Fires ignited by threats such as warhead fragments and armor-piercing incendiary (API) rounds are a major concern for both fixed- and rotary-wing aircraft. This concern is primarily due to the large presented area of aircraft components containing flammable liquids, such as fuel tanks, fuel lines, hydraulic reservoirs, hydraulic lines, lubricants, and electronics cooling fluids. The Next Generation Fire Model (NGFM) effort was launched in response to a recognized need by the Director, Operational Test and Evaluation (DOT&E) and the aircraft vulnerability community for enhanced fire prediction and modeling capability beyond current capabilities.

As the Computation of Vulnerable Area Tool (COVART)—formerly called the Computation of Vulnerable Areas and Repair Time—approaches its 44th anniversary as a system-level vulnerability/lethality (V/L) evaluation tool, it is now supporting the third generation of engineers and analysts it has seen since its initial release in 1973. The specifics of the software have changed over the last four decades, but COVART’s mission has remained the same: provide decision-makers with the V/L information they need to make informed acquisition decisions.

On 17 June 1861, Thaddeus Lowe and another observer surveyed the Confederate positions located south of Washington, DC, across the Potomac River. What made this survey unusual was that Lowe and his companion were suspended in a basket below a hot air balloon at an altitude of 500 ft above the city. The observer was relaying their observations to the White House and War Department via telegraph. Near real-time intelligence collection and communication was born. However, the Confederate soldiers under observation did not let this intelligence collection go without a response.
24 OPTIMIZING M&S APPROACHES FOR PENETRATING PLATFORM SURVIVABILITY TESTING
by CPT Maxim Olivine

Analysts have generally assessed aircraft combat survivability, particularly in the electronic warfare domain, through a series of scientific analyses, as well as developmental and operational testing (including laboratory and flight test events) during the design, development, and fielding stages of a particular weapon system [1]. More recently, with the help of advanced computer processing power, modeling and simulation (M&S) has begun to play a larger role in aircraft survivability test approaches by allowing mathematical approximations to examine survivability characteristics in ways not possible in traditional laboratory, ground, and flight test.

28 EXCELLENCE IN SURVIVABILITY: LEANNE MCKAY
by Ron Dexter

The Joint Aircraft Survivability Program Office (JASPO) is pleased to recognize Ms. LeAnne McKay for her Excellence in Survivability. An accomplished vulnerability analyst and project leader, LeAnne—who currently serves as the Deputy Manager of the SURVICE Engineering Company’s Dayton Area Operation—has been providing the survivability community with critical computational, analytical, and test support on a wide range of foreign and domestic weapons programs for nearly three decades.

30 NDIA 2016 COMBAT SURVIVABILITY AWARD
by Robert Gierard

In November 2016, the National Defense Industrial Association (NDIA) Combat Survivability Division (CSD) Awards Committee, joined by the division 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.
GREG CZARNECKI RETIRES

After 40 years of Federal service, long-time subject-matter expert (SME) and survivability community leader Greg Czarnecki has retired. Mr. Czarnecki’s Government career began in 1972 with enlistment in the Navy, where he served as an Operations Specialist aboard the USS Courtney (DE 1021) and later the USS McCloy (DE 1038). Upon completion of his active duty obligation, he transitioned to the Navy Reserve for 2 years and then to the Ohio Army National Guard. In 1993, he retired from the military with 21 years of combined active, reserve, and guard service.

Concurrent with his military service, Mr. Czarnecki earned a B.S. degree in engineering from the University of Dayton in 1980 and began his civilian career in aircraft survivability with the Air Force Research Laboratory (AFRL) at Wright-Patterson Air Force Base, OH. In 1992, he earned an M.S. degree in materials engineering from the University of Dayton and soon thereafter completed his Ph.D. coursework. In 1999, Mr. Czarnecki and the aircraft survivability mission transferred to the 96th Test Wing and eventually to the Arnold Engineering Development Center. As a 36-year member of the Aerospace Survivability and Safety Office, Mr. Czarnecki promoted the development, advancement, application, maturity, and credibility of modeling and testing methodologies for aircraft survivability. Early in his career, he applied emerging nonlinear finite element (FE) methods to predict antiaircraft artillery damage effects on F-4, A-7, and F-15 aircraft structures. In the late 1980s, he coupled his FE and test experience with evolving structural optimization routines to perform a fly-off of composite materials under consideration for the Advanced Tactical Fighter. Materials proving to have greatest damage resistance were later adopted for application on the F-22.

In addition, Mr. Czarnecki organized and cohosted a Hydrodynamic Ram Workshop in the early 1990s that matured, verified, and validated ram modeling procedures. After the turn of the century, he collaborated with General Electric and RHAMM Technologies to couple an FE model of a Man-Portable Air Defense System (MANPADS) missile with that of a large aircraft engine. This effort marked the first time that a dynamic, rotating engine model was reconfigured to credibly consider damage caused by a MANPADS impact. It also yielded an engine-MANPADS modeling procedure applicable to other engagement conditions and engine types.

Separate from his FE endeavors, in the early 1990s Mr. Czarnecki led an in-house impact physics initiative that investigated complex dynamic behavioral characteristics of composite materials. His own research (culminating in his master’s thesis) involved the discovery and quantification of shear and stress-wave damage sequences within impacted composite laminates. Mr. Czarnecki continued to work with senior researchers and doctoral students to advance the knowledge base associated with impact physics of composites. His contributions advanced instrumentation technologies, identified impact energy absorption mechanisms, and produced an economical method of predicting the threshold penetration velocity.

As a Joint Aircraft Survivability Program (JASP) member since 1984 and the JASP Structures and Materials Committee Chairman since 1998, Mr. Czarnecki coordinated with Army and Navy representatives to promote ballistic-, ram-, and laser-toughened composite structures. His investigations included assessment of asymmetric ram and open-air pressure fields generated by high-explosive munitions; development of a hydrodynamic ram simulator and determination of ram-resistant skin-spar joints; and evaluation of ballistic, fire, and laser damage effects on composites. All of these efforts transitioned to model improvements, serving aircraft acquisition program offices and Live Fire Test and Evaluation.

Responding to a 1997 Office of the Secretary of Defense query concerning what could be done to limit aircraft vulnerability to the MANPADS threat, Mr. Czarnecki joined with JASP leadership to survey the state-of-the-art and recommend solutions. He helped
organize and chair the first National MANPADS Workshop, which assessed the magnitude of aircraft-MANPADS incidents, the ability to perform MANPADS vulnerability assessments and damage predictions, and what might be done to limit aircraft vulnerability to the MANPADS threat. He and other JASP members then led the charge to assess and improve aircraft survivability by assessing MANPADS blast and fragmentation, advancing aircraft-MANPADS modeling methodologies, and identifying a JASP course of action for further assessment of MANPADS issues.

In 2001, Mr. Czarnecki and a tri-Service modeling and simulation (M&S) team took a first look at the ability of M&S to credibly achieve MANPADS hit-point predictions. In 2005, he and JASP supported a Joint Test and Evaluation project that developed near-term aircraft survivability solutions using optimal combinations of susceptibility and vulnerability reduction techniques. Results were provided to in-theater Iraq/Afghanistan aviation commanders to reduce the operational risks of cargo and rotary-wing aircraft.

In other MANPADS-related efforts, Mr. Czarnecki arranged Joint Live Fire (JLF) Program teaming with the National Aeronautics and Space Administration (NASA) to evaluate MANPADS damage effects on the horizontal tails of large aircraft. Data supported a determination of safety-of-flight for aircraft experiencing similar damage. And under his leadership, JASPO, JLF, NASA, the Department of Homeland Security, and General Electric performed a first-ever model-test-model assessment of MANPADS damage effects on large turbofan engines. This and previous efforts significantly improved the community’s understanding of the MANPADS threat and will support aircraft survivability for years to come.

Mr. Czarnecki also authored/co-authored more than 40 published reports and 35 papers (including numerous contributions to Aircraft Survivability) during his four-decade career. And he received numerous awards and honors, including the AFRL’s Senior Engineer/Scientist of the Year award in 1998, JASPO’s Excellence in Survivability recognition in 2008, and the National Defense Industrial Association’s Combat Survivability Award for Technical Achievement in 2014.

The JASP congratulates Mr. Czarnecki on his distinguished career, thanks him for his many professional contributions to our community, and wishes him the best throughout his retirement transition to Alaska.

The JASP mission has evolved from combat damage collection in Southeast Asia in the 1960s to the collection in Southwest Asia over the last 15 years. In November 2016, the Joint Requirements Oversight Council (JROC) approved the Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities, and Policy (DOTmLPF-P) Change Recommendation (DCR) for Air Combat Damage Reporting (ACDR). The DCR approval formalizes the ACDR process for training, personnel assignment, and reporting requirements “across the full range of military operations” for support to “assist in identifying threats to task force air operations.” The approval pushes forward further commonality in executing the JASP mission across the Services and sets the stage for the JASP “Next-Gen.” The JASP mission is evolving to include (much like the current Aviation Shoot Down Assessment Team [ASDAT] model) being capable of deploying a rapid reaction team. The DCR approval solidifies the requirement to mobilize and deploy folks for larger-scale operations, as seen during Operations Enduring Freedom and Iraqi Freedom, in conjunction with a Request for Forces (RFF). Additionally, the DCR approval helps to secure a broader means of data collection by rebasing data storage and maintenance with the Intelligence community for use in developing tactics and improving the survivability of our aircraft and aircrews.

