivery order is limited to a 12-month period of performance and may not exceed \$1 million in value. The lead time from completion of a Performance Work Statement (PWS) to delivery order award can be as little as 2 months.

If a customer requirement is expected to exceed the CAT time/funding threshold, a more expansive IAC contracting vehicle called a Technical Area Task (TAT) may be used. A TAT is a separate multi-award contract vehicle that is competed among a pool of large prime contractors and that may have a period of performance greater than 12 months. More information on IAC contracting vehicles can be found on the DTIC IAC website at <http://iac.dtic.mil/>.

As part of its core mission, DSIAC also collects, electronically catalogs, and preserves government-owned STI for future discovery and dissemination in the DTIC R&E Gateway. DSIAC can collect, transport, and digitize surplus or orphan collections of technical reports at no charge to your organization. Please contact DSIAC if you are aware of any technical reports that merit preservation.

Finally, customers can conveniently request all DSIAC products and services via the DSIAC website at [www.dsiac.org](http://www.dsiac.org). After users register for a free account and establish a community of interest profile, they can access the free TI submission page, register for technical meetings and training, and use DSIAC’s ever-expanding portfolio of technical products and controlled-access databases. TIs submitted via the web portal are placed into an automated

workflow for immediate assignment and attention. DSIAC encourages all members of the DoD, U.S. government agencies, and contractor community to explore how DTIC and the IAC program can assist you. If you have any questions, please do not hesitate to call us at 443-360-4600.

(Note: If you received this issue of the *Aircraft Survivability*, then you are already registered with DSIAC).

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Mr. Tom Moore is an employee of the SURVICE Engineering Company and was named the first Director of DSIAC in January 2014. As a 30-year veteran of the aerospace/defense industry, he has held senior program management and engineering positions at Alliant Techsystems (ATK), Hercules Aerospace, and the Chemical Propulsion Information Analysis Center (CPIAC), where he last served as Deputy Director. Mr. Moore received a B.S. in mechanical engineering from West Virginia University and an M.S. in technical management from The Johns Hopkins University. He is a certified Project Management Professional (PMP) and Associate Fellow of the American Institute of Aeronautics and Astronautics.

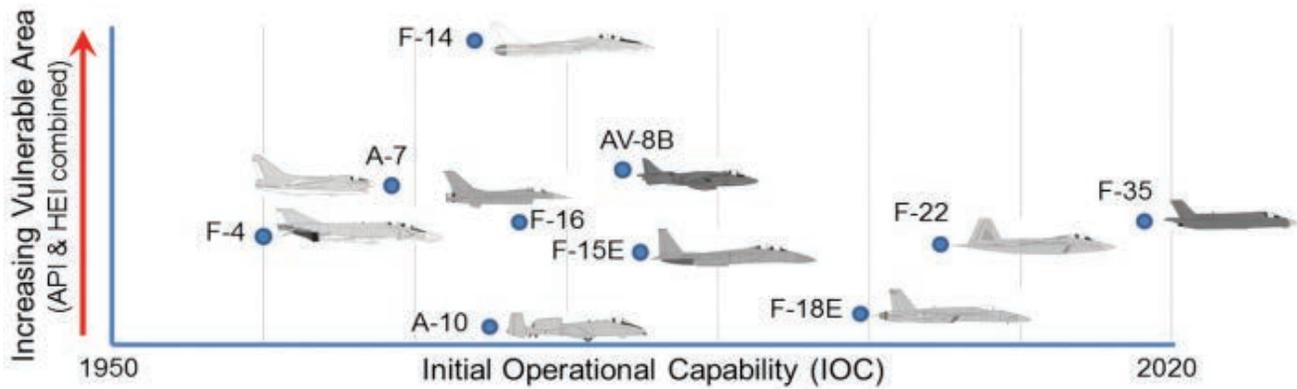
# AIRCRAFT SURVIVABILITY, LFT&E, AND THE FUTURE

by Sandra Ugrina



*U.S. Air Force photo*

To this day, the United States still relies on some technology development efforts initiated in the 1970s. The research of that era matured a vast suite of aircraft survivability technologies and capabilities largely in response to the historic events of that time. Vietnam War theater maps displaying locations of the hundreds of fighter aircraft downed by enemy fire demonstrated the need for, and significance of, survivability to combat-induced damage as a primary aircraft design element. Grim statistics of pilots that had to eject over enemy territory, many of whom became prisoners of war, might have been altered if aircraft were hardened enough to allow the pilots to continue to fly for even 5 additional minutes, permitting them to eject over the (then) rescue-friendly South China Sea instead. The A-10 platform delivered to the fleet in 1975 epitomized the aircraft design philosophy borne from the invaluable lessons learned of that time. And after nearly 40 years, it is still the most hardened tactical aircraft (at least against small arms, visually directed anti-aircraft guns, and unguided threats). As shown in Figure 1, the A-10 will retain that notoriety for some time as the vulnerability requirement for the fifth-generation aircraft are written to equate to that of the F-16, another product of the 1970s, albeit designed against other priorities. As the Deputy Director for Live Fire Test and Evaluation (LFT&E), I ask, even when placed in the appropriate context, what might these data suggest for the future of aircraft survivability and the LFT&E of aircraft systems?



AIRCRAFT	F-4B	A-7D	F-14A	A-10	F-16A	AV-8B	F-15E	F-18E	F-22	F-35
IOC	1960	1968	1974	1975	1977	1984	1985	1999	2005	2018?
<b>FUEL &amp; FIRE:</b>										
Ullage Protection				✓	✓		✓	✓	✓	✓
Dry Bay Fire Protection				✓			✓	✓		
Leak Resistant Fuel Tanks			✓	✓	✓			✓		
Self-Sealing Fuel Lines			✓	✓			✓	✓		
Flammable Fluid Shutoffs	✓	✓	✓		✓		✓		✓	
<b>PROPULSION:</b>										
Multiple Engine Redundancy	✓		✓	✓			✓	✓	✓	
Engine Fire Extinguishing	✓		✓	✓			✓	✓	✓	
<b>FLIGHT CONTROLS:</b>										
Separation	✓	✓		✓	✓		✓	✓	✓	✓
Redundancy	✓	✓		✓	✓		✓	✓	✓	✓
<b>BALLISTIC PROTECTION:</b>										
Cockpit				✓						
Ammunition				✓						

**Figure 1** Average Vulnerable Areas for a Range of Tactical Aircraft

Military aircraft survivability and, consequently, combat mission effectiveness in current and emerging threat environments are critical for maintaining U.S. air superiority, U.S. national security, and U.S. pilot/copilot/crew safety. LFT&E engineers and scientists across the Services have been testing and evaluating aircraft to assess their survivability capabilities in an effort to reveal and, more importantly, address any deficiencies prior to handing these systems over to our troops to deter, fight, and win wars. The LFT&E community has made significant contributions in the last 4+ decades to protect our troops in combat and to support the Combatant

Commanders' needs in meeting their objectives. While the community should be proud of those achievements, the advancement of technology and continually changing operating environment do not allow us to simply ride on past victories. Gen. Alfred Gray, a former Marine Corps Commandant said, "Like war itself, our approach to warfighting must evolve. If we cease to refine, expand, and improve our profession, we risk being outdated, stagnant, and defeated." The same holds true for LFT&E: we must evolve, innovate, and adapt to avoid the risk of being outdated and to continue contributing to our important mission.

With the proliferation of advanced and ever-more-lethal conventional threats, as well as the emergence of new nonkinetic threats, such as directed energy and cyber weapons, technology development efforts initiated in the 1970s cannot outpace the more complex and volatile operational environments our forces and coalitions face today. Thus, the LFT&E community, chartered to assess Department of Defense (DoD) major systems' survivability (and lethality), must adapt and stretch beyond existing capabilities and fields of expertise. We must understand, help prioritize, and advocate for the most effective capabilities to reduce susceptibility and

vulnerability and to provide force protection in support of the more challenging U.S. aircraft missions. As a reminder, the ongoing acquisition programs, the Joint Aircraft Survivability Program (JASP), the Joint Technical Coordinating Group for Munition Effectiveness (JTTCG/ME), and the Joint Live Fire (JLF) Program comprise the spectrum of venues available to the LFT&E community to help deliver cost-effective, threat intelligence-based improvements to existing systems and next-generation aircraft.

