13
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# AIRCRAFT SURVIVABILITY

## SUSCEPTIBILITY REDUCTION



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On the cover:
MH-53J Pave Low IIIE from the 20th Special Operations Squadron, 16th Special Operations Wing, Hurlburt Field, FL, expends flares over the Atlantic Ocean to demonstrate its defensive capabilities. Photo by Senior Master Sgt. Rose Reynolds.

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# NEWS NOTES

by Dennis Lindell

## RANDY SHORT LEAVES NAVAIR

Randy Short, Joint Aircraft Survivability Program (JASP) Navy Principal Member since March 2008, left government service with the Naval Air Systems Command (NAVAIR) on 23 February 2013. Randy served NAVAIR for many years and was highly decorated as both an officer and a civilian. As director of the NAVAIR Survivability & Lethality Division, he provided outstanding leadership to JASP, working closely with his counterparts in the Air Force and Army to steer JASP to success. We all appreciate Randy's contributions to the Navy, JASP, and the soldier and wish him the very best.

Bill Dooley, who has been named the acting director of the NAVAIR Survivability & Lethality Division, will also serve as the JASP Navy Principal Member. A longtime friend of JASP, Bill is looking forward to supporting the program in this new role. Please join us in welcoming Bill to the JASP leadership!

# JCAT CORNER

by Lt Col Chuck Larson, USAF, CAPT Cliff Burnette, USN, and CW5 Bobby Sebren, USA

## LOOKING TO THE FUTURE OF AVIATION COMBAT FORENSICS

At the start of each major conflict, a similar capability to the Joint Combat Assessment Team (JCAT) has never been available or authorized to collect combat damage data. Each time, however, the value of this capability was recognized, spun up, trained, and deployed after the highest intensity combat had occurred. Because of the fragility of combat forensic data, this delay has resulted in the collection of incomplete data, the lack of some types of data, and the biasing of aviation combat data towards the later stages of conflict. JCAT has been working with the Office of the Secretary of Defense to improve this situation through an effort called the Aircraft Combat Damage Reporting (ACDR) Initiative.

**Figure 1** Lt Col Chad Ryther (USAF) Leads the Deployed JCAT in Afghanistan

The ACDR Initiative has already demonstrated automated aviation combat incident reporting capabilities into the Combat Damage Incident Reporting System (CDIRS); however, the more difficult task of establishing Department of Defense directives that require the collection of data throughout a conflict as well as the inclusion of JCAT capabilities in first entry forces is still in work. This is partially because aviation combat forensics investigation requires cross-disciplinary coordination, needing engineering, science, intelligence, operations, and maintenance cooperation. Finding a single place to "codify" requirements within the current regulations has been challenging and, much like safety, may require a separate instruction. To ensure we capture data at the start of future conflicts, this effort will require support from all disciplines. Please contact the Joint Aircraft Survivability Program if you can aid in supporting the ACDR Initiative.

In December 2012, CAPT Cliff Burnette relieved CAPT William Little as the Commanding Officer of the NR NAVAIR In-Service Engineering (ISEL) Unit. The ISEL Unit consists of 27 officers assigned to train and equip aircraft battle damage assessors for worldwide deployment to evaluate combat damage incidents, assess the threat environment for operational commanders, and collect data to support aircraft survivability research and development. To this end, the headquarters unit is located at Naval Air Station Patuxent River, MD and detachments located at Wright-Patterson Air Force Base, Dayton, OH; Naval Air Weapons Station (NAWS) China Lake, CA; Camp Leatherneck (RC/SW) Afghanistan; and 3d Marine Aircraft Wing Headquarters, Marine Corps Air Station Miramar, CA.

Capt Little, a two-time deployer for the JCAT mission, led the establishment of a permanent 330 acre JCAT Assessor Training Facility at NAWS China Lake and directed the establishment of Navy JCAT resources in Operation ENDURING FREEDOM. Capt Little received orders to the NR NAVAIR Volunteer Training Unit, where he will be performing numerous assignments, including the Inspector General function for NAVAIR.

CAPT Burnette is a designated aerospace engineering duty officer-maintenance and a member of the Acquisition Corps. His previous JCAT/survivability experience includes serving as the LNO/OIC for JCAT-Operation IRAQI FREEDOM, ISEL, DET A, and OIC. Capt Burnette is the former Commanding Officer of NR NAVAIR Expeditionary Logistics and recipient of the 2012 Admiral Stan Arthur Award for logistics team excellence and the 2012 NR NAVAIR RADM Hugh Smith Unit of the Year award.

Army JCAT has maintained a high operational tempo both at home and abroad while also continuing to adapt to the ever-changing battlefield. The formerly known as the Aircraft Shoot-Down Assessment Team (ASDAT) adopted a new name, Aviation Survivability Development and Tactics Team, to better describe and represent the responsibilities and duties the team is charged with to provide to the aviation community. The acronym, ASDAT, remains the same along with the highest level of support that soldiers expect and deserve.

In February 2013, Army JCAT organized and hosted another iteration of Phase I of the Joint-Combat Assessor Training at Fort Rucker, AL. Thirty-one personnel from the Army, Navy, and Air Force attended the training. Each student received classified briefings and instruction in the classroom and hands-on training on Army rotor-wing aircraft. The week of training culminated with the class working in small groups and conducting an assessment on a battle-damaged aircraft. For the first time, Army Tactical Operations Officers (TACOPS), who will be deploying in the near future, were invited to Phase I. With this collection training in their tool box, TACOPS will be able to better assist JCAT down-range to ensure timely and accurate assessments of real world-events.

ASDAT would like to welcome two new comers to the team, CW3 Rob Olson and CW3 Brian Bartee, as well as their families. Both recently returned from a year-long deployment in Afghanistan with the 82d Combat Aviation Brigade, and will bring a wealth of knowledge and current expertise to the team. CW3 Olson, an OH-58D pilot, and CW3 Bartee, an AH64D pilot, both served as Task Force TACOPS during their rotation. With the addition of these two fine young officers, JCAT Army is finally back to 100% manning and prepared to answer the call of duty when needed.

**Threat Weapons and Effects Seminar:** Due to budgetary uncertainty and the desire to provide an exceptional seminar, we have cancelled the 2013 Threat Weapons and Effects Training Seminar. We expect that the seminar will continue in 2014 and hope to see you there! ASJ

COVER STORY

# CHALLENGES IN INTEGRATED AIRCRAFT SURVIVABILITY EQUIPMENT (IASE)

by Tim "TO" Oldenburg

The idea of IASE is an old concept that is continually evolving. The first time someone carried a gun on an aircraft to prevent an adversary from shooting them down (refer to Figure 1) was the beginning of IASE. Initially, IASE was simply "if I see someone shooting at me, I point my gun at them and shoot back." When more sophisticated methods for shooting down aircraft were implemented, ways to counter those methods had to be developed that efficiently used the available resources.

This article explores four major challenges that the developers of IASE systems struggle to overcome:

- Hostile threat characterization
- Data assimilation/processing
- Space, weight, and power (SWAP) constraints
- Interoperability

These four challenges are main concerns for current programs/projects, and are further discussed in the articles presented in this issue.

**Figure 1** Advent of Air War Operations IASE [1]

## THREAT DETECTION/ IDENTIFICATION/ GEO-LOCATION

In this day and age, most aircraft have to counter a growing set of hostile threats, from simple bullets to sophisticated missiles. The varied types of threats that an IASE system must detect, identify, and/or counter include small arms fire, rocket propelled grenades, anti-aircraft artillery, man-portable air defense systems, and mobile/fixed infrared (IR) and radio frequency (RF) surface-to-air missiles (refer to Figure 2).


**Figure 2** Multiple Threat Scenario [2]

To distinguish and characterize the threat, one needs to sense the threat in one or more of the following spectrums: IR, acoustic, ultraviolet, RF, and visual. Typically, applying multiple spectrums increases the fidelity of the detection, identification, and geo-location, while reducing false alarms. Fusing these varied streams of data in the IASE processing suite for automatic countermeasure dispense and presentation to the aircrew requires sophisticated analysis and human factors integration.

## DATA/SENSOR FUSION

Data fusion is the integration of raw data from multiple sources to produce an output that is more useful than the individual inputs. Correlating different sensors (laser, acoustic, radar, optical) and other types of data into usable information for the IASE system is a major challenge. As you can see in Figure 3, it is a formidable task to fuse a missile warning system, radar warning receiver, laser warning system, countermeasures dispensing system, battlefield intelligence and geo-location data into one single processor. As more and more sensors and their associated data are incorporated into the IASE suite, memory and data storage become an issue.

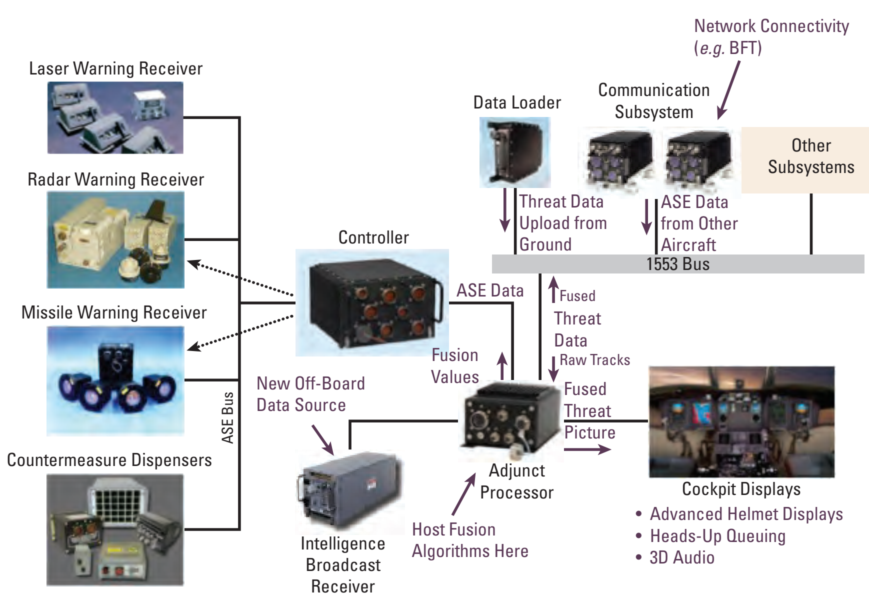


**Figure 3** Onboard/Offboard IASE [3]

A key aspect of dealing with the volume and diversity of data is integrating it at the appropriate fusion level, and then sorting and prioritizing the information so it provides actionable guidance to the system and aircrew. Figure 4 depicts the building blocks for a fusion engine example. Each of the following levels has a specific piece of information to aid in the correlation process:

- **Level 0**—Electromagnetic type of information (*e.g.,* IR, RF, acoustic)
- **Level 1**—Object detection/ recognition/identification and tracking data
- **Level 2**—Information relationships to environment, other sources, and self
- **Level 3**—Interpolation/extrapolation of situation to identify potential impacts/consequences
- **Level 4**—Optimum information selection
- **Level 5**—Human-computer factors interpretation and integration

## SPACE, WEIGHT, AND POWER (SWAP)

SWaP is a major constraint in aircraft systems development. Optimizing an IASE system is not just a function of sensor type and processor power, but it is the number and location of components that will fit within the aircraft's SWaP requirements. A good example of optimizing SWaP is the F-35 Lightning II, Joint Strike Fighter (JSF). The JSF incorporated an extensive array of sensors in its design and development effort, including design space for future implementation of an advanced IR countermeasures system. Optimization is best achieved in new design aircraft like the JSF. It is much more difficult to optimize SWaP in individual or federated systems that are added to legacy platforms, which results in lower IASE performance at higher SWaP than is possible in an integrated or clean slate design.