JASP continues to collect combat damage data in theater using JASP-trained and deployed U.S. Air Force depot liaison engineers and Army Aviation Mission Survivability Officers (AMSOs). These active duty Air Force engineers operate downrange on a...
rotating basis, supporting the collection of combat battle damage for Air Force maintenance units and assisting with aircraft repairs that exceed the published tech order limits. Combat Aviation Brigade (CAB) AMSOs collect combat damage while deployed to assist JCAT’s collection and assessment efforts. Additional depot liaison engineers and CAB personnel are attending the 2017 Joint Combat Assessor training curriculum to support JCAT data collection during upcoming deployments.

The Army Component of the JCAT hosted the 2017 Phase 1 of the Joint Combat Assessor training at the Army Aviation Center of Excellence in Fort Rucker, AL, the week of 23 January. This one-week training event is the first of two courses that qualify a JCAT Officer to assess combat damaged aircraft. This year’s class trained nine Air Force and nine Navy officers (pictured in Figure 1) assigned to JCAT, as well as seven members of the Army’s 16th CAB. Phase 1 training focused on weapons and warhead effects, combat damage data collection, and casualty information collection. This training prepares the students for their Phase 2 training conducted at the Naval Air Warfare Center (NAWC) in China Lake, CA, where they will conduct combat assessment scenarios on aircraft test articles.

In December 2016, Navy JCAT bid farewell to CAPT David Storr, as he completed his tour as Commanding Officer (CO) of the Navy Reserve In-Service Engineering and Logistics (NR ISEL) unit. CAPT Storr has been a longstanding member of the Navy JCAT, influencing the JCAT community with his leadership and expertise. He had been instrumental to the successful deployment of personnel forward while embedded with the 3d Marine Aircraft Wing (MAW) and provided exceptional leadership as the unit’s CO. CAPT Matt “Marty” Butkis has taken the helm of NR ISEL, based at Naval Air Station in Patuxent River, MD, as well as the Navy JCAT membership. CAPT Butkis brings a wealth of knowledge and experience (including 28 years of active duty and Reserve service), having served as an Aviation Maintenance Duty Officer (AMDO) with the Navy since 1989. His most recent deployment was with the 3d MAW as the Officer-in-Charge (OIC), Forward Deployed Combat Repair at Camp Bastion, Afghanistan.

Additionally, both detachments of the unit saw changes of charge. CDR Sean Neally relieved CDR Chad Runyon as the OIC of Detachment A, based at Wright-Patterson Air Force Base, OH, and CDR Joe Toth relieved CAPT Jon Rugg as the OIC of Detachment B, at Naval Air Weapons Station in China Lake, CA. CDR Neally and CDR Toth have both deployed forward as part of the JCAT mission and have a wide range of active and Reserve experience.

In addition, the Air Force JCAT officially welcomes CPT Dan Adducchio to the team. CPT Adducchio comes to the team from the 123d AW out of Louisville, KY. He has an extensive background in aircraft system failure analysis, has contributed to a number of Air Force Safety Investigation boards, and builds the team’s expertise with more than 12 years of aircraft maintenance experience.

Likewise, in February 2017, the Army component of JCAT bid farewell to CW4 Mitch Villafania. CW4 Villafania served with the ASDAT since 2015 and has been reassigned as the AMSO, 2d CAB, Korea. As a recent graduate of the AH-64 Aircraft Qualification Course (AQC), CW4 Villafania will take the 2d CAB to the next level with the knowledge he gained during his assignment with JCAT, his skills as an OH-58D aviator, his audacity as Cavalryman, and his experience as an AMSO.

Significant changes have occurred over the last quarter that will expand and solidify the JCAT mission. We bid a “Fair Winds and Following Seas” to all the outgoing members of the team as well as a “Welcome Aboard” to all the JCAT members joining us. And we charge these new members to maintain the tradition and level of expertise required to collect combat damage and improve the survivability of our aircrews and aircraft.
Fires ignited by threats such as warhead fragments and armor-piercing incendiary (API) rounds are a major concern for both fixed- and rotary-wing aircraft. This concern is primarily due to the large presented area of aircraft components containing flammable liquids, such as fuel tanks, fuel lines, hydraulic reservoirs, hydraulic lines, lubricants, and electronics cooling fluids. The Next Generation Fire Model (NGFM) effort was launched in response to a recognized need by the Director, Operational Test and Evaluation (DOT&E) and the aircraft vulnerability community for enhanced fire prediction and modeling capability beyond current capabilities. This need spawned from the increased cost of test and test assets, growing challenges to integrate optimized vulnerability reduction technologies onboard aircraft, and the outgrowth of current fire modeling tools. This last realization is based on the increased knowledge gained in recent years from test programs that have been able to improve data diagnostic information, resulting in a better understanding of the detailed aspects for threat characterization, fluid spray, and, ultimately, ignition. This knowledge has also justified taking a fresh look at fire modeling and the establishment of a path forward.

BACKGROUND AND NEED

There are two main reasons that predicting fire is a top concern to the aircraft vulnerability community: aircrew survivability and economics. The former reason was raised by a review of air combat data in Southeast Asia that showed that fire and explosions contributed to more than 50% aircraft losses. The economic data are more current. As of FY13, the Air Force alone had spent tens of millions of dollars on dry bay fire testing, making fire the largest cost contributor for Live Fire Test and Evaluation (LFT&E) programs. The need for all this testing was driven by a large estimated uncertainty in total platform vulnerable area (Av) driven by probability of kill (PK) due to ballistic-ignited fires. The total uncertainty is a product of the fire uncertainty compounded by the large presented area of components.
containing flammable liquids in aircraft. Knowledge in understanding all aspects for the physics of fire and the development of models to simulate that understanding are insufficient within the survivability community for supporting advanced aircraft designs and growing requirements.

In the past, the vulnerability community has had two primary methods to evaluate fire. The older method, still in use today, is to use legacy test data if the aircraft conditions align with the test conditions that generated the data. If legacy data are insufficient, then more applicable data must be generated. The cost to run a test program is expensive particularly if production aircraft components are needed and the test requires external airflow to be sufficiently realistic. The second method uses IGNITE and/or the Fire Prediction Model (FPM).

FPM was developed organically over a number of years beginning in the 1990s. The model uses a combination of empirical relationships as well as basic physics, heat transfer, and chemistry to predict the chain of events beginning with penetration, through hydrodynamic ram (HRAM), fuel spray, droplet vaporization, and chemical reaction to predict the probability of ignition. In addition, FPM simulates events beyond ignition, including sustained combustion. IGNITE is a computer library consisting of components (modules) of FPM solely related to ignition. IGNITE was created to be called by higher level vulnerability codes and has been demonstrated with the Computation of Vulnerable Area Tool (COVART). The higher level codes are responsible for computing threat penetration and tank wall damage while IGNITE calculates the remaining elements of the ignition chain and returns a probability of ignition.

Although it has been recognized that existing methods have had their shortcomings, there were no suitable alternatives for modeling ignition. In 2014, DOT&E and the Joint Aircraft Survivability Program Office (JASPO) recognized the increased need for better tools. They also appreciated that to generate these tools, an increased understanding of fire processes was needed. This appreciation initiated an effort to investigate and execute a plan for the development of an enhanced fire modeling capability—hence, NGFM.

**NGFM INITIAL PLANNING**

An initial fire model development planning effort was funded by the Joint Aircraft Survivability Program (JASP) with the main focus of forming a tri-Service team to determine community-wide fire modeling requirements and establishing an initial path forward. The project was established as JASP project M-14-11.

In October 2014, the Institute for Defense Analyses (IDA), an early proponent of improved fire modeling tools, hosted an initial working-level meeting with representatives from across the Department of Defense (DoD), as well as industry, academia, and the national laboratories. The panel of subject-matter experts (SMEs) were convened to establish, and then evaluate, the functional areas of the fire chain. The group’s collective experience included penetration, fire testing, fire protection, vulnerability analysis, hydrodynamics, aerodynamics, and combustion. The panel included participants from the U.S. Army Research Laboratory’s Survivability/Lethality Analysis Directorate (ARL/SLAD), the Air Force Life Cycle Management Center’s Combat Effectiveness and Vulnerability Analysis Branch (AFLCMC/EZJA), the Naval Air Warfare Center Weapons Division at China Lake (NAWCD/CL), the Johns Hopkins University Applied Physics Laboratory (JHU APL), the Lawrence Livermore National Laboratory (LLNL), the Air Force Institute of Technology (AFIT), and the SURVICE Engineering Company. The team was led out of the Air Force Materiel Command’s (AFMC’s) 96th Test Group (96 TG/OL-AC), which is now the 704 TG/OL-AC, with oversight from DOT&E.

From the beginning, the ultimate goal of NGFM was to provide the analysis and test community with a model that is:

- **Fast-Running:** The model must support higher level vulnerability analysis codes, which need to run as many as tens of thousands of scenarios for a single threat at a single velocity. Therefore, NGFM must be capable of running in the submillisecond timeframe (i.e., faster than real time).

- **Credible and Validated:** A key reason for the lack of confidence in current tools is the lack of validation. To avoid this problem, NGFM must be validated at the most basic level as part of the development process.

- **Modular:** Modular development has many benefits, including supporting validation, allowing for parallel development efforts, and aiding in incremental development, where improved modules can easily replace less effective versions.

**IGNITION: PRIORITY 1 IN THE FIRE KILL CHAIN**

When most engineers and analysts outside of the vulnerability analysis community think of fire modeling, they think of a tool such as the National Institute of Standards and Technology’s
(NIST’s) Fire Dynamics Simulator (FDS) or the Sandia National Laboratories’ codes ARIA and FUEGO, which can be coupled to look at complex fires involving composite materials. However, these codes concentrate only on the sustained combustion phases of fire. The user must already have knowledge of the initial events, the ignition phase. Given the complexity of threat-initiated ignition and the fact that there are currently well-supported codes that focus on combustion, it was determined early on in the NGFM plan development initiative that understanding and modeling the ignition phase of the fire kill chain would be a priority.