To enable continuous modernization and to respond to Combatant Commanders' needs in an operationally timely and relevant manner, LFT&E's efficiency, sense of urgency, and ability to leverage and build on current survivability efforts are critical to improving performance while reducing the time and cost of our acquisition processes. During Defense Secretary Ash Carter's confirmation hearing, it was mentioned that in 1975, it took roughly the same time (6 years or so) to bring a new automobile, a new commercial aircraft, and a new military aircraft from concept to operation. Today, those timelines have wildly diverged: the automobile is down to 2 years; commercial aircraft are up to about 7 years; and military aircraft are up to 23 years.

This divergence is a DoD-wide concern, but, from our perspective, more coordinated efforts between test engineers and analysts and across the survivability-related functional areas would go a long way to improve this process. It would allow us to more quickly build more robust modeling and simulation tools, freeing up our test resources and efforts to get ahead of the next emerging threat or combination of threats; and it would help us more strategically leverage various aspects of these functional areas

to combine their effects and optimize survivability.

The mission of the U.S. Army Research Laboratory (ARL) to "discover, innovate, and transition science and technology to **ensure dominant strategic land power**" is something to contemplate—in particular, the mission of its Survivability/Lethality Analysis Directorate (SLAD) to "provide expert technical advice and solutions that enable U.S. personnel and equipment to survive and function effectively in hostile circumstances." ARL/SLAD, which is composed of four major elements, recognized that to execute this mission, it should coordinate and evaluate **electronic warfare, cybersecurity, ballistics, and systems of systems** to affect the survivability/lethality of major Army systems against the full spectrum of battlefield threats. This approach is broader and far more effective to LFT&E than the traditional sole focus on destructive testing. A similar structure and alignment would benefit all Services to coordinate and optimize all survivability- and safety-related efforts and to **ensure dominant U.S. airpower.**

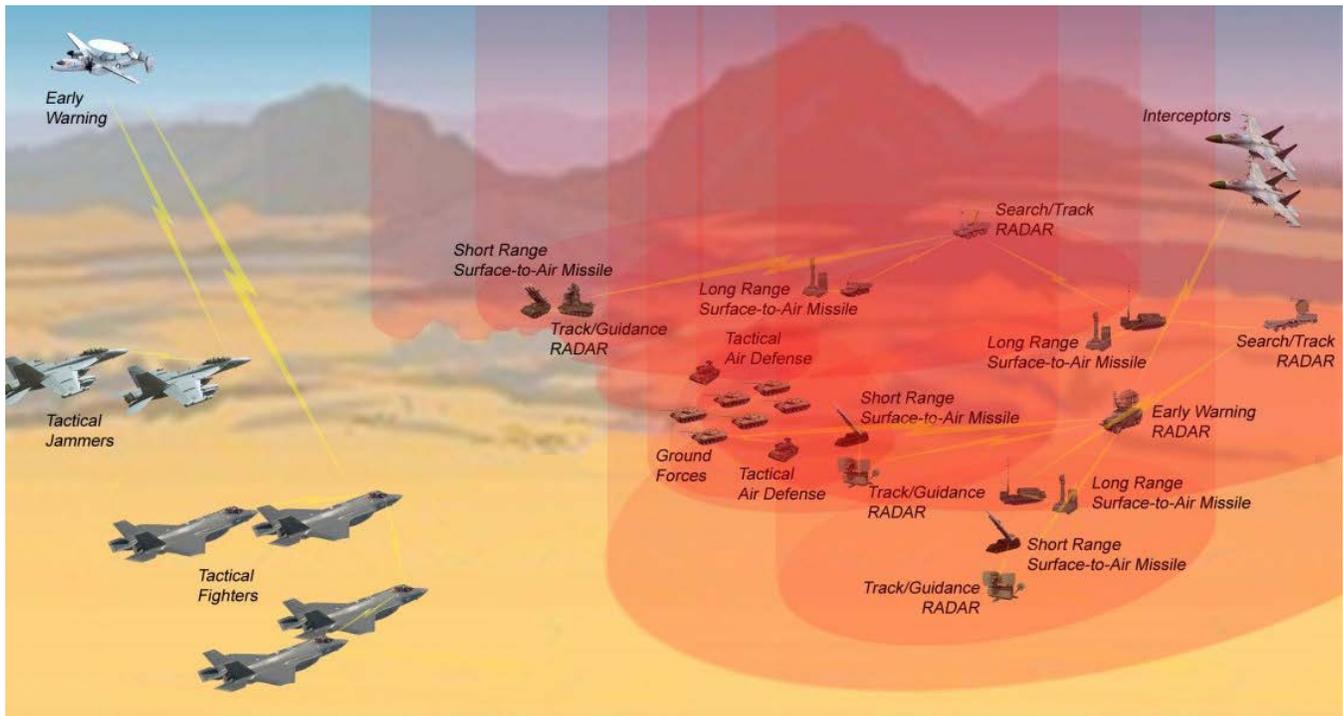
The ever-increasing capabilities of our adversaries make the problem of advancing the sciences of aircraft combat survivability compelling, complex, and challenging. While the importance of situational awareness and battlefield intelligence is as old as the first military use of aviation, an operational intelligence-based approach (as shown in Figure 2) that is tailored to specific U.S. missions continues to be as critical to aircraft effectiveness and survivability, but with complexities that are orders of magnitude higher.

Via the JASP, LFT&E can help develop measures to improve crew situational awareness, to counter anti-access/

area-denial capabilities, and to counter a range of emerging threats. Inevitably, some aircraft will be drawn into close combat and will be engaged by threat weapons systems. And the results of these engagements could be devastating, as demonstrated by the helicopter combat loss statistics of the most recent wars. However, addressing these measures to detect and counter threats, to absorb the damage more effectively, to avoid aircraft destruction, and to save the crew during an attack or crash requires unconventional and more disciplined scientific approaches.

LFT&E can contribute by responding to the new JASP initiatives to help identify and extract less obvious survivability benefits, some of which focus on investigating the range of technical areas, from signal manipulation, flight control laws, structural dynamics, thermodynamics, and many other perspectives. Enhancing these capabilities will help U.S. aircraft work through the near-peer or second-tier threat environments, mitigating the risk to the crew while expanding the range of possible combat missions.

LFT&E also leverages the JTTCG/ME and JLF to respond to the emerging and unconventional types of warfare. For decades, the JTTCG/ME has been delivering premier joint munitions effectiveness data and products for the DoD, including the Joint Anti-Air Combat Effectiveness (J-ACE) weaponeering tool. This tool enables the air warfare community—in particular, the Navy Strike Fighter and the Air Force Weapons Schools—to develop tactics, techniques, and procedures (TTP) manuals for air superiority applications. The development of this tool is heavily reliant on data collected in acquisition LFT&E and the JLF programs.



**Figure 2** Complex Combat Environments U.S. Forces and Coalitions Face Today

To adapt to the complex operational environment, the JTCG/ME has recently applied its expertise in kinetic threats to cyber operations, in coordination with the Air Force Targeting Center. Consequently, the JTCG/ME is now collecting nonkinetic joint weapons effectiveness data for operational Warfighters, analysts, targeteers, and planners to analyze offensive cyber capability effectiveness. The LFT&E community can and should support the development of this process with data characterizing aircraft vulnerability and specific weapon-target pairings, either via the traditional acquisition programs or through the JLF program.

LFT&E has also played a critical role in aircraft survivability evaluation and advancement. As with those in operational testing and evaluation, those of us in LFT&E pride ourselves in getting meaningful results from final, production-representative, full-up system-level testing using operationally realistic weapons. However, our largest service to the Warfighter is, in my view, tied to

the inherent ability that LFT&E has to affect system design.

