AIRCRAFT SURVIVABILITY

Published by the Joint Aircraft Survivability Program Office

Spring 2003

Susceptibility Reduction

JAS
JOINT AIRCRAFT SURVIVABILITY

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**
4. TITLE AND SUBTITLE **Aircraft Survivability: Susceptibility Reduction, Spring 2003**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **JAS Program Office,200 12th Street South,Crystal Gateway #4, Suite 1103,Arlington,VA,22202**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**48**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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

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Director's Notes

CDR Andrew (Andy) Cibula

Welcome back to another issue of *Aircraft Survivability*. Quite a bit has happened since the last issue was printed, so I have a lot to talk about. Not to waste any time, let's get started.

Here's the big news. The Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) merged with several other organizations within the aircraft survivability community to form the Joint Aircraft Survivability Program Office (JASPO). What did this cost us? Absolutely nothing. What did we gain by this? The most well balanced organization within the Department of Defense focused solely on the advancement of the aircraft survivability discipline. Whereas the JTCG/AS was focused mostly on research and development of advanced technologies and methodologies, the JASPO now has the mission of live fire test and evaluation under the Joint Live Fire Program for Aircraft Systems (JLF–Air); combat damage assessment and reporting under the Joint Service Air Defense Lethality Team (JSADLT); and support of the verification, validation, and accreditation of models and simulations used in acquisition programs across the Services through the Joint Accreditation and Support Activity (JASA). But before we get into all the details of the JASPO, I would like to spend a little time talking about some of the articles in this issue.

This issue of *Aircraft Survivability* is about susceptibility reduction features currently being assessed by the aircraft survivability community. I have intentionally avoided this subject in the past because susceptibility still baffles me. You see, I was a civil engineer as an undergraduate and an aeronautical engineer in graduate school. I avoided anything electrical because it scared me. I received a shock as a little boy and from that point on, I knew electricity was not for me. Unfortunately, most things relating to susceptibility reduction have something to do with electricity, so now I have to face my fears! This is not to say that susceptibility reduction is not important. Quite the opposite is true. In this era of aircraft survivability development, hit avoidance is the preferred approach to making survivable aircraft. So, I'll leave it to you to read the articles on the Joint Surrogate Seeker, Directed Infrared (IR) Countermeasures, and Radio Frequency countermeasures. I'll just talk about some of those things I can understand.

Aerogels have been a buzzword in the area of IR signature reduction lately. That is because we have seen some dramatic and promising results when using aerogels as a thermal blanket on aircraft. The development of a usable aerogel blanket was probably a little more difficult than anticipated, but the results were worth the wait. The article on aerogels (page 38) describes the successful JASPO program that was funded with the Army to produce a product that will go into production aircraft in the next few years.

Another article that is sure to stir things up is Paul Caffera's on the MANPADS threat to commercial aircraft. Officially, Mr. Caffera's views do not reflect the views of the JASPO or the Government. But he does provide some interesting insight into the world of commercial aviation and their response to the MANPADS threat. Prior to publishing, we had several of our experts review it and we quickly received some very strong, and not necessarily agreeable, opinions about the article. That is because the aircraft survivability community has known of the MANPADS threat for quite some time. Unfortunately, this issue is not new to us. The MANPADS threat is real and we are addressing it. By looking at MANPADS attacks on military aircraft during Desert Storm, we have proven that we can defeat this threat. While not all aircraft survived hits, many did. DoD has come to the understanding that we can defeat the MANPADS threat. Through a combination of vulnerability and susceptibility reduction efforts and tactics, techniques, and procedures, military aircraft are starting to reclaim the low and mid-altitude battlespace that many thought we had lost.

Today, the JASPO is funding no less than 15 projects that could be applied to reducing the threat of MANPADS to either commercial or military aircraft. There are also numerous organizations within Government and industry that are dedicated to defeating this threat. However, I must confess that reducing the MANPADS threat to commercial aircraft is a different problem than the one our Military faces. There are political considerations and public opinion that weigh heavily on the types of methods that can be used to deal with the threat. It must be known that we are actively working the problem and are applying knowledge gained from the DoD to commercial aircraft. We have come a long way toward defeating this threat and I am confident that we will continue to make all our aircraft safe and survivable against it.