The amount of information available to help support solving the unique threat-initiated ignition problem is minimal so the planning team began definition of the requirements by establishing definitions of the discrete ignition events referred to as functional areas. These categories for API rounds are shown in Figure 1. (Similar definitions were generated for fragment penetrators.) The categories were further broken down by elements that could encompass a process or that could be broken down further into subelements, such as a property or state at the end of a process. Examples include residual mass, residual velocity, function type, fuel droplet size, etc. Based on the community’s current state of knowledge, lists of functional areas were developed for both API rounds and warhead fragments. High-explosive incendiary (HEI) rounds were not evaluated.

For one reason, API rounds and fragments have several common elements along their respective ignition chain of events, while HEI rounds are so dissimilar that little leveraging of API and fragment data can be done. Adding HEI rounds would greatly expand the scope, while the interest in the aircraft community is primarily concerned with API rounds and fragments.

### IGNITION FUNCTIONAL AREA BASE KNOWLEDGE AND PRIORITY

After the functional areas were established, the team worked to develop evaluation criteria for how each element affected each of the four functional areas (i.e., how important is it), as well as to evaluate the state-of-the-art in terms of the community’s understanding and ability to model each of the elements.

The elements varied slightly depending on whether the threat was an API or fragment, and therefore the two chains were evaluated separately. SMEs filled out worksheets, recording their

---

**Figure 1** Threat-Initiated Ignition Chain of Events and Associated Functional Areas

- **Penetration**: Threat penetration into the dry bay and tank, Projectile stability, Impact mechanics – air/liquid-backed plates, Plate fracture, Projectile fracture/erosion
- **Energy Deposition**: Ignition source characterization, API – pyrophoric reaction/fragment – metal oxide reactions, Flash/function location (back-face, front-face), Temperature and size time history
- **HRAM/Fuel Deposition**: Penetration through the liquid and fluid release, Threat tumbling through fuel - cavity formation, Multiple fuel sprays into bay, Droplet formation
- **Ignition**: Liquid vaporization and reaction with deposited energy, Droplet vaporization, Vapor mixing, Vapor-air reaction
judgments using a numerical scale, which was color-coded using shades of red and green with yellow, indicating a rating midway along the scale. The darker shade of red in the Importance evaluation indicated the more critical the element was to a given functional area, while green meant no effect. In addition to providing ratings, SMEs provided justification, commentary on the current state-of-the-art, and recommendations for future work to improve the state-of-the-art.

Due to the interdependent nature of the chain (e.g., penetration elements can affect three of the four functional areas), as well as its sequential nature (i.e., down-the-chain elements do not really affect up-the-chain elements), it became challenging to evaluate the importance of some of the elements. An element such as the Ballistic Limit ($V_{50}$) initially seemed to be the most important element for understanding ignition.

Table 1 shows the final Importance ratings for API rounds while Table 2 shows the Importance ratings for fragments. The Knowledge ratings were also captured but are not reproduced in these tables. They followed the same rating logic as the Importance ratings. In general, the more ratings that are redder (or higher numerical value) across both categories indicate the more motivation there is to study that element, as it would be both important and we lack the knowledge/capability. In theory, improving our understanding of any one of these highest ranked elements has the potential to lead to dramatic improvements in prediction capability. Granted, improving understanding of a particular element may show the overall ignition chain is less sensitive to that element.

Table 1 Importance Ratings for API Rounds

<table>
<thead>
<tr>
<th>Functional Area/Element</th>
<th>Importance Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Threat Penetration</td>
</tr>
<tr>
<td>Ballistic Limit ($V_{50}$)</td>
<td>5</td>
</tr>
<tr>
<td>Velocity Slowdown (Vr)</td>
<td>5</td>
</tr>
<tr>
<td>Mass Reduction (Mr)</td>
<td>5</td>
</tr>
<tr>
<td>Projectile Yaw</td>
<td>5</td>
</tr>
<tr>
<td>Velocity (Liquid)</td>
<td>5</td>
</tr>
<tr>
<td>Tumbling (Liquid)</td>
<td>5</td>
</tr>
<tr>
<td>Hole Size/Shape</td>
<td>5</td>
</tr>
<tr>
<td>Function Probability</td>
<td>1</td>
</tr>
<tr>
<td>Function Type</td>
<td>1</td>
</tr>
<tr>
<td>Incendiary Reaction/Temperature/Composition</td>
<td>1</td>
</tr>
<tr>
<td>Function Duration</td>
<td>1</td>
</tr>
<tr>
<td>Function Size</td>
<td>1</td>
</tr>
<tr>
<td>Function Origin</td>
<td>1</td>
</tr>
<tr>
<td>Pressure History</td>
<td>1</td>
</tr>
<tr>
<td>Pressure Reflection</td>
<td>1</td>
</tr>
<tr>
<td>Wall Failure</td>
<td>1</td>
</tr>
<tr>
<td>Cavity Size History</td>
<td>1</td>
</tr>
<tr>
<td>Pressure History</td>
<td>1</td>
</tr>
<tr>
<td>Spurt Ejection Time</td>
<td>1</td>
</tr>
<tr>
<td>Spray Geometry</td>
<td>1</td>
</tr>
<tr>
<td>Droplet Distribution</td>
<td>1</td>
</tr>
<tr>
<td>Multiple Spruts</td>
<td>1</td>
</tr>
<tr>
<td>Spurt Ejection Time</td>
<td>1</td>
</tr>
<tr>
<td>Spray Geometry</td>
<td>1</td>
</tr>
<tr>
<td>Droplet Distribution</td>
<td>1</td>
</tr>
<tr>
<td>Spatial Overlap</td>
<td>1</td>
</tr>
<tr>
<td>Time Overlap</td>
<td>1</td>
</tr>
<tr>
<td>Vaporization</td>
<td>1</td>
</tr>
<tr>
<td>Vapor Mixing</td>
<td>1</td>
</tr>
<tr>
<td>Vapor/Air Reaction</td>
<td>1</td>
</tr>
</tbody>
</table>
However, reducing the number of elements that are critical is almost as important since resources may be better applied studying other elements.

At the end of the evaluations and discussions, the rankings resolved into three broad priorities for further work:

- Any Threat Penetration elements that affect either Energy Deposition or Fuel Deposition–HRAM elements.
- Any Energy Deposition elements that affect the Temporal or Spatial Overlap comparisons between the flash/function cloud and the liquid spray.
- Fuel Deposition–HRAM elements that affect Fuel Deposition–Spurt elements, including Spray Geometry, Spurt Ejection Time, and Droplet Distribution.

Three methods for advancing the community’s understanding were explored: additional research, testing, and advanced modeling. Regardless of the method, solid documentation would be required to continually build our understanding.

Additional research was recommended in elements that had no counterpart outside of the vulnerability community, or if there was a counterpart but the applicability to the ignition chain problem was unknown.

Exploratory testing could also be considered a form of research while more focused testing could serve model development or validation. Regardless, the key was the testing had to either be dedicated or have a primary objective of supporting the model. The number of tests and the detailed data required would always be at odds to piggyback on an LFT&E event.

### Table 2 Importance Ratings for Fragments

<table>
<thead>
<tr>
<th>Functional Area/Element</th>
<th>Importance Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Threat Penetration</td>
</tr>
<tr>
<td><strong>Threat Penetration</strong></td>
<td></td>
</tr>
<tr>
<td>Ballistic Limit ((V_{50}))</td>
<td>5</td>
</tr>
<tr>
<td>Velocity Slowdown</td>
<td>5</td>
</tr>
<tr>
<td>Mass Reduction</td>
<td>5</td>
</tr>
<tr>
<td>Penetrator Debris</td>
<td>5</td>
</tr>
<tr>
<td>Target Debris</td>
<td>5</td>
</tr>
<tr>
<td>Frag Orientation</td>
<td>5</td>
</tr>
<tr>
<td>Velocity (Liquid)</td>
<td>5</td>
</tr>
<tr>
<td>Tumbling (Liquid)</td>
<td>5</td>
</tr>
<tr>
<td>Hole Size/Shape</td>
<td>5</td>
</tr>
<tr>
<td><strong>Energy Deposition</strong></td>
<td></td>
</tr>
<tr>
<td>Flash Cloud Size</td>
<td>1</td>
</tr>
<tr>
<td>Flash Location</td>
<td>1</td>
</tr>
<tr>
<td>Cloud Temperature</td>
<td>1</td>
</tr>
<tr>
<td>Cloud Duration</td>
<td>1</td>
</tr>
<tr>
<td><strong>HRAM</strong></td>
<td></td>
</tr>
<tr>
<td>Pressure History</td>
<td>1</td>
</tr>
<tr>
<td>Pressure Reflection</td>
<td>1</td>
</tr>
<tr>
<td>Wall Failure</td>
<td>1</td>
</tr>
<tr>
<td>Cavity Size History</td>
<td>1</td>
</tr>
<tr>
<td><strong>Pre-Spurt Dynamics</strong></td>
<td></td>
</tr>
<tr>
<td>Pressure History</td>
<td>1</td>
</tr>
<tr>
<td>Spurt Ejection Time</td>
<td>1</td>
</tr>
<tr>
<td>Spray Geometry</td>
<td>1</td>
</tr>
<tr>
<td>Droplet Distribution</td>
<td>1</td>
</tr>
<tr>
<td><strong>Primary Spurt and Beyond</strong></td>
<td></td>
</tr>
<tr>
<td>Multiple Spurts</td>
<td>1</td>
</tr>
<tr>
<td>Spurt Ejection Time</td>
<td>1</td>
</tr>
<tr>
<td>Spray Geometry</td>
<td>1</td>
</tr>
<tr>
<td>Droplet Distribution</td>
<td>1</td>
</tr>
<tr>
<td><strong>Ignition</strong></td>
<td></td>
</tr>
<tr>
<td>Spatial Overlap</td>
<td>1</td>
</tr>
<tr>
<td>Time Overlap</td>
<td>1</td>
</tr>
<tr>
<td>Droplet Vaporization</td>
<td>1</td>
</tr>
<tr>
<td>Vapor Mixing</td>
<td>1</td>
</tr>
<tr>
<td>Vapor/Air Reaction</td>
<td>1</td>
</tr>
</tbody>
</table>
Modeling using advanced codes would be too computationally intensive to solve the entire ignition chain problem on their own. However, the use of validated advanced modeling (e.g., hydrocodes, three-dimensional [3-D] multi-phase computational fluid dynamics [CFD] codes, etc.) could complement testing by allowing detailed study of phenomena of certain elements or processes. Advanced models could also be used to develop and “validate” faster running algorithms that could be used in NGFM.