When compared to operational test communities, we get to the susceptibility and vulnerability design and technology issues much sooner through initial, component-, and system-level testing; we are the venue to recognize and affect design early and to set the systems up for a successful full-up system-level test and operational capability. Large doors swing on small hinges, and small or incremental LFT&E technical developments, early in the design, could result in meaningful improvements to systems or requirements, giving our troops the capabilities and the confidence to deter wars, disable adversaries, and secure our nation, and then to return safely back home. [ASJ](#)

#### **ABOUT THE AUTHOR**

Dr. Sandra Ugrina is the Deputy Director for LFT&E in the Office of the Director, Operational Test and Evaluation (DOT&E), where she oversees survivability and lethality testing and evaluation of major DoD systems and munition programs.

Prior to this position, she served as a research staff member at the Institute for Defense Analyses and as an aircraft systems and weapons staff specialist in the DOT&E office. Dr. Ugrina has also worked as a research associate resident at the National Institute of Aerospace/National Aeronautics and Space Administration Langley Research Center, where she defined and executed interdisciplinary research on the design and analysis of advanced aerospace vehicle concepts and technologies. In addition, she has authored numerous articles, scientific publications, and studies and has served as a college aerospace engineering lecturer and as a consultant for Airbus North America. Dr. Ugrina is a recipient of the National Fellowship for Exceptional Researcher, awarded by the United Nations Educational, Scientific and Cultural Organization and the American Association for the Advancement in Science. She holds a B.S. in aerospace engineering from the U.S. Naval Academy and a Ph.D. in aerospace engineering from the University of Maryland.

# KC-130J HARVEST HAWK ALTERNATE LFT&E PROGRAM

By Raena Phillips  
and Les Bowman



Figure 1 USMC KC-130J In Flight

The U.S. Marine Corps KC-130J Harvest Hercules Airborne Weapon Kit (designated Harvest HAWK) provides the KC-130J tactical refueller aircraft with multi-sensor imagery reconnaissance (MIR) and close air support (CAS) capabilities. When configured, the armed KC-130J (shown in Figure 1) includes the addition of weapon systems, facilities, and personnel to control those weapon systems. The Harvest HAWK mission system is a response to an urgent need of the Marine Corps to provide a roll-on, roll-off (RORO) system that quickly adds MIR and CAS capabilities to an existing airframe. Because of its RORO status, the Harvest HAWK system has no impact on airworthiness; however, by virtue of its added capabilities, there is a potential change in vulnerability. Thus, the Harvest HAWK is covered by U.S. Code, Title 10, Section 2366 as a product improvement program requiring incremental live fire test and evaluation (LFT&E) [1].

## **LFT&E FOR AN URGENT NEED**

The focus of the Alternate LFT&E (ALFT&E) Test and Evaluation Test Plan/Strategy for Harvest HAWK was to meet the Title 10 requirements at reasonable expense while providing valuable survivability information to both the Office of the Secretary of Defense (OSD) and the program office.

The Test Plan/Strategy was developed as a coordinated effort between test and evaluation personnel. The lead test and analysis engineers worked together to focus the ALFT&E on the added munitions systems and added crew as those additions would have the most impact in the change in vulnerability of the air vehicle. The ability to satisfy the Title 10 requirements through the ALFT&E Test Plan/Strategy, while maintaining a compressed timeline, was accomplished through leveraging the use of existing live fire (LF) and vulnerability data on similar systems.

### ***Leveraging and Cooperation***

The Harvest HAWK ALFT&E team maximized use of existing data sources by entering into a Memorandum of Agreement (MOA) between the U.S. Air

Force and the U.S. Navy. This MOA provided the Navy with the Air Force C-130J vulnerability analysis, complete with input files, and allowed the Navy to build from existing C-130J analysis and test only the additional munitions systems. The MOA also benefited the Air Force, through a reciprocity provision, allowing the Air Force to leverage Harvest HAWK vulnerability analysis, test plans, and reports for HC/MC-130J analysis.

## **ALFT&E TEST SERIES**

Within the Harvest HAWK ALFT&E team, continuous cooperation was demonstrated through a truly integrated team. The Harvest HAWK ALFT&E was divided into three test series, each focusing on one of the added weapon systems. Each test series plan was authored by both a test and an analysis engineer. The test events were tailored to provide the maximum impact on the development of the vulnerability analysis inputs.

Early in the test planning phase, the test and analysis engineers noted appreciable data voids for each of the three weapon systems slated for testing. The decision was made to institute a phased test series for each weapon system. The phased approach

maximized the limited budget and timeline by focusing on evaluating the Harvest HAWK's vulnerability impact on the airframe and on its crew, maximizing the influence of LF data on the vulnerability analysis. This approach streamlined the process and strengthened both the test and analysis efforts.

The tested Harvest HAWK system configuration added MIR and CAS capability to the KC-130J airframe by adding three weapon systems and the means to control them. These weapon systems were the wing-mounted missiles deploying Hellfire munitions, the cargo ramp-mounted standoff precision-guided munitions (SOPGM) deploying Griffin missiles, and a 30-mm gun system located out the aft paratrooper door (tested, but not fielded). Controlling these weapon systems is an added crewmember, the Fire Control Officer (FCO), who resides on the palletized fire control station (FCS), relying on inputs from the Harvest HAWK intelligence, surveillance, and reconnaissance (ISR) pod. The added systems and approximate locations are shown in Figure 2.

The incremental ALFT&E plan laid out in the KC-130J Harvest HAWK Test Plan/Strategy focused on the



**Figure 2** KC-130J Harvest HAWK Added Systems

vulnerability associated with the weapon system additions. The crewmembers are inherently considered a system of the aircraft and were considered throughout both test and analysis. During the test series, simulator dummies were positioned at crewmember locations, and pressure and temperature data were collected to determine the effect on the crewmembers. Among the data obtained during the test events, analysis on the potential shielding provided to the crewmembers by the aircraft was considered and was documented in the survivability assessment report.

### **Wing-Mounted Munitions**

The wing-mounted munitions test series focused on the vulnerabilities associated with the addition of Hellfire missiles on outboard wing stations (Figure 3). The collaboration between the test and analysis engineers allowed the test series to be tailored to maximize the benefit for LF requirements while filling the data voids, thereby creating a more complete analysis.

The test series was split into component-level testing (Phase 1), which focused on the Hellfire's energetic sections, the rocket motor and the warhead. Phase 1 pre-test predictions focused on expected component results based on historical LF data. A total of six shots were taken under Phase 1 testing, investigating the rocket motors' and warheads' response to impact by ballistic threats not previously considered under prior testing.

The second phase of testing (Phase 2) was full-up system-level (FUSL) testing. These tests addressed the potential synergistic or sympathetic effects at the system level, fulfilling the Title 10

requirements. Pre-test predictions for Phase 2 incrementally updated the vulnerability model based on Phase 1 post-test analysis. The post-test analysis for Phase 2 then updated the vulnerability model's assumptions and methodologies to incorporate Phase 1 and Phase 2 data as well as historical insensitive munitions (IM) data.

### **Cargo Ramp-Mounted SOPGM**

The cargo ramp-mounted SOPGM test series was also conducted in two phases. However, as the SOPGMs are internally carried (Figure 4), additional considerations for addressing crew survivability were made.



**Figure 3** Hellfire Configuration on Left Wing of the KC-130J



**Figure 4** Cargo Ramp-Mounted SOPGM for Testing (Ramp Closed During Event)

Ballistic impact of the internally stored energetic materials could induce an energetic reaction, producing smoke. Therefore, not only were crewmember locations equipped with pressure and temperature data recording devices, but the smoke was collected and analyzed for toxicity.

Phase 1 component testing investigated the reaction of the Griffin warhead and rocket motor to ballistic impact by the threats of interest. As nearly no prior testing had been conducted on the new Griffin weapon system, the pre-test predictions were based on historical data of similar systems without the benefit of existing IM data.