## INTEROPERABILITY

A key belief of IASE is interoperability. Interoperability is not only the ability of one system to talk to another, but it is also the ability of a soldier to share and understand the information from other operators in the battle space. The first challenge to overcome is a language barrier. Not all aircraft systems talk the same language. Creating a common language and interface standards for fusion process communication is key to efficiently integrating data from multiple sources and providing the resulting information to various end users.

The ability to use data from, and feed data to, offboard assets may provide the biggest IASE return on investment, but also poses greater technical and operational challenges than onboard integration. Providing a common operational picture (COP) for both the aircrew and other coordinating operatives in the battle space is a key element in ensuring the mission is accomplished while minimizing loss of life and/or equipment.

Another important aspect of interoperability is human systems integration. Presenting the information in a manner that provides actionable cues with readily apparent situational awareness is a major requirement. The COP provided to the aircrews must help them execute missions, while reducing their workload and distractions; otherwise, the results can be catastrophic. Human systems integration and tactics, techniques and procedures development must begin at the start and continue through the development and fielding of any new IASE system.

## FUTURE PLANS

IASE is playing a much greater role in the overall concept development and design of future systems like the JSF, Future Vertical Lift, and Joint Multi-Role platforms. The Future Airborne Capability Environment and the Rotorcraft Avionics Innovation Laboratory are developing future onboard and offboard battle space environments for rotorcraft. Integration to address other flight hazards (*e.g.,* brown-out) and hostile threats with

*continued on page 13*

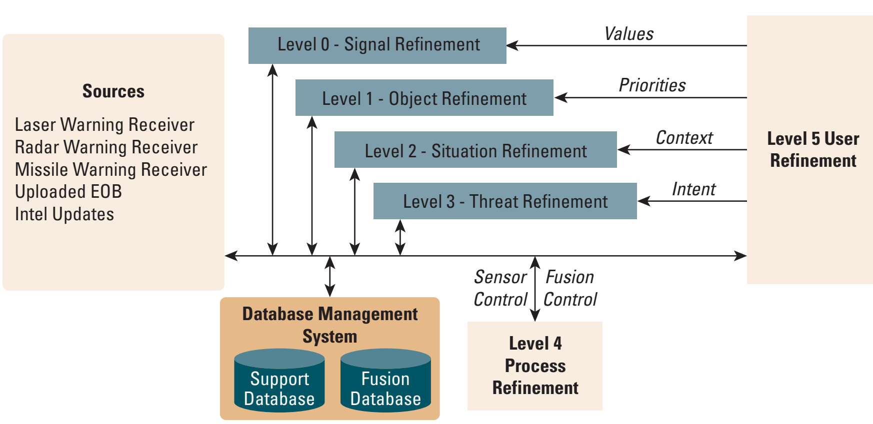


**Figure 4** Fusion Inputs/Outputs [4]

# RUGGED, HIGH TRANSMISSION INFRARED (IR) FIBER CABLES FOR IR COUNTERMEASURES (IRCM)

by Lynda Busse, Fred Kung, Catalin Florea, L. Brandon Shaw, Ishwar Aggarwal, and Jas Sanghera

This article presents successful results of high mid-IR laser power transmission as well as as military specification (MIL-SPEC) environmental testing (thermal cycling and vibration testing) of ruggedized, IR-transmitting chalcogenide glass fiber cables. The cables tested included chalcogenide fiber cables with endfaces imprinted with anti-reflective “moth eye” surfaces, where the reflection loss is reduced from about 17% per end to less than 3%. The cables with these moth eye surfaces also show excellent laser damage resistance.

## BACKGROUND

IR-transmitting optical fibers are of great interest for various applications, including anti-missile aircraft protection systems, fiber sensors, and imaging. The Naval Research Laboratory (NRL) has pioneered the development of IR fibers based on arsenic sulfide glasses, and has shown they can handle the flexible and strong laser powers; however, ruggedized cables are needed for the fibers to enable their practical implementation in aircraft applications.

Ruggedized cable fabrication is routinely done for telecommunications-type fibers based on silica glass. These cables are used in military systems and tolerate a variety of harsh environments; however, the construction of these cables is specific to the telecom-type fibers based on silica, and is not directly suitable for the IR fibers due to their different mechanical and thermal properties. Previous cables fabricated using IR fibers has shown failures especially during thermal cycling tests. In particular, cable vendors were using the wrong methods to terminate and polish the fiber ends in the cables, or were using unsuitable materials for the cable construction.

The NRL proceeded to identify cable fabrication vendors with the capability to make ruggedized, environmentally reliable cables with the IR fibers. Initially a wide variety of vendors were surveyed, and many were unable to meet the environmental requirements or were unable to make cables with the IR fibers. Of all vendors surveyed, Coastal Connections (in Ventura, CA) was found to be the most capable to make the ruggedized cables with IR fiber. Their cables were evaluated at the NRL under a Joint Aircraft Survivability Program (JASP)-funded project S-11-03 using a newly installed thermal/vibration facility. The NRL reports on both thermal cycling and vibration tests that were conducted according to MIL-SPEC requirements to determine the reliability of cable designs. The NRL also reports on results for laser transmission using high power lasers in the mid-IR region. These results include transmission through IR fiber cables, where the NRL has fabricated on the endfaces a patterned, anti-reflective surface (*i.e.,* moth eye) to reduce Fresnel reflections from the ends, which is the process that was developed under JASPO project S-10-01. These cables show remarkably high laser damage resistance, which is comparable to the bulk material.

## IR FIBER CABLES ENVIRONMENTAL TESTING

Coastal Connections fabricated the IR fiber cables (examples shown in Figure 1). The cable construction used by Coastal Connections was ruggedized steel with steel fiber channel (FC) connectors used for the cable terminations. The polish quality was excellent, as observed with an optical microscope.

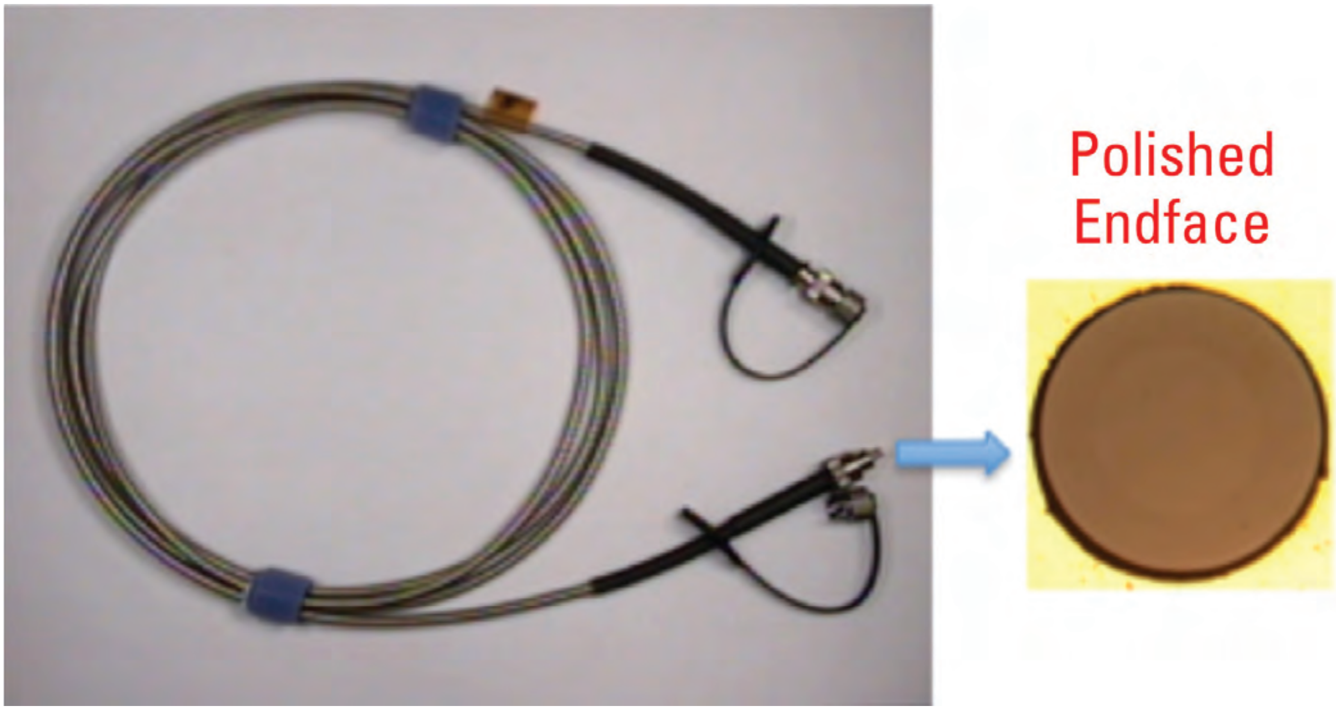


**Figure 1** Ruggedized IR Fiber Cables Fabricated by Coastal Connections and High Quality Polished FC Connectors

The reliability testing was conducted at the NRL, utilizing a new system (displayed in Figure 2) acquired specifically for thermal/vibration testing. It has the capability to do thermal cycling, vibrations, and humidity testing with the following features:

- Programmable thermal cycling capability (-73°C to +177°C) at 5 to 10°C/min
- Programmable vertical axis shaker system with profiles to simulate any aircraft or vehicle platform
- Capability for independent vibration/thermal tests or simultaneous testing
- Humidity control is capable of 20-98% Relative Humidity
- Large chamber is 41 cu. ft. (40" width x 40" depth x 44" height)

Additionally, there are removable shelves that can be used for cables or other components with thermal cycling and side ports for access to electrical cables to run from the chamber to external equipment or power sources as needed. Two side tables are located on either side of the chamber to hold external equipment. Note that the left side of the table is out of view in Figure 2.

For the tests conducted, the NRL followed MIL-SPEC test protocols [1], which involved thermal cycling from a maximum of 71°C to a minimum of -54°C. Both simultaneous thermal/vibration cycling was conducted according to a fixed schedule, as well as vibration cycling at room temperature. Each test run consisted of 8 hours, alternating between the thermal cycling with vibrations or only the vibration cycles with the temperature held at 25°C.


**Figure 2** Government Thermal/Vibration System with Side Tables for External Equipment

A modular test fixture was designed and fabricated to hold multiple cables for testing, and it was affixed to the shaker. This setup is mounted inside the chamber that is displayed in Figure 2, with a close-up view displayed in Figure 3. Each cable was affixed to a plate attached to the test fixture and held down, simulating actual implementation

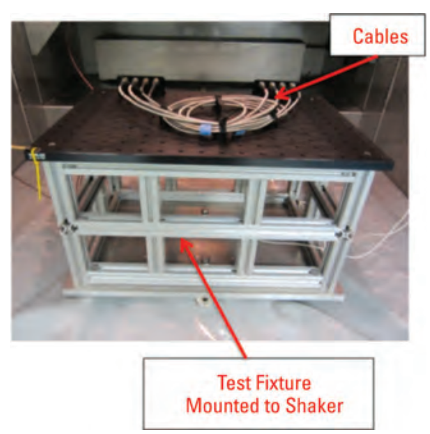


**Figure 3** Test Fixture Mounted to Shaker in Chamber

in a platform. The test fixture was designed to accommodate other types of components testing as well.