There were also discussions about the foundation for each of the modules, empirical vs. first-principles/physics-based. In theory, empirical models can be developed more quickly, but there needs to be a wide breadth as well as depth of testing to develop enough data to cover the spectrum of scenarios and ensure test results have sufficient repeatability to make the model credible. A physics-based approach would demonstrate how well we understand a process but could be challenging for processes that are unstudied outside of our community. If feasible, a series of physics-based modules is the desired outcome. But it is recognized that for simulating some processes, an empirical approach may be the only solution, at least in the near term. Fortunately, with the modular approach, NGFM is never locked into a particular approach permanently. If a better, physics-based module can be developed, then it can replace an empirically based one.

**FY17 NGFM-RELATED PROGRAMS**

The first two modules scheduled for development are fragment flash duration for aluminum striker plates and HRAM fuel spurt timing/spray characterization. The two coordinated three-year efforts are funded by JASP and closely monitored by IDA and DOT&E.

The fragment flash project (Fragment Flash Characterization, V-17-02) is being led by AFLCMC/EZJA, with involvement from the Naval Surface Warfare Center Dahlgren Division (NSWCDD), 704 TG/OL-AC, ARL/SLAD, and industry. The purpose of the project is to improve the ability to predict front face and back face flash durations from single and two-panel aluminum target arrays. Fragment flash characterization is critical to understanding if the fuel spurt and threat flash coincide in time and space. Given the shorter duration of fragment flashes and lower temperatures vs. API function durations, the fragment ignition chain is highly sensitive to this particular element. The approach is to use a combination of shock physics M&S combined with an extensive test series. The end product will be a library/module for predicting flash durations. Ideally, it will be physics-based, but the test data can be used to develop an empirical model.

The 704 TG/OL-AC will lead the HRAM project (HRAM Spurt Model Development and Validation, V-17-01), with involvement from AFLCMC/EZJA, ARL/SLAD, LLNL, and industry. The objective of this effort is to be able to accurately predict fuel spurt timing for flash/function cloud overlap calculations. As with V-17-02, the approach to the problem will be two-pronged: development of test data for validating an advanced model as well as statistical data analysis to develop an alternate empirical approach. Both this effort and V-17-02 will begin with detailed modeling to ensure the proper data are collected in each test series. Similar to V-17-02, the preference will be to develop a physics-based module using the advanced model to develop a set of faster-running reduced complexity algorithms; but at a minimum, an empirically based module will be developed.

Another NGFM effort taking place under the HRAM project is to develop the first version of the NGFM Software Development Plan (SDP). The SDP is a living document that will define the model framework and flesh out all the modules, including the data going into and out of each. As new modules are developed or modified, the SDP will be updated. Where it is known, the accuracy requirements for each module will be defined, and an evaluation of the state-of-the-art will be documented. Although not traditionally the role of an SDP, future versions of this SDP will also be used to identify the path forward in terms of which modules are in most need for updating.

As part of the NGFM planning efforts, an overall model structure was envisioned. Figure 2 shows the planned flow of information through NGFM, including the use of the two existing penetration codes: Projectile Penetration Model (ProjPen) for API rounds and Fast Air Target Encounter Penetration (FATEPEN) for warhead fragments. Their outputs along with the shotline boundary conditions and other properties would all enter the model. Simulations of in-tank HRAM events would predict the timing and nature of fuel spurts that would interact with the thermal energy (Energy Deposition) generated by either incendiary function or fragment flash. The outcome of this prediction in turn would lead to a check to determine if the spray and function/flash cloud simultaneously overlap. If not, then no ignition can occur. If they do coincide, then additional calculations are made to
check into calculations to determine if the duration is long enough to vaporize and ignite the fuel spray. Then the model will check if the heat generated by the ignition is greater than the heat lost to the bay or vaporizing additional droplets. If yes, then ignition is assumed to occur. In general, the model’s structure is not dissimilar from IGNITE, which is not surprising since the order of ignition chain events dictates which pieces of information are available as reactions unfold.

Because the first draft of the SDP is being developed in parallel with the flash and HRAM projects, the requirements for those two modules will be defined first to ensure their plans are well-synced with the overall NGFM effort.

**NEXT STEPS**

The vulnerability community has come a long way in improving our understanding of the different elements of the ignition chain. We are now heading toward the ability to credibly predict these different processes and eventually reliably predict ignition across all ballistic scenarios of interest to the fixed- and rotary-wing communities. The first steps may appear to be limited in scope, but as identified by the original team, they will fill a big gap in our knowledge/capability in addressing fuel spray and threat flash overlap. From there, we can move onto composite materials and other scenarios. Then we can start drilling down into other elements to which the ignition chain is also sensitive. As modules are developed, NGFM will improve at each iteration, giving the community the capability it needs.

**ABOUT THE AUTHOR**

Jim Tucker currently serves as a senior engineer for the SURVICE Engineering Company. He has more than 21 years of specialized experience in aviation-related fire research and modeling, as well as the development, testing, and modeling of fire protection tools and methodologies. He is a current member of the NGFM Integrated Product Team. Mr. Tucker holds a B.S. in mechanical engineering as well as an M.S. in fire protection engineering from the Worcester Polytechnic Institute.
Not Your Grandfather’s COVART

By Rodney Stewart

As COVART has definitely grown and evolved over the years. Since its initial creation (from the merging of the VAREA and HART codes developed in the 1960s), COVART development teams have added modeling techniques for new threat types, expanded the number of supported materials, provided additional methods for capturing system damage from threats, and improved assessments of threat penetration. And despite various quirks and idiosyncrasies that have arisen within the tool over time, the COVART we have today is more accurate and capable than any other COVART in history.

RECENT IMPROVEMENTS

As shown in Figure 1, the Joint Aircraft Survivability Program (JASP) has been instrumental in making improvements to COVART possible. Over the last 15+ years, JASP has provided near-continual funding for model management and
sponsored numerous projects supporting a range of analysis needs. Recent examples of JASP-supported enhancements include the modularization of COVART, the integration of FASTGEN and BRL-CAD into COVART (i.e., COVART6), the verification of community-shared modules, and the development of common threat file formats supporting numerous Department of Defense (DoD) V/L models. Numerous Air Force programs and the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) have also provided support for COVART in the past.

In FY16, funding under JASP project M-16-01 (the current model management project) led to the resolution of 31 software change requests (21 for COVART and 10 for FASTGEN) and resulted in an updated testing process, which will aid the verification of future releases. One of the major JASP-funded changes last year was the extraction of ProjPen-related material substitution decisions from COVART and the integration of these decisions in ProjPen. This change will improve the development team’s ability to conduct verification and validation (V&V) of ProjPen in the future by providing consistent material assumptions. Other fixes made under M-16-01 this year addressed an air blast distance calculation issue and a number of discrepancies observed in shared module verification testing. The Combat Effectiveness and Vulnerability Analysis Branch (EZJA) of the Air Force Life Cycle Management Center (AFLCMC) merged these improvements with updated FASTGEN and FLASH modules developed by the KC-46 program to create COVART 6.8, which was released in December.

Moving forward, JASP is providing the funding to realize the next step of COVART’s evolution. Under M-16-01, the COVART development team will start employing software parallelization, reorganize COVART’s damage estimation library to make it more portable, update the underlying code to a newer language standard, and remove older, deprecated features. The goal of this task is to place COVART in a position where it can be more easily maintained and aid future projects, which will standardize how the community addresses V/L questions.

### PARALLELIZATION

Parallelization is the next step in improving the runtime performance of COVART. Efforts funded by JASP project M-12-02 and the KC-46 program investigated approaches to improve the speed at which FASTGEN traces rays. M-12-02 identified other ray tracing approaches with a potential speed improvement and experimentally implemented the Spatially Enumerated Auxiliary Data Structure (SEADS) ray tracer in FASTGEN to evaluate its effectiveness. The results of the study highlighted the need for the optimization of COVART processing to realize the benefits of modern ray tracing algorithms. KC-46-funded speed improvement efforts paved the way for future parallelization by creating a thread-safe version of FASTGEN. With this preliminary work completed, the next step is to optimize COVART to take advantage of this earlier work and to process rays in parallel. COVART 6.9, scheduled for a summer 2017 release, will include changes to improve ray tracing runtimes. Future development efforts will then investigate other areas of COVART to determine where
parallelization may be used to make further speed improvements.