Now I would like to talk a little more about the new Joint Aircraft Survivability Program organization. About nine months ago, Mr. Larry Miller, Director for Live Fire Test and Evaluation, held an off-site with most of the investment programs within Director, Operational Test and Evaluation (DOT&E). His intention was to have all organizations brief each other on missions and on-going efforts to identify areas of overlap and common interests. The results were surprising. We found that many of us had common interests we weren't previously aware of and that significant leveraging opportunities existed. As a result, the JTCG/AS identified several other groups with which they were already affiliated, and created a proposal to integrate all efforts under one common name—the Joint Aircraft Survivability Program (JASP). By doing so, we realized the immediate benefits of consolidating meetings, travel, and administrative expenses. But the real payoff will be in consolidating research, development, test, and analysis efforts across the entire aircraft survivability spectrum. This includes vulnerability and susceptibility reduction development efforts, coordination in modeling and simulation (M&S) development, Verification, Validation, and Accreditation (VV&A) and model manager support, live fire test and evaluation capabilities, and joint battle damage assessment efforts that are done nowhere else in the DoD. We convincingly have the most comprehensive aircraft survivability program dedicated to increasing the value of aircraft survivability products delivered to the acquisition community and providing a customer-based organization responding to the needs of the warfighter.

So who is in this new organization? The organization is an integration of associated activities with the purpose of providing full spectrum aircraft survivability support to the Service acquisition program and industry partners. So how did we create the JASP? First, the JASP structure is based on the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS). However, different from the other organizations in the JASP, the JTCG/AS' name and function is replaced in both by the Joint Aircraft Survivability Program. The mission of the JASPO has not changed dramatically but several roles were added to the charter. The purpose and missions of the JASPO are—

Purpose

a. Coordinate the inter-service exchange of information on individual Service aircraft survivability programs to increase the survivability of aeronautical systems in a nonnuclear threat environment.

b. Implement efforts to complement the Service acquisition and survivability programs.

c. Maintain close liaison with Service staffs to ensure that aircraft survivability research and development data, analytical methodologies, and systems criteria are made available to the developers of new aircraft and supporters of aircraft systems.

d. Conduct Joint Live Fire tests on assets not covered by the Live Fire Test law to identify system vulnerabilities and to test and verify survivability enhancements.

e. Provide support for verification, validation, and accreditation of models and simulations used in acquisition programs across the Services via JASA.

Mission

To achieve increased economy, readiness, and effectiveness through the use of joint development and testing of survivability (susceptibility and vulnerability reduction) technologies and survivability assessment methodologies—

a. Provide technical information and inputs for survivability improvements to cognizant managers of Service aircraft programs and systems.

b. Establish and maintain survivability as a design discipline.

c. Interface with research laboratories on research and development efforts contributing to the reduction of vulnerability and/or susceptibility for aeronautical systems in a threat environment.

d. Plan and propose critical technology development and methodology programs that capitalize on common requirements and potential solutions.

e. Interface as appropriate with other DOT&E investment programs as well as the intelligence community and other federal agencies with the goal of improving military and civilian aircraft survivability.

f. Collect, review, and analyze data on combat damage of aeronautical systems and disseminate this information to Service acquisition programs with recommendations on aircraft survivability upgrades.

g. Serve as the Joint Aeronautical Coordinating Group (JACG) focal point for aircraft survivability matters.

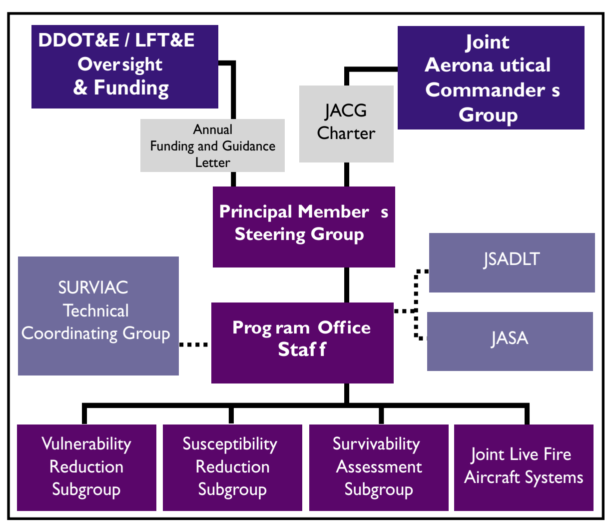

Figure 1. Joint Aircraft Survivability Program Office (JASPO) organization.

h. Conduct studies to assess enhanced survivability design features in a combat environment.

i. Plan, coordinate, and conduct joint service tests.

j. Serve along with Joint Technical Coordinating Group/Munitions Effectiveness (JTCG/ME) as executive agent for the Survivability/Vulnerability Information Analysis Center (SURVIAC).

k. Determine and implement methods of instruction to user commands to provide quantified survivability direction in Capstone Requirements Documents (CRDs), Operational Requirements Documents (ORDs), and Mission Need Statements (MNS).

l. Coordinate with the Live Fire Test and Evaluation (LFT&E) Office on supporting acquisition LFT&E programs.