To evaluate the cables after each 8-hour run, the NRL set up two test beds for evaluating the fiber transmission. The first was used to test transmission directly at 1.94µm and 3.39 µm using laser input to the cables. The NRL tested by looking for any significant drop in transmission that would signal a break in the fiber.

In the second setup, the NRL used an optical backscatter reflectometer (OBR), which is designed specifically for finding defects or breaks in a fiber with millimeter-range axial resolution. The NRL utilized the OBR to determine if there were any breaks or cracks in the fiber, which would show on the scan as a peak in the transmitted profile. Care was taken to utilize a fiber mode scrambler at the input of the cable to make sure all the modes in the fiber were excited by the incoming laser light, and not just the lowest order modes.

| | | | Run | | SUTx | Cumulative |
|---|---|---|---|---|---|---|
| | | Temp | Time | SUT | Run Time | RVT Time |
| Run # | Vibration | Profile | (hours) | Qty | (hours) | (hours) |
| 1 | yes | Ambient | 8 | 2 | 16 | 16 |
| 2 | yes | Hot/Cold | 8 | 2 | 16 | 32 |
| 3 | yes | Ambient | 8 | 2 | 16 | 48 |
| 4 | yes | Hot/Cold | 8 | 4 | 32 | 80 |
| 5 | yes | Ambient | 8 | 4 | 32 | 112 |
| 6 | yes | Hot/Cold | 8 | 4 | 32 | 144 |
| 7 | yes | Ambient | 8 | 4 | 32 | 176 |
| 8 | yes | Hot/Cold | 8 | 4 | 32 | 208 |
| 9 | yes | Ambient | 8 | 4 | 32 | 240 |
| 10 | yes | Hot/Cold | 8 | 4 | 32 | 272 |
| 11 | yes | Ambient | 8 | 4 | 32 | 304 |
| 12 | yes | Hot/Cold | 8 | 4 | 32 | 336 |
| 13 | yes | Ambient | 8 | 4 | 32 | 368 |
| 14 | yes | Hot/Cold | 8 | 4 | 32 | 400 |
| 15 | yes | Ambient | 8 | 4 | 32 | 432 |
| 16 | yes | Hot/Cold | 8 | 4 | 32 | 464 |
| 17 | yes | Ambient | 8 | 4 | 32 | 496 |
| 18 | yes | Hot/Cold | 8 | 4 | 32 | 528 |
| 19 | yes | Ambient | 8 | 4 | 32 | 560 |
| 20 | yes | Hot/Cold | 8 | 4 | 32 | 592 |

SUT = System Under Test

RVT = Reliability Verification Test

*1 cable had damage after 80 hrs.

**Table 1** Results for Thermal/Vibration Testing

Table 1 details the overall results for the reliability testing on the cables. A total of five cables were tested with 20 alternating 8-hour runs of vibration tests only and combined thermal/vibration tests. During the tests, only one cable showed a failure due to a break near the end termination after 80 hours of testing. The other four cables showed no change in transmission or evidence of breaks following the tests. As shown, the overall cumulative test time obtained for the cables was 592 hours.

## IR FIBER CABLES LASER TRANSMISSION

To be practical for laser systems that utilize the fiber cables, the NRL proceeded to test high laser power transmission through the IR fiber ruggedized cables. A pulsed mid-IR optical parametric oscillator laser was used for these tests with output from 3-5 μm.

The results showed that for a total of 20 IR-transmitting chalcogenide fiber cables tested, there was no damage on the surface of 37 out of 40 of the fiber end faces, and no damage observed along the fiber length inside the cables. Remarkably, the cables that showed end face damage continued to transmit laser power. In contrast, the tests run on two fluoride fiber cables (indium fluoride-based compositions) showed immediate damage on the input ends upon laser irradiation, whereby the cables stopped transmitting power.

We also tested three fiber cables made with the NRL process to imprint an anti-reflective moth eye surface on the end faces, which reduced the 17% Fresnel reflection from the fiber end face to less than 3% reflection loss. The details of the moth eye design and fabrication processes for the chalcogenide fibers were previously reported. [2]

Due to the apparent fragile nature of the anti-reflective moth eye surface, many believed that it would suffer damage at high incident laser power. Table 3 shows that the testing done at a commercial laser testing facility (Spica Technologies, Inc.) on NRL chalcogenide fibers, using a pulsed laser at 2.12 μm with 4 nsec pulsewidth, presented no damage up to at least 1.8 GW/cm$^2$ on fiber ends with the moth eye surface as compared to 0.8 GW/cm2 for a cleaved fiber end. [3]

In addition, three ruggedized IR fiber cables with end faces having the NRL moth eye treatment showed no damage to the fiber end faces after high power laser irradiation using the pulsed OPO laser at 3-5 μm. This highly successful demonstration shows the practical utility of IR fiber cables that are not only rugged, but also able to transmit high laser power with minimal reflection loss from the ends.

## CONCLUSIONS

The successful fabrication of ruggedized, IR transmitting fiber cables that can withstand practical environmental conditions is essential for implementation in systems for aircraft, fiber sensors, and other applications requiring durability. The NRL successfully utilized an outside vendor, Coastal Connections, to fabricate ruggedized IR fiber cables. These cables were then tested using the new government test facility at the NRL for environmental testing of cables and optical components.

Testing protocols were derived from MIL-SPEC standards, and a total of five cables were tested, using alternating runs of thermal and vibration testing, followed by vibration testing only. The cables were evaluated before and after testing by measuring transmission and conducting OBR scans to check for breaks. All of the cables were unchanged after a total of 20 8-hour runs, except for one cable that suffered a break near the end after it had been tested for 80 hours. A total of 592 cumulative hours of testing was achieved for the IR fiber cables.

In addition, laser transmission tests done on 20 IR fiber cables were highly successful in that only three out of 40 end faces showed damage at high power in the 3-5 μm region. These tests included three cables that had an anti-reflective moth eye surface

| Fiber Endface | Maximum Power Density* (GW/cm$^2$) |
|---|---|
| Cleaved (No Moth Eye) | 0.8 |
| With Moth Eye | 1.48 [ > 1.8x Improvement] |

**Table 2** Laser Damage Test Results on Fiber Ends

imprinted on the ends that increased fiber end face transmission from 83% without moth eye to 97% with moth eye on the ends. None of the moth eye-treated end faces showed damage after high power laser testing. These results are indicative of the practical utility of rugged, highly transmissive IR fiber cables for high power laser transmission in the mid-IR. ASJ

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**[1]** MIL-SPEC test conditions derived from MIL-STD-810G.

**[2]** Sanghera, J., Florea, C., Busse, L., Shaw, L. B. Miklos, F., and Aggarwal, I., "Reduced Fresnel losses in chalcogenide fibers by using anti-reflective surface structures on fiber end faces," *Optics Express*, Vol. 18, 26760 (2010).

**[3]** Busse, L. E., Florea, C., Sanghera, J. S., Shaw L. B., and Aggarwal, I. D., "Moth Eye Anti-Reflective Surface Structures for IR Fiber Cables," *Proc. of the MSS Specialty Group on Electro-optical and IR Countermeasures*, Vol. 1, Monterey, CA, 24-26 April 2011.


# CHALLENGES IN INTEGRATED AIRCRAFT SURVIVABILITY EQUIPMENT (IASE)

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legacy and future sensors is a major focus of these IASE efforts. As more and better information is shared across the COP, aircrews will be able to interpret, adjust, and act more quickly and efficiently to improve mission effectiveness and survivability. ASJ


### *Special Contribution Acknowledgement*

*Lieutenant Colonel (LtCol) Steven Sprout from the US Marine Corps provided valuable insight for this article.*


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**[1]** WWI archive file photo. *http://www.earlyaeroplanes.com/archive/image3/imag0714.jpg*

**[2]** AATD, HFI Threat System Geolocation Brief, 31 March 2011.

**[3]** NACRA, ASE Fusion for Rotorcraft Survivability Brief, 29 January 2013.

**[4]** Adapted from Hall, D.L., McMullen and S.A.H., "Mathematical Techniques in Multisensor Data Fusion," Artech House, Norwood MA, 2004.

# INTEGRATED AIRCRAFT SURVIVABILITY EQUIPMENT TECHNOLOGY DEMONSTRATION PROGRAM (IASE TDP)

by Curt McMullen

There is currently an untapped potential for improving aircraft survivability through the integration and coordination of aircraft survivability equipment (ASE) systems onboard military aircraft. This article describes a recent US Army Science and Technology (S&T) effort that identified near-term methods for survivability improvement in the context of the Army's current ASE suite and aircraft fleet; implemented US Army-owned software reference algorithms for select ASE integration concepts; and developed a hardware-in-the-loop (HWIL) test capability suitable for evaluating the integration algorithms.

## BACKGROUND

The IASE TDP was a recent S&T effort conducted by the US Army's Program Management Office for Aircraft Survivability Equipment (PMO ASE) and the Communications-Electronics Research, Development, and Engineering Center Intelligence and Information Warfare Directorate (CERDEC I2WD) between 2010 and 2012.

The IASE TDP built on continuous efforts by the PMO ASE and CERDEC I2WD to develop, test, and deploy US Army ASE as well as to plan future capabilities to integrate these ASE systems with avionics systems and off-board communications links to improve survivability in today's evolving multi-spectral threat environment.

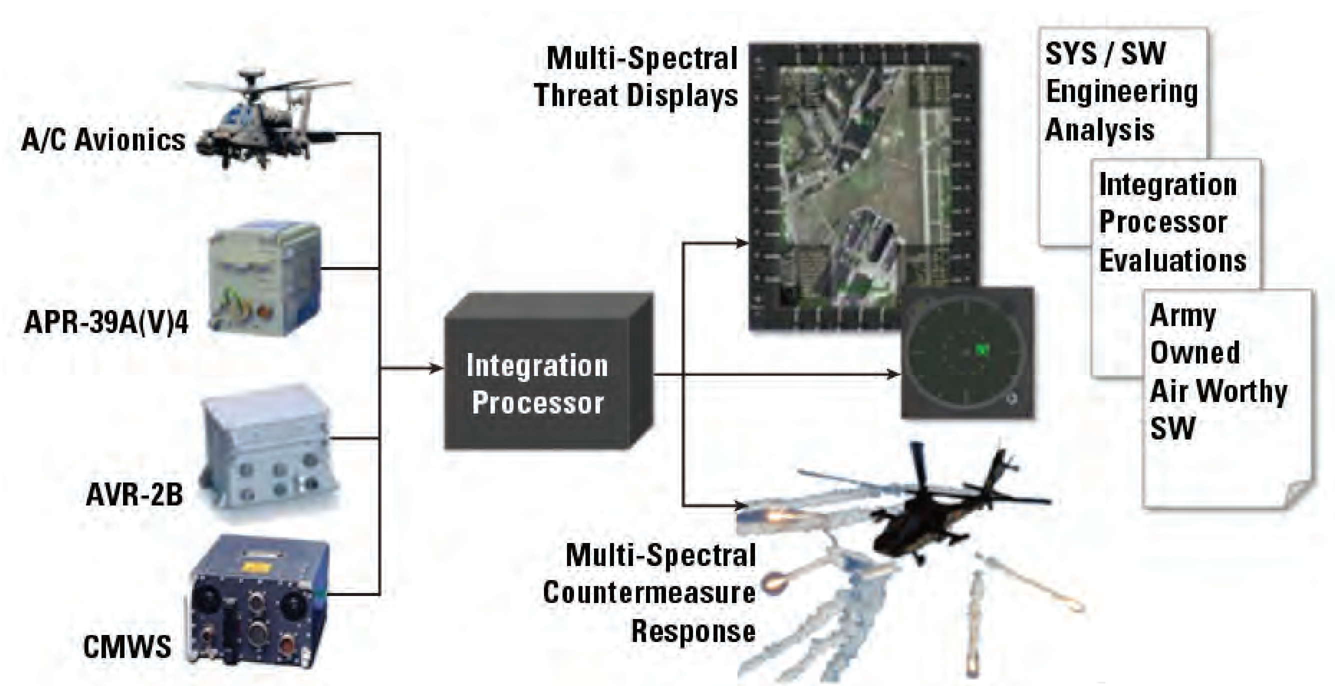


**Figure 1** IASE TDP System Architecture

With these previous integration efforts showing the potential for improved aircraft survivability through multi-spectral threat identification (and resulting improvements in situational awareness and countermeasure selection), the PMO ASE launched the IASE TDP.

