JCAT Airman and Mission Featured on Air Force Website
page 7

Multifunctional Structural Composite With Integrated Electromagnetic Shielding
page 9

Utilization of Hydrodynamic Ram Simulator to Determine the Dynamic Strength Thresholds of Structural Joints
page 20

2018 NDIA Survivability Symposium Awards
page 29
# TABLE OF CONTENTS

4 NEWS NOTES  
by Dale Atkinson

5 JCAT CORNER  
by CW5 Scott Brusuelas, LCDR Matthew Kiefer, and LTC Andrew Roberts

7 JCAT AIRMAN AND MISSION FEATURED ON AIR FORCE WEBSITE  
by Eric Edwards
In October 2018, the U.S. Air Force website (www.af.mil) featured an article on Joint Combat Assessment Team (JCAT) member 1st Lt. Collin Dart and his duties in support of the JCAT mission. Lt. Dart is the chief aircraft battle damage and repair engineer for the Air Force Life Cycle Management Center at Robins AFB, GA, as well as a depot liaison engineer for the 386th Expeditionary Maintenance Group (EMXG).

9 MULTIFUNCTIONAL STRUCTURAL COMPOSITE WITH INTEGRATED ELECTROMAGNETIC SHIELDING  
by Harry R. Luzetsky
Military aircraft operate in a widely varied electromagnetic (EM) operational environment, which can critically affect onboard electrical/electronic systems, especially those characterized as level A or mission-critical. This environment includes emissions from sources that radiate radio frequencies (RF) that are coupled onto internal cables or produce aircraft internal field strengths of 5 to 200 V/m or greater. It also includes transients from some forms of EM encounters, such as lightning, EM pulse (EMP), and high-power microwave (HPM). The result can be upsets and/or hard failures of electronic systems, causing temporary or permanent damage to systems and aircraft function.

18 EXCELLENCE IN SURVIVABILITY: NICK GERSTNER  
by Ron Dexter
The Joint Aircraft Survivability Program Office (JASPO) is pleased to recognize Mr. Nick Gerstner for his Excellence in Survivability. Currently serving as the Air Systems Team Leader and overseeing all aircraft survivability programs for the SURVICE Engineering Company’s Dayton Area Operation (DAO), Nick is an accomplished vulnerability analyst, project leader, manager, mentor, and vulnerability subject-matter expert (SME). He has been providing the survivability community with critical computational, analytical, and test support on a wide range of acquisition and research programs for nearly 18 years.
20 UTILIZATION OF HYDRODYNAMIC RAM SIMULATOR TO DETERMINE THE DYNAMIC STRENGTH THRESHOLDS OF STRUCTURAL JOINTS

by Brandon Hull

The field of aircraft combat vulnerability is primarily responsible for determining the effects of man-made threat encounters on the operation, performance, and potential loss of an air vehicle. Fuel tank damage is one of the primary contributors to aircraft losses due to the large presented area and inherent volatility. Hydrodynamic ram (HRAM) is one of the leading damage modes related to fuel tanks alongside dry bay fire and ullage deflagration events. During an HRAM event, high-speed projectiles enter the fluid body and generate pressures in excess of 10,000 psi. The interaction of this fluid pressure and the surrounding structure causes high-strain-rate dynamic loading that leads to catastrophic failure, especially at joint locations between skins, spars, and ribs. When these joints are compromised, massive fuel loss through the damage location is likely. Also, if the fuel tank boundary is integral to the structure, primary load paths may be lost, leading to aircraft-level structural failures and the subsequent loss of aircraft. It is therefore imperative to understand the tolerance of fuel tank joints to HRAM loads.

29 2018 NDIA SURVIVABILITY SYMPOSIUM AWARDS

by Robert Gierard

Each year, the National Defense Industrial Association (NDIA) Combat Survivability Division (CSD) recognizes superior contributions to combat survivability by presenting awards for leadership, technical accomplishment, lifetime achievement, and excellence in a young professional. This year’s awards, which were part of the annual NDIA Aircraft Survivability Symposium on 6–8 November 2018, were presented at the Naval Postgraduate School’s (NPS’s) historic Herrmann Hall in Monterey, CA.
DAVIS NAMED JASPO DEPUTY PROGRAM MANAGER

In October 2018, Mr. James Davis joined the Joint Aircraft Survivability Program Office (JASPO) to serve as a Deputy Program Manager, leading modeling and simulation (M&S) efforts across the JASP portfolio.

For more than 17 years, Mr. Davis has contributed to increasing the survivability of U.S. aircraft and aircrews. While serving as a vulnerability analyst and live fire test engineer, he made a direct impact on the survivability of 15 air platform Programs of Record, including both fixed-wing and rotary-wing aircraft. His work directly supported analyses of alternatives, requirements development, requirements verification, and live fire test and evaluation (LFT&E) test design, review, and analysis of test results.

Most recently, Mr. Davis worked as a Science and Technology (S&T) manager for the Air Force Research Laboratory (AFRL). During his time at AFRL, he was the Operational Analysis (OA) and M&S lead for his division and was charged with the responsibility of providing the means to evaluate, through M&S, developmental technologies in an operationally relevant scenario to inform long-term investment/strategic decisions. A large portion of this work involved the development of M&S tools that accurately represent the operational scenario, including the threats, assets, and environment (e.g., clutter, atmosphere). Mr. Davis led laboratory work to observe and define hardware responses to stimulus, as well as the associated M&S work to capture the physics and associated effects within a digital representation. He also served as the technical lead for numerous projects focused on developing state-of-the-art technological solutions to reduce the susceptibility and vulnerability of U.S. aircraft.

Mr. Davis holds a B.S. in mechanical engineering from the University of Dayton in 2002 and an M.S. in engineering design from Wright State University in 2011.

NEW ARMY PRINCIPAL MEMBER STEERING GROUP (PMSG)

In September 2018, Mr. Kent Smith, who had served as the Army Joint Aircraft Survivability Program (JASP) Principal Member since 2014, passed the PMSG baton to Mr. Rusty Graves. Mr. Smith has moved on to Project Manager (PM) Unmanned Aircraft Systems (UAS) as its Engineering Operations Branch lead.

Mr. Graves has been an Army civilian for 35 years. He has worked at the U.S. Army Aviation and Missile Research, Development, and Engineering Center (AMRDEC) for his entire career, starting in Directed Energy Weapons before moving to Army Aviation. He was the Aviation Survivability Equipment (ASE) lead engineer for Program Executive Office (PEO) Aviation; the Systems Engineering Branch Chief for PM Non-Standard Rotary Wing Aircraft; the Chief of Plans, Programs and Support for the AMRDEC Aviation Development Directorate; the Chief Systems Engineer for PM ASE; and, currently, the PEO Aviation Advanced Technologies Program Manager.

Mr. Graves holds a B.S. in electrical engineering from the University of Tennessee.
This past year was a busy one for the Joint Combat Assessment Team (JCAT). The team spent much of 2018 involved in current combat damage assessments, JCAT qualification training, Threat Weapon Effects (TWE) training, and the Survivability Reduction Work Group (SRWG).

The SRWG, which was held 5–7 September at Fort Rucker, AL, was a new undertaking for JCAT. A total of 80 industry and Department of Defense (DoD) partners from the modeling and simulation (M&S) and survivability communities attended the event to identify capabilities for tactics, techniques, and procedure development using M&S. JCAT will continue this effort over the course of the next year to identify gaps and develop a road map to close these gaps.

In January, JCAT-Army (the Aviation Survivability and Tactics Team [ASDAT]) hosted the annual JCAT Phase 1 training at Fort Rucker, AL. A total of 27 personnel received training on weapons and warhead effects, aircraft combat damage data collection, casualty information collection, and assessment techniques. In support of upcoming deployment, five Army personnel received training on aircraft combat damage collection. Additionally, 14 Navy and 8 Air Force personnel received initial JCAT qualification training in preparation for JCAT Phase 2 training at the Naval Air Warfare Center (NAWC) China Lake, CA.