Post-test analysis of Phase 1 test events provided additional data for vulnerability modeling and pre-test predictions for Phase 2. The test and analysis engineers devised shotlines that maximized penetration of threats, for Phase 2 testing. The shotlines also

took into account shielding provided by aircraft structure. The use of these threats, velocities, and shotlines were consistent with the aircraft being fired at while in ascent from takeoff or descent to landing at a forward airfield.

Post-test analysis of Phase 2 then updated the assumptions and methodologies within the vulnerability assessment. Additionally, toxicology reports for the smoke collected, as well as temperature and pressure data for the crew, were analyzed to assess the vulnerability associated with the Griffin system to the KC-130J aircraft and the crew.

### **30-mm Gun System**

The 30-mm gun system testing series focused on the ammunition associated with a gun system. The location of the ammunition canisters within the KC-130J's cargo hold means that the crewmembers are not physically separated from the ammunition canisters.

While the proposed ammunition (Figure 5) itself has undergone IM testing, additional data were needed for the vulnerability assessment. Collaboration of the test and analysis teams resulted in another two-phased test series. Phase 1 predictions and testing focused on individual round reactions to ballistic impact, as a

function of threat size, threat velocity, and impact location (e.g., primer, propellant, projectile, and fuze).

Phase 1 test data and historical IM test data were combined, creating an initial vulnerability model for the ammunition. Phase 2 testing pulled the pieces together, investigating the potential for synergistic or sympathetic effects of the ammunition system within the aircraft. As was performed for the SOPGM testing, a shotline analysis was conducted to maximize the penetration capabilities for the threats of interest for Phase 2.

Congruently with the wing and ramp munition test series, the criteria for selection of Phase 2 shots hinged on historical data available, Phase 1 test results, and shotline analysis. Criteria imposed by the team included that the threat chosen for Phase 2 testing was the smallest threat, at the lowest velocity, for which there was high confidence of producing the most severe reaction observed during Phase 1 testing.

## **VULNERABILITY ANALYSIS**

Results of the phased tests were pooled along with historical data to create a vulnerability model of the new systems. The MOA reached with the Air Force meant that more time was



**Figure 5** 30-mm High-Explosive Incendiary (HEI) Ammunition (PGU-13A/B)

devoted to creating and documenting the systems added as part of the Harvest HAWK. Building from the Air Force C-130J vulnerability data and focusing the test and analysis efforts on the added systems maximized the limited budget and scope of the ALFT&E. The vulnerability analysis conducted focused on the change in vulnerability associated with the addition of the Harvest HAWK systems, and therefore the change was documented as a change in vulnerability increase over the baseline. The baseline for the vulnerability analysis took the Air Force C-130J vulnerability model and created the baseline KC-130J tanker model.

The incremental approach and focus on the change in vulnerability provided information regarding the vulnerabilities associated with the added mission capabilities, while also creating a set of government-owned vulnerability data for the KC-130J, as well as the Harvest HAWK system (Block E and Block F) upgrades.

## CONCLUSIONS

Analysis and test personnel were included in all aspects of test planning, beginning with the Test Plan Strategy and extending throughout all subsequent test plans. This close relationship allowed for the identification of data voids in available historic data to be addressed in the test series. All three test series included a phased approach driven by the analysis team's needs, with influence from test experience, to collect component-level data. As such, test plan details, including test matrices, shotlines, and instrumentation, were developed in a coordinated effort between experienced test and analysis personnel.

Pre-test predictions were provided by the analysis team prior to test execution, under the oversight of OSD. Pre-test predictions, while not required for the Phase 1 tests, were completed to complete the model-test-model cyclical approach. Phase 1 pre-test predictions built on any applicable historical data were used to identify data voids. Phase 1 test results were then analyzed post-test; and the combination of the historical data, predictions, results, and post-test analysis was fed into the design of and predictions for Phase 2 system-level testing. The Phase 2 results were then incorporated with Phase 1 and historical data into the vulnerability assessment.

This phased, highly coordinated approach maximized the limited budget and timeline, focusing the test series on evaluating the Harvest HAWK system's vulnerability impact on the airframe, while also maximizing the influence of LF data on the vulnerability analysis. This approach was made possible by the coordination between the Harvest HAWK ALFT&E team, including the test engineers, analysts, and program office representatives.

Further, collaborating with the Air Force provided the program with a vulnerability dataset, the leveraging of which created a more complete analysis. Through the MOA with the Air Force, the Air Force's HC/MC-130J analysis can then leverage the results and findings under the Harvest HAWK ALFT&E test and analysis. This approach streamlined the process, strengthened both the testing and the analysis efforts, and provided a valuable set of government-owned models for future use. [ASJ](#)

## ABOUT THE AUTHORS

Raena Phillips has been with NAVAIR 418400D (Systems Engineering Department; Combat Survivability Division; Survivability Assessment Branch) for approximately 5 years. She has supported Navy and Marine Corps vulnerability analyses, as well as Joint Aircraft Survivability Program Office (JASPO) and Joint Technical Coordinating Group for Munitions Effectiveness (JTCEG/ME) programs.

Les Bowman has been with NAVAIR 418300D (Systems Engineering Department; Combat Survivability Division; Vulnerability Branch) for approximately 5 years. Previously, he worked for the Navy for 34+ years. He has served as a test engineer and as the head of fire science working on fire suppression, and he has performed engine research and development.

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## References

- [1] [U.S. Code, Title 10, Section 2366.](#)

# GOBIGGS: THE NEW PLAYER IN EXPLOSIVE ULLAGE TREATMENT

by Raymond (Lou) Roncase, Jr.



The Green On-Board Inert Gas Generating System (GOBIGGS), developed by Phyre Technologies Inc., has been selected by Sikorsky Aircraft Corp. as the next-generation system to inert explosive ullage gasses. GOBIGGS was selected as a component system of the Combat Tempered Platform Demonstration (CTPD) Project awarded to Sikorsky in 2012. The CTPD project is a \$12-million demonstration program tasked to develop and integrate a suite of advanced technologies (some having previously low technology readiness levels [TRLs]) to increase the performance and survivability of U.S. military platforms. The best and most beneficial of these technologies will be matured and fully integrated into our next-generation or block upgrade aircraft to improve the performance and survivability of U.S. military aircraft. The aircraft chosen for this CTPD was the UH-60 BLACK HAWK series aircraft.

Phyre Technologies Inc. is a small, San-Diego-area-based research and development company founded in 2003. Its initial research efforts resulted in the development of Phyre's Advanced De-Oxygenation System (PADS), a fuel deoxygenating system that capitalized on the properties of "Henry's Law" to draw the oxygen out of fuel and process this oxygen through catalytic reaction to remove it in a closed-loop system (see Figure 1). Henry's Law is best visualized by opening a bottle of soda and seeing and hearing the dissolved CO<sub>2</sub> escape. Some of the benefits of deoxygenated fuel are the thermal stability, significantly decreased coking in the fuel delivery system, and the ability to elevate the fuel temperature, which can decrease fuel consumption and allow the fuel to be used as an on-board cooling medium for aircraft systems.

Developers soon realized the potential of the catalytic reaction, which removes the oxygen from the air in the PADS system, to also be used to remove the oxygen leg of the "fire triangle" to reduce the flammability of the ullage in a conventional fuel cell. A second benefit of this catalytic reaction is the removal of the hydrocarbons in the ullage air as well, resulting in a faster reduction in explosive gaseous components in the ullage mixture. Thus, GOBIGGS was developed to specifically target the explosive ullage air for the aviation industry.

The current system most deployed on U.S. military aircraft, the On Board Inert Gas Generating System (OBIGGS), is a membrane-based approach developed for the medical industry. The membrane divides the air particles by molecular weight into oxygen-enriched air (OEA) and nitrogen-enriched air (NEA). For medical use, the OEA is supplied to the patients and the NEA is discarded or

stored (depending on the manufacturer). This system has also been adapted for use on aircraft and is called On-Board Oxygen Generating System (OBOGS). OBIGGS uses the NEA generated by the membrane and pumps the NEA into the flammable ullage to reduce the oxygen content in the ullage to below 9%; the excess gases are vented to the atmosphere. Although this system is considerably lighter than a liquid nitrogen type of system, it is heavy

compared to GOBIGGS, and negative performance and maintenance issues have been documented.