## IASE TDP PROGRAM DEFINITION

The mission of the IASE TDP was to refine and demonstrate these ASE integration concepts in a hardware environment that represented the Army's current ASE suite and aircraft fleet, with an end goal of a flight demonstration on an Army aircraft.

A program strategy was developed to maximize the Army's ability to leverage the products of the IASE TDP in near-term deployments; this strategy led to the following program constraints:

**Platform Architecture—**The test aircraft would be selected from current US Army inventory. The ASE suite on the aircraft would consist of the AN/AVR-2B Laser Warning Receiver, the AN/APR-39A(V)4 Radar Warning Receiver (RWR), and the AN/AAR-57(V) Common Missile Warning System (CMWS). Kit modifications were to be limited to minor wiring changes required for integration. A major constraint was that the IASE software was to be hosted on an existing B-Kit to achieve a 0 space, weight, and power (SWaP) penalty.

**Software—**All software developed for the IASE TDP would be government-owned and architected in such a way that the platform integration specifics would be separate from the platform independent ASE integration algorithms (referred to as the IASE TDP Correlation Algorithms). These correlation algorithms were to be designed and implemented such that they would be easily portable to other hardware architectures and operating systems for future re-use. In addition, software would be developed in accordance with a process that satisfied the requirements of an Army air worthiness release.

## SYSTEMS ENGINEERING

**Key System Capabilities—**To document the capabilities of the IASE TDP system and communicate them to stakeholders, the IASE TDP Operational Concept Description (OCD) document was written. This document includes system states and modes, required system data, key system capabilities, and aircraft interfaces. The following is the list of capabilities documented in the OCD that are enabled through ASE and aircraft data integration:

- Threat Identification Capabilities
  - Gun vs. Missile Distinction
  - Earlier Threat ID Using Tactical Threat Intelligence (TTI) Data
  - Local Threat Environment History
  - Local Missile Environment History

- Display Capabilities
  - Display List Prioritization
  - Improved Angle of Arrival (AoA)
  - Improve Limited AoA
  - Threat Geo-location
  - Age-out Management

- Countermeasures Capabilities
  - Improved Countermeasure Selection
  - Display Earlier Missile Warning

- Audio Capabilities
  - Audio Warning Management

- Data Capabilities
  - Mission Data Log
  - Off Board/Onboard TTI Update

- Degraded Mode Capabilities
  - Degraded Operation

- Training Capabilities
  - Embedded Training

**Multi-spectral Correlation Defined—**Most of the above capabilities are enabled through the core capability of the IASE TDP system—multi-spectral correlation—which is described as follows: Individual ASE systems report signal detections of threat system emitters and provide data characterizing the parameters and angle of arrival of these emitters. The IASE TDP system is able to identify the engaging threat system by analyzing the detected emitter track combinations according to known threat system emitter relationships. Using a series of user-defined templates loaded from the mission data file, the IASE TDP system groups two or more emitter track entries through a process called "correlation" to identify the engaging threat system.

Each correlation template is uniquely associated with a multi-emitter threat system and specifies the emitter relationships that form the identification patterns of a particular threat system. These relationships include the sequence of emitters and time bounds for temporal correlation as well as the rules for spatial correlation that are required to satisfy the identification patterns of a particular threat.

Spatial correlation is achieved when multiple emitters are detected along the same AoA from a threat system, while temporal correlation involves detecting emitters from a threat system in a certain sequence or relative time window. Also included in the correlation templates are technical signal parameters that assist the IASE TDP Correlation Algorithms in selecting certain templates while eliminating others to meet the threat identification criteria. When a group of reported ASE emitters meet all of the criteria specified within a correlation template, the IASE TDP system identifies the engaging threat system.

**Platform Selection—**To determine which Army helicopter platform would meet the program constraints, a platform integration study was performed that examined the ASE suite present on each aircraft, the wiring between ASE suite components and the aircraft pilot vehicle interface, and the installed equipment's potential for hosting the IASE TDP software. The result showed that the Apache AH-64D EBII met the program platform architecture constraints. The modern Apache platform architecture included a 1553 Electronic Warfare Bus, an Avionics 1553 Bus, and the aircraft gateway processor (AGP), which was well positioned to serve as the IASE TDP software host. The architecture proved programmatically difficult to integrate with the AGP, so a surrogate Host B-Kit for the AGP was selected that provided equivalent input/output, operating system (VxWorks 6.x), and CPU/memory capabilities while still targeting the Apache AH-64D EBII architecture.

**System Specification—**Once the system capabilities and the aircraft architecture were defined, the IASE TDP System Specification and System Design Description were written. These documents clearly stated the requirements of the system as well as the system architecture, and served as the primary input for the software engineering process.

## SOFTWARE ENGINEERING

Software for the IASE TDP system was separated into two computer software configuration items (CSCIs). The first was the host CSCI, which is responsible for providing the correlation CSCI with access to all required data from ASE and avionics systems on the aircraft; this includes data available on host hardware interfaces (*e.g.,* 1553 busses, serial ports, ethernet, discretes). The host also provides the operating system environment for the correlation CSCI.

The second CSCI was the correlation CSCI, which is responsible for implementing all IASE TDP System Key System Capability functionality. The main purpose of the correlation CSCI is to perform multi-spectral correlation. Support functions of this CSCI include the loading of configuration files that control the operation of the correlation; decoding of ASE and aircraft system messages to provide inputs to the multi-spectral correlator; encoding of commands to enhance operation of the countermeasures systems; and provision of outputs of the correlation process to enhance warnings to the pilot. Special effort was taken to make the correlation CSCI easily portable to other operating systems and hardware architectures. This was achieved through the use of the Portable Operating System Interface for Unix for inter-process communications, threading, time management, *etc.* as well as the use of an operating system and hardware platform abstraction layer.

The operating system used for the IASE TDP System was VxWorks 6.5.

## HWIL LABORATORY DEVELOPMENT

To test the IASE TDP system response to specific multi-spectral threats, a HWIL test capability was developed at I2WD headquarters in Aberdeen Proving Grounds, MD. This capability consists of two laboratories that are controlled collaboratively to replicate the threat engagement emissions detected by the ASE suite.

The ultraviolet/infrared (UV/IR) laboratory provides stimulation of the CMWS UV missile warning sensors and the AVR-2B's IR laser warning sensors using UV lamp and IR laser sources. These ASE sensors are mounted on a centrally located 3° of freedom onship motion table (OMT), which replicates aircraft pitch, roll, and yaw motion with respect to the threat stimulation sources. The UV/IR stimulation sources are mounted on five stacked tracks that make up a 110° circular arc with the OMT at the center. This geometry allows the UV/IR laboratory to create an environment where ASE sensors mounted on the OMT (the air platform) experience independent line of sight rate changes with the threat systems, simulating flight motion as the air platform flies toward and past the threat systems.

The I2WD Radio Frequency System Integration Laboratory (RF-SIL)—also located at Aberdeen Proving Ground, MD—provides a high fidelity RWR stimulation capability to the IASE TDP. The RF-SIL is equipped with three Combat Electro-Magnetic Environment SIMulator (CEESIM) systems, two stationary and one portable. Each CEESIM is capable of simulating scenarios that contain multiple simultaneous emitters and dynamic platforms. CEESIM uses an emitter library database to store emitter parametric data. An extensive emitter library has been programmed into the CEESIM systems using parametric data from the Electronic Warfare Integrated Reprogramming Database. The RF emissions from multi-spectral threats in the test scenario are coordinated with the UV/IR emissions of the threat, resulting in a true multi-spectral stimulus to the ASE systems that feed the IASE TDP system.

## RESULTS

The IASE TDP development was structured into two builds. The purpose of the first build was to demonstrate that the hardware/software architecture was robust and that the host CSCI and the correlation CSCI processes were able to run on the ALQ-213, and provide expected messages throughout their communications with each other and with the ASE systems external to the ALQ-213. The build test was successfully conducted in February 2012.

The purpose of the second build was to implement the core multi-spectral correlation capability of the correlation CSCI and all system external interfaces. This build was successfully tested in the IASE TDP software laboratory in November 2012 with further HWIL testing pending. The test consisted of CSCI-level requirements verification as well as scenario-based testing that demonstrated the correlation capabilities in a simulated environment that consisted of a virtual aircraft, ASE suite, and threat.

## CONCLUSIONS

The IASE TDP successfully demonstrated that the integration of ASE and aircraft systems to improve survivability is technically possible and is beneficial in the context of today's threat environment and ASE systems.

For future efforts that seek to implement an integrated ASE approach, the following lessons learned on the IASE TDP will be helpful:

**Threat Research—**Concrete examples of how multi-spectral correlation can improve aircraft survivability must be tied to in-depth knowledge of current and evolving threats.

**Influencing Countermeasures—**
Any ASE integration program that plans to influence countermeasures must be robust. The rigor required to architect, build, and test a system that influences countermeasures is much greater than that required for a system that only provides situational awareness to the aircrew.

**Test Interfaces—**The IASE TDP identified a number of ASE test interfaces that were able to provide additional information about ASE preliminary tracks and additional track parametric data. Configuration control and air worthiness issues were raised when suggesting these interfaces be used in a flight test.

**Metrics—**Establishing tests and metrics for quantifying survivability improvements due to integration of ASE is difficult and should be considered from the start of any ASE integration effort.

**Government Acquisition Planning—**
To deploy an IASE solution, long-term planning is required to define the integration concepts and requirements.

**Requirements—**A truly capable IASE solution will require new requirements to be levied onto each system in the ASE suite, the aircraft displays, the cockpit controls, *etc*.

For additional information concerning the IASE TDP, please contact Curt McMullen, CERDEC, I2WD, or RDER-IWE-EA. ASJ

# ACOUSTIC SITUATIONAL AWARENESS FOR SURVIVABILITY

by Melissa McDaniel and Zach Hall

For manned military aircraft, survivability is a critical system characteristic that has evolved into a separate design discipline. This design discipline has resulted in several technological advances for aircraft survivability equipment (ASE): threat detection, warning, electronic and physical countermeasures, vehicle signature analysis, and mission planning. For this article, ASE refers to efforts to reduce the vulnerability of the aircraft in flight, allowing the aircrew to accomplish their mission and survive. [1]

Initially, the attention to survivability was not given to unmanned systems due to their lower cost and the obvious reason that a human was not on board; however, as the role of the unmanned aerial systems (UASs) has evolved from "dull, dangerous, and dirty" to a mission critical gathering of persistent, full-motion video supporting intelligence, surveillance, and reconnaissance, survivability of our remotely piloted sensor platforms has become a larger concern. For unmanned aircraft, situational awareness and route planning provide the best means of aircraft survivability. In particular, situational awareness requires knowledge of a vehicle's signature profile, including the acoustic, infrared, radar, and visual profiles. For the purpose of many surveillance flights, the acoustic profile of the vehicle may be the most critical. With proper knowledge of the UAS's acoustic profile, mission planning can be used to increase aircraft survivability and enhance mission effectiveness.