JCAT also has some hails and farewells to give. JCAT-Army hails CW4 Tyson Martin, who came to the team in August. CW4 Martin brings a wealth of

NEW AMC HEAD LOOKS TO IMPROVE AIRCRAFT SURVIVABILITY

In September 2018, Gen. Maryanne Miller assumed control of the U.S. Air Force’s Air Mobility Command (AMC), taking over the reins from retiring AMC Commander, Gen. Carlton Everhart. In doing so, Gen. Miller told reporters at the Air Force Association’s annual Air, Space and Cyber Conference in National Harbor, MD, last fall that the command is focusing on four key areas to improve the survivability of mobility aircraft. These areas include:

- Situational awareness of the battlefield
- New countermeasures to operate in a combat environment
- Self-defense systems
- Disciplined signature management.

AMC’s survivability improvement efforts, which are a continuation of the work performed under Gen. Everhart, include a recently completed “High Value Airborne Asset.” The study assessed ways to improve aircraft survivability in hostile environments, ultimately making recommendations for improvements in the areas of communications, situational awareness, and self-protection systems.

Gen. Miller noted that, to meet the Services’ increasing need for integrated situational awareness on the battlefield, the development of both new sensors and new air frames will likely be needed. The command is particularly interested in air frames that will have common cockpits; advanced propulsion systems; and payload, offload, range, speed, and fuel efficiency.

In addition, AMC continues to study advanced self-protection technologies in areas such as light armor, signature management/detection avoidance, and high-energy lasers. In fact, the possibility of installing lasers on mobility aircraft, such as the KC-135, has long been a consideration of AMC leadership. The command also continues to work to improve secure communications on the C-17 and other platforms.


Gen. Maryanne Miller
experience, coming off of a recent deployment to Afghanistan with the 16th Combat Aviation Brigade.

Likewise, in December CAPT Marty Butkis was relieved by CAPT Kelvin Askew as Commanding Officer of the Naval Air Systems Command (NAVAIR) In Service Engineering and Logistics (ISEL) unit. Although CAPT Askew is new to the JCAT mission, he is getting immersed in the training and has a good outlook for the future of JCAT.

Additionally, LCDR Matt “Gerbil” Kiefer took over as the Navy JCAT Program Manager from CDR Jay Kiser, bringing more than a decade of JCAT experience with him.

JCAT farewells CAPT Butkis and CDR Kiser and would like to thank them for their strong and steadfast leadership and support over the past 2 years.

Finally, JCAT would like to remind everyone that the 2019 Threat Weapon Effects (TWE) training event is scheduled for 23–25 April 2019 at Eglin AFB/Hurlburt Field, FL. Attendees must register via the Defense Systems Information Analysis Center (DSIAC) at https://www.dsiac.org.
In October 2018, the U.S. Air Force website (www.af.mil) featured an article on Joint Combat Assessment Team (JCAT) member 1st Lt. Collin Dart and his duties in support of the JCAT mission. Lt. Dart is the chief aircraft battle damage and repair engineer for the Air Force Life Cycle Management Center at Robins AFB, GA, as well as a depot liaison engineer for the 386th Expeditionary Maintenance Group (EMXG).
The article, which was written by Staff Sgt. Christopher Stoltz, began by explaining that although the desired outcome for any military conflict is to achieve victory without injury or damage, many lessons can be learned by studying combat outcomes that aren’t desirable (such as an aircraft shootdown or other sustained damage). And that’s where JCAT comes in.

The article went on to detail some of Lt. Dart’s background, responsibilities, and approaches, while also highlighting the overall roles of JCAT personnel to evaluate aviation combat damage incidents, assess the threat environment for operational commanders, and collect data through combat forensics to support aircraft survivability research and development.

Furthermore, the article explained that having JCAT members such as Lt. Dart deployed as part of a military unit can often provide a unique force multiplier to the unit (and even the entire theater). For example, Col. Lindsay Droz, commander of the 386th EMXG, noted that having Lt. Dart’s cross-airframe engineering knowledge and communication skills on site has greatly expedited the unit’s ability to support virtually any repair, incident, or mishap anywhere in theater.

“Rather than going back and forth with engineers in the states,” Col. Droz said, “we can work directly with Lt. Dart to capture our needs. This often cuts the number of iterations we have to go through to get an approved engineering solution. With the time differences, weekends, and amount of time engineers need to work through a solution, cutting down on even a single iteration can save us two to five days on any given repair.”

And, the article noted, the benefits go both ways. Although Lt. Dart admitted the work can be mentally and physically exhausting at times, he is proud of what he does and continues to be excited by its “puzzle-solving” challenges.

“Looking at the evidence and piecing together the story from the tiniest details is intriguing and rewarding,” he said. “It is also comforting knowing that the evidence I collect ensures our aircraft are stronger in the future.”

To read the full article on Lt. Dart and his JCAT work, visit www.af.mil/News/Article-Display/Article/1675378/jcat-airman-uses-combat-forensics-to-evolve-the-afcent-mission/.

---

2019 AIRCRAFT SURVIVABILITY SYMPOSIUM

SAVE THE DATE

Evolving Today’s Force to Dominate Tomorrow’s Threat

Join representatives from across the survivability community as we convene to discuss the latest technological advances, future threat trends, combat lessons learned and more in a classified setting.

Naval Postgraduate School | Monterey, CA
November 5 – 7 | NDIA.org/Aircraft
Military aircraft operate in a widely varied electromagnetic (EM) operational environment, which can critically affect onboard electrical/electronic systems, especially those characterized as level A or mission-critical. This environment includes emissions from sources that radiate radio frequencies (RF) that are coupled onto internal cables or produce aircraft internal field strengths of 5 to 200 V/m or greater. It also includes transients from some forms of EM encounters, such as lightning, EM pulse (EMP), and high-power microwave (HPM). The result can be upsets and/or hard failures of electronic systems, causing temporary or permanent damage to systems and aircraft function.
While circuit architecture can address some of these concerns, the traditional approach is to create a Faraday cage for aircraft electronics enclosures in the form of a heavy steel or aluminum box. As shown in Figure 1, these boxes are often installed in racks on the aircraft platform. Due to stringent weight requirements, the weight associated with a dedicated Faraday cage or shielding is often traded against aircraft performance. In many instances, shielding is thus eliminated to reduce weight and preserve aircraft performance. Without appropriate shielding, however, intensive energy fields produced by various EM sources, such as HPM and EMP, can instantly overload or disrupt electrical circuits at a distance. And modern high-technology microcircuits are especially sensitive to power surges and EM effects associated with external energy sources.

Through incorporation of EM shielding material into a structural composite, a Faraday cage structure that combines effective EM shielding, ballistic tolerance, low weight, and structural durability is now possible. The result is a lightweight alternative to the traditional means of providing aircraft electronics protection from the deleterious effects of EM radiation, thereby enhancing aircraft survivability. The metal composite hybrid material, developed by the SURVICE Engineering Company, provides a lightweight, affordable approach to achieving the desired level of EM protection of existing and emerging requirements, such as HPM and EMP/high-altitude EMP (HEMP).

**MATERIAL EM SHIELDING PROPERTY DEFINITION**

EM shielding properties were based on military standards and measurements from an aluminum enclosure that was previously constructed and tested by the Air Force Research Laboratory (AFRL). These military standards were used to establish the basic shielding design envelopes and actual test data from the enclosure to provide a measurement unit for comparison purposes.

Reviews of the military standards for EM environments were used to establish a basic design envelope for the composite enclosure in the harshest RF environments [1–3]. Figure 2 illustrates the relationships between field intensity and frequency that were developed from these reviews and required for the material design. These relationships established the EM environment that electronic components and systems could experience in operation and defined the basic EM protection levels required for the material design.

From the basic EM environment requirements, a comparative physical model using a typical electronics enclosure geometry was created to determine the effectiveness of the developed material in achieving the desired level of EM protection. Comparing the EM shielding effectiveness of the physical model against an existing baseline supported...
quantification of the shielding effectiveness of the multifunctional material.