As illustrated in Figure 2, GOBIGGS is simplicity in design and integration. It consists of nothing more than three small pumps to circulate the ullage gases and cool the heat exchanger and catalytic converter, a catalytic converter to burn off the oxygen and hydrocarbons, a small control unit that manages

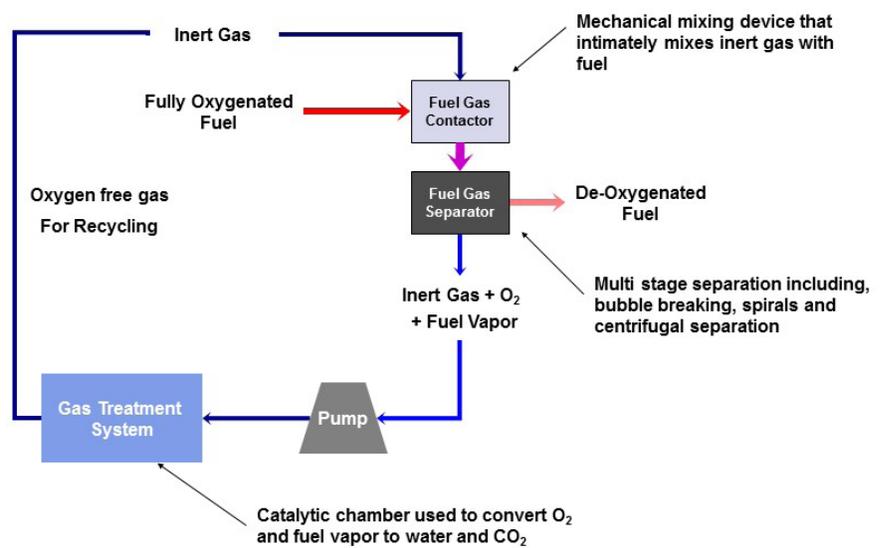


Figure 1 PADS Diagram

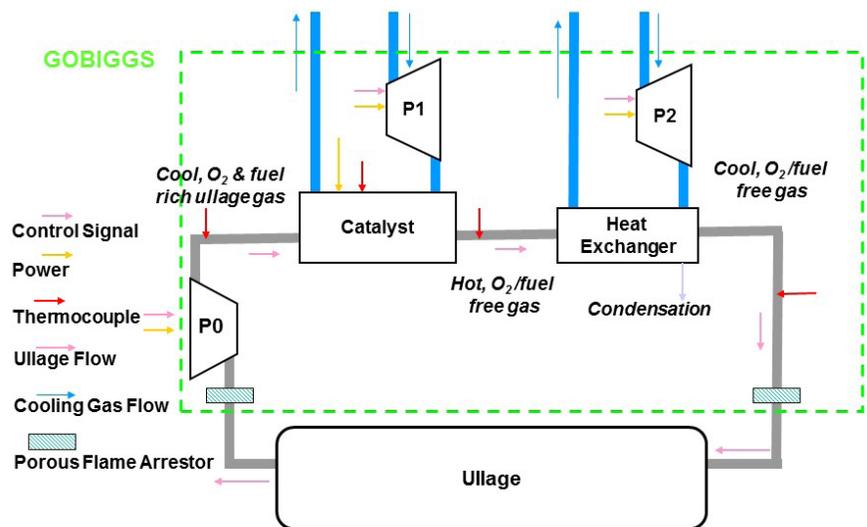


Figure 2 GOBIGGS Diagram

the system operation, and thermocouples that provide the inputs to the control unit. And all of this is contained in a small box (shown in Figure 3). External components consist of the tubing that will run between the fuel cells, isolation valves, and an overboard vent for the heat exchanger. The entire vent and gas transfer lines can be as lightweight and flexible as the other platform fuel system venting components, as GOBIGGS operates at the aircraft's ullage pressure specifications. In addition, the system is scalable to large or small aircraft.



**Figure 3** CTPD GOBIGGS UNIT

GOBIGGS was first demonstrated in 2006 to the Federal Aviation Administration (FAA) in Atlantic City, NJ, for use in the commercial aviation industry as a viable option to conventional ullage treatment systems to prevent another TWA Flight 800-type tragedy. As is typical in a developmental system demonstration, the system that was taken to Atlantic City was large and cumbersome. And although the FAA demonstration was successful at proving the technology, the low TRL and the lack of an established requirement to protect commercial aircraft fuel cells kept this technology on the shelf for several years.

However, the technology was eventually brought to the attention of the Joint Aircraft Survivability Program Office (JASPO), and in 2010 Phyre was awarded a contract to demonstrate GOBIGGS in a realistic environment,

with the assistance of the engineers and technicians at the Naval Air Warfare Center-Weapons Division (NAWCWD) Weapons Survivability Lab (WSC) in, China Lake, CA. The test scenarios were designed to demonstrate the ability of GOBIGGS to inert a large fuel cell ullage volume, to inert during fuel offload/burn down conditions, and to operate at different catalytic converter temperatures.

The outstanding performance of the GOBIGGS system during the JASPO test series (the results of which were published in the fall 2012 edition of the *Aircraft Survivability* journal) brought GOBIGGS to the attention of the survivability engineers at Sikorsky. And through their efforts, the system was selected as one of the advanced technologies being demonstrated during the CTPD program cycle. GOBIGGS will exit the CTPD Program at TRL 6–7, as it has proven to be a viable ullage treatment option. The H-60 series aircraft do not currently have ullage protection, and GOBIGGS will provide the users with a level of protection not yet realized by other aircraft operating using the current OBIGGS system. **ASJ**

#### **ABOUT THE AUTHOR**

Raymond (Lou) Roncase, Jr., works as a vulnerability engineer in the Combat Survivability Division of the U.S. Naval Air Systems Command (NAVAIR) in China Lake, CA. He has almost 40 years of experience in LFT&E testing, including developmental/operational flight testing, sled track testing, explosive ordnance testing, and (for the last 13 years) vulnerability and JASP program management and testing at the WSL. Mr. Roncase has also served 8 years in the U.S. Marine Corps as an avionics technician, maintaining the AV8 A, B, and C series aircraft.

# NAWCWD COMPLETES MOST COMPLEX WEAPONS SURVIVABILITY TESTS TO DATE

by Brian Wulfekotte and Ron Schiller



**Figure 1** An LFT&E Missile Approaching a KC-46 Tanker During the Weapons Survivability Test at NAWCWD's WSL on April 7. The LFT&E missile is the first of its kind, with a custom-designed warhead to evaluate the highest threat scenario possible (WSL photo).

On 7 April 2015, the Naval Air Warfare Center Weapons Division (NAWCWD) successfully supported the KC-46 tanker program with the most detailed, advanced weapons survivability test series ever conducted at the Weapons Survivability Lab (WSL) in China Lake, CA. The KC-46, a derivative of the commercially available Boeing 767-2C, is a refueling aircraft. An estimated 179 KC-46's will be procured to replace one third of the existing aerial refueling fleet.



**Figure 2** The KC-46 Weapons Survivability Test at the WSL. On the left (in white) is the High-Velocity Airflow System, which fired its nine jet engines to simulate realistic flying conditions of the KC-46 (far right). In the center is the cannon that fired a live warhead into the aircraft's left pylon (U.S. Navy photo by Mark P. McCoy).

"Excellent tests," said Mr. Scott Wacker, a KC-46 lead engineer and weapons survivability expert. "These have never been done before, so I'm happy to say that we met all our objectives. I believe that we are advancing the state of the art in understanding vulnerability in aircraft."