## AURAL DETECTION

Sound is defined as a time dependent change in the density, pressure, and temperature of fluid (*i.e.,* air) particles due to a vibration or disturbance. A distinguishing feature is that sound or acoustic disturbances propagate rapidly through a fluid medium at a speed referred to as the speed of sound. [2] That disturbance eventually reaches the human ear as a recognizable noise (refer to Figure 1). The sound generated by an aircraft is typically referred to as the acoustic profile or acoustic signature. To avoid unintended aural detection, it is important to understand the acoustic profile of the vehicle in question. Such understanding can result in better-planned and more effective missions.

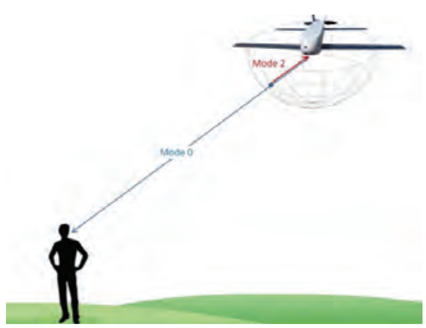


**Figure 1** UAS Aural Detection

A vehicle's acoustic signature is dependent on several factors. For the most propeller-driven UASs, the combination of engine noise and propeller noise tends to be the dominant portion of the acoustic profile. Aerodynamic noise (*e.g.,* vortex shedding from landing gear and other protuberances) can also play a significant role in the aircraft noise signature. The acoustic profile of a vehicle is usually characterized by a sound hemisphere, shown generically in Figure 2. The sound hemispheres contain data about the sound pressure level of the noise source, or aircraft, at a discrete distance from the source.

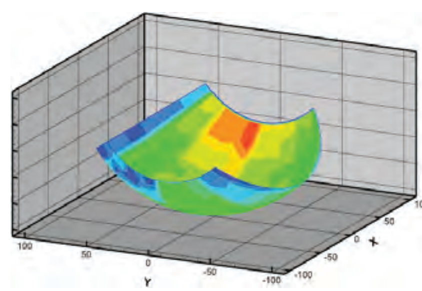

**Figure 2** Generic Sound Hemisphere

## ACOUSTIC DATA COLLECTION AND PROPAGATION

The only way to obtain the acoustic profile of a vehicle is to measure it in flight. Since the profile will vary with engine RPM, altitude, and velocity, flight profiles must be carefully planned. The typical method for measuring an acoustic profile is through the use of a microphone array. A pre-determined number of microphones are located at various locations to represent a series of listeners. The vehicle

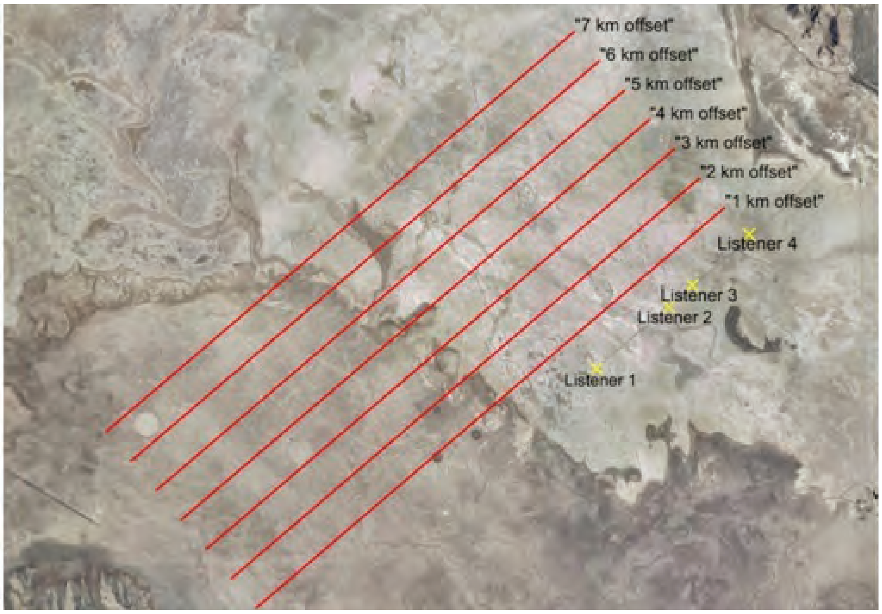


**Figure 3** Example Flight Path Variation

is then flown through multiple flight paths around the microphones and the acoustic data is collected (indicated in Figure 3). This data is then processed into a family of sound hemispheres for the known speeds and altitudes.

As previously noted, the sound hemispheres represent the acoustic pressure level at a fixed distance from the source. To estimate the sound at an arbitrary listener location, acoustic propagation techniques must be utilized. Codes, such as the National Aeronautics and Space Administration's Rotorcraft Noise Model and the Scanning Fast Field Program, are often used for propagation. [3,4] These codes use the sound hemispheres and knowledge about the atmospheric conditions to determine the acoustic pressure level at a listener location. The information generated by these codes can then be used for mission planning purposes.

## MISSION PLANNING FOR INCREASED SURVIVABILITY

One of the more useful techniques for UAS survivability is route planning. Using knowledge of the vehicle's acoustic profile, the terrain, and the atmospheric conditions, a specific mission can be tailored to avoid or minimize audible detection by a listener on the ground. Depending on the mission specifics, this can be performed in real time during flight or as a pre-planning exercise. Each method has its own advantages and disadvantages.

The major advantage of the real-time mode is that the air vehicle operator (AVO) has all of the information needed to alter the flight plan as updated threat information becomes available. The major drawback to the real-time mode is the computational requirements for the ground control station computers. This limitation can be resolved in the short term by reducing the number of ground listener locations that are calculated. In the long term, the computational capabilities of our ground control stations are anticipated to increase to a point where the sound propagation computational requirements are less significant. Additional human factor studies are also needed to ensure that the display of the probability of detection data does not distract the AVO from the primary flight control mission.

The ability to pre-plan a mission removes the problem of computational power. More data points can be added to the analysis, allowing a high fidelity acoustic footprint to be developed for route planning purposes. While providing better understanding of a larger acoustic footprint, the computational requirements dictate that this mode is performed prior to a mission. Many tactical UAS missions are not pre-planned; therefore, this ability would not necessarily benefit those profiles.

## SUSCEPTIBILITY REDUCTION

The topics of this article focus on characterizing the acoustics of a vehicle for increased situational awareness and survivability; however, to truly increase survivability, aero-acoustic analysis should be conducted during the vehicle design phase. Aero-acoustic analysis will result in UAS platforms that are designed for a low acoustic footprint while maintaining aerodynamic performance of the vehicle.

Improvements, such as retractable landing gear and aerodynamic fairings, to minimize separation are ways to reduce the acoustic noise and improve the aerodynamic efficiency of the vehicle. Propeller optimization studies should be conducted that address propeller design, location, and number of blades to improve performance and reduce acoustic footprint.

Aircraft survivability for UAS is an emerging field. By applying the techniques learned from manned aircraft and making survivability a critical system component, the effectiveness of UAS missions can be greatly enhanced. Projects supported by the Joint Aircraft Survivability Program Office have taken important steps to the characterization

*continued on page 28*

# EXCELLENCE IN SURVIVABILITY
# RONALD TUCKER

by Bud Holloway

The Joint Aircraft Survivability Program (JASP) is pleased to recognize Ronald Tucker for his Excellence in Survivability. Ron is the integrated product team (IPT) lead for the AN/AAR-47 Ultra-Violet Missile Warning System (MWS) in the Program Executive Officer Tactical Aircraft, Advanced Tactical Aircraft Protection Systems (ATAPS) Program Office (PMA-272) out of Patuxent River, MD. Ron is responsible for providing total life cycle management for the services' premier missile warning system that is installed on over 3,100 aircraft platforms in the US Navy, Marine Corps, Army, Air Force, Coalition Forces, Allies, State Department, and more. Ron received a commission in the US Navy and a BS in political science from The Citadel, The Military College of South Carolina, in 1992. He completed an MS in international management from Troy University in Troy, AL in 2004.

Ron retired from the US Navy in 2003 after 20 years of faithful service, where he started as a deck seaman and signalman. He worked his way up through the ranks to Chief Petty Officer, obtaining his commission on completion of his BA degree. Ron joined the US Navy's Military Sealift Command as a program manager, overseeing a ship's protection and security program that included the installation of infrared (IR) cameras. In 2006, he was hired by System Planning Corporation (SPC) of Lexington Park, MD, providing management and analysis services on a classified program of national importance.

Since 2007, Ron has been working in the US Navy's ATAPS Program Office, providing management, technical, and analytic expertise to the development and procurement of advanced aircraft survivability equipment for US Navy and Marine Corps tactical, assault, and assault support aircraft. He is listed as a susceptibility reduction subject matter expert in the JASP Specialist Directory.

Ron was an integral member of the PMA-272 ATAPS Science and Technology (S&T) team, providing technical guidance on cutting-edge technologies targeted for transitions to programs of record that provide countermeasures and susceptibility reduction for US Navy and Marine Corps aircraft. As the Assault S&T lead, Ron ensured that technology projects had direct linkage to programs of record to reduce risk for technology insertion to pace the threat.

Ron successfully concluded the $18M Joint Capabilities Technology Development in 2010 for the multi-function threat detection short-wave IR sensor for missile warning and hostile fire detection. While the US Navy did not transition this technology, it was enthusiastically transferred to the US Army Technology Advanced Program Office for integration into the enhanced AN/AVR-2.

Ron oversaw a portfolio of small business innovative research (SBIR) and small business technology transfer (STTR) programs that exceeded $7M in aggregate, including six SBIR Phase I efforts and six SBIR and STTR Phase II and Phase II.5 programs. He was responsible for recommending, selecting, and evaluating topics for SBIRs as well as overseeing and managing their successful execution and transition. Some of his more successful projects are the zinc-oxide nano-wires for high probability of UV detection and low false alarm rate; tellurite fiber for super-continuum lasers; and linear pulse amplifier for ultra-short pulse lasers.

Ron broke the code on the new Congressionally-appropriated funds for rapid innovative funding (RIF), proposing a new laser warning avalanche photo diode technology in FY11 that greatly improves the sensitivity and false alarm rate over the currently deployed high angular resolution laser irradiance dector-based laser warners. This $2.5M project was the first RIF contract to be awarded under this new program by any service. Again in 2012, Ron was able to get another project through the RIF selection process—high-dynamic range, two-color, IR scene projector—that tests the Navy's new two-color, IR missile warning sensor—the AN/AAR-59 Joint and Allied Threat Awareness System.