AFRL provided an aluminum electronics enclosure test box (shown in Figure 3) to support data to evaluate the shielding effectiveness of the multifunctional material. The characteristics of this box established the baseline for the shielding effectiveness comparison. The box measured 8 × 13 × 19 inches, had 1/8-inch-thick walls, and weighed 32.5 lbs.

Shielding effectiveness testing for the aluminum baseline box provided by AFRL was conducted at Wyle Laboratories with the test setup shown in Figure 4 to establish minimum shielding requirements. A baseline measurement was made in the anechoic chamber to ensure that the proper field intensity or electric field (E-field) would be available when the box was present.

The field intensity inside the box was recorded and used with the radiated field to calculate the shielding effectiveness:

\[
S.E. = 20 \log \left( \frac{E-field \; received \; from \; source \; with \; no \; shield}{E-field \; received \; from \; shielded \; source} \right)
\]

The calculated shielding effectiveness for the baseline enclosure from 8 MHz to 18 GHz is presented in Figure 5. Per the constraints of the test setup, the highest field that could be radiated in the anechoic chamber was 200 V/m. When the baseline box was radiated with a field of 200 V/m and the received field inside the box was recorded from 10 kHz to 1 MHz, a field could not be detected. Therefore, it is known that the baseline box provided greater than 120-dB shielding in that frequency range. These test results defined the EM parameters required for demonstration of the multifunctional material.

MULTIFUNCTIONAL MATERIAL COMPONENT SELECTION

The selection of appropriate constituent materials was critical to the development of the multifunctional material as these materials established the potential weight, shielding effectiveness capability, and structural design capability. Making this selection required consideration of the operational environment of the material, including durability, environmental, and handling attributes. The basic weight and physical attributes of the material were driven by the baseline composite material while electrical properties were developed through integration of a uniquely shaped, high electrically conductive material in the design.

The selected baseline resin material was a semicrystalline polyetheretherketone (PEEK). This material was established as the baseline due to a combination of its environmental resistance, tolerance of various types of man-made fluids (including machine oils and fuels), superior impact properties, and excellent durability and wear resistance. These characteristics are a result of the resin highly ordered molecular structure associated with its semicrystalline nature.

With consideration of the operational aspects of the electronic enclosure, the key parameters for the fiber selection was driven by mechanical properties, electrical conductivity, and cost. The fibers considered for potential use in the enclosure design were graphite and nickel (Ni)-coated carbon fibers. Properties associated with the potential fibers are provided in Table 1.

Two fiber types were selected for evaluation in development of the multifunctional material: the AS4 graphite fiber and the Ni-coated carbon
(NiC) fiber. The selection process was driven by similar mechanical properties, low AS4 fiber cost, and potential enhanced electrical properties associated with the NiC fibers. Selection of these two fibers permitted evaluation of the effectiveness of the Ni coating in enhancement of electrical properties. In addition, the resin compatibility with each of the graphite fibers supported interchangeability to achieve greater mechanical properties.

In addition to the consideration for incorporating layers of NiC fibers to supplement the electrical shielding provided by the selected resin/fiber combination, metal layers were evaluated as an alternative. These layers were composed of an expanded copper mesh (Cu-\text{mesh}) film, which provides an effective shield against EM interference, RF interference, and electrostatic discharge. It is formed from a solid sheet of metal foil, in which the shape and pattern of the open areas are engineered precisely to match shielding requirements. The effect of mesh shape and size is illustrated in Figure 6. In addition, the mesh can be conformed to nearly any shape, readily bonds to the resin matrix, and has been demonstrated to work in in-situ tape fabrication processes.

**MULTIFUNCTIONAL MATERIAL FABRICATION**

Integration of the NiC fibers and/or expanded Cu-\text{mesh} with the base graphite/PEEK was accomplished with “on-the-fly processing,” which provides a methodology to integrate Cu-\text{mesh} with minimal impact to the structural properties while enhancing EM shielding of the developed material. With this process, the part is fully consolidated as the raw material is being put into place. There are no intermediate debulking steps or post-processing needed with the in-situ process. This process uses a nitrogen gas, which is heated as it passes through an electrically resistive heating element to elevate the raw material temperature up to its melting point. The material is then passed between a rigid steel roller and the processing tool to consolidate/compact the material, as illustrated in Figure 7.

The first layer of material is placed onto a cold tool. Subsequent layers are placed on top of the previous layers to form the laminate of desired thickness and fiber orientation. Each new layer is melt-bonded to the previous layer. Through additive manufacturing, the laminate or structure is built to the

<table>
<thead>
<tr>
<th>Property/Fiber</th>
<th>AS4</th>
<th>IM6</th>
<th>IM7</th>
<th>IM8</th>
<th>NiC*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength (ksi)</td>
<td>385</td>
<td>745</td>
<td>785</td>
<td>750</td>
<td>399</td>
</tr>
<tr>
<td>Tensile Modulus (Msi)</td>
<td>34</td>
<td>40</td>
<td>40</td>
<td>45</td>
<td>31</td>
</tr>
<tr>
<td>Strain to Failure (%)</td>
<td>1.1</td>
<td>1.75</td>
<td>1.85</td>
<td>1.63</td>
<td>1–2</td>
</tr>
</tbody>
</table>

* Estimated value
desired specifications, and then the complete component is removed from the tooling.

The critical integration feature for the Cu\textsubscript{mesh} is minimizing resin required to ensure a good bond between the mesh and base graphite/PEEK composite. Because the resin acts as an insulator, the more resin surrounding the Cu\textsubscript{mesh}, the greater the potential is for lower shielding effectiveness than with minimal resin.

MULTIFUNCTIONAL MATERIAL DESIGN

The design of the multifunctional material was based on percolation theory, where the composite is viewed as a series of conductive and nonconductive regions. The fibers and Cu\textsubscript{mesh} represent the conductive layers, while the resin is nonconductive. As material is added, there is a point where the overall laminate will begin to assume the electrical characteristics of the conductive layers. This occurrence is largely dependent on the electrical characteristics of these components and the overall thickness of the laminate.

Several laminate design configurations were developed and tested to determine the EM shielding effectiveness of various laminate designs and EM shielding effectiveness of their constituent components. Laminate configurations evaluated included variations of AS4/NiC and AS4/Cu\textsubscript{mesh} in a PEEK matrix. All panel designs were compared against an aluminum baseline electronics enclosure design. A custom test fixture was designed that permitted shielding effectiveness measurements of the flat panels while in an electronics enclosure box configuration. This fixture and test setup are shown in Figure 8.
As illustrated in Figure 9, while the NiC fiber tape was worked directly into the lamination process as the base fiber resin, integrating the Cu\textsubscript{mesh} into the laminates required more care to ensure that the mesh was securely encapsulated between layers of the base fiber and resin. In this manner, the resin migrates though the mesh, locking the copper substrate in place, which in combination with the adhesive characteristics of the resin securely bonds the mesh in the laminate in a manner that permits it to function as an integral ply of the laminate and not a “foreign layer” subject to delamination.

A comparison of the panel test data, showed similarity in shielding effectiveness between each of the panels tested in both magnitude and trending. In every instance, effectiveness levels associated with the composite panels exceeded the established minimum 60-dB requirement. From the comparison, it was determined that the combination of AS4/PEEK and expanded Cu\textsubscript{mesh} provided the greatest combination of structural properties and EM shielding effectiveness.

**MULTIFUNCTIONAL MATERIAL SHIELDING VALIDATION**

To validate functionality of the multifunctional material, an electronics box with the same geometric configuration as the baseline aluminum box was constructed using AS4/PEEK and two plies of expanded Cu\textsubscript{mesh}. As shown in Figure 10, the box was designed with end enclosures that could be either bonded and/or mechanically fastened to the body of the box.

EM shielding tests were conducted on the composite enclosure and compared with those for the aluminum baseline enclosure. The test setup and comparative results are provided in Figures 11 and 12, respectively.