The JTCG/AS was first chartered in 1971 by the Joint Logistics Commanders to coordinate tri-service aircraft survivability efforts. Funding was first provided for a three year Test & Evaluation for Aircraft Survivability (TEAS) program. The success of these efforts led to a permanent funding line for the JTCG/AS and ensured its survival over the years.

During the history of the JTCG/AS, the subgroups have been reorganized into the current arrangement of the three subgroups with their committees (see Figure 1). Four other committees or groups that were active for several years are the SURVIAC Steering Group, the Aircraft Battle Damage Assessment and Repair (ABDAR) Committee, the Joint Live Fire Test Program (Aircraft), and the Chemical, Biological, Radiological Defense (CBRD) Committee. In 1988, a technical advisory group with three additional civilian positions was added to the Central Office staff. Today the Principal Members Steering Group (PMSG) is still the executive committee that overseas the program from a senior level. The Program Office consists of the only full time staff charged with the responsibility of managing the day-to-day activities of the organization. This includes the distribution of funds, management of the projects funded, and coordinating activities between the member organizations of the JASPO. The subgroups include Vulnerability Reduction, Susceptibility Reduction, Survivability Assessment, and now include the JLF–Air program as well. There is one important difference between the JLF–Air program and the other subgroups. Only Mr. Larry Miller will approve JLF–Air projects. Otherwise, the project selection and funding processes are the same.

The PMSG and JASPO will not provide direct oversight to SURVIAC, JASA, and JSADLT, but will function more in an advisory and coordination role. The goal is to combine efforts of all organizations to reduce costs, increase the quality of products and provide better support to the Service acquisition programs and the warfighter.

The Joint Live Fire Program, Aircraft Systems (JLF–Air) was described in some detail in the last edition of the *Aircraft Survivability* newsletter (Fall 2002, page 18), but I would like to refresh your memory on who they are and what they do. The JLF–Air program was initiated by the Office of the Secretary of Defense (OSD) in March of 1984 as part of the overall Joint Live Fire Program to establish a formal process to test and evaluate fielded U.S. systems against realistic threats. Originally, the JLF–Air Program was chartered to assess the vulnerability of fielded U.S. armored vehicles and combat aircraft to threats likely to be encountered in combat and to evaluate the lethality of fielded U.S. munitions against realistic targets. The program continues today under the leadership of the Office of the Deputy Director, Operational Test and Evaluation/Live Fire Testing (DOT&E/LFT) (this office also oversees the congressionally mandated Live Fire Testing program of major defense acquisition systems). DOT&E/LFT provides test execution funding and provides technical and financial oversight.

At the inception of the JLF–Air program in 1984, the emphasis was on fielded air combat systems. Numerous aircraft have been tested and evaluated since the JLF–Air program began. Tested systems include much of the U.S. Army's helicopter fleet (AH–64, UH–60, AH–1S, CH–47); U.S. Air Force and U.S. Navy frontline aircraft (F–15, F–16, F–18, AV–8A/B, F–14, and C–130) and several former Soviet Union (FSU) attack helicopters and fighters (MI–24, MiG–21, and MiG–23). The four goals of the JLF–Air Program are—

a. Gather empirical data on the vulnerability of U.S. systems to foreign weapons and the lethality of U.S. weapons against foreign targets.

b. Provide insight into design changes necessary to reduce vulnerabilities and improve lethalities of U.S. weapon systems.

c. Enhance the database available for battle damage assessment and repair; and validate/calibrate current vulnerability and lethality methodologies.

d. Validate/calibrate current vulnerability and lethality methodologies.

The JLF–Air program often discovers small changes that have large impacts on survivability. For example, the following simple, low-cost items or measures have been implemented as a result of JLF–Air testing and evaluation—

- Lighter, more survivable, jam-resistant actuators for aircraft

- Shielding for system critical components
- Adding redundancy to mission critical components such as wiring harnesses and hydraulic systems
- Relocating detectors to improve warnings
- Modifying software to enhance operations and response
- Revising munitions and supply stowage to save lives
- Shock mounting soft components for durability
- Added fire suppression systems to reduce vulnerability to dry bay fires
- Replacement of jammable flight control system
- Opportunities for battle damage assessment and repair personnel to apply techniques to realistically damaged systems
- Simple, low-cost engineering design changes to horizontal stabilator attachment points
- Added features to reduce the chances that an impact on the fuel tank would lead to engine fuel ingestion
- JLF–Air test data is a significant enhancing factor in ballistic vulnerability assessments of aircraft systems and increases the efficiency and benefit of acquisition Live Fire Testing and Evaluation.