**MODULARIZATION AND LANGUAGE STANDARD UPDATE**

Apart from parallelization, another goal under M-16-01 over the next two years is to complete the modularization of COVART and update the underlying language standard to improve maintainability. COVART was initially modularized under JASP project M-04-03, which led to the creation of COVART5. Efforts under JASP project M-07-03 carried forward this modularization concept in merging FASTGEN, BRL-CAD, and COVART into COVART6. However, areas remained where the conceptual interfaces between the major functions of the software were not as clean as they should be. One of the areas needing most work is the component damage function of the program. In this case, all of the code related to the feature does not entirely lie within the boundaries of the library containing it. This fact makes COVART-specific damage estimation methodologies less portable and difficult to V&V separately. Efforts under M-16-01 in FY17 will address this functional boundary issue.

The primary programming language employed in COVART is FORTRAN; however, the software includes a mixture of subroutines written in FORTRAN77 and FORTRAN90. To support the features found in modern compilers, it is important to uplift the FORTRAN77 portions of the program to a newer standard. In FY17, the COVART development team will uplift the code in the component damage and vulnerable area calculation libraries to the FORTRAN 2008 standard, and future year efforts under M-16-01 will uplift other portions of the software until it is consistent.

**MAINTAINABILITY**

Unfortunately, several features that have been added to the program over the last 20 years have not weathered the test of time. Some of them no longer work as intended, reference older programs that have disappeared over time, or simply do not provide benefit to the typical user. Under M-16-01, the COVART development team will remove deprecated features to improve maintainability and reduce the effort required to conduct a thorough V&V of the software. The features with the highest visibility on the shortlist for removal include support for the JTCG/ME fragment penetration equation library (sometimes called FRAGPEN) and the legacy mode of COVART6, in which users call FASTGEN/RTG3 and COVART alternatively to conduct studies. Moving ahead in this regard is a necessary step to standardize how the V/L community approaches and performs V/L analyses.

**FIDELITY**

While efforts under M-16-01 will address the maintainability of COVART, a second JASP project, V-17-04, will improve the fidelity possible for V/L studies. From its creation, COVART has assessed threat penetration two-dimensionally. The threat, acting as a point mass with a velocity and orientation, travels along a ray and makes contact with target components modeled as lines of sight with orientations. Figure 2 provides a generalized illustration of the current 2-D process/construct that COVART uses to estimate threat penetration and component damage.

The ray tracers commonly used by the V/L community process the target in three dimensions with three axes of rotation, but COVART requires them to simplify their outputs to fit the aforementioned 2-D construct. Recent improvements in the penetration methodologies employed by COVART (initially FATEPEN and now ProjPen with the near conclusion of JASP project M-15-03) have made it possible for them to estimate penetration using 6 degrees of freedom (6DOF).

Unfortunately, because COVART still forces the ray tracers to strip the second and third axes of rotation, the development team has had to make assumptions to provide the orientation information FATEPEN and ProjPen require. This practice has led to unintentional errors in

---

**Figure 2** COVART’s Current 2-D Process
COVART results because this assumed orientation often varies from the real orientation of the threat and target at impact. However, these errors can be eliminated by expanding COVART to handle 6DOF from the ray tracers through the penetration assessment. This capability is the goal of V-17-04, which will create the next generation of COVART, COVART7.

CONCLUSION

Without a doubt, COVART7 will be radically different from the COVART that first appeared in 1973. All ray tracing will be performed internally, and parallelization will lead to improved runtimes for both parallel-ray and diverging-ray analyses. In addition, the code itself will be more functionally organized, will be trimmed of unnecessary features, will reflect a more recent programming standard, and will have much less of the “spaghetti” processing found in previous versions. Finally, COVART7 will improve the realism and fidelity available for the modeling of threat penetration. As always, the overall mission of COVART will not change, but the upcoming versions of the tool will be, quite frankly, nothing like your grandfather’s COVART.

ABOUT THE AUTHOR

Rodney Stewart serves as a systems analysis engineer for the Air Force Life Cycle Management Center at Wright-Patterson Air Force Base in Dayton, OH. He currently serves as the Model Manager for FASTGEN and COVART and has more than 10 years of experience in the development, use, and management of these models. Mr. Stewart has a B.S. in mechanical engineering from the University of Colorado at Colorado Springs and an M.A. in leadership from Barclay College.
AIRCRAFT SURVIVABILITY
THE EARLY YEARS (PRE-WORLD WAR I TO WORLD WAR I)

by David Legg
On 17 June 1861, Thaddeus Lowe and another observer surveyed the Confederate positions located south of Washington, DC, across the Potomac River. What made this survey unusual was that Lowe and his companion were suspended in a basket below a hot air balloon at an altitude of 500 ft above the city. The observer was relaying their observations to the White House and War Department via telegraph. Near real-time intelligence collection and communication was born. However, the Confederate soldiers under observation did not let this intelligence collection go without a response and began shooting at the balloon. Over the course of the Civil War, Mr. Lowe earned the title of “the most shot-at man of the war.” [1]. One could also say that this event ushered in the birth of “anti-aircraft” fire.

In September of 1911, the Ottoman Empire invaded modern-day Libya, which resulted in a war with Italy. Later, on 23 October, Italian Air Force pilot CPT Carlo Piazza flew the first wartime mission using an airplane. He flew his Bleriot XI on a reconnaissance mission near Benghazi. The first time an airplane was hit by gunfire during war followed soon after. Italian Air Force pilot CPT Ricardo Moizo’s Nieuport IVG airplane was hit by three bullets on 25 October.

One of the earliest, if not the earliest, attempts at armoring aircraft was accomplished by Louis Bleriot in 1913. Bleriot—who is better known for conducting the first flight, in a heavier-than-air aircraft, across the English Channel in 1909—built a canard pusher monoplane, designated the Bleriot XLII. *Flight Magazine* described the aircraft as follows: “The body of the machine, which is arranged so that the observer lies flat and looks through windows, is covered with steel plate to protect the occupants from rifle fire.”

Bleriot continued his work on armored observation airplanes, which included the Bleriot XXXVI and XXXIX tractor-configured monoplanes. The latter aircraft was armored with 3-mm chrome nickel from its nose to aft of the pilot’s seat. Testing was conducted on the armor, and it was determined that rifle bullets fired at a range of 400 yards would either glance off or dent the armor [2, 3].

Subsequent to Bleriot’s efforts, the first operational requirement for armored aircraft (i.e., survivability) was issued in September 1913 by GEN Félix Bernard, Director of French Military Aviation [2]. Unfortunately, the instruction was never implemented, and the French would make little use of armored aircraft in the forthcoming conflict.

**THE RISE OF THE COMBAT AIRPLANE**

World War I saw the first large-scale use of the airplane in combat roles. Initially, operations were limited to the use of unarmed airplanes conducting reconnaissance of enemy field positions and troop movements. As opposing reconnaissance airplanes came more frequently into contact, their pilots and observers would exchange pistol or rifle shots at each other. Other pilots took more unusual measures. Russian pilot CPT Alexandr Kaskov dragged hooks suspended by cables behind his Morane monoplane and brought down an Austrian biplane. He would later become Russia’s leading ace of the war, scoring 20 aircraft kills.

With the introduction of improved cameras and radio, the airplane became so effective as an intelligence gatherer that some sort of countermeasure rapidly needed to be found. Here, the French took the early initiative in developing the fighter airplane as we know it. On 5 October 1914, the first credited air-to-air shoot-down was accomplished by French pilot SGT Joseph Franz and his gunner, CPL Louis Quenault, in their Voisin Type III biplane. Quenault fired a few dozen rounds from his Hotchkiss 8-mm machine gun, hitting the German Aviatik B.I biplane’s fuel tank, catching the plane on fire, and causing its loss.

As the war continued from 1914 into 1915, more powerful engines were fitted to reconnaissance airplanes, thereby increasing their performance, allowing for the carriage of more payload, and leading to the expansion of the airplane’s role to include infantry support (i.e., close air support) and eventually strategic bombing. The success of the airplane in these mission areas resulted in the development and employment of countermeasures, consisting of ground-based anti-aircraft artillery defenses, dedicated fighter airplanes, and, in the case of England, an integrated air defense system (IADS) for the protection of London.
GUNS VS. PLANES

The Allied and Central Powers’ tactical level anti-aircraft defenses employed machine gun and anti-aircraft artillery units (such as those shown in Figures 1 and 2). These units included personnel, equipped with binoculars, dedicated to aircraft spotting and manned range finder equipment. The British Vickers machine gun’s capabilities are representative of a typical Allied or Central Powers machine gun. The machine gun was of .303-inch caliber with a 450-rounds/min rate-of-fire, a 2,440-ft/s muzzle velocity, and a 2,000-yd effective range. The Germans also fielded a variety of medium-caliber anti-aircraft cannon. The 3.7-cm Flak M14 automatic cannon fired a 37-mm x 95R Hotchkiss round with a 250 rounds/min rate-of-fire, and a 2,500-yd effective range.

Larger-caliber anti-aircraft weapons were also fielded by both sides. The German KRUPP 7.7 CM K-Flak fired a 76-mm high explosive (HE) with a 20 to 25-rounds/minute rate-of-fire and an effective range of 15,000 ft. Few aircraft were actually directly shot down by these larger-caliber anti-aircraft guns, each requiring an average of 4,000 to 4,500 shells, but these guns were often employed in aerial barrages to deny airspace to aircraft rather than to simply shoot down individually targeted aircraft. These barrages brought attacking aircraft within range of defensive machine guns.