Validation test results illustrated a shielding effectiveness that tracked closely with that of the aluminum box while yielding enhancements at both the low- and high-frequency levels. The
selected design successfully demonstrated:

- Weight reduction of 70% over traditional metallic enclosures (e.g., aluminum).
- Equivalent structural/operational characteristics to a base composite.
- Excellent durability and tailorable thermal conductivity.
- Shielding effectiveness exceeding all applicable MIL-STD-461, -464, and -2169B requirements [1–3].
- Resistance to chemicals/fluids (air and ground); chemical, biological, radiological, and nuclear (CBRN) effects; and decontamination exposure.
- Productivity and scalability to large and small structures with the capability to tailor the structure to structural and EMI requirements.
- A level of damage tolerance exceeding that associate with epoxy-based composites.

While other techniques exist for introducing EM shielding to composites, levels are typically below 60 dB and do not address the greater levels demonstrated by this multifunctional material. In addition, with high structural properties, the surrounding structure can be designed with integrated shielding, reducing the need for high protection levels in electronic enclosures. Compared to these other shielding techniques, the developed multifunctional material generates shielding levels minimally greater than 90 dB with certain frequencies exceeding 110 dB, thereby extending the application and operational environment capabilities. In addition, with the use of the additive manufacturing process, there is the potential to increase these levels even further with discrete placement and quantity of mesh. Figure 13 illustrates the shielding effectiveness capability of the developed material and how it reduces the existing protection gap with current technology.

The integration methodology of the structural graphite reinforcement and Cu\textsubscript{mesh} has minimal impact to the structural characteristics of the base composite material. While this result is largely dictated by the amount of Cu\textsubscript{mesh} introduced into the structure, as well as its location in the laminate, any concern over structural degradation is mitigated in the design process. With in-situ tape placement, various types of simple and complex structures are possible due to precision placement of the mesh within the laminate and a reduced need for dedicated enclosure boxes/structure.

Application of this technology to an aircraft structure is illustrated in Figure 14, where the material provides the structural load-carrying capability for the design and the added Cu\textsubscript{mesh} provides EM shielding levels required...
to protect internal electronics in the electronics bay. The mesh is added only to those areas that require the EM shielding, and the composite is transitioned in and out of these regions to tailor both structural and EM properties. These properties can be tailored to provide windows for sensor transmission while providing protection for other areas from EM energy levels between 80 and 120 dB across various frequencies.

CONCLUSIONS

Due to the multifunctional aspects for the developed material form (structural and EM shielding), and the manufacturing integration process, custom designed structures can be developed with shielding integrated into those areas necessary to protect contained electronics.

In summary, the multifunctional composite material provides the following features:

- A 30–70% weight reduction over traditional metal and composite structural configurations where EM interference shielding is required.
- Equivalent structural/operational characteristics to metallic and composite materials, including excellent durability and tailorable thermal conductivity.
- Sufficient shielding effectiveness to support all applicable MIL-STD-461, -464, and -2169B requirements.
- Resistance to chemicals/fluids (air and ground), CBRN effects, and decontamination exposure, as well as producibility and scalability to large and small structures using a fabrication methodology that is compatible to standard manufacturing processes.
- Compatibility with highly automated manufacturing and assembly processes.
- Ability to be tailored to individual requirements.
- Ability to seamlessly integrate continuous metallic bond for gaskets and connectors, which is achievable due to Cu meshes layers.
- Adaptability to aircraft structural designs by providing a capability to integrate EM shielding into a structure that also provides structural efficiency (high strength-to-weight ratio), damage tolerance, durability, and environmental resistance.
- Supportive of EM shielding signature reduction from a structural integration design perspective.

ABOUT THE AUTHOR

Mr. Harry R. (“Rick”) Luzetsky is currently a composites and aircraft survivability subject-matter expert at the SURVICE Engineering Company. With nearly 40 years of experience in design, test, research, and development, including 30 years with the Boeing Company, Mr. Luzetsky has helped develop and assess survivability features for numerous aircraft and has been active in composite design for vehicle performance and survivability.
improvements. He is the lead engineer for SURVICE’s role in the development of the EMI multifunctional material for a composite electronics enclosure, as well as a thermoplastic drive shaft. He also is a coauthor of two patents on an advanced fuel containment technology. Mr. Luzetsky holds a B.S. in materials engineering from Drexel University.

References
EXCELLENCE IN SURVIVABILITY
NICK GERSTNER

by Ron Dexter

The Joint Aircraft Survivability Program Office (JASPO) is pleased to recognize Mr. Nick Gerstner for his Excellence in Survivability. Currently serving as the Air Systems Team Leader and overseeing all aircraft survivability programs for the SURVICE Engineering Company’s Dayton Area Operation (DAO), Nick is an accomplished vulnerability analyst, project leader, manager, mentor, and vulnerability subject-matter expert (SME). He has been providing the survivability community with critical computational, analytical, and test support on a wide range of acquisition and research programs for nearly 18 years.

An Ohio native, Nick began his survivability career as a college intern at SURVICE in 2001. From his initial work building BRL-CAD and FASTGEN models to his current leadership and SME roles, Nick has repeatedly proven himself and demonstrated a keen ability to understand “big-picture” problems and thoughtfully sort through the details to arrive at effective solutions.

After his indoctrination to vulnerability modeling and simulation (M&S) with FASTGEN and the Computation of Vulnerable AREAs Tool (COVART) on the B-2 program in 2001 and 2002, it was clear that Nick possessed not only the technical aptitude for conducting detailed and accurate analyses but also the skill to effectively communicate his thoughts and ideas to improve analyses and the processes necessary to conduct them. Thus, Nick quickly earned a role assessing the Army’s top-priority RAH-66 Comanche helicopter, supporting SURVICE subcontracts from both Sikorsky and Boeing. During this time, he continued to hone his skills in geometry modeling and was one of the pioneers for developing a process to efficiently convert manufacturer CATIA models into BRL-CAD and FASTGEN target descriptions. This process resulted in the next generation of detailed target description models, models that retained the details of the original manufacturer’s design but without the unnecessary geometry contours and features that are known to slow analysis code run times.

The long list of fixed- and rotary-wing aircraft that Nick has influenced over the years includes the S-92, S-97, H-60, RAH-66, CH-47, CH-53E, CH-53K, CH-148, CRH, F-16, AV-8B, KC-46, C-27, F-16, F-35, and multiple foreign systems.

He has also participated in numerous turbine engine vulnerability programs (such as General Electric’s F-136 and GE38-1B) and weapon programs, including developing characterization data for projectile threats (under the Air Force Pedigree program). In addition, his many customers have included Sikorsky, Boeing, General Electric (GE), General Atomics, Bell, LifePort, SAIC, the Naval Air Systems Command (NAVAIR), NAVAIR PMA-261, the Naval Air Warfare Center Weapons Division (NAWCWD), the Naval Surface Warfare Center (NSWC) Crane, the Air Force Life Cycle Management Center’s Combat Effectiveness and Vulnerability Analysis Branch (AFLMC/EZJA), and the 704 TG-OL/AC.

In addition to his engine and platform acquisition programs, Nick also leads and conducts research and development programs and specialized design studies and analyses. For example, he was SURVICE’s project lead for a CH-53E Urgent Need requirement to design and evaluate a critical systems armor package in conjunction with NAWCWD. As part of the CH-53E armor team, Nick
conducted an armor panel location and design optimization study, providing recommendations and corresponding protection level options for several armor package designs. In recognition of these and other efforts, the Government and contractor team was presented with two Navy Gold Star awards.

Nick has also served as SURVICE’s program and technical lead on the CH-53K program (under subcontract to Sikorsky Aircraft), which dates back to concept studies before the CH-53K was a program of record. He has been influential in the vulnerability design, evaluation, and test of the helicopter and continues to successfully lead the COVART M&S contractor team, as well as play a key role in integrating live fire test and evaluation (LFT&E) data into the M&S processes and applying M&S tools for pre-test and post-test analysis.