It would be difficult to catalog the number of design improvements that are on combat aircraft today that are a direct result of JLF–Air Testing. But it is safe to say that our aircraft are much more survivable because of the direct contributions of JLF–Air.

The Joint Accreditation Support Activity (JASA) is one group that we have not spent much time on in this publication, even though they provide an invaluable service to the aircraft survivability community. The goal of the JASA is to provide a continuing central resource supporting verification, validation, and accreditation (VV&A) of models and simulations (M&S) used in system acquisition programs across the Services. JASA provides unique M&S VV&A services to DoD acquisition programs, system developers, mission planners, the test and evaluation (T&E) community, and anyone desiring assistance with accreditation of M&S that are used to support their program objectives. These services include: assisting customers with the identification of M&S requirements and acceptance criteria for their particular applications; comparing these requirements and acceptance criteria to existing M&S characteristics, including VV&A information; maintaining an established, accepted, and documented VV&A process for application to customer M&S; developing M&S risk assessments and risk mitigation strategies based on analysis of M&S shortfalls with respect to customer requirements and acceptance criteria.

JASA leverages the M&S VV&A support infrastructure and technical expertise developed under the JTCG/AS funded Susceptibility Model Assessment and Range Test (SMART) project, conducted in FY92 – FY96. Under that project, a cost-effective VV&A process was developed for survivability M&S; that process was exercised for a set of survivability models resident in SURVIAC; and a number of major weapons systems acquisition programs were provided M&S VV&A support. These programs were the first customers of JASA, continuing the M&S accreditation support activities conducted for them under the SMART project. Tri-service personnel active under SMART became part of the resources available to JASA.

Since its inception in FY96, JASA has supported numerous programs and other activities with M&S accreditation support services, expanding beyond the survivability M&S domain. These customers have included the Joint Strike Fighter program, F/A–18E/F, AIM–9X, Rolling Airframe Missile, Evolved SeaSparrow Missile, Tomahawk, Missile Defense Agency, and a number of Joint Test and Evaluation (JT&E) programs. In addition to support for programs, JASA personnel have contributed to the development of VV&A procedures and standards for, among others, the Defense Model and Simulation Office (DMSO), the Navy's Operational Test and Evaluation Command (OPTEVFOR), the JT&E Program Office, and the International Test and Evaluation Steering Committee's Working Group of Experts on V&V.

The mission of JASA is to provide and maintain—

a. Technical expertise in the development of M&S VV&A requirements and acceptance criteria based on continuing analysis of customer applications.

b. Technical expertise in the planning, execution, and management of VV&A programs in accordance with proven and documented VV&A procedures.

c. An archive of documented assessments of M&S credibility that have been funded by customers.

d. A Web site that provides M&S credibility process and product information, with links to other organizations such as the JTCG/ME (access to the JASA site can also be found through the JASP Web site).

e. A training syllabus in M&S credibility processes and procedures.

Taken as a whole, these products and services provide a resource to the acquisition community that reduces the risk of using M&S to support system acquisition, reduces the cost of M&S VV&A, and promotes consistent VV&A processes and products across the Services.

The final addition to the JASP is the Joint Service Air Defense Lethality Team (JSADLT). First, I must say that we are looking at options to change their name for we recognize that it is a mouthful. Second, this group performs one of the most important, yet overlooked, missions in aircraft survivability. Readers to the *Aircraft Survivability* newsletter should be familiar with this organization for we have catalogued quite a bit of their activities over the years.

History is full of cases where the collection and analysis of combat data has made immeasurable improvements in the survivability of aircraft under development. Unfortunately, history is also full of cases where the collection of this data quickly atrophies after the latest conflict. During the Southeast Asia conflict, specialized teams were constituted to gather combat damage data. These teams found that by analyzing every aspect of combat damage, trends emerged pointing to vulnerabilities of specific aircraft. Over the course of the conflict, many vulnerability reduction modifications were performed on aircraft of all types from all Services. These changes are credited with the safe return of many aircrew that otherwise would have perished or become prisoners of war. Also, changes to doctrine and tactics were also made to increase the probability of survival of aircrews.

Unfortunately, during the conflicts in Panama, Grenada, and Libya, there was no one close to the action to document what happened to our aircraft during combat. Efforts to reconstruct the data after the fact were "hit and miss" at best. When Operation Desert Storm began, several combat data collection teams were hastily assembled and trained. However, none were permitted in-theater to perform real-time data collection, and many post-conflict reconstructions yielded mixed results. During the early 1990s, the Air Force Research Laboratory (AFRL) attempted to address the issue of institutionalizing combat data collection. With support from the DDOT&E/LFT&E Testing and Training Initiative, they developed the Air Defense Lethality Team, an Air Force Reserve team tasked with the collection of threat induced combat damage data.