The tests, which were outlined by the KC-46 Live Fire Test and Evaluation Program (LFT&E) and witnessed by representatives from NAWCWD, Boeing, the Air Force, the Institute for Defense Analyses, and other stakeholder organizations, will be used to assess KC-46 system-level survivability in high-fidelity operational environments against ballistic and advanced threats. The results provided a wide range of data that are instrumental in mitigating worst-case scenarios for the aircraft, which will directly improve and preserve warfighting capability.

"There were over 330 channels collecting raw data, 10 high-speed cameras recording 10,000 to 100,000 frames per second, and 30 real-time video feeds," said KC-46 LFT&E engineer Eric Brickson. "We had a very extensive list of requirements, and NAWCWD met them all."



**Figure 3** Program Officials at the KC-46 Weapons Survivability Test at the WSL. From left to right are Jeff Wuich (KC-46 Program Office), Scott Wacker (KC-46 Program Office), 1st Lt. Kerollos Marzouk (KC-46 Program Office), Ron Schiller (WSL Engineering Section Head), Col. Chris Coombs (KC-46 Program Office), Bill Franklin (KC-46 Program Office), Lt. Col. Pete Sandness (KC-46 Program Office), and Jay Kovar (WSL Branch Head) (U.S. Navy photo by Mark P. McCoy).

"It was a very successful test," added Air Force Col. Chris Coombs. "We designed these tests against the aircraft to see how it would perform, so we'd know if the people, whether they are pilots, operators or passengers, could survive on this plane under the most relevant of circumstances."

The WSL consists of six separate test sites, including an engineering and test coordination lab, multiple shops (including machine, sheet metal, jet engine, assembly, coatings, and welding), and a test article preparation area. The WSL provides engineering, test planning and execution, instrumentation, data acquisition and controls, and video and communication networking capabilities. **ASJ**

### ABOUT THE AUTHORS

Mr. Brian Wulfekotte works for the NAWCWD Public Affairs Office.

Mr. Ron Schiller is the Range Engineering Section Head for NAWCWD's WSL. He has supported survivability LFT&E efforts at China Lake for the past 20 years. He holds a B.S. in mechanical engineering from California State University, Fresno, and an M.S. in mechanical engineering from California State University, Northridge.

# CREW COMPARTMENT FIRE SURVIVABILITY

by Adam Goss



Air vehicle fatalities over the past decade have prompted defense leaders to emphasize crew protection as a focus area for survivability program initiatives. In 2014, a crew compartment fire survivability project was conducted to investigate the impact of environmental hazards on combat personnel during fire events inside medium-sized transport military aircraft. The project was based on the premise that occupants may not have sufficient time or technology to effectively suppress the fire. Associated hazards such as smoke, heat, and toxic gases could potentially incapacitate aircrew from effectively reacting to the situation or interfere with the pilot's situational awareness for sustaining flight. Accordingly, the project's primary objective was to collect thermal, optical, and toxicity data to characterize the physiological hazards within military aircraft crew compartments resulting from fuel fires. In addition, occupant survivability was subsequently assessed in terms of time-to-incapacitation ( $t_i$ ) relative to physiological limitations published in medical literature.

## TEST APPROACH

Cabin fires were established inside a generic fuselage by igniting JP-8 fuel sprays generated from surrogate fuel nozzles representing a range of fuel line damage. The test scenarios varied five parameters: fuel pressure, nozzle size, vent configuration, mean internal cabin airflow, and fire location. Instrumentation in the cockpit and cabin collected data on temperature, visibility levels, and toxic gas concentrations for an assessment of occupant incapacitation by these hazard modes. The cockpit instrumentation was located in the general area of the pilot/co-pilot's head. Occupant incapacitation in the cabin was primarily assessed from video cameras, gas samples, and temperature data collected at the center of the cabin. Additional temperature data were collected with 90 thermocouples distributed throughout the cabin.

## TEST RESULTS

A total of 51 test events formed a sample set of fire cases from the full population of possible scenarios. All hazards that triggered their respective incapacitation limit prior to the end-test point are shown in the cumulative failure plots for the cockpit location (Figure 1) and cabin floor (Figure 2). Similar plots (which are discussed in the final report) were produced for the cabin ceiling and center levels [1]. The number of incapacitation occurrences for each hazard mode is given as cumulative percentages of the 51 tests. Data slopes show the rate of incapacitation by the respective hazards, and sudden changes in slope indicate a critical time for incapacitation by the associated hazard.

It is apparent that loss of visibility and second-degree burns are the dominant incapacitation modes, at least for the latter 70% of the time period. Visibility

degradation and second-degree burns may not truly "incapacitate" an occupant by definition, but they could interfere enough to prevent or disrupt action, such as maintaining flight control. More direct incapacitations are a result of inhalation of high-temperature air and oxygen depletion below 16%.

Among the four locations assessed for time-to-incapacitation, the data suggest that the floor level is the best location to prolong an occupant's  $t_i$  (Figure 2). Data slopes at the floor were much flatter by comparison with higher locations, so an incapacitation limit for a given hazard would occur much later at the floor, if at all. Considering the two hazards of

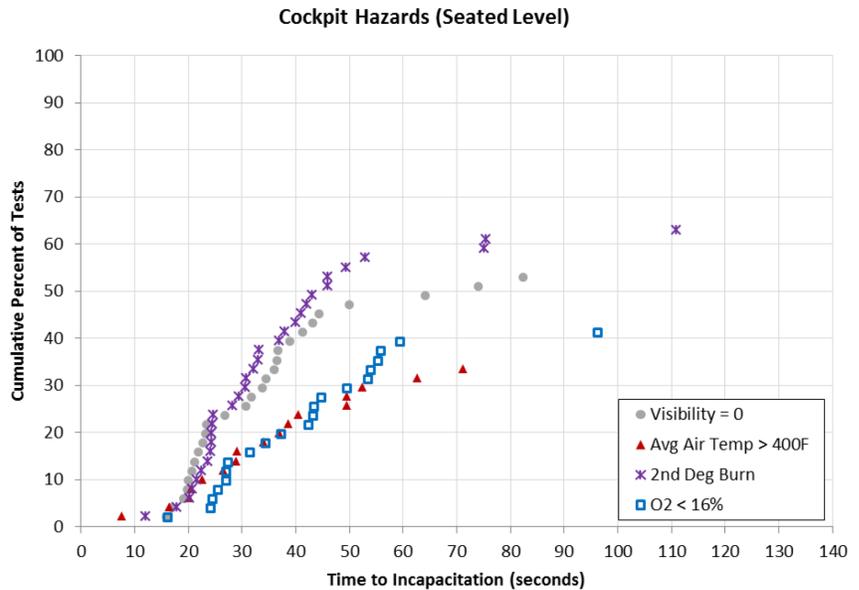


Figure 1 Hazard Incapacitation Data for Cockpit

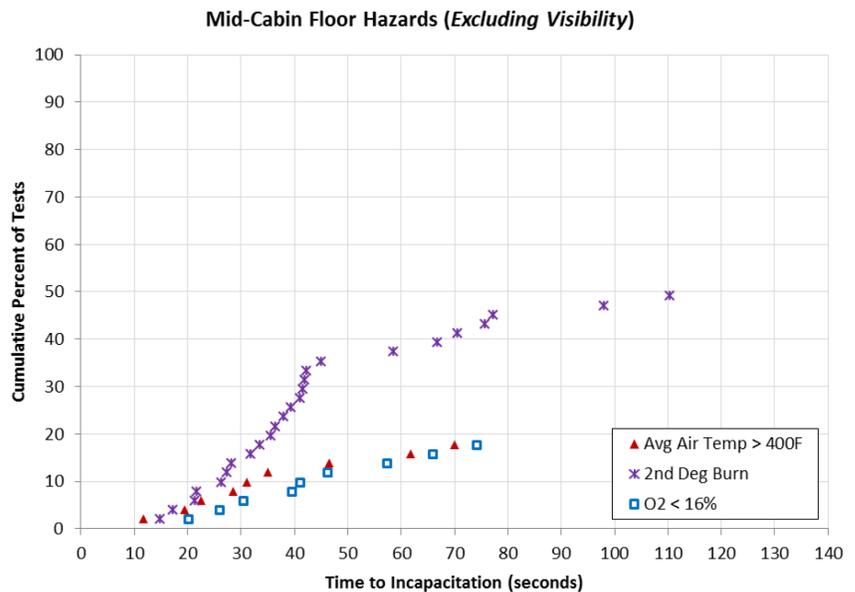


Figure 2 Hazard Incapacitation Data at Mid-Cabin Floor

high-temperature air inhalation and oxygen depletion, less than 20% of tests resulted in their incapacitation limits being triggered within the first half of the time period shown in the figures. Just 3 ft higher at the seated location, however, incapacitation by these two hazards nearly doubled within the same period.