Likewise, on the KC-46 development and acquisition program, Nick worked in conjunction with Boeing and AFLMC/ EZJA to evaluate vulnerability, support LFT&E, and conduct nontraditional studies for Crew and Passenger Survivability (CAPS), as well as low-energy laser vulnerability evaluation. He led the development of an OCA methodology that was approved and implemented by the Air Force on subsequent programs. He also led the aircraft’s test and analysis efforts to update fire $P_{eh}$ development by innovatively integrating LFT&E results into COVART, in near real time. This information was used to create a more accurate survivability posture of the aircraft in the specification compliance vulnerability analysis. For this and related work, the KC-46 Program Office presented Nick and the other members of the Survivability team with multiple recognitions.

Nick has also become recognized for his expertise in the test and evaluation aspects of vulnerability, performing a wide range of test planning, on-site test oversight and guidance, post-test data reduction, and integration of test data into the M&S processes to validate analyses and enhance accuracies. Not many individuals in the survivability discipline can be said to have such wide-ranging experience and expertise in both M&S and T&E, for both fixed- and rotary-wing aircraft, and for both Government and industry customers. Without a doubt, this unique combination makes Nick one of the current experts and leaders in the survivability discipline.

Nick’s proven technical expertise, however, is matched only by his willingness and ability to train others in the craft. Throughout his career, he has selflessly mentored newer (and even experienced) vulnerability analysts and answered requests for input and suggestions on a multitude of survivability-related programs. He has also conducted numerous formal and informal training sessions with industry partners looking to grow their in-house survivability capabilities.

As far as his education goes, Nick earned a bachelor’s degree in electrical engineering from the University of Dayton and a master’s degree in engineering management from Ohio University. In addition, he has published more than 100 vulnerability reports, developed multiple award-winning poster papers, and delivered numerous survivability-related presentations at national conferences.

Finally, when not at work, Nick spends time with his wife and three young children, enjoying sports, boating, camping, and other outdoors activities.

Congratulations, Nick, for your Excellence in Survivability and for your past, present, and future contributions to the aircraft survivability community.

**ABOUT THE AUTHOR**

Mr. Ron Dexter is the SURVICE Engineering Company’s Vice President for Air Force and Navy Sectors. He has more than 30 years of experience in aircraft and munitions survivability and lethality, including nearly a decade of that at Sikorsky Aircraft. In addition, he currently serves as President of the DaytonDefense organization, is a board member of the National Defense Industrial Association (NDIA) Combat Survivability Division, and is a former Chairperson of the American Institute of Aeronautics and Astronautics (AIAA) Survivability Technical Committee.
UTILIZATION OF HYDRODYNAMIC RAM SIMULATOR TO DETERMINE THE DYNAMIC STRENGTH THRESHOLDS OF STRUCTURAL JOINTS
INTRODUCTION

The field of aircraft combat vulnerability is primarily responsible for determining the effects of man-made threat encounters on the operation, performance, and potential loss of an air vehicle. Fuel tank damage is one of the primary contributors to aircraft losses due to the large presented area and inherent volatility. Hydrodynamic ram (HRAM) is one of the leading damage modes related to fuel tanks alongside dry bay fire and ullage deflagration events. During an HRAM event, high-speed projectiles enter the fluid body and generate pressures in excess of 10,000 psi. The interaction of this fluid pressure and the surrounding structure causes high-strain-rate dynamic loading that leads to catastrophic failure, especially at joint locations between skins, spars, and ribs. When these joints are compromised, massive fuel loss through the damage location is likely. Also, if the fuel tank boundary is integral to the structure, primary load paths may be lost, leading to aircraft-level structural failures and the subsequent loss of aircraft. It is therefore imperative to understand the tolerance of fuel tank joints to HRAM loads.

The RamGun at Wright-Patterson Air Force Base (WPAFB) was developed in the mid-2000s to assess this issue. Funded by the Joint Aircraft Survivability Program Office (JASPO), the RamGun was developed to address a need for low-cost evaluation of structural joint designs to HRAM loading [1, 2]. Rather than building and testing an entire fuel tank, coupon-sized joints are manufactured, instrumented, mounted in the test chamber, and exposed to controlled HRAM loads. For this article, all joints were mounted such that the base was normal to the load, simulating a symmetric pull-off event.

Historically, the RamGun has been operated in such a way that the structural joints were driven to complete failure. Single-axis strain gauges were placed on the base and web of the joint. The base strain gauges monitored flexural symmetry, and the web gauges monitored bending and recorded the strain rate and pull-off strain-to-failure. The fluid pressures were also measured at the specimen location using pressure transducers in the test chamber [1]. While this approach permitted the determination of strain-to-failure, it did not enable a determination of load-at-failure. This value is critical for establishing material allowables from which aircraft designs can be influenced.

The approach outlined in this article was modeled after the up-and-down method used to determine the \( V_{so} \) limit of ballistic materials [3]. The goal of such an approach was to establish a pressure range—termed the “zone of mixed results”—in which the composite joint has an equivalent chance of surviving and failing. This range is particularly important for bonded composites since the failure of the adhesive bond is more complex than the failure of bolted joints.

TEST METHODOLOGY

As described previously, the novelty of the information provided in this article is the approach used to assess the tolerance of bonded composite joints to HRAM loads and the corresponding results. The goal of the up-and-down method applied was to establish a zone of mixed results. This type of test procedure is conditional in that the parameters of each test point were influenced by the results of previous testing in the same series. This method is particularly effective when the number of available test assets is limited. Rather than testing conditions that are not particularly informative regarding the joint performance, this adaptive procedure allows for a rapid convergence of test events on the area of interest.

The following is an example test procedure:

- **Test 1:** Execute at a pressure for which the coupon is absolutely expected to survive.
- **Test 2:** Execute at a pressure for which the coupon is absolutely expected to fail.
- **Test 3:** Execute at the midpoint of the pressures used in Test 1 and Test 2.
- **Test 4:** If the coupon fails Test 3, execute at the midpoint between Test 3 and Test 1 in hopes of survival. If it survives Test 3, execute at the midpoint between Test 3 and Test 2 in hopes of failure.

This process was repeated for as many specimens as were available for testing. At the end of the test series, roughly half of the specimens should have failed, and roughly half should have survived. Given the continuum nature of failure in bonded composite joints, there should also exist a range of pressures for which...
some joints failed and some survived. This range is the zone of mixed results. An example visualization of this zone is shown in Figure 1. Identical figures are provided in the results section for the four other configurations tested.

For this configuration, exactly half of the coupons survived the HRAM event, and the other half failed. However, as shown, the highest pressure for which a coupon survived was 810 psi, and the lowest pressure for which a coupon failed was 716 psi. The region between these two values is the zone of mixed results.

The terms survival and failure were qualitative assessments of the joint status following testing. After each event was completed, the coupon was inspected for visible signs of damage. In all test cases categorized as a failure, this damage was a separation at the adhesive interface between the web and the base of the joint coupon. If there was no visible sign of damage, the coupon was categorized as a survival.

There was an additional hypothesis that joints that survived but fell within the boundary of the zone of mixed results would have degraded residual strength properties. To investigate this hypothesis, all coupons that survived the RamGun were preserved and tested in a quasi-static test fixture. The test methodology applied to these coupons was the same as that applied to two pristine coupons of the same configuration. This approach allowed for a comparison of failure load between pristine coupons and potentially compromised (i.e., RamGun-tested) joints of the same configuration.

If the pull-off load at failure for the RamGun-tested coupons was significantly less than the pristine coupons, it could be deduced that the internal microstructure of the composite or the adhesive bond was compromised in the RamGun testing despite the absence of a catastrophic failure. This hypothesis is further examined in this article.

**TEST SETUP**

**Test Articles**

To fully test out the methodology, five different article configurations were manufactured. They comprised three main constituents: a base, a web, and a pi preform. The base was constructed from unidirectional carbon fiber tape, the web was constructed from two-dimensional woven carbon fiber fabric, and the pi preform consisted of three-dimensional woven carbon fiber. All of the joint constituents were pre-impregnated with an epoxy resin system.