In order to sustain the team during the periods between conflicts, the team took on the mission to synthesize the data available in the SURVIAC archives and develop a Threat Warheads and Effects training program. With additional support and funding from JASPO, bridges were built between all Services to develop a tri-service combat data collection capability. The result of all this effort is the JSADLT. The Team is currently made of Reservists from the Air Force Materiel Command's 46 OG/OGM/OL–AC at Wright-Patterson AFB, Ohio, the Naval Air Systems Command, Patuxent River, Maryland and China Lake, California, and the Army's Aberdeen Test Center, Aberdeen Maryland.

Together, all these organizations create the Joint Aircraft Survivability Program.

Another big news item is the establishment of our new Web page at http://jas.jcs.mil. While I acknowledge that the site is still a work in progress (and probably will be for some time as we like to tinker too much in this office), it does provide an excellent venue for our Service, Industry, and DoD partners in the aircraft survivability community to communicate with us. It allows an open forum for exchanging ideas, collaborating on projects, and providing access for government and industry to the many projects we fund each year. We in the Joint Aircraft Survivability Program recognize that it is not always easy to discover what others are working on, so we will provide a complete list of funded efforts for review. Hopefully, those in the acquisition and R&D worlds will consider this a resource for consideration of future efforts. After all, it doesn't make much sense for us to spend millions of dollars each year if our products are not used.

Along with the Web site comes another perk. This year we will place all the forms and instructions for submitting project proposals on our site. This will make it easy for any organization (government and industry) to submit proposals for FY04 funding. I knew that would grab your attention! It is our goal to fund the best ideas for survivability enhancements, regardless of origin. The process is simple. Just download the templates, instructions and guidance and return the forms to the Program Office. We will then forward them to the appropriate subgroup for review and consideration. Complete guidance on what types of projects we anticipate funding is available for your use when preparing proposals. We also have plenty of examples of funded projects available for review, which should help. The bottom line is that we are looking for the best projects to fund so feel free to let us know what you are working on.

That wraps it up for now. If you have comments or questions about any of the articles in this issue of *Aircraft Survivability*, please let us know. We consider the readers of this publication part of our customer base. As such, our goal is to see that your needs are met. ■

CDR Andrew Cibula, USN
Director, JASPO

The First JASPO Change of Command

by CDR Andrew Cibula, USN

During the Joint Aircraft Survivability Program Office (JASPO) Principal Members Steering Group (PMSG) meeting in Key West, Florida, Mr. Richard (Tim) Horton was officially inducted as the new JASPO PMSG Chairman. He replaces Dr. Steven Messervy, the outgoing JASPO Chairman from the U.S. Army. Mr. Larry Miller, the Director for Live Fire Test and Evaluation, presided over the event and presented Dr. Messervy with a letter of appreciation for his service.

Dr. Messervy was designated Chairman of the PMSG in 2000. He is the 2002 recipient of the National Defense Industry Association (NDIA) Survivability Leadership Award. He is also Project Manager for the Army Aviation Electronic Systems Project Office. As the Chairman of the then JTCG/AS, Dr. Messervy was instrumental in integrating numerous elements of the aircraft survivability community into one program that will provide full spectrum survivability excellence.

“The Joint Aircraft Survivability Program was fortunate to have Steve in a key leadership position during this highly transitional period” said Mr. Larry Miller as he applauded Dr. Messervy for his outstanding service as the Chairman of the PMSG.

Mr. Horton, of the Naval Air Warfare Center, Weapons Division (NAWCWD), assumed the PMSG Chairmanship. Tim, a retired U.S. Army Officer, first became involved with the JASPO as the U.S. Army Military Representative to the JASPO predecessor, the JTCG/AS Central Office, where he served as the Executive Director. Upon retiring from the U.S. Army, Tim supported the JASPO and was a significant force in establishing the Joint Live Fire Program.

Hired by NAWCWD, Mr. Horton has served as a Vulnerability Reduction Subgroup co-chairman, and has progressed to be the U.S. Navy Principal Member and now Chairman of the PMSG. He is the Head of NAWCWD’s Survivability Division, as well as its Reliability and Maintainability, Manufacturing Engineering, and Systems Safety Divisions of the Systems Engineering Department. ■

Mr. Larry Miller (right) presents Dr. Steven Messervy (left) with a letter of appreciation for his service as PMSG Chairman.

Dr. Steven Messervy (right) presents Mr. Tim Horton (left) with the PMSG Chairman’s Trophy, an ionomer panel.