During 1916 and 1917, as surface-to-air defenses became more prevalent and lethal, both sides sustained heavy losses of infantry support aircraft. During the Battle of Cambrai, Australian and British DH.5 aircraft were used heavily in trench strafing, bombing, and support. Australian Flying Corps No. 2 Squadron took 35% casualties. The DH.5 incorporated no vulnerability reduction (VR) features.

ARMORING UP

The Allies did little to respond to the mounting losses. The Germans, however, did. The German Inspectorate of Aviation Troops issued a 1917 spec for armored infantry support aircraft (J-type aircraft). The pilot, gunner, engine, and fuel were to be protected by 5-mm steel armor against .303-inch-caliber projectiles. The following aircraft were developed in response to the 1917 J-type specification:

- The AEG J.I used 5-mm steel armor (400 kg bolted onto the metal frame) to protect the cockpit, observer/gunner position, and engine; double lift-bracing wires were used for structural redundancy; and double control cables were used for flight control redundancy. The AEG J.I radiator remained unarmored to save weight; however, this design made the aircraft vulnerable, resulting in the follow-on AEG J.II version adding radiator armor.
- The Albatros (Alb) J.I included the same features with the addition, in 1918, of a 20-mm anti-tank Becker cannon.
- The Junkers J.I (shown in Figures 3 and 4) used a 5-mm-thick armored “bath tub” to protect the crew, engine, fuel tanks, and wireless equipment from ground fire. The fuselage, flying, and control surfaces were made of steel tube. The fuselage, from the back of the gunner.
to the rear, was covered in fabric while the flying and control surfaces were covered in .015-inch-thick corrugated duraluminum sheeting. Control lines ran through steel tubing in the wings. The armor protecting the engine was hinged to provide access for maintenance (as seen in Figure 3). There is no recorded instance of a Junkers J.I being shot down. On 23 September 1917, a Junkers J.I returned to base with 85 hits.

Without a doubt, one could call these J.I series of aircraft the A-10 Warthogs of World War I.

OTHER VR EFFORTS

As the war drew to a close, additional VR features were being developed by the Germans. The Zeppelin (Dornier) D.I and Siemens-Schuckert Werke D.VI fighter aircraft designs both included a jettisonable fuel tank carried underneath the fuselage. In case of fire, the fuel tank could be jettisoned by the pilot. Note that these tanks contained the entire fuel load of the respective aircraft. Thus, once the tank was jettisoned, the pilot would have to glide back to his side of the front lines. These aircraft were to have been deployed in 1919 had the war continued.

The Germans also developed the specialized AEG D.II single-seat armored fighter designed to attack Allied ground attack aircraft flying at low altitude. The design features included cockpit, engine, and fuel tank protection provided via a steel frame, forming an integral part of the airframe and including the replacement of vulnerable wing and wing-to-fuselage bracing wires with substantial I-section struts. The first flight of the AEG D.II was in 1917, but it was too late for service in World War I.

While the French had developed the first “operational requirement” for armored aircraft, it appears that they had not made much progress beyond generating the requirement. However, the French Air Force did employ the Salmson 2 A2 reconnaissance airplane, which included self-sealing fuel tanks. And in the final year of the war, the French military defined requirements for a two-seat tactical reconnaissance aircraft with light armor to protect it from small-caliber fire at distances over 300 m. The Salmson 4 Ab2, a fairly straightforward development of the successful Salmson 2 A2 observation aircraft, was built in response to these requirements. The additional weight of the armor was compensated by giving the Salmson 4 Ab2 a three-bay biplane wing of larger span.

A dozen of these aircraft were in service when the war ended; no more were built.

The Royal Flying Corp (RFC) also eventually developed an armored close air support aircraft. The Sopwith T.F.2 Salamander (shown in Figure 5) was an armor-clad version of the Sopwith Snipe fighter. The T.F.2 included 492 lb of armor to protect the pilot and included double control levers on the ailerons and corresponding double inter-aileron wires for flight controls redundancy (as seen in the figure). The double wires and the upper wing aileron actuators can be seen in the prototype underwent its initial trials in April 1918 and was sent to France for evaluation in May 1918. By the end of the war, only 37 T.F.2’s had been accepted by the RFC, and only two of these were in France. With the end of the war, there was no need for a specialist close support aircraft, so no
squadron was ever fully equipped with the T.F.2, and it disappeared from RFC service altogether by the mid-1920s [4].

CAMOUFLAGE AND SUSCEPTIBILITY REDUCTION

While the survivability of World War I aircraft was primarily limited to the development and employment of VR features, there were limited efforts to address susceptibility reduction.

The primary observable exploited during World War I was visual signature. Therefore, susceptibility reduction was primarily limited to camouflage painting of aircraft. The French aircraft were typically painted using a six-color camouflage consisting of ecru (which is French for raw or unbleached), light green, dark green, chestnut brown, and black on the upper surfaces with a light yellow finish on the lower surfaces.

The RFC primarily used a standard scheme of khaki-green on the upper surfaces with clear-doped fabric underneath. On RFC Home Defense Squadron night-fighting aircraft (based in England), the white portion of the national insignia was sometimes painted over in khaki-green to reduce observability by German bomber crews.

Due to the unique look-down background of the barren, shell-holed, front line positions of the Western Front, the RFC also experimented with camouflage that was specific to this environment. The camouflage was designed to hide low-flying close air support aircraft from higher flying fighter aircraft. A Sopwith T.F.2 Salamander was painted in this experimental camouflage per Confidential Information Memorandum No 733, dated 3 September 1918. Four colors were used: dark purple earth, green, light green-grey, and light earth. The outline of each area was picked out by a black line varying in width from 2 to 4 inches. The upper-wing roundels were of different diameters, presumably to confuse the aim of any attacking aircraft.

In addition to this type of camouflage, the German Air Force experimented with a more aggressive approach. A Fokker Eindecker fighter was covered with Cellon, a transparent material from acetate cellulose that was developed in 1901 as a replacement for the explosive nitrocellulose. Overall, the woven Cellon had a thickness of 0.4 mm. While existing photographs of an in-flight side-by-side comparison of a conventional fabric vs. Cellon-covered Fokker Eindecker illustrate the effectiveness of the Cellon, the fabric had a few drawbacks. Cellon strongly reflected sunlight in some conditions and resulted in an increase in detection. In addition, the cellon stretched and fluttered in rain, which resulted in fabric tears, loss of lift, and potential crashes. Thus, Cellon was not adopted for use.

THE EARLY IADS

World War I also saw the implementation of the first IADS. In response to German Zeppelin and bomber raids, the London Air Defense Area (LADA) was developed and was fully operational by September 1918. The LADA brought together units composed of coastal and inland observation posts, sound locators, searchlight and anti-aircraft artillery stations, balloon aprons, and fighter aircraft. Reports from the units were fed through to subcenters and then onward from the subcenters through to the LADA central operations room. Reports were then displayed in the LADA central operations room on a squared map. Ten plotters transferred the incoming information with different-colored symbols and discs onto maps and a vertical plotting chart.

Searchlight crews were connected with the squadron headquarters by telephone. The searchlights were placed forward of the nearest RFC Home Defense Squadron airfield to allow time for the defending aircraft to reach the required height of 5,000 ft to intercept. When news was received that enemy aircraft were approaching, the normal practice was to send up two or three aircraft from each flight to patrol the specified areas.
Each balloon apron consisted of three Caquot balloons (and two spherical types) joined together by a horizontal wire, and from this were suspended 1,500-ft-long weighted wires, set 50 yd apart. These balloon aprons formed obstacles to day and night bombing aircraft. The first apron started operating on 6 October 1917, and by the end of the war, 10 aprons were in operation. The aprons had considerable morale effect on the German pilots, and in March 1918, German General von Hoeppner made a report that “the aprons had increased enormously, and that they added greatly to the difficulties of the attack. If they were increased and improved much more, they would make a raid on London almost impossible” [5].

While the LADA was only declared fully operational near the end of the war, it formed the basis of the IADS that would later prove key to the success of the Royal Air Force during World War II’s historic Battle of Britain.

CONCLUSION

The efforts put forth by the Allied and Central Powers in World War I were the beginnings of what we consider aircraft combat survivability today. And many of the modern VR efforts and technologies still being developed can trace their roots back to this first global conflict. Unfortunately, for many aircrews at the beginning of World War II (as well as in many of the conflicts that have occurred since then), these early lessons learned over the bloodied skies of France during the early 1900s would have to be relearned.

ABOUT THE AUTHOR

David Legg is currently the Fixed-Wing Aircraft Branch Head of the Naval Air Warfare Center – Aircraft Division. With more than 32 years of experience in the aircraft survivability discipline, he has also served as the Survivability Team Lead for many U.S. Navy aircraft, including the P-8A Maritime Patrol and Surveillance Aircraft, and weapons programs, and he assisted in the rapid development and implementation of tactical paint schemes for in-theater U.S. Marine Corps helicopters during Operation Desert Shield/Storm. Mr. Legg was named a NAVAIR Associate Fellow in 2011 and holds bachelor’s degrees in mathematics and mechanical engineering from Saint Vincent College and the University of Pittsburgh, respectively.