A film adhesive was used to bind these three constituents together into a single joint coupon. The adhesive was formed into a pocket for the web and the pi preform clevis and laid flat to adhere the pi preform to the base. These components were all cured according to the process instructions inherent to the epoxy resin and adhesives. A schematic of the pi joints is shown in Figure 2.

The dimensional properties of these constituents were varied to generate five unique configurations. For each configuration, eight coupons were constructed for RamGun testing and two coupons were constructed for quasi-static testing. Twelve additional Configuration 1 coupons were tested in the RamGun as well, and results from those tests are included.

**RamGun**

As previously introduced, the HRAM simulator (RamGun) is located at WPAFB’s Aerospace Vehicle Survivability Facility (AVSF) and operated by the Air Force’s 704th TG/OL-AC. The RamGun was developed and has undergone improvements for the past decade, largely funded by JASPO. The apparatus was developed to impart
HRAM loading on structural joints and evaluate their high-strain-rate failure in a more cost-effective manner than assembly-level testing. Since 2003, it has been used to test numerous joint designs, ranging from welded metal to bonded composites.

The RamGun is capable of generating fluid pressure waves similar to those expected during HRAM events. These pressure waves travel down a water-filled test chamber and are imparted onto the test coupon mounted at the end of the chamber. The test chamber of this apparatus is shown in Figure 3.

During operation, pressurized air is pumped into the gas chamber. This is the controlled variable during testing. When this gas pressure is released, it forces a Delrin puck down the gas gun barrel at velocities that range from 100 to 1,400 ft/s. At the end of the barrel is a steel plate, onto which the puck impacts. This causes fluid pressure waves to be generated in the water reservoir and travel toward the coupon location, as shown in the simulation in Figure 4.

The coupon is placed at the end of the test chamber. The base of the coupon is not restrained and rests against a foil membrane, which retains the fluid in the chamber. The web of the coupon is held in place by a web holder and affixed using torqued bolts. As the fluid pressure imparts itself on the base of the coupon, the web is restrained and the base is forced through the foil membrane, leading to a separation of the web and base in a failure event. If the joint survives, it is retained by the web holder.

The primary data sets collected from a RamGun test are the fluid pressure (measured through a combination of five pressure gauges) and strain response of the specimen mounted at the end of the fluid chamber. For the purposes of this test series, seven strain gauges were mounted to each specimen. The visual indication of failure and information from these instruments was used to draw conclusions on the performance of the joints and their resistance to HRAM loads.

**Quasi-Static Fixture**

The purpose of quasi-static testing was to identify coupons whose residual strength was degraded after exposure to RamGun testing. This testing was conducted using a four-point, roller-restraint setup with a constant applied strain of 0.04 in/min until joint failure. Two pristine specimens of each joint configuration were tested, and the load measured by the fixture’s load cell was used to establish a baseline performance. The same method was also applied to each test coupon that did not fail during RamGun testing. The test apparatus is shown in Figure 5.

**RESULTS AND DISCUSSION**

During RamGun and quasi-static testing, all joint coupons failed at the adhesive layer between the bottom of the pi preform and the base. There were no undesired failures in the web or at the clamp location. For some failed coupons, the entire pi appeared to disbond uniformly and immediately,
while others appeared to peel and delaminate a few layers of the base during failure. Although this difference is interesting, there was no discernible effect on the pressure at which the joints failed.

Examples of a survived and failed specimen are presented in Figure 6, followed by a description of the RamGun test results and the quasi-static test results.

Examples of a survived and failed specimen are presented in Figure 6, followed by a description of the RamGun test results and the quasi-static test results.

**RamGun Results**

As stated previously, the purpose of the methodology employed during this experiment was to test each configuration at discrete pressure values such that a zone of mixed results for the pressure load at failure could be established. The results are shown in Figures 7–11 for the tested configurations. A brief description of each test series is provided after each figure.

The configuration of the RamGun used in this test is shown in Figure 1. Each discrete test event is plotted on the corresponding axis. The green box represents the pressure range for which there were no failures, and the red box represents the range for which there were no survivals. The zone of mixed results is the overlap of these two regions.

Configuration 1 had 20 test points. Of all points tested, 13 coupons failed and 7 survived. The lowest pressure at the coupon location that caused a failure was 256 psi. The highest pressure for which a coupon survived was 484 psi. Several coupons were tested at extremely high pressures to explore the influence of strain-rate effects on absolute strain at failure. However, information related to this portion of the test is not included in this article.

Configuration 2 had eight test points. Of all points tested, four coupons failed and four survived. Given the construction of this configuration, it was expected to outperform Configuration 1, and the results matched the expectations. The lowest pressure at the coupon location that caused a failure was 716 psi. The highest pressure for which a coupon survived was 810 psi. The average pressure in the zone of mixed results was 763 psi, which is more than double the Configuration 1 performance for pressure load at failure.

Configuration 3 had eight test points. Of all points tested, two coupons failed and six survived. Although the up-and-down method was applied to these coupons, the variability of the RamGun caused more survivals than desired. The puck velocity correlates well with the air chamber pressure; however, there is variance in the puck impact angle and fluid pressure wave attenuation through the water column that affect the pressure at the coupon location. Configuration 3 testing was the most affected test series by this variance. The zone of mixed results for this configuration had the smallest range of all configuration tested, from 692 to 707 psi.

Configuration 4 had eight test points. Of all points tested, three coupons failed and five survived. This was the only configuration tested for which the zone of mixed results did not emerge. The gap between the highest survival pressure and the lowest failure pressure was 80 psi. If more test coupons were available, it is probable that a zone of mixed results would emerge by testing around this region. Configuration 4 survived the highest pressures of the five configurations tested, with an average of the survival and failure gap pressures of 1,252 psi.

Configuration 5 had eight test points, an even number of which passed and failed during RamGun testing. The average pressure in the zone of mixed results was 781 psi. This result was similar to the performance of Configurations 2 and 3.

Upon conclusion of the RamGun test series, the up-and-down method was shown to be successful for identifying failure pressure regimes using discrete test events. Configuration 1 clearly withstood the lowest pressures, and Configuration 4 withstood the highest pressures. Configurations 2, 3, and 5 all performed similarly and roughly averaged the performance of Configurations 1 and 4.

**Quasi-Static Results**

After the RamGun testing was completed, quasi-static testing was conducted on two pristine coupons of each configuration and all
Figure 7. Configuration 1 RamGun Results.

Figure 8. Configuration 2 RamGun Results.

Figure 9. Configuration 3 RamGun Results.

Figure 10. Configuration 4 RamGun Results.
RamGun-tested coupons that survived. The first item of note pertains to the quasi-static pristine coupon pull-off load compared to the RamGun pressure loads at failure. Table 1 shows the results.

The general trend of configuration performance discovered in the RamGun testing was similar to that exhibited during quasi-static testing. In general, Configuration 1 failed at the lowest loads and Configuration 4 failed at the highest loads. However, during quasi-static testing, the Configuration 2, 3, and 5 performances were substantially different from one another, whereas their average failure pressure during RamGun testing were all within 100 psi. This result indicates that the dynamic nature of RamGun testing and the corresponding high strain rates affect the performance of the joint, and those effects are construction-specific.

At the outset of this test, it was hypothesized that a relationship may have been made between quasi-static performance and dynamic performance. After the completion of both test series, no numerical correlation between the two values could be made given the available test data. However, given the apparent and consistent nature of the general trends, qualitative determinations of joint design characteristics that result in the worst and best performance can be made. This information is pivotal during the iterative design process to achieve a survivable fuel tank configuration.