News Notes

■ by Mr. Joseph Jolley

The "new" SURVIAC has expanded mission

On March 5, 2003, Mr. Ron Hale, the DoD Information Analysis Center (IAC) Program Manager hosted the SURVIAC Kick-off and TCG meeting during which he announced that on January 9, 2003, Booz Allen Hamilton had been competitively awarded a new ten-year contract to operate SURVIAC. What was different about this award was that the "New SURVIAC" as it was described has an expanded focus that now includes space and homeland security in addition to its traditional focus on aircraft combat survivability. Additionally, Booz Allen Hamilton has expanded its team of partners from two to eight. In addition to past partners SURVICE Engineering and Battelle, ITT Industries, Excel Management Systems, Veridian, AttoTek, Stellar Solutions, and Mount Vernon-Lee Enterprises have joined the team to provide a broad array of technical and support services to meet the needs of their expanded mission and SURVIAC's new customer base. Contact JASPO for more information.

JASPO Web site to see improvements

The JASPO Web site (http://jas.jcs.mil) is up and running. The site consists of a public side and a controlled side. Look for positive changes to the site in the near future as we incorporate improvements to make it effective not only as a source of information, but equally important, as the primary means for developing the JASPO funded project list each year. The first major test of the site will begin this May as we begin planning the FY04 Program. Proposed project statements of work will be posted on the Web site where they will be reviewed and prioritized and the final program approved. This activity will take place on the controlled side of the site.

In addition, there is only one logo for the organization as shown below. ■

Susceptibility Reduction Subgroup Update

■ by Dr. Frank Barone, JASPO Susceptibility Subgroup Chairman

Recent attempts to attack both military and civilian aircraft using MANPADS has resulted in a renewed interest in survivability technologies, especially Susceptibility Reduction (SR). The MANPADS threat is being taken very seriously and has even recently stimulated the introduction of a bill in Congress mandating commercial aircraft protection. It seems timely that this issue of Aircraft Survivability be dedicated to Susceptibility Reduction. The SR subgroup of the JASPO has been successful over the years in technology development that has found its way to the warfighter. The subgroup successes have covered the gamut from chemical constituents in expendables to the development of component technology, such as digital RF memory, to successfully demonstrating new system concepts. We are fortunate in that we can support efforts that span the spectrum from technology development thru P3I for fielded systems. It is also fortunate that our decision cycle lends itself to being able to adjust our focus to address the short term warfighter needs. We have been able to balance this with the longer term needs of the government and contractor technology and system developers. The current mix of efforts reflects this philosophy.

In the issue you will read descriptions of SR technologies that have recently been deployed. In all of which JASPO has played some role in the development. The component technology that is under development may impact SR systems in the near term and has longer-term impact.

We have recently begun the planning process for next year's efforts. The subgroup, with guidance from OSD, the PMs, and JASPO, has put together topical areas that we believe we should focus our resources. We have recently begun to look at the application of SR technologies to the protection of UAVs. These assets are becoming more heavily relied upon to enhance battlespace awareness, act as a stand in jammer and to play a more active offensive role. Hence interest in protecting these assets has risen. We have also been looking at technologies to defeat advanced threats in IR, such as imagers. In the RF arena we are looking into small angle of arrival RF warning receivers to enhance the situational awareness capability for more widely used RF threat warning. In the signature management area we have attempted to assess the potential of using aerogels to reduce the EO/IR signature. Details of the efforts are sensitive, so to obtain more information contact JASPO. ■

Test Assesses C–130 Vulnerability to MANPADS

by Mr. Cliff Lawson

The vulnerability of large, fixed-wing aircraft to shoulder-launched anti-aircraft weapons is not well understood. But the increasing proliferation of these small, inexpensive, and easily launched missiles requires that their lethality against such aircraft be investigated.

An important step in that investigation took place recently when NAVAIR China Lake's Survivability Division conducted a vulnerability test of a C–130 aircraft by firing a live Stinger missile at it.

Small missile

The Stinger, a 23-pound, supersonic, fire-and-forget man-portable missile, was fielded in 1981. Fired from a 12-pound launcher, the missile tracks an aircraft's infrared (IR) signature and makes the kill with an impact-fuzed high-explosive warhead.

The Stinger is combat proven. The British used it in the Falklands and, according to Jane's Information Group, Mujahideen guerrillas destroyed more than 250 Soviet fixed-wing and rotary-wing aircraft during the Afghanistan Conflict using U.S.-supplied Stingers.

The Stinger was chosen for this test because it represents a class of Man-Portable Air Defense Systems (MANPADS). Other widely deployed MANPADS include China's CMPIEC HN/5, Egypt's Sakr Eye, Russia's SA–7 and SA–14, and Britain's Blowpipe.