References


OPTIMIZING M&S APPROACHES FOR
PENETRATING PLATFORM
SURVIVABILITY TESTING

By CPT Maxim Olivine

Analysts have generally assessed aircraft combat survivability, particularly in the electronic warfare domain, through a series of scientific analyses, as well as developmental and operational testing (including laboratory and flight test events) during the design, development, and fielding stages of a particular weapon system [1]. More recently, with the help of advanced computer processing power, modeling and simulation (M&S) has begun to play a larger role in aircraft survivability test approaches by allowing mathematical approximations to examine survivability characteristics in ways not possible in traditional laboratory, ground, and flight test (and often at a fraction of the cost). The traditional survivability model has been a customized software set, based on proven mathematical algorithms, created for each unique test article and data analysis requirement. Unfortunately, custom-built software and computation tools often require a large amount of resources to generate and can serve as an exercise in “re-inventing the wheel” for each respective acquisition program. This article presents a modular approach to M&S that could serve as a universal “go-to tool” for analyzing aircraft survivability in many diverse applications.
From an engineering perspective, one of the key aspects of improving survivability in the radio frequency (RF) domain can be described as the act of minimizing the RF signature of an aircraft, also known as the radar cross section (RCS). A smaller, “stealthier” RCS improves aircraft survivability by making the platform not able to be detected easily or consistently by enemy integrated air defense systems (including RF early warning, target acquisition, and target tracking radars), especially at longer ranges [1]. Developers attempt to reduce RCS by using various RF dampening methods such as specialized paint coatings, exotic materials, and clever airframe designs, to name a few [1]. A major aspect of the testing of these stealth aircraft to determine if the signature reduction techniques were successful/sufficient is by examining the aircraft RCS using representative threat systems.

As shown in Figure 1, the testing spectrum ranges from a controlled laboratory environment to an open-air, combat-realistic environment. Overlapping those two, and spanning the entire spectrum, is M&S. In the past, flight testing would be conducted directly after laboratory testing, often leading to an enormous number of required sorties, taking valuable time and carrying greater cost and risk. M&S has not replaced laboratory or flight testing, and likely never will, but it can bridge the uncertainty gap between the two while reducing the cost and risk of both.

The laboratory/scientific approach to survivability testing deals with various tests in microenvironments traditionally located in laboratories. These methods are intended for specific analyses and generally prevent the types of interference from outside agents that occur when an aircraft is flying in an operational environment. This approach results in a clean, repeatable, pure measurement, though not necessarily a realistic one.

While useful from a preliminary design perspective, such laboratory test methods are incapable of representing the complex survivability scenarios a weapon system might encounter in combat. What laboratory testing does well is to analyze specific, critical aspects such as materials, air vehicle design, software programming, and electronics in a consistent and controlled environment, thus laying the groundwork for transition into less controlled, more operationally representative assessments.

The operational test approach provides the most realistic and accurate survivability assessment environment, shown in Figure 2. In a typical operational test scenario, operational users operate a production-representative system in an operationally representative combat environment on various ranges throughout the world. The testers gather data on the threats and test article, along with all anomalies, including weather, noise, electromagnetic interference, etc. If the test team executed the event successfully and generated sufficient data for statistically valid analysis, the testers will be able to provide an accurate assessment of weapon system survivability.

Unfortunately, while being the most effective approach, operational testing is also by far the most expensive and, due to test asset and test range availability, can take months to years to generate sufficient data for a valid evaluation. Open-air range missions for an operational test can easily cost $1 million or more per sortie. Creating a perfect operational assessment of an aircraft, which can require dozens of range missions, might prove cost-prohibitive for most Department of Defense (DoD) programs.

Even more importantly, modern platforms are encountering more and more severe open-air range limitations. For example, around 50% of operational test points for modern weapon systems are not executable on today’s open-air ranges. Coupled with issues such as resource limitations, technological plateaus, and the inability to keep up with the continually evolving threat systems, these limitations are forcing the test community toward M&S as the best supplement to lacking capabilities.

After microenvironments in laboratories and costly flight test events, the third option for aircraft survivability testers is the M&S approach. Using modern computing power, we are able to simulate an operational environment with extreme precision. We are capable of emulating a realistic environment by using random number generators to provide distributions of performance,
red and blue system data, and mathematical algorithms proven to reflect actual performance through rigorous analysis and comparisons between M&S results and flight testing [1]. These scenarios include the system under test and other blue forces executing operational mission actions in the presence of integrated air defense systems that are representative of threats the system will encounter in combat around the world.

The downside is most M&S packages typically in use today are proprietary and have been custom-built over many months or even years by development/contractor teams. The complexity of the proprietary design forces the inefficiency of the development and drives the modeling tool to be more expensive and take more time than the program leadership desires.

**THE WAY FORWARD**

The proposed solution is to blueprint a design for a portable, easy-to-use, one-stop-shop software suite that packs all of the tools necessary to simulate or model any aircraft in any survivability scenario—almost like having a Microsoft Office-like toolkit for M&S. With such a tool, a user would select his/her parameters for the test article and the test environment from a list of available threat environments; no expensive and time-consuming coding or customization would be required.

Moreover, plugins and scripts should be available as options if unique tasks need to be performed, such as hardware or man-in-the-loop tests. Because the vast majority of aircraft M&S software packages use the same methods and techniques, combining their solvers into a single, universal package through a common medium, such as the Distributed Interactive Simulation standard [2], should be manageable. A personal computer (PC)-based graphical user interface will serve as the medium through which users customize their simulations, and it will be able to add an adequate number of functions that could provide ample modification options.

The Air Force Operational Test and Evaluation Center (AFOTEC) is one of the major drivers of such a universal platform—namely, the Joint Simulation Environment (JSE), a government-owned M&S battlespace setting that is undergoing initial phases of development at the Naval Air Systems Command in support of the F-35 Lightning II Joint Strike Fighter program. The JSE is being developed at Naval Air Station Patuxent River, MD, and future expansion will be to an M&S campus at the Virtual Warfare Center at Nellis Air Force Base, NV.

Currently, the JSE is being built to support a man-in-the-loop, multisecurity caveats operational test of the F-35. However, the system’s modular capabilities should allow for future integration of fifth-generation platforms—namely, the F-22 Raptor, the B-2 Spirit, and the B-21 Raider.

Ultimately, the environment should allow for integration (such as illustrated in Figure 2) of most DoD air systems, including command and control, intelligence, surveillance, and reconnaissance assets, as well as fourth-generation platforms (F-16s, F-15s, B-1s, etc.). What the JSE is intended to provide is a universal, real-time, effects-based environment where any test team can bring an operational flight program (OFP) cockpit representation of its system to test with other blue assets in operationally representative threat environments.

The current prototype at Navy Pax is not designed with personal device (PC, laptop, tablet, etc.) portability in mind, nor is it controlled through a single user-friendly interface. The system must be operated by a team of personnel with hardware-in-the-loop mock-up cockpits of the F-35 to create the most realistic scenario possible for the upcoming operational test. Admittedly, this is a long shot from Microsoft Office running on one’s tablet. However, the use of the JSE to support the operational test of the F-35 will provide the M&S community with the building blocks of the universal simulation environment. The ideal solution will build from the JSE to a more mobile product (a disc-carried distribution, for example) that can potentially link and run with any representation of a blue system under test, from an all-digital model to a high-fidelity hardware/operator-in-the-loop cockpit, and test together with other blue assets in combat-representative environments.

**CONCLUSION**

To assess an aircraft’s survivability in an electronic warfare environment accurately, we need to test its survivability against threat systems. We do so through a consortium of a scientific laboratory-based approach, an open-air range test approach, and M&S. Unfortunately, laboratory testing provides fundamental and controlled data but not necessarily real-world characterization. Operational flight test events can be far too expensive, take too much time, and, as the threat evolves, may not be able to reflect the intended environment on its own. And unique M&S packages can take excessive amounts of time to produce and are not as cost-effective as desired.
The proposed universal M&S suite or toolkit approach described herein has the potential to revolutionize the way we test for RF survivability by minimizing resources required for the process via the leveraging of a common suite while providing a solution as accurate as traditional M&S. The future of M&S lies in this realm as current proprietary approaches are unsustainable in the modern defense world of low-density, high-value assets.

ABOUT THE AUTHOR

CPT Maxim Olivine is the Director of Engineering for the Air Force Operational Test and Evaluation Center, Detachment 5, at Edwards Air Force Base, CA. He provides oversight, technical guidance, and analytical expertise to test new weapon systems in realistic, combat-oriented environments. He also serves as the Deputy Division Chief for the Detachment Test Support Division. CPT Olivine holds a B.S. in computer engineering from the University of California, Davis and an M.B.A. from Wright State University. He is currently pursuing a Ph.D. in systems engineering from Colorado State University.

References


EXCELLENCE IN SURVIVABILITY

LEANNE MCKAY

by Ron Dexter

The Joint Aircraft Survivability Program Office (JASPO) is pleased to recognize Ms. LeAnne McKay for her Excellence in Survivability. An accomplished vulnerability analyst and project leader, LeAnne—who currently serves as the Deputy Manager of the SURVICE Engineering Company’s Dayton Area Operation—has been providing the survivability community with critical computational, analytical, and test support on a wide range of foreign and domestic weapons programs for nearly three decades.

A native of Perryville, MD, LeAnne began her survivability career as a college intern at SURVICE’s Bel Air, MD, location in the late 1980s. During this time, she had the opportunity to begin learning many aspects of vulnerability analysis and testing from some of the founders and early leaders of the survivability engineering discipline (including James Foulk, Don Mowrer, Walt Vikestad, and Walt Thompson). In 1988, she graduated with a B.S. in applied mathematics from Towson University and began combining her education fundamentals with extensive hands-on and theoretical analysis experience to support numerous survivability/lethality projects, involving everything from ground vehicles to rotary- and fixed-wing aircraft.