Toxic byproducts of fuel combustion do not appear to be a driving mode of incapacitation since the defined gas exposure limits were not triggered in any of the tests. However, the lack of toxic gases appearing on the incapacitation plots does not positively discount the threat of these hazards. Events in this test series were necessarily time-limited to mitigate heat damage to test assets. Standard Live Fire exposure criteria underlying the toxic gas assessment are generally intended for long-time events, so applying the criteria in the test events was inappropriate for accurately assessing toxic incapacitation. Without standardized criteria for short-duration exposure limits, toxic gas incapacitations are more appropriately supported by the oxygen concentrations.

A statistical model was developed from the test data, from which probability-of-incapacitation ( $P_i$ ) could be estimated. According to modeled results, ventilation generally decreased incapacitations by visibility loss ( $P_{i|visibility}$ ) and second-degree burns ( $P_{i|2D Burn}$ ) in the cockpit and cabin. Increasing ventilation by opening the fuselage side door and rear ramp decreased  $P_{i|visibility}$  as much as 50%. For second-degree burns, the increased ventilation reduced  $P_{i|2D Burn}$  by 20–30%. Airflow also significantly impacted the modeled results. Increasing airflow reduced  $P_{i|visibility}$  in the cockpit as much as

70% in some cases. Combining airflow with any amount of ventilation drove  $P_{i|visibility}$  in the cockpit to nearly zero.

## CONCLUSIONS AND RECOMMENDATIONS

Collected data from this test program contained significant variability but still yielded clear trends for identifying the critical hazards of fire events, as well as the approximate timing for these hazards to reach incapacitating levels. Second-degree burns and loss of visibility due to smoke are considered to be the most dominant threats for occupants at all locations above floor level, closely followed by the potential for immediate incapacitation due to elevated temperature and oxygen depletion. According to the collected data, deleterious gases are not a factor of concern within the available time before optical incapacitation by smoke, and respiratory incapacitation by high temperature and oxygen depletion. Ultimately, data from this test series indicate that the occupant incapacitations can be driven to zero the more rapidly a fire is extinguished, or the more rapidly ventilation is increased and emergency egress is executed.

Rapid fire suppression methods are thus recommended to protect against crew compartment fires. In absence of an automatic suppression system, a training goal for aircrew should be to minimize reaction time and activate an extinguisher as rapidly as possible. **ASJ**

## ABOUT THE AUTHOR

Adam Goss currently works with the 96th Test Group at Wright-Patterson Air Force Base, testing and evaluating aircraft vulnerabilities to combat threats, as well as researching and developing technologies to enhance aircraft survivability. He holds B.S. and M.S. degrees in aerospace engineering from The Pennsylvania State University, where his academic research involved experimental aeroacoustics of supersonic exhaust jets from high-performance aircraft, as well as computational investigations into the aeroelastic effects of damaged flight surfaces.

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## References

- [1] Goss, Adam E., Andrew Drysdale, Ryan Arthur, and Leonard Truett. "Crew Compartment Fire Survivability Phase II." JLF-TR-13-04, Joint Live Fire (JLF) Aircraft Systems Test Report, April 2015.

# EXCELLENCE IN SURVIVABILITY

## SUZAN DEROSA

by Rich Hampson

The Joint Aircraft Survivability Program (JASP) is pleased to recognize Ms. Suzan (Suzi) DeRosa for her Excellence in Survivability. Suzi is currently the Survivability, Live Fire Test and Evaluation (LFT&E), and Classified Lead for the Combat Rescue Helicopter (CRH) Program at Sikorsky Aircraft Inc. in Stratford, CT. She is responsible for total survivability integration, vulnerability testing, survivability requirement compliance, and execution of the LFT&E Program for the Air Force's future HH-60W platform. She is being specifically recognized for her vulnerability reduction work on the Combat Tempered Platform Demonstrator (CTPD) program in the area of increased fire protection.



With a passion for helicopters that was sparked by a flight experience on a UH-60L in high school, Suzi knew that she would work with rotorcraft no matter what—even if it meant washing windows! However, her real exposure to helicopters and ballistic vulnerability came shortly after she was hired at Boeing-Mesa in 2002 to become the new AH-64D Vulnerability Analyst. Teachings in independent study on rotorcraft stability and control as well as rotorcraft

blade theory from her alma mater would help her along her path to rotorcraft operations and design integration. During her 5-yr career at Boeing, her most significant accomplishments included internal research and development (IRAD) testing of a new blast fragmentation barrier, software and integration testing of the Future Combat Systems (FCS) Capstone effort, support of the Composite Main Rotor Blade (CMRB) ballistic vulnerability qualification, and the initial layout of the framework for the AH-64E vulnerability analysis.

In 2007, Suzi left Boeing to take a Platform Lead position at Sikorsky, working across all H-60 platforms. She quickly adapted to the Sikorsky culture, reveled in Sikorsky's history, and reached out to work vulnerability reduction on other programs, such as the CH-148, CH-53K, and Joint Multi Role (JMR). Her work on CH-53K crashworthiness—specifically, seat crashworthiness—helped her again gain a better understanding of early survivability integration and a

broader appreciation of the survivability discipline. Suzi's most notable work with Sikorsky has been in the arena of armor requirements, armor military standard compliance, armor testing and design, and production armor quality. As her career progressed, her specific work in vulnerability reduction afforded her the opportunity to manage the Composite Survivability (CS) effort and lead the Advanced Fire Management (AFM) Task of the CTPD program starting in 2012.

CTPD is a 40-month, \$25-million effort to mature, demonstrate, and prepare the transition of technology to the BLACK HAWK platform. The objective is to demonstrate an integrated platform solution that exemplifies both operational durability and total survivability without deleterious effect on mission performance. The CTPD technical approach builds on high impact technology themes (Combat Tempered Airframe, AFM, Full Spectrum Crashworthiness, Damage Adaptive Control Laws, Durable Main Rotor, and Zero Vibration Helicopter), which emerged from a thorough

inspection of mishap reports, combat data, and maintenance databases. The Joint Combat Assessment Team (JCAT) reports were extremely critical to Suzi's work. The proposed low-risk, high-value technologies are matured as part of the optimized Combat Tempered Platform (CTP) Configuration to significantly impact Operational Availability (Ao), Crashworthiness Index (CI), and CS. The integrated demonstration strategy validates CTPD capabilities and metric improvements through system-level testing, full-scale fuselage structural and crash testing, and dedicated flight testing.

The AFM System comprises METSS Corp. exoskeleton high-performance fuel bladders, Green On-Board Inert Gas-Generating System (GOBIGGS) fuel inerting technology, and Firetrace Dry Bay Fire Suppression to improve CTPD metrics, thus mitigating deadly combat incidents. As a participant in the annual JASP review, Suzi first learned about GOBIGGS via the early work accomplished at China Lake, and she immediately saw the value of the next-generation technology in helping to mitigate some of the battle damage incidents that she had researched as part of the CS metric. Her CTPD specific focus on vulnerability reduction was centric to higher order threats beyond the design requirements of the H-60. Suzi also knew from her interaction with other customer

programs that AFM technologies were marked for critical needs.