Large aircraft

The C–130 is the workhorse of the military. First flown in 1954, the aircraft is used by more than 60 countries in a broad range of missions. The U.S. employs C–130 variants as transports, tankers, gunships, aeromedical units, and aerial sprayers. They are also used in firefighting, disaster relief, airlift support, and special operations missions. And it is the C–130 that delivers the largest conventional weapon in the U.S. arsenal—the 15,000-pound BLU–82.

With a wingspan of 132 feet, length of nearly 100 feet, and height of 38 feet, the C–130 is not low profile. (Comparable numbers for an F/A-18C are 40, 56, and 15 feet, respectively). Nor does the four-turboprop C–130 have the speed or maneuverability of its fighter and attack counterparts.

Just as the Stinger represents the MANPADS family of weapons, the C–130 represents a family of large, multi-engine aircraft. The survivability of these aircraft is a matter of keen interest.

Vulnerability reduction

The C–130/MANPADS test was conducted under the auspices of the Joint Live Fire (JLF) Aircraft Systems program. JLF testing focuses on the vulnerability and lethality of fielded U.S. platforms and weapons.

The purpose of this test was to obtain data from an actual missile/aircraft interaction-data that will be used to refine and validate vulnerability analysis computer models. Ultimately, the goals are to determine how survivable the C–130 is, and to investigate ways to further reduce the vulnerability of the C–130 and other aircraft to MANPADS.

Computer modeling is an important tool for assessing the vulnerability of a variety of platforms. Vulnerability models such as COVART (Computation of Vulnerable Areas and Repair Time) and AJEM (Advanced Joint Effectiveness Model) are used by the U.S. Army, Navy, Marine Corps, Air Force, Coast Guard.

For the models to have maximum utility, they must be based on empirical data: for example, warhead A detonating at point B yields damage C. The more precise the data are, the more realistic the computer model. Before the recent test at China Lake, very few data existed on the interaction of a C–130 and MANPADS.

Technical challenge #1

Engineers from the Survivability Division faced several challenges in gathering precision data for the computer modelers. Foremost was the task of identifying the point of MANPADS warhead detonation to within a fraction of an inch.

China Lake engineers called on the expertise of Johns Hopkins University/Applied Physic Laboratory (JHU/APL) researchers who had developed a Blast Initiation Detector (BID). This electro-optical sensing system relies on sacrificial fiber-optic cables running from a central processor to points located strategically throughout the target. The BID had been successfully tested at Naval Surface Warfare Center, Dahlgren, Virginia.

BID measures the point in time when "first light" from the warhead detonation is received at each sensor, and uses the time differences to calculate the exact location of the blast. In preparation for the test, JHU/APL personnel visited China Lake and assisted with the installation of the BID on the C–130.

Technical challenge #2

The Survivability Division engineers also wanted a detailed visual recording of the missile/aircraft end-game interaction. For this they selected a Photo-Sonics, Inc., Phantom 4 high-speed digital video recorder.

The recorder's storage system can be post-event triggered to save the most recent set of data. To activate the storage system and capture the end game at 7,100 frames per second, an accurate determination of the missile's time of arrival was required.

With the help of JHU/APL, the video recorder was integrated with the BID. The first optical input from the BID—the light from the warhead detonation—activated the camera storage, providing more than enough time to record missile entry, detonation, and blast damage.

The test

A 30-foot-high dirt hill was constructed, and the C–130 was towed onto it. This height would allow the Stinger some maneuvering room as it flew toward the aircraft.

The outboard port engine—a T–56 jet engine that is gearboxed to the propeller—was operated at maximum continuous power with fuel supplied from a remote tank (the aircraft's fuel tanks were drained). There was no wing loading for the test. Instrumentation consisted of the BID, digital recorder, pressure transducers, and high-speed film cameras.

Raytheon Corporation, manufacturer of the Stinger, installed a remote-control missile launcher at a distance from the C–130 that simulated a tactical engagement. Two initial attempts to conduct the test were unsuccessful. Engineers re-evaluated the test setup, made some minor adjustments, and prepared for a third attempt.

When all was ready and the firing safety officer gave the go-ahead, the Stinger system was activated and, after achieving target lock, the missile was fired.

Figure 1. The 5-foot-long Stinger is seen approaching the C–130 from the rear.

Figure 2. The missile's 2.2-pound warhead detonates inside the engine nacelle.

The Stinger flew directly to the aircraft and entered the engine's exhaust pipe. The contact fuze fired, and the warhead detonated inside the engine. All test instrumentation functioned properly.

A Joint Service Aircraft Battle Damage Repair (ABDR) team traveled to China Lake to conduct a post-test examination of the C–130. Their findings will contribute both to computer modeling efforts and to vulnerability issues relating to wing-mounted engine installations. These include fuel shut-off valve locations; fire barriers between the nacelle and wing; systems that may be critically damaged, such as fuel and hydraulic; and the potential for cascading damage through fire.