In 2011, coalition forces in Afghanistan experienced losses to rocket-propelled grenades (RPGs). At the request of Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Ron coordinated efforts to query industry on state-of-the-art technology to propose possible quick reaction capabilities to counter this threat. Based on his work, the US Army's Rapid Deployment Force initiated the FY12 Helicopter Active Protection System with a requirement of using onboard sensors for cueing, and the AN/ALE-47 Countermeasures Dispenser for the launcher of a kinetic-kill vehicle that intercepts ballistic threats. The US Navy picked up the requirement through a similar effort for a FY14 Future Navy Capability STRIKE Enabling Capability to develop the Rotorcraft Advanced Protection from IR/EO/RPG. Both of these efforts continue to seek a solution to this current threat.

Since 2012, Ron has been the ATAPS IPT lead for the readiness and sustainment of the AN/AAR-47 Ultra-Violet MWS. The AN/AAR-47B(V)2 is currently the only MWS deployed with an integrated hostile fire indication capability. His team was recently awarded $48M in FY12 funding to the original equipment manufacturer for production units of the AAR-47 MWS to protect helicopters and fixed-wing aircraft from surface-to-air threats. The AAR-47 is accredited with multiple aircraft and aircrew saves in Afghanistan, including the reported sighting by a US Marine Corps AH-1W SUPERCOBRA in November 2012 of a man-portable air defense system that failed to guide after being detected by the AAR-47, and was decoyed by onboard flares automatically ejected by the AN/ALE-47 Countermeasures Dispenser.

Ron has received a number of awards and letters of appreciation, including the Under Secretary of Defense letter in 2009 for his work on the Study of Rotorcraft Survivability Team; the Secretary of the Navy Civilian Meritorious Service Award in 2006 for his efforts at the Military Sealift Command for Force Protection; the Navy Commendation Medal in 2003; and the Navy Achievement Medal in 1997.

When asked what motivates him, Ron says, "My daughter [Megan] wears Army Green, and she is my personal hero." Megan, a US Army 1st Lieutenant, currently flies the OH-58 KIOWA WARRIOR with the 4th Air Cavalry Reconnaissance Squadron of the 16th Combat Aviation Brigade, stationed at Joint Base Lewis-McChord, WA. She deploys next year, and he wants to ensure that she and her fellow aviators have the best aircraft survivability equipment possible so they will return safely to their families.

Ron lives in Mechanicsville, MD with his wife, Jane, as empty-nesters with their seven cats and labrador retriever on the banks of the Potomac River. Between them, they have five daughters, one son, and a beautiful 1-year-old granddaughter. His hobbies include Ultimate Frisbee, fishing on the river, bird watching (eagles and ospreys), and riding his Harley with Jane on Skyline Drive in the Shenandoah National Park on warm summer days.

It is with great pleasure that JASP honors Ron Tucker for his Excellence in Survivability contributions to JASP, the survivability discipline, and the soldier.

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# THE cASE FOR MEETING THE CHALLENGES OF INTEGRATING AIRCRAFT SURVIVABILITY

by Rick Makowski

The dynamics of the threat environment coupled with acquisition challenges requires a different way to conduct business and provides our soldiers with the best-integrated and affordable protection while in the air. Because of this, the Project Management Office (PMO) Aircraft Survivability Equipment (ASE), under Program Executive Office (PEO) Intelligence, Electronic Warfare, and Sensors (IEW&S) is in the process of researching the benefits of a consortium to improve the performance of aircraft survivability systems to the soldier. The consortium research effort is spearheaded by the University of Alabama at Huntsville (UAHuntsville) Rotorcraft Systems Engineering and Simulation Center (RSESC). A Consortium for Aircraft Survivability Environment (cASE) will provide a collaborative environment to bring government, industry, and academic stakeholders together. The goal of the consortium is to understand needs, share a common vision, and advance the future of aircraft survivability.

## EVOLUTION OF AS TO DATE

A PMO ASE briefing to members of the 8th Air Force Historical Society highlighted how far the mission of ASE has progressed over the years. The society is comprised of a spirited group of World War II aviators. These aviators were amazed at how sensors (beyond their M1A1 eyeballs) are now able to detect and warn pilots of impending danger and then actually counter a threat automatically. This capability is much better than their primary method of ASE was back then—which was just a prayer.

The need for ASE was born in Vietnam. Helicopter operations became the new combat multiplier on the battlefield. As this multiplier became more effective, so did the threat and each was dealt with over the years in a standard programmatic and engineering process of "we have a problem, and here is a fix." The result today is a suite of separate systems that are often unique for each threat type, aircraft type, and in some cases, platform. The integration of the outputs of these systems in terms of alerts and warnings is, for the most part, currently performed in the pilot's head. The warnings are also highly dependent on the pilot's interpretation of the multiple inputs and success that is dependent upon his/her reaction to the different threats which, over time, are constantly changing.

The acquisition process supports this evolution very well, but maybe too well, creating a unique product and life cycle for each individual system. The term "integration" typically meant the integration of ASE hardware onto the aircraft that encompassed physical installation, power, signal, display, and audio. The acquisition process was focused on each individual system rather than an integration of a holistic capability across systems. As these systems progressed in their life cycle, we encountered a diminished capability to make major technology improvements due to proprietary legacy investments.

## TODAY'S REALITIES AND CHALLENGES

After over two decades of missions in Iraq and Afghanistan, the dynamics of the threat against aviation assets increased significantly and became more complex. With our combat operations in those regions winding down, we find ourselves with a perfect opportunity to reflect and plan for the future. An objective assessment of where we are at with respect to our systems capabilities and how well we are meeting and prepared to meet the dynamic threat is warranted. Some of the realities include:

**Acquisition Approach—**The need to spend more money to improve the performances from lessons learned in recent combat is countered by the realities of the budget climate. We see decreasing limits on future budget authority, and the cycle times for replacing entire proprietary systems are long and unaffordable. Our unique stove pipe systems result in higher maintenance costs and higher total cost of ownership. With the shrinking budget, it becomes even more imperative that we need to spend what we do have even smarter.

**Integration—**The future need is well beyond interoperability upgrades and the interfacing of existing systems. To achieve the performance needed on today's and tomorrow's battlefield, newer ways of doing business (programmatics and engineering) must be considered to achieve a higher level of integration and closer coupling of current systems/technologies. Future systems must be designed to be factory integrated into the aircraft rather than strap on afterthoughts; components must be modular and easily removable and replaceable into likewise, modular installation kits. The complexities of the aircraft survivability mission are integrating across systems; a single prime contractor approach limits a modular design. What is needed is an open systems approach to bring the best sensors together with the most effective countermeasures, and also coordinate with a highly integrated aircraft survivability management and processing capability.

**SWaP—**Every system on an aircraft platform, including ASE, is a calculated trade on space, weight, and power (SWaP) with the trade space being armament, bullets, payload, range, and/or other capabilities. These capabilities might often be mission dependent, so flexibility of an ASE complement and information sharing among platforms for a more payload constrained aircraft is another dimension to be explored. Reducing the ASE footprint, while maintaining capability, is highly desired.

**Expanding Requirements—**Current systems conduct track management, processing, and presentation independently. Though this will certainly continue, we also need to determine how best to conduct track management and processing across the different sensor technologies. This tracking will improve performance presentation to the pilot through a higher level of sensor integration and processing management. Initiatives from as high as the Office of the Under Secretary of Defense (OUSD)—such as Common Operating Environment (COE), Modular Open Systems Approach (MOSA), and Future Airborne Capability Environment (FACE™) (software interface implementation standards)—drive changes to the platform and supporting system architectures. This change will enable a more efficient and economical architecture in which evolving and future systems must fit. The operational mission area and requirements of aircraft survivability, such as degraded operations, are also expanding beyond traditional ASE and must be part of the overall integration of platform sensors.

**Joint and International—**The aircraft survivability mission area includes the joint community and also extends overseas to our international partners. As the aviation and ASE community work towards synergies of system solutions and economies in the midst of decreasing defense budgets, leveraging solutions with our joint and international partners is imperative. The initial cASE outreach includes the joint community; however, it will take some time ensuring appropriate procedures are followed to include our international partners.

## WHY cASE?

A collaborative approach from a wider range of participants than currently involved is required to work the complexities that include ever-changing and more capable threats, high technology sensor and countermeasure systems, decision-making/processing capabilities, pilot/crew workload challenges, aircraft platform/systems improvements, and the acquisition/budget climate. Each of the current vendors has a lot to offer; however, working the problem and solution sets of tomorrow easily expands beyond current systems and activities.

The vision of cASE addresses a widespread set of challenges with an objective of improving aircraft survivability (depicted in Figure 1). cASE provides a forum for collaboration across the different government organizations, multiple industry partners with new and different capabilities to the expanding mission area, and academic talents

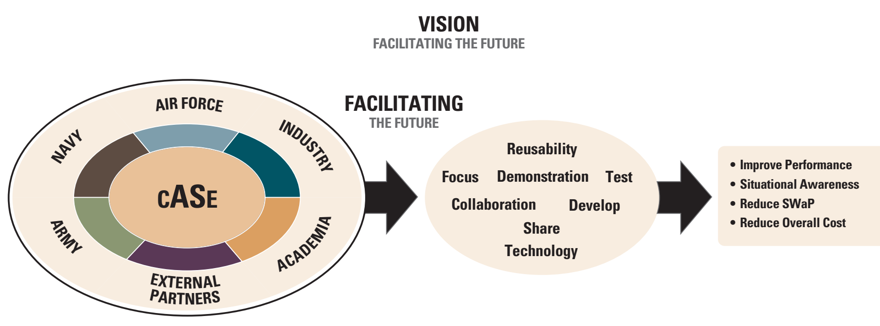


**Figure1** Facilitating the Future

needed to round out the team with technical and system-of-systems expertise. Greater government collaboration and cooperation *via* cASE between the user, platforms, ASE, aircraft survivability, respective labs, and aviation systems activities ensures a higher level of consistency and a focused soldier solution set. Government cooperation will also allow industry to better plan for and focus independent research and development efforts, and will help the government in its science and technology efforts. With strong direction from industry, both the ASE "veterans" (current prime contractors) and others with talents needed for the future, coupled with strong support from the academic base, the cASE team is postured in an environment to enable the cooperation and success to work toward efficient and economical solutions.

The objective of cASE is an architecture that is grounded in the near-term evolution of our existing systems, which will invoke new and evolving industry standards at component interfaces for future upgrades. These upgrades will allow for interchangeable components from multiple vendor sources, data sharing among multiple sensor driven applications, decision-making processing, optimal counter actions, commonality between all aircraft types, and shared network infrastructure (on and off platform) with growth.

**cASE will help facilitate the future of aircraft survivability.**

## cASE STATUS AS OF MAY 2013

After successful evaluation of the benefits of a consortium, UAHuntsville may launch cASE. The consortium is in the development stages with focus on organizing its infrastructure. The development includes researching and evaluating other consortiums, structure, and operations to determine the best mix for the mission of this effort. An industry focus group meeting or initial marketing survey of a representative set, of over 15 different companies, was conducted in conjunction with the Army Aviation Association of America ASE Symposium in November 2012 to introduce the idea, obtain feedback from a key group of future stakeholders, and determine if/how it should continue.

The meeting contained introductions by the project manager (PM) ASE and the deputy project manager ASE on each of the 2-day, 1-2 hour sessions provided a government perspective and why PMO ASE is interested in this approach. The bulk of the time each day was spent with UAHuntsville and industry discussing pros/cons, what makes sense, and critical items to work to make this consortium useful and successful. The result of this start by industry was guarded, but very positive, and they are actively working to help shape the consortium.