Upon completion of Preliminary and Critical Design efforts on the CTPD GOBIGGS, a successful full-scale ground test/demonstration effort in an integrated H-60 test bed was completed. Suzi oversaw the project to ensure that the following additional goals were successfully achieved: demonstration of rapid system warm-up and initial time to inert, maintenance of inert ullage throughout the aircraft's operating regime, demonstration of fit and function on a H-60, evaluation of exhaust gas route and airframe temperature impingement, overall system temperature characterization, and demonstration of water removal from the tanks. And her continued program efforts currently consist of working with the GOBIGGS manufacturer to market the technology and continue the transitioning of the hardware into other programs. These efforts helped moved GOBIGGS from a TRL 5 to nearly a TRL 7.

Not surprisingly, Suzi has received numerous awards for her efforts, including the Joint Expeditionary Forces Exercises (JEFX) recognition award in 2004, the Connecticut's Women of Innovation Award in 2008, and the 2014 CRH Outstanding Achievement award for progressing that effort from proposal to contract win. She holds a B.S. in

aerospace engineering and an M.S. in technical management from Embry-Riddle Aeronautical University (ERAU) and has pursued a Ph.D. in business administration. She has also authored numerous technical papers and presentations for the American Helicopter Society (AHS) and the National Defense Industrial Association (NDIA). **ASJ**

## **ABOUT THE AUTHOR**

Rich Hampson is currently the Chief of Survivability for Sikorsky Aircraft. During his 28 years at Sikorsky, he has also served in the positions of Comanche Aircraft Systems Management (ASM) Engineer, Mission Equipment Package (MEP) Systems Requirements Lead, Chief System Engineer on the Unmanned Combat Armed Rotorcraft (UCAR) and Naval Hawk Programs, Special Projects Chief Engineer, and Program Manager. Mr. Hampson holds a B.S. in aerospace/avionics engineering from Parks College of Saint Louis University.

# NDIA COMBAT SURVIVABILITY DIVISION PRESENTS 2015 COMBAT SURVIVABILITY AWARDS

by Robert Gierard



**Figure 1** Aircraft Survivability Symposium Awards Ceremony at the Naval Postgraduate School. From left to right; Combat Survivability Division founder Rear Adm. Robert Gormley, David Legg, Kevin and Diane Crosthwaite, Thomas and Terry Burbridge, and Division Chairman Brig. Gen. Stephen Mundt

On 5 November 2015, the National Defense Industrial Association (NDIA) Combat Survivability Division (CSD) Awards Committee, joined by CSD founder Rear Adm. Robert Gormley, presented its Combat Survivability Awards during the group's annual Aircraft Survivability Symposium at the Naval Postgraduate School (NPS) in Monterey, CA. The awards were given in recognition of superior contributions to combat survivability in the areas of leadership, technical achievement, and lifetime achievement.

## **GORMLEY COMBAT SURVIVABILITY AWARD FOR LEADERSHIP**

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

Mr. David K. Legg, U.S. Navy Naval Air Systems Command (NAVAIR) Branch Head for Combat Survivability, Fixed Wing Aircraft, and Associate Fellow for Combat Survivability, was presented this year's leadership award in recognition of his extensive history and increasingly responsible leadership roles addressing aircraft survivability and vulnerability efforts in support of a wide variety of manned and unmanned aircraft programs, as well as his technical leadership as an aircraft survivability subject-matter expert within naval aviation.

## **COMBAT SURVIVABILITY AWARD FOR TECHNICAL ACHIEVEMENT**

The annual Combat Survivability Award for Technical Achievement is presented to a person who has made a significant technical contribution to any aspect of survivability. It may be presented for a specific achievement or for exceptional technical excellence over an extended period. Individuals at any level of experience are eligible for this award.

Mr. Thomas E. Burbridge, Senior Manager and Leader of the Survivability Design and Integration Group of the Boeing Phantom Works, was presented this year's technical achievement award in recognition of the breadth of his leadership in electro-physical design, analysis, testing, and production of low observable aircraft and missiles. His technical work has significantly contributed to the survivability and mission effectiveness advantages that those platforms and weapons have provided to our commanders and aircrews.

## **COMBAT SURVIVABILITY AWARD FOR LIFETIME ACHIEVEMENT**

The annual Combat Survivability Award for Lifetime Achievement is presented to a person who has made significant technical and leadership contributions throughout his/her professional career, spanning many or most of the numerous facets of aircraft combat survivability. This award, the recipient of which is nominated by the executive board, is intended to recognize an individual's lifetime of accomplishments and dedication to the aircraft survivability community and to the aircrews the community serves.

Mr. Kevin R. Crosthwaite, former Director of the Survivability/Vulnerability Information Analysis Center (SURVIAC), was presented this year's lifetime achievement award in recognition of his long and active involvement with, and support of, the aircraft survivability community, as well as his continuing and tireless support of the many activities, goals, and ideals of the CSD. His work has significantly contributed to the development and success of generations of aircraft survivability experts and, thus, the survivability and mission

effectiveness advantages the community provides to commanders and aircrews.

Congratulations to all three of the 2015 awardees for their many accomplishments and contributions.

## **LOOKING AHEAD TO 2016**

It is not too early to consider who is deserving of recognition this coming November at the 2016 NDIA Aircraft Survivability Symposium, which will again be held at NPS. The CSD Awards Committee encourages community members to consider individuals in their staffs and organizations who have demonstrated technical achievement or leadership in the survivability discipline and are thus deserving of nomination. Nomination deadlines and submission procedures will be published later in the year. But there is no need to wait; the committee is happy to accept nominations now. To make a nomination and/or discuss the process further, please contact Mr. Robert Gierard at [robert.a.gierard@raytheon.com](mailto:robert.a.gierard@raytheon.com) or 310-200-1060. [ASJ](#)

### **ABOUT THE AUTHOR**

Mr. Robert Gierard is Chairman of the NDIA Combat Survivability Division Awards Committee.

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# CALENDAR OF EVENTS

## MAY

### 8th Annual EW Capability Gaps & Enabling Technologies

10-12 May in Crane, IN  
<http://www.crows.org/event/192-aoc-conferences/2016/08/10/54-8th-annual-ew-capability-gaps-and-enabling-technologies-operational-technical-information-exchange.html>

### Air Vehicle Survivability Workshop

10-12 May in Lexington, MA  
<https://conferences.ll.mit.edu/avs/>

### SeaAirSpace 2016

16-18 May in National Harbor, MD  
<http://www.seaairspace.org/page.cfm/link=1>

### DoD Electro-Magnetic Windows Symposium

16-19 May in Arlington, VA

### AHS Forum 72

17-19 May in West Palm Beach, FL  
<http://www.vtol.org/events/forum-72>

### AFCEA's TechNet Air Symposium

22-24 May in San Antonio, TX  
<http://events.jspargo.com/Air15/public/enter.aspx>

### Advanced Technology for National Security Workshop

24-26 May in Lexington, MA

## JUNE

### 7th Annual Electronic Warfare/Cyber Convergence Conference

7-9 June in Charleston, SC  
<http://www.crows.org/event/192-aoc-conferences/2016/06/07/53-7th-annual-electronic-warfare-cyber-convergence-conference.html>

### JASP FY17 Proposal Review

7-9 June in Atlanta, GA

### AIAA Aviation and Aeronautics Forum and Exposition

13-17 June in Washington, DC  
<http://www.aiaa-aviation.org/>

### Kittyhawk Roost Technical Interchange

13-17 June in Dayton, OH

### 48th Combined Light Armor Survivability Panel (CLASP)

28-29 June in Idaho Falls, ID

## JULY

### AIAA Propulsion and Energy Forum and Exposition 2016

25-27 July in Salt Lake City, UT  
<http://www.aiaa-propulsionenergy.org/>

## SEPTEMBER

### JAS Program Review

27-29 September

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

DSIAC Headquarters  
4695 Millennium Drive  
Belcamp, MD 21017-1505

Phone: 443/360-4600  
Fax: 410/272-6763  
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