Many players

Along with Raytheon, JHU/APL, and the ABDR team, several individuals and organizations contributed to the test's success.

Leo Budd of the Survivability Division was the project engineer for

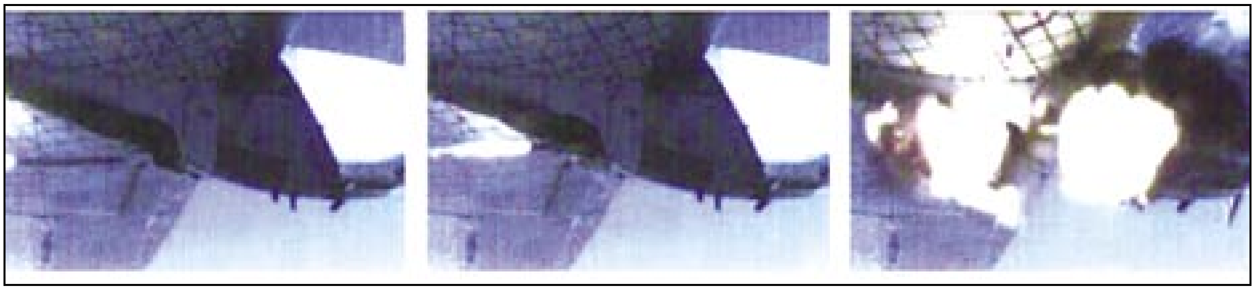

Figure 3. Three frames from a 7,100-frame-per-second camera show the Stinger approaching the engine, entering the exhaust pipe, and detonating.

the test, and Phil Cote of the Pacific Ranges and Facilities Department was the test manager. The China Lake Fire Department stood by to ensure that the C–130 test asset would not be lost to a post-test fire.

The Army's Short Range Air Defense (SHORAD) Project Office provided consultation on missile operations and performed a fly-out of the C–130/MANPADS scenario on their IR missile simulation program.

Also contributing to the test planning were the Army Research Laboratory, Army Materiel Systems Analysis Activity, Air Force 46th Operations Group, FAA, aircraft prime contractors, and the Institute for Defense Analyses.

An expanding test capability

The C–130/MANPADS test marks another milestone in NAVAIR's live-fire test capability. In previous projects at China Lake, the Survivability Division and the Weapons Survivability Laboratory have fired Stingers against a helicopter tail boom, two F–14s, and an F–16 with its engine running.

The data from these tests will lead to aircraft that are less vulnerable, more survivable, and more likely to bring their aircrews safely home at mission's end. ■

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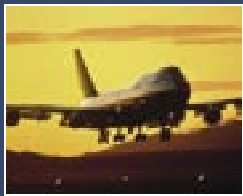
In July 1999, the DOT&E JLF program performed a live fire test shot of a Stinger missile against a recently retired F–14 Tomcat. The test was the first in a series of tests with complete aircraft to assess the vulnerabilities of our aircraft to MANPADS.

photograph by Danny Zurn



The Vexing Problem of Protecting Airliners from MANPADS

The Survivability Community's Next Big Challenge

■ by Mr. Paul J. Caffera

Editor's Note: The views expressed in this article are those of the author and do not necessarily reflect the views of the Joint Aircraft Survivability Program Office or the Department of Defense.

Has the time come to build and operate our civil aviation fleet with consideration given towards reducing susceptibility and vulnerability from attacks by man-portable air defense systems (MANPADS)? Not too long ago, it would have struck many as unnecessary to seriously debate this question. Certainly, the danger of a MANPADS attack within the United States has been a theoretical possibility for several decades—nonetheless, it has seemed an unlikely prospect. Recent events have changed the calculus of assessing this threat.

Since the September 11 attacks, many assumptions that undergirded Americans' pursuit of daily activities have been altered in ways unimaginable just two years ago. Until recently, the threats posed by anthrax and smallpox were academic questions, far removed from the experience of daily living. Currently, much of the mail entering the Washington, DC area is being irradiated to defend against anthrax-filled packages, and mail rooms and post offices are routinely swabbed in a search for anthrax spores. Likewise, healthcare workers and first responders are being vaccinated against smallpox—a disease not found outside of a limited number of secure laboratories for many years—as defense against a biological attack launched by terrorists. The list goes on and on. Some of the greatest changes since the September 11 terrorist attacks have occurred in the area of aviation security. Given the central role that a safe, secure, and dependable aviation industry plays in the economy, significant efforts have been undertaken to make passengers feel safe from the threat of terrorism while