The next step was an introductory briefing tour to government organizations, and the approach was to brief each of the PMs, PEOs, and lab leadership levels separately to gauge support, before assembling a government focus group. It is critical the government be fully supportive of cASe, and reflect it in their actions if the industry is expected to provide proactive participation. The results so far are very encouraging; most of the government organizations were briefed by late March.

UAHuntsville prepared and produced drafts of the charter, operating procedures, and membership agreement and, in February, reached out for feedback from the industry, government, and academia so the stakeholders have an influence over how cASE is formed and conducted. A cASE website—*http://case.uah.edu*—*was* activated for a Membership Drive, which provides the foundation with information sharing.

## cASE GAME PLAN

Starting in January 2013 and as part of the evolution of the consortium, cASE organizers understood that the consortium should focus on the key challenges and achieving results, rather than being a social exercise. The team identified and is in the process of refining initial taskings for the cASE membership to consider. The intent is, at the kick-off, groups will meet to address and even start to define the problem space of these challenges, and then identify how to organize event teams to work the solution.

The official cASE Kick-off meeting is planned for the July – August 2013 time frame, and will be a multi-day event. After introductions and administration aspects of the consortium are completed, the cASE membership will immediately get to work. Some of the tasks that are expanding in definition in preparation for the kick-off include initiate architecture studies, standards development candidates and collaboration with the FACE™ Consortium, identify and organize technology demonstrations, identify key integration items, and define aircraft surviability for future vertical lift.

The intent is to start out with quarterly cASE meetings (or as travel budgets will allow), and to leverage members traveling for other events/activities to

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# JOINT MULTI-ROLE TECHNOLOGY DEMONSTRATOR (JMR-TD) MISSION SYSTEMS EFFECTIVENESS TRADES AND ANALYSES

by Timothy S. Rouse

Over the course of the past decade, Army aviation assets have experienced a considerable increase in operational tempo between three and four times of that expected during peacetime operations. [1] Many of these aircraft have been in service for a number of years and most of their core designs are outdated, making the effect of these increased stresses all the more detrimental. The most recently developed and fielded vertical lift aircraft, the AH-64 Apache, began production in 1982 [2], and the oldest design currently in the fleet, the CH-47 Chinook, entered service in 1962. [3] While this is not to say that the aircraft currently in the field are well represented by the original designs, extensive upgrades have been carried out to maintain a combat edge for the current battlefield.

Recent developments in technologies and the future direction of the combat role of these vertical lift aircraft suggest that a revolutionary, clean sheet design is appropriate; recent combat stresses on the current fleet would suggest that now is the time to carry out this process. In a budgetary environment where it is necessary to do more with less, and where the logistics of fuel and support has been demonstrated to be and is expected to remain extremely costly, this revolutionary leap has further become a necessity. The current designs are inherently unable to meet range, speed, and reliability goals, which would provide soldiers with a leap-ahead capability. Further justifying this need is the reality that developing survivability and lethality technologies cannot be properly utilized on these older architectures. The additional processing, electrical power, mount points, lifting capacities, sizing, *etc.* must all be incorporated into the baseline design. With the evolving demands of future theaters of operation and the systems development this drives, such gaps will only widen as time progresses.

This environment, along with the expected capabilities of novel aircraft design, allows for the development of an integrated aircraft survivability equipment package solution. Such a system creates a new paradigm of situational awareness and greatly expands the capability of the soldier to be successful and to survive. These are systems that are best included in baseline aircraft design and initial fielding.

Not only is the physical mounting of an item a concern, but the processing power and display technologies required to bring pertinent information to the attention of the soldier is required. As many aspects of this concept are relatively novel in Army aviation, early incorporation into the ground-up design is necessary. To incorporate these technologies, the effects of these technological and environmental variables along with their interactions must first be understood. Only after having an understanding of what is possible and grasping the ideals of trade space determinations, requirements can be identified in developing this next generation of vertical lift air vehicle.

## JMR-TD

The JMR-TD is an effort to gain an understanding of what is possible and what is necessary for the future combat roles of vertical lift aircraft. The JMR-TD is also a means to estimate and analyze the cost and effectiveness of various technologies, and is being undertaken with the purpose of posturing the projected program of record, future vertical lift (FVL), for success. The US Army Aviation and Missile Research Development Engineering Command (AMRDEC) is leading the JMR-TD program, along with the participation of numerous government organizations as well as the industry. The JMR-TD program is comprised of two major efforts:

- **Phase 1—**Build of technology demonstrator aircraft
- **Phase 2—**Mission systems demonstration

Of these efforts, the Mission Systems Effectiveness and Trades Analysis (MS-ETA)—carried out in support of and in preparation for Phase 2—is especially pertinent to aircraft survivability. Figure 1 displays the schedules and inter-relationships of the MS-ETA effort along with the Phase 2 effort.

The following sections of this article will detail the following two contracts that have been awarded that pertain specifically to the survivability side of mission systems:

- Survivability Analysis to Sikorsky Aircraft Corporation
- Lethality Effectiveness and Affordability Decision Aid (LEADA) / Survivability Effectiveness and Affordability Decision Aid (SEADA) Toolset Development to SURVICE Engineering

## SURVIVABILITY ANALYSIS – SIKORSKY AIRCRAFT CORPORATION

The Sikorsky Aircraft Corporation is commencing the Survivability Analysis contract *via* a technology investment agreement, which represents an agreement where the government and the contractor are invested in the outcome. A final report will document a series of trade studies carried out to introduce and analyze future technologies in aircraft survivability. The Sikorsky Aircraft Corporation will consider eight distinct survivability-based areas of interest:

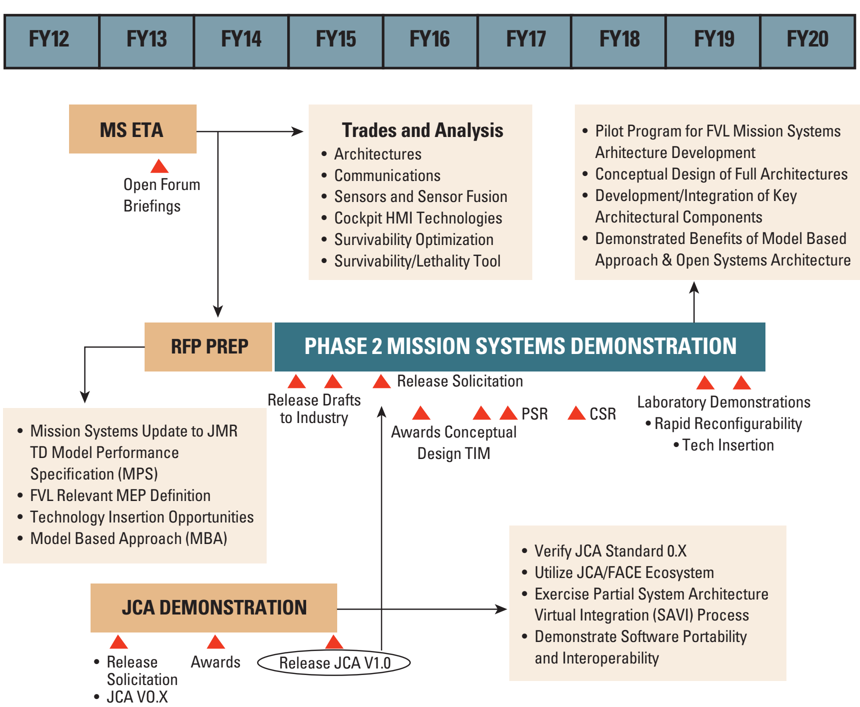


**Figure 1** MS-ETA Effort [4]

1. Infrared
2. Hostile fire
3. Radio frequency
4. Acoustics
5. Laser warning and dazzle
6. Future threat determination
7. Route optimization
8. Passive signature reduction

Within each of these areas of interest, the Sikorsky Aircraft Corporation will consider an aircraft with a clean baseline, current technologies incorporated, near future technologies, and finally, more radical, less mature technology solutions. Within each area of interest, the Sikorsky Aircraft Corporation will investigate the effectiveness of the identified technologies and will determine the cost, technological readiness, and the level of effort required to transition these capabilities. They will then combine and conduct these studies and trades to determine the optimal combinations of technology for compilation in the delivered report. The goal of the report will be to specify a configuration for combat overmatch through an integrated solution.

## LEADA/SEADA TOOLSET DEVELOPMENT – SURVICE ENGINEERING

The SURVICE contract has been awarded for the development of a simulation toolset, with one focusing on survivability and one on lethality. This toolset is to harness the capabilities of the US Army's version of the Advanced Tactical Combat Model (ATCOM) mission-level simulation program in an easy-to-use graphical user interface (GUI). A Boeing code, the Army's version of ATCOM is configuration-controlled and run certified by the US Army Materiel Systems Analysis Activity, and is exercised by the Air Maneuver Battle Lab. The Boeing code must go through a thorough verification and validation process prior to a particular set of runs, and must be executed by personnel deemed to be experts in its use. Much of the information needed for ATCOM must be in tabular form, and is often processed with a probabilistic approach. These tabulated values are typically generated by the various Department of Defense organizations that hold expertise in a particular field; while this process allows for important, overarching simulations to be run, a good deal of expertise is required in preparation, reduction, and analysis of results. As such, the expense associated with ATCOM's use hampers the potential for small-scale evaluations of specific systems and configurations.

The goal of this SURVICE contract is to build a GUI program whose delivery will allow the Aviation Design Directorate (ADD), among others, the ability to conduct in-house trades using the ATCOM. This capacity allows for quick analyses into the effectiveness of emerging technologies, creating an environment where more valuable and accurate funding decisions may be made.

More specifically, SURVICE Engineering will deliver to the government, with unlimited rights, software that allows for two distinct capabilities. These capabilities are represented by the two toolsets: SEADA and LEADA. These toolsets will rely on a library of technologies and scenarios, which will be GUI selectable, and shall be delivered in such a way that manipulation of and additions to these libraries can be readily made.

Such libraries will be developed alongside the government during the course of this effort, and will involve a large amount of cooperation between several organizations. The programming itself will operate along a path where after a user has selected the aircraft's configuration—as made available from these libraries—a model is automatically generated and entered into the ATCOM program. ATCOM will then be command run across multiple missions, as they exist in additional libraries, and the results tracked. The post processors of this GUI-based program will then organize and present a multitude of output parameters for comparison among configurations. This data will be further entered into financial algorithms, again pulling from developed library data, to assign a cost to each configuration.

This programming will provide government users an in-house ability to determine preferred mission systems packages by allowing for the trade of technologies as a process of determining the optimal combination for a specific mission set. With this approach, interdependent relationships between seemingly unrelated capabilities will be combined and the value of emerging technologies may be seen. This toolset development by SURVICE Engineering introduces a much simpler and readily available method of analyzing these interdependencies and determining a configuration that represents the best value added system of systems.

## OBSERVATIONS

An emphasis must be placed on integrated survivability and a total systems package in these programs and in the future of Army aviation. Many categories of survivability overlap, and many of the interactions of relevant technologies have a major effect on combined total performance. Survivability, in particular, has become an area of concern where the sum of the parts is much greater than individual technology, making a system-of-systems mindset a necessity.

The current approach to analyzing newer technological systems involves modeling of the system itself and inputs into simulations of one-on-one or few-on-few simulated engagements. Expanding this approach to evaluate interdependency of systems represents an important path ahead, especially considering the reduced budgetary environment and heightened demands of the battlefield. This approach, as well as recent technological advancements, allows an integrated aircraft survivability solution. As an example, the development of low level flight capabilities reduces the ability of aggressor radar detection, which increases the effectiveness rate of short range radar warning systems in overall mission success.