One of the first programs LeAnne supported was evaluating the effectiveness of the early Computation of Vulnerable Areas and Repair Time (COVART) tool—now the Computation of Vulnerable Area Tool—against the OV-10A aircraft. She also spent much of her early career supporting foreign system analysis, including conducting exploitation and lethality studies of ground and air systems in support of weapon development programs. It didn’t take long for LeAnne to build a keen skillset for reverse engineering foreign targets, as well to gain specialized expertise in developing BRL-CAD and FASTGEN geometric models. In addition, her intimate understanding of the physical and functional operation of foreign systems through her Damage Mode and Effects (DMEA) analyses and fault tree evaluations naturally led to her development of component kill probabilities and to the conduct of vulnerability/lethality assessments using internally developed codes, scripts, and COVART toolsets.

LeAnne supported many different organizations in government and industry during this early period, including the National Air and Space Intelligence Center (NASIC), the U.S. Army Research Laboratory’s Survivability/Lethality Analysis Directorate (ARL-SLAD), the Naval Air Warfare Center Aircraft Division (NAWCAD), the Naval Air Warfare Center Weapons Division (NAWCWD), the National Surface Warfare Center Dahlgren Division (NSWCDD), the Air Force Armament Center (AAC), Sikorsky Aircraft, Boeing, and General Electric.

Notable systems she analyzed during this time included the Soviet SU-27 Flanker; MiG-29 Fulcrum; Mi-8J/K helicopter; Soviet GAZ-66 and ZIL-131 trucks; Soviet SS-21, F 106 Delta Dart; RAH-66; AV-8B; and the T800, F119A, and F120 engines. Many of the analyses that LeAnne performed during this early period helped to enhance the effectiveness and lethality of U.S.
In addition to performing modeling and simulation analyses, LeAnne also supported various test efforts for the Joint Live Fire and Live Fire (JLF/LF) programs. She also tested the effects of high-speed fragments against surrogate missile targets in a program with the University of Dayton Research Institute. Little did she know at the time that she would eventually call Dayton her home.

In 1997, LeAnne left SURVICE to move with her young family to Michigan, where she worked for American International Airways. This move gave her yet another opportunity to gain hands-on knowledge of aircraft design and repair (particularly for the Boeing 747 and 727). However, when SURVICE decided to open an office in Ohio in the summer of 1998, LeAnne’s calling to work in the survivability community was sparked once again. And in the spring of 1999, she returned to serve as a lead analyst in SURVICE’s new Dayton Area Operation.

Promoted to the position of Deputy Manager in 2004, LeAnne has continued to manage and lead a wide range of vulnerability/lethality programs, particularly fixed- and rotary-wing aircraft, turbine engines, and threat characterization programs. She has also become the wearer of many hats, assisting not only in the daily administrative and technical management of the operation but also in performing vulnerability/lethality analyses (using COVART and the Advanced Joint Effectiveness Model [AJEM]), planning live fire test and evaluation programs, and assisting and mentoring fellow survivability practitioners.

Primary organizations she has supported in this role include the Air Force Life Cycle Management Center’s Combat Effectiveness and Vulnerability Analysis Branch (AFLCMC/EZJA), the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME), the U.S. Army Evaluation Center (AEC), AAC, NAWCWD, the Air Force’s 645th Aeronautical Systems Group (645 AESG) and 704 Test Group (TG) (previously the 96th TG), Sikorsky Aircraft, General Electric, and General Atomics.

Notable programs she has contributed to in this role include the B-2, A-10 Warthog, MH-68, HH-65, F-16, F-117, Joint Cargo Aircraft, MiG-19, KC-46, C-27, Twin Otter, Dash-8, Predator, RAH-66, H-60 (multiple derivatives), S-92 (multiple derivatives), the Combat Rescue Helicopter, and the iconic B-52.

She has also supported numerous turbine engine vulnerability programs (such as General Electric’s F-136 and GE38-1B programs) and weapon and threat programs (such as the AGM-86 Air-Launched Cruise Missile and the Surface-Launched Advanced Medium-Range Air-to-Air Missile programs), as well as helped to develop characterization data for projectile threats (under the Air Force Pedigree program). Her many contributions have not only helped to provide data for missile enhancement and development but also to verify compliance with specification requirements for U.S. air systems, with the ultimate purpose of improving those systems’ survivability.

Finally, based on her longstanding experience and leadership within the community, LeAnne has led multiple workshops that have brought together engineers from across the survivability discipline to enhance the development of probabilities of damage and analysis of crew, fire, and blast. She is also the author of, and has contributed to more than, 50 technical reports and papers on various survivability/lethality and related topics and is an active member in the National Defense Industrial Association and the American Helicopter Society.

LeAnne currently lives in Springboro, OH, with her family. She has two daughters, one a junior at the Ohio State University and the other a soon-to-be freshman at the University of Kentucky. She has been an active member in the Springboro community (including serving as a leader in the Girl Scouts) and an increasingly active member in the area’s equestrian community (supporting her youngest daughter’s riding passion).

Congratulations, LeAnne, for your Excellence in Survivability and for your past and present contributions in the aircraft survivability community.
In November 2016, the National Defense Industrial Association (NDIA) Combat Survivability Division (CSD) Awards Committee, joined by the division founder RADM 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**

The Gormley 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. Joseph C. “Jay” Rodgers, U.S. Navy Naval Air Systems Command (NAVAIR) Senior Aircraft Survivability Engineer and Associate Fellow, was presented with this year’s Gormley award in recognition of his leadership roles as a Marine pilot and commander; as an aircraft developer, tester, and program manager; and as a contributor to many different aspects of aircraft...
survivability—from research, development, and acquisition to combat employment. Throughout Mr. Rodger’s career, he has been recognized by his peers and leadership alike for his unmatched work ethic, pursuit of excellence, and wide spectrum of knowledge and experience.

COMBAT SURVIVABILITY AWARD FOR TECHNICAL ACHIEVEMENT

This 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.

Dr. David J. Ebel, MIT Lincoln Laboratory Associate Group Leader and U.S. Air Force Red Team Systems Analysis Lead, was presented this year’s award in recognition of his long history of technical leadership in support of the Air Force Air Vehicle Survivability Evaluation Program. Dr. Ebel is nationally recognized for providing clear and compelling systems analyses involving foreign air defense systems, as well as a myriad of advanced aircraft platforms, concepts, and survivability technologies. His numerous assessments have contributed to the survivability analyses and requirements definition for every major advanced Air Force air vehicle.

COMBAT SURVIVABILITY AWARD FOR LIFETIME ACHIEVEMENT

This 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. The recipient of this award is nominated by the executive board in recognition of an individual’s lifetime of accomplishments and dedication to the aircraft survivability community and to the aircrews the community serves.

This year, the committee recognized Dr. Tilden N. “Mike” Mikel, former Vice President and Chief Engineer – Military Programs, Bell Helicopter Textron, for his more than 40 years of military and civilian involvement in the combat survivability community. Dr. Mikel has served as an attack helicopter pilot and a command and staff officer in the U.S. Army, and he transitioned to ever-increasing technical and programmatic responsibilities for the development and sustainment of numerous Army and Marine rotary-wing programs at Bell. In addition, his continuing and tireless support of the many activities, goals, and ideals of the CSD has significantly contributed to the development of generations of aircraft survivability experts, as well as the impact of this community on the survivability and mission effectiveness of our aircraft and aircrews.

Congratulations to all three of our 2016 awardees for their many accomplishments and contributions.

LOOKING AHEAD TO 2017

It is not too early to start considering who is deserving of recognition this coming November at the 2017 NDIA Aircraft Survivability Symposium, which will again be held at NPS in Monterey, CA. The CSD Awards Committee encourages community members to consider individuals in their staffs and organizations who have demonstrated technical achievements or leadership in the survivability discipline and are thus deserving of nomination. Nomination deadlines and submission procedures will be published later in 2017. But there is no need to wait; the committee is happy to discuss and accept nominations now. To make a nomination and/or discuss the process further, please contact Mr. Robert Gierard at robert.a.gierard@raytheon.com or 310-200-1060.

ABOUT THE AUTHOR

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

APRIL

SeaAirSpace
3–5 April in National Harbor, MD
http://www.seaairspace.org/welcome

Aircraft Combat Survivability Short Course
4–6 April in Dayton, OH
https://www.dsiac.org/events/aircraft-survivability-short-course

JASP Model Users Meeting (JMUM)
11–13 April in Dayton, OH
https://www.dsiac.org/resources/events/summer-joint-aircraft-survivability-program-jasp-model-users-meeting-jmum

JASP FY18 Proposal Review
25–27 April in Dayton, OH

AOC 46th Annual Collaborative EW Symposium
25–27 April in Point Magu, CA
www.crows.org

AAAAA Mission Solution Summit
26–28 April in Nashville, TN
http://www.quad-a.org/2017Summit/index.php/home

MAY

JCAT TWE
2–4 May at Hurlburt Field, FL
http://jasp-online.org/event/jcat-twe/

Air Vehicle Survivability Workshop
9–11 May in Lexington, MA
https://conferences.lill.mit.edu/avs/

9th Annual EW Capability Gaps and Enabling Technologies Operational & Technical Information Exchange
9–11 May in Crane, IN

American Helicopter Society Forum 73
9–11 May in Fort Worth, TX
https://vtol.org/annual-forum/forum-73

JUNE

2017 AIAA Aviation Forum
5–9 June in Denver, CO
https://www.aiaa-aviation.org/

JLF Midyear Review
20–22 June, Location TBD

JULY

2017 AIAA Propulsion and Energy Forum
10–12 July in Atlanta, GA
http://www.aiaa-propulsionenergy.org/