The second purpose of the quasi-static testing was to identify coupons that did not completely fail but had residual strength losses following RamGun testing. All 17 coupons that survived RamGun testing were subjected to the same quasi-static test as the pristine coupons. A load rate of 0.04 in/min was applied until separation of the web and base occurred. Of all coupons tested, there were three that failed at a significantly lower load than the pristine coupons: two were Configuration 3, and

Table 1. Quasi-Static and RamGun Performance Comparison

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Average Static Pull-Off (lbf)</th>
<th>Percentage over Configuration 1</th>
<th>Average RamGun Failure (psi)</th>
<th>Percentage over Configuration 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,218</td>
<td>-</td>
<td>256</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>1,898</td>
<td>56%</td>
<td>763</td>
<td>198%</td>
</tr>
<tr>
<td>3</td>
<td>1,288</td>
<td>170%</td>
<td>700</td>
<td>173%</td>
</tr>
<tr>
<td>4</td>
<td>4,293</td>
<td>252%</td>
<td>1,252</td>
<td>389%</td>
</tr>
<tr>
<td>5</td>
<td>2,796</td>
<td>130%</td>
<td>781</td>
<td>205%</td>
</tr>
</tbody>
</table>

Figure 11. Configuration 5 RamGun Results.

Figure 12. Pull-Off Load for All Quasi-Static Tests.
one was Configuration 5. Figure 12 displays the pull-off load for all quasi-static tested coupons.

The three coupons that suffered residual strength losses are highlighted in the figure. All three of these coupons fell within the zone of mixed results for their respective configurations. The Configuration 3 coupons were tested at 707 and 698 psi. As shown in the results, both of these values are within the extremely tight zone of mixed results for this configuration (692–707 psi). Their failure loads were 73% and 44% less than the pristine sample, respectively. The third joint that displayed compromised residual strength was a Configuration 5 coupon that was exposed to 804 psi and failed at a load 23% less than the pristine sample. This coupon is also in the zone of mixed results for Configuration 5 (695–867 psi).

This result indicates that the microstructure of these coupons was compromised during RamGun testing even though complete failure did not occur. This indication is understandable since these coupons all fell within the zone of mixed results, meaning that other coupons of the same configuration completely failed at or below these test pressures. However, since there were many coupons that also fell within the zone of mixed results but did not exhibit degraded performance, additional investigation would be necessary to understand the cause of the strength loss. It is suspected that a loss of bond integrity initiated but did not fully propagate for those coupons. Techniques such as nondestructive inspection (NDI) could be used in future testing to check for the presence of anomalies in the bond line.

CONCLUSIONS

This article has presented a method for establishing the dynamic failure limit of bonded composite joints exposed to HRAM loading. This method was inspired by the up-and-down procedure used to determine the $V_{50}$ ballistic limit of armor [4]. Using the RamGun, various joint configurations were exposed to HRAM pressure loads, and their survival or failure was recorded. The goal of the test was to establish failure regions of pressures, or zones of mixed results, in which various joint configurations could potentially fail or survive. This information could be used to influence aircraft analysis and design to achieve a more survivable product with respect to HRAM event tolerance. After the completion of RamGun testing and assessment of the data, it was apparent that the proposed up-and-down method was successful in identifying failure regimes for all configurations tested. Of the five configurations, four had clearly identified zones of mixed results. For the fifth configuration (Configuration 4), the gap between the highest pressure for survival and lowest pressure for failure is only 80 psi. If more coupons were available for test, it is likely that a zone of mixed results for this configuration would have emerged as well.

There was a secondary hypothesis that, for joints that survived but fell within the boundary of the zone of mixed results, the residual strength properties would be compromised. This hypothesis was examined through the use of quasi-static testing. Pristine coupons of each configuration were pull-off-tested with quasi-static loading (0.04 in/min) to establish a baseline performance for failure load. All joints that survived RamGun testing were subjected to the same procedure, and their failure loads were determined.

Of the 18 coupons that survived RamGun testing and existed in the zone of mixed results, three coupons showed significantly degraded performance compared to the pristine coupons during quasi-static test. Two of the joints were Configuration 3 coupons. Their failure loads were 73% and 44% less than the pristine sample, respectively. The third joint failed at a load 23% less than the pristine sample. All of these coupons were RamGun-tested in the zone of mixed results for their respective configurations. It is likely that the internal microstructure of the composite or the adhesive bond for these three coupons was compromised in RamGun testing, although a catastrophic failure did not occur.

Qualitative conclusions regarding joint configuration performance to HRAM loading can be made from the test results. Configuration 1 is the most susceptible to failure to HRAM, and Configuration 4 retains its integrity to the highest loads. This information matches the quasi-static test results and can be used to influence designs and achieve a more survivable fuel tank configuration. Unfortunately, the test did not allow for the development of a numerical relationship between quasi-static pull-off performance and RamGun pressure loads at failure. This result is likely due to the complexities of high-strain-rate effects during dynamic events.

ACKNOWLEDGMENTS

The RamGun is managed and operated by Mr. Jason Sawdy, 704th TG/OL-AC, at WPAFB, OH. The guidance of Mr. Sawdy and his team during test planning and execution was pivotal to the test’s success. In addition, Mr. Ron Hinrichsen of Skyward Ltd. offered extensive assistance related to HRAM modeling.
Finally, significant input related to the approach was provided by Mr. Tim Staley, AFLCMC/EZJA, and incorporated into the final product described herein.

ABOUT THE AUTHOR

Mr. Brandon Hull has worked as an aircraft vulnerability engineer at Northrop Grumman Corporation’s Aerospace Systems since 2016, performing vulnerability analyses, supporting live fire test planning and execution, analyzing test results, providing design guidance for vulnerability reduction, and evaluating vulnerability reduction features and technologies for implementation. Prior to that, he served as a structural and ballistic survivability engineer at Boeing Phantom Works and completed his master’s thesis at NASA Langley Research Center. Mr. Hull holds bachelor’s and master’s degrees in aerospace engineering from Virginia Polytechnic Institute and State University.

References


Note

This article was presented at the American Institute of Aeronautics and Astronautics (AIAA) SciTech Forum in January 2019. Reprinted with permission. Copyright 2019 by AIAA, Inc. All rights reserved.
2018 NDIA SURVIVABILITY SYMPOSIUM AWARDS

by Robert Gierard

Each year, the National Defense Industrial Association (NDIA) Combat Survivability Division (CSD) recognizes superior contributions to combat survivability by presenting awards for leadership, technical accomplishment, lifetime achievement, and excellence in a young professional. This year’s awards, which were part of the annual NDIA Aircraft Survivability Symposium on 6–8 November 2018, were presented at the Naval Postgraduate School’s (NPS’s) historic Herrmann Hall in Monterey, CA.

COMMEMORATION OF THE PROFESSOR ROBERT E. BALL YOUNG PROFESSIONAL AWARD FOR COMBAT SURVIVABILITY

In response to the heavy aircraft and aircrew losses incurred during the conflict in Southeast Asia, the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) was formed in the early 1970s with a major goal of establishing aircraft combat survivability (ACS) as a new design discipline. The timely intersection of this goal with an energetic, young NPS aerospace engineering professor named Robert Ball, as well as forward-thinking leadership at NPS and the Naval Air Systems Command (NAVAIR), resulted in the first formal graduate-level course on ACS. Dr. Ball’s ACS course eventually led to two editions of a seminal text, The Fundamentals of Aircraft Combat Survivability Analysis and Design, which became the foundation for 4 decades of NPS and JTCG/AS-sponsored courses across academia, industry, and Government.

In recognition of these efforts and Dr. Ball’s long-time contributions as an educator, author, and mentor, the CSD was pleased this year to present a commemorative award to the quintessential survivability expert. Dr. Ball was then invited to assist in recognizing this year’s recipient of the Young Professional Award, which was named in his honor.

Figure 1. 2018 Combat Aircraft Survivability Symposium Awards at NPS. From Left to Right: Laura Trench, Lee Venturino, Robert Wirt, and Lou Colangelo.
PROFESSOR ROBERT E. BALL YOUNG PROFESSIONAL AWARD FOR COMBAT SURVIVABILITY

The Young Professional Award—which was first given last year—is presented to an early- to mid-career person (35 years of age or younger at the time of award) who has made a significant technical, analytical, or tactical contribution to any aspect of aircraft survivability.

This year’s award was presented to Ms. Laura B. Trench, a young engineer, leader, and recent Deputy Program Manager of the Virtual Warfare Center at Boeing Phantom Works. In her 7 years at Boeing, Ms. Trench’s roles have evolved from laboratory device/system testing to flight testing to large-scale simulation and analysis of complex system-of-systems concepts involving all aspects of Red and Blue survivability and lethality. In addition, her leadership responsibilities have grown from Lab Test Engineer to Test Integrated Product Team (IPT) Lead to System Integration & Test Director to Deputy Program Manager of the Virtual Warfare Center.

COMBAT SURVIVABILITY AWARD FOR TECHNICAL ACHIEVEMENT

The Technical Achievement Award 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. Lee “LV” Venturino, President and CEO of First Principles Inc., was recognized this year for his sustained technical leadership in the balanced development and application of stealth and electronic warfare technologies, both as an Air Force officer and as the founder and CEO of his systems engineering consulting company. Mr. Venturino has successfully integrated these technologies into numerous weapons systems, from ballistic missiles to numerous very low observable (VLO) aircraft—most notably, the F-35. With more than 30 years of flight testing and defining electronic attack/electronic protection operational requirements, he has also become a key member of numerous Defense Science Board (DSB), Air Force Scientific Advisory Board (AFSAB), and Office of the Secretary of Defense (OSD) studies.

RADM ROBERT H. GORMLEY COMBAT SURVIVABILITY AWARD FOR LEADERSHIP

The Leadership Award 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 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. Louis A. Colangelo, Deputy Mission Area Executive for Precision Strike at the Johns Hopkins University Applied Physics Laboratory (JHU/APL), was recognized this year for his sustained leadership in the integration of electronic attack capabilities into U.S. aircraft programs and combat operations. Mr. Colangelo’s long association with the EA-6B and EA-18G programs, at both Grumman Corp-Aerospace & Electronics Group and JHU/APL, have labeled him as the “technical conscience” of the program. His expertise then widened across the entire offensive strike kill chain, resulting in his current position as APL Deputy Mission Area Executive Precision Strike. He has been
recognized for his many contributions to DSB and OSD/Cost Assessment and Program Evaluation (CAPE) studies, NAVAIR trade studies, source selections, and analyses of alternatives. In addition, Mr. Colangelo has been described by OSD leadership as a “star player” for his highly respected expertise and “superb analytic products” in support of electronic warfare and aircraft vulnerability.

**COMBAT SURVIVABILITY AWARD FOR LIFETIME ACHIEVEMENT**

The Lifetime Achievement award 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 is nominated by the CSD Executive Board and is intended to recognize an individual’s lifetime of accomplishments and dedication to the aircraft survivability community and to the aircrews we serve.

Mr. Robert “Rowdy” Wirt, Technical Director, Directorate of Special Programs, Secretary of Air Force (SAF/AQL), was recognized this year for his more than 33 years of active duty and civil service support to U.S. Air Force and Navy aviation programs, as well as to the U.S. intelligence and air combat survivability communities. He has provided leadership and expertise in low observable (LO) and counter low observable (CLO), electronic warfare, and aircraft survivability technologies, as well as all source threat analysis and net assessments. He has also been directly involved with survivability and lethality improvements to the B-2, F-22, F-35, and many other classified weapon systems. Furthermore, as the current technical director of SAF/AQL, he has been a senior technical advisor to the Secretary of the Air Force and the Chief of Staff of the Air Force, as well as the Department of Defense LO/CLO Executive Committee in matters concerning the department’s most sensitive and highly classified air, space, and cyber capabilities.

**BEST POSTER PAPER AWARD**

Finally, the winner of this year’s NDIA Survivability Symposium Best Poster Paper Award was Ms. Tara Bell from the Special Operations Forces (SOF) Rapid Capability Development and Deployment, who submitted a paper on the Chemical-Biological Aircraft Survivability Barrier (CASB) (shown in Figure 3). In addition to submitting the paper, Ms. Bell and her team brought a prototype of the CASB, which was a first at the NDIA Survivability Symposium. The CASB was developed in response to a U.S. Special Operations Command requirement to sustain tactical force operations with the focus on regenerating multiple sorties intratheater before transitioning to intertheater redeployment. The Air Force and Army Special Operations Commands will employ the CASB to protect the interior of the DoD’s critical airlift assets from cross-contamination by chemical/biological (CB)-contaminated personnel and equipment under transport. This tactical arm of airlift airpower comprises high-demand, low-density, and expensive assets. Accordingly, the loss of any single asset from a CB-contaminated event would result in the effective loss of that asset.

**LOOKING AHEAD TO 2019**

As always, it’s not too early to consider who among our ranks is deserving of recognition next November at the 2019 NDIA Aircraft Survivability Symposium in Monterey. Is there someone in your own staff/organization who has demonstrated technical or leadership achievement in the survivability community? Also, is there someone among your early-to-mid career staff who has demonstrated a flair for the survivability discipline and is deserving of early recognition?

The CSD will publish award nomination deadlines and submission procedures later in 2019, but there is no need to wait. Interested nominators should contact Awards Subcommittee Chairman Robert Gierard at robert.a.gierard@raytheon.com or 310-200-1060 for more information or to discuss the nomination process in greater detail.

**ABOUT THE AUTHOR**

Mr. Robert Gierard is Chairman of the NDIA CSD Awards Committee.
CALENDAR OF EVENTS

MARCH

Counter UAS Summit 2019
12–14 March 2019 in Washington, DC
https://counteruas.iqpc.com

Military Radar Summit 2019
12–14 March 2019 in Washington, DC
https://www.militaryradarsummit.com/

2019 Cyber-Augmented Operations Division Spring Conference
26–27 March 2019 in Austin, TX
http://www.ndia.org/events/2019/3/26/cyber-spring---9841

2019 AUSA ILW Global Force Symposium and Exposition
26–28 March 2019 in Huntsville, AL
http://ausameetings.org/globalforce2019/

APRIL

20th Annual Science & Engineering Technology Conference
2–4 April 2019 in San Diego, CA
http://www.ndia.org/events/2019/4/2/set-conference___9720

Army Aviation Mission Solutions Summit
14–16 April 2019 in Nashville, TN
https://s15.a2zinc.net/clients/aaaa/aaaa19/Public/Enter.aspx

SPIE
14–18 April 2019 in Baltimore, MD
http://spie.org/conferences-and-exhibitions/defense-commercial-sensing?SSO=1

JCAT TWE
23–25 April 2019 in Hurlburt Field, FL

AUVSI XPONENTIAL 2019
29 April to 2 May 2019 in Chicago, IL

MAY

AIAA DEFENSE Forum
7–9 May 2019 in Laurel, MD
https://defense.aiaa.org/

62nd Annual Fuze Conference
13–15 May 2019 in Buffalo, NY
http://www.ndia.org/events/2019/5/13/62nd-annual-fuze---9560

Vertical Flight Society’s 75th Annual Forum and Technology Display
13–16 May 2019 in Philadelphia, PA
https://vtol.org/forum

Aircraft Combat Survivability Short Course
29–31 May 2019 in Atlanta, GA

JUNE

66th JANNAF Propulsion Meeting
3–7 June 2019 in Dayton, OH

AIAA Aviation Forum
17–21 June 2019 in Dallas, TX
https://aviation.aiaa.org/CalforPapers/

Optical Sensors
25–27 June 2019 in San Jose, CA
https://www.osa.org/en-us/meetings/osa_meetings/optical_sensors_and_sensing_congress/program/optical_sensors/

Directed Energy Systems 2019
26–28 June 2019 in Washington, DC
https://distributedlethality.iqpc.com/?utm_medium=portal&mac=1OPCCORP

JULY

The Wright Dialogue With Industry
16–18 July 2019 in Dayton, OH
http://www.wrightdialogue.org/index.html

SEPTEMBER

Air Vehicle Technology Symposium
10–12 September 2019 in Dayton, OH
http://www.avtechsymposium.com/index.html

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
Email: contact@dsiac.org

To update your mailing address, fax a copy of this page with changes to 410/272-6763 or scan and email it to contact@dsiac.org.