In considering these and similar effects, the Army may obtain better performing systems at a reduced cost as compared to the traditional approach. The efforts within the MS-ETA represent important first steps under which the government will gain an understanding of what is possible, what is available, and what is being developed. These efforts further help in developing a process of evaluating a system-of-systems, an integrated approach to aircraft survivability.

## CONCLUSION

In carrying out the two awarded contracts, the Army will be further prepared for the FVL program of record, and will begin to evolve the method of outfitting aircraft mission systems for survivability. This work will shed light on future technologies that need to be accounted for, and will further develop an understanding of the capabilities these bring. The future technologies will allow for the identification of the most tactical and cost-effective integrated aircraft survivability equipment packages, helping the government to develop a best value funding profile and technology emphasis to pursue.

The outcomes of the FVL program will eventually drive the evolution of two prime areas of interest: tactics, techniques, and procedures (TTPs) and modeling and simulation (M&S). TTP updates and training must take place so that the capabilities of these developed configurations may be used to their fullest. This process, however, must be preceded by a deeper understanding of these capabilities and how they will play out in a tactical environment. This understanding is most economically gained from M&S. The future of military vertical lift will, however, utilize many technologies that were not fully developed during previous iterations of M&S. The flight envelope of these future vehicles also exceeds what has been previously fielded and modeled. The new aircraft design must drive an evolution in M&S, not only to ensure discovering the full potential of the vehicle, but to be utilized in the design itself and in the determination of requirements.

The MS-ETA efforts represent an important first step in the success and of development into many areas. These efforts represent the initial step in an exciting program that will greatly improve the capability of the Army's vertical lift components. In creating more capable vehicles, which themselves drive newer methods of employment, the effectiveness and survivability of the soldier may be expanded and the capabilities of the Army furthered. ASJ


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## ACOUSTIC SITUATIONAL AWARENESS FOR SURVIVABILITY

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of UAS acoustic profiles and mission planning (JASP-S-10-02-003). Future efforts will further these improvements.

*This information product has been reviewed and approved for public release. The views expressed herein are those of the author and do not reflect the official policy or position of the Department of the Army, Department of Defense, or the US Government. Reference herein to any specific commercial, private or public products, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement, recommendation, or favoring by the United States Government.* ASJ


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# NATIONAL DEFENSE INDUSTRIAL ASSOCIATION'S (NDIA) COMBAT SURVIVABILITY DIVISION (CSD) ANNUAL SYMPOSIUM & AWARDS CEREMONY 2012

by Dr. Mike Mikel and Walt Whitesides

NDIA's CSD held its annual Aircraft Survivability Symposium at the Naval Postgraduate School on 23 – 26 October 2012. The symposium started with a day of tutorials on aircraft survivability. The morning session is commonly referred to as the Undergraduate-level course with the afternoon session considered the Graduate-level course in survivability. This year's sessions were "Aircraft Survivability – Susceptibility and Vulnerability Reduction in a Modern Combat Aircraft" taught by Mike Markway and Mark W. Stewart, and "Infrared Radiation Countermeasures – An Afternoon of Confusion, Distraction and Seduction" taught by Charles Carstensen and Dennis Clark.

The Aircraft Survivability 2012 theme was "Designing for Survivability throughout the Life of the Aircraft." As the theme implied, the agenda was divided into six sessions designed to foster the technical exchange of information on current and emerging threats, and the aircraft technologies being developed and tested for mitigating, eliminating, and surviving these threats. The keynote speakers were Richard Sayre, Deputy Director, Operational Test and Evaluation, Live Fire Test and Evaluation; and Thomas J. Hartmann, Senior Vice President, United States Government Customer Business, Rolls-Royce, Defense Sector. The six general sessions covered analysis of current and future threats; aircraft survivability in the low-, mid-, and high-altitude battlespace; challenges in implementing battle damage repair and chemical, biological, radiological, and nuclear survivability; emerging vulnerability and susceptibility reduction techniques; warfighter perspectives; and development of improved countermeasures.

The NDIA CSD Awards are presented annually at the Aircraft Survivability Symposium. These awards are intended to recognize individuals or teams who demonstrate superior performance across the entire spectrum of survivability, including susceptibility reduction, vulnerability reduction, and related modeling and simulation.

The Admiral Robert H. Gormley Leadership Award—named in honor of the CSD's founder and Chairman-Emeritus—was presented to David E. Hamilton. The NDIA Combat Survivability Award for Technical Achievement was presented to Ken Foulke. The presentations were made immediately before the Thursday Symposium luncheon by Jack Rau, CSD Awards Committee Chairman, and Brigadier General Stephen D. Mundt, US Army (Ret), CSD Chairman. Rear Admiral Robert H. Gormley, US Navy (Ret), joined the presentation party for the Admiral Robert H. Gormley Leadership Award presentation.

## ADMIRAL ROBERT H. GORMLEY LEADERSHIP AWARD

The Admiral Robert H. Gormley Leadership Award is presented annually to a person who has made major contributions to enhancing combat

**Figure 1** David Hamilton Accepting the Admiral Robert H. Gormley Leadership Award

survivability through demonstrated outstanding leadership in enhancing the overall discipline of combat survivability, or played a significant role in a major aspect of survivability design, program management, research and development, modeling and simulation, test and evaluation, education, or the development of standards. The emphasis of this award is demonstrating superior leadership of a continuing nature.

The 2012 Admiral Robert H. Gormley Leadership Award was presented to Mr. Hamilton for exceptional leadership in the field of aircraft combat survivability. Mr. Hamilton was recognized for a range of contributions that increased the survivability of USAF weapon systems, leading to dramatically superior combat capability. He played a key leadership role in the development of low observable aircraft, unmanned aerial vehicles, and advanced weapons. During military assignments at the Air Force Flight Test Center, Air Combat Command, Directorate of Special Programs, and the USAF Rapid Capabilities Office (RCO), he provided technical guidance, acquisition oversight, program initiation, and leadership in fielding numerous successful systems, such as the F-117, B-2, and multiple other classified programs. Mr. Hamilton's breadth of experience in modern aircraft survivability is unmatched in scope, technical fidelity, and resulting military utility. He has promoted the synergy of low signature and electronic warfare, reaching the proper balance of cost and robustness for multiple applications. In his role as Director of the RCO, he has shown the USAF that acquisition can be done better and faster. The military capabilities developed under Mr. Hamilton's leadership ensure that this nation will prevail in future combat with minimum loses.

## COMBAT SURVIVABILITY AWARD FOR TECHNICAL ACHIEVEMENT

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

The 2012 Combat Survivability Award for Technical Achievement was presented to Mr. Foulke, recognizing his exceptional technical achievement in the field of aircraft combat survivability. During his more than 50-year career, he has contributed to many advanced weapon and aircraft programs, working in the development, testing, and implementation of combat survivability technology. His particular area of expertise is the development of stealth technologies to defeat and degrade enemy radar systems. Mr. Foulke began working air combat survivability in 1962 when he joined the Naval Air Development Center as an engineer, and continued with support for numerous current and developmental survivability programs and technologies, with a focus on radio frequency (RF) low observable susceptibility reduction technologies. During his career, Mr. Foulke has been an integral part in, and led, teams that have determined achievable signature reduction levels on a number of aircraft, including the F/A-18, F-14, P-3,

**Figure 2** Ken Foulke Accepting NDIA Combat Survivability Award for Technical Achievement

V-22, F-117, and the B-2. Additionally, he has worked on numerous classified programs that incorporated low observables technologies. Mr. Foulke is currently a senior engineer for Engility Corporation, where he continues to work with the Naval Air Systems Command CSD in a crucial role of product development and verification for the Navy. In this role, he has been active in Naval Aircraft systems technologies, including the development and integration of the APG-79 Active Electronic Scanned Array Radar, continued radar cross section verification of post-production and fleet aircraft, oversight of numerous survivability programs, and the implementation of new technologies. Mr. Foulke's work has greatly contributed to improved survivability characteristics of the soldiers' air combat vehicles.

## BEST POSTER PAPER AWARDS

Three awards were also presented for the best poster papers displayed as part of the symposium's Exhibits and Poster Papers feature. First place went to Richard Pokrass from Sensor Concepts Inc. for his paper on "Portable High Speed Measurements of RF Signature Reduction Technologies." Second place went to Robert Bocchieri from Applied Research Associates for his paper on "Composite Damage in Minor Aircraft Fires." Third place went to Jennifer Lalli from NanoSonic, Inc. for her paper on "Multifunctional Lightweight Materials."

## AIRCRAFT SURVIVABILITY 2013

Preparations are now underway for Aircraft Survivability 2013, scheduled for early November 2013. Watch for the 2013 Call for Presentations and 2013 CSD Survivability Award Nominations.

If you are in the survivability business, the Naval Post Graduate School is the place to be in the fall!

Special thanks are given to the numerous volunteers from the NDIA CSD Board for their dedication, tireless efforts, and professionalism that goes into making this event such a huge success. The co-chairs for this year's symposium were Dr. Mark Couch and Andrew Smith. As the tutorials continue to be one of the highlights of the session, thanks are given to the superior instructors and the quality of the content with special thanks to Gary Wollenwebber. Ron Dexter once again showed his professionalism and tenaciousness in pulling together the display of poster papers and the awards. The CSD could not do this on its own, and relies heavily on the professional staff of the NDIA, which is led by Christy Mason and Laura Yuska; the CSD is grateful for their unwavering support and dedication to our efforts. ASJ

# THE CASE FOR MEETING THE CHALLENGES OF INTEGRATING AIRCRAFT SURVIVABILITY

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schedule cASe meetings. Video teleconferencing and teleconferencing will be available to connect members who are not able to travel. As event teams are formed per the cASe Operating Procedures, they will organize, plan for, and set their own schedule, and then report their status to the membership and board at scheduled cASe meetings.

## CONCLUSION

cASe will provide a collaborative environment for the government, industry, and academic stakeholders working together towards a common vision. Please visit the website to get more information on activities and events, and join cASe to be part of the solution for the future of aircraft survivability. ASJ

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# CALENDAR OF EVENTS

## JUL

**5th Annual Military Vehicles Exhibition & Conference**
31 July–1 August 2013
Detroit, MI
*http://www.bahdayton.com/JCAT*

## AUG

**2013 Warheads & Ballistics Classified Symposium**
5–8 August 2013
Monterey, CA
*http://www.ndia.org/meetings/3480/Pages/default.aspx*

**AIAA Aviation 2013**
12–14 August 2013
Los Angeles, CA

**Directed Energy Systems Symposium**
26–30 August 2013
Monterey, CA
*http://www.deps.org/DEPSpages/DESystemsSymp13.html*

## SEP

**AIAA Space 2013 Conference & Exposition**
10–12 September 2013
San Diego, CA

**AFA Annual Air & Space Conference and Technology Exposition 2013**
16–18 September 2013
National Harbor, MD
*http://www.afa.org/events/conference/2013/*

**2013 Biometric Consortium Conference and Technology Expo**
17–19 September 2013
Tampa, FL
*http://events.jspargo.com/biometrics13/public/MainHall.aspx?ID=40656&sortMenu=101000*

**JASP Joint Program Review**
24–26 September 2013
TBD
*http://jaspo.csd.disa.mil/calendar.html*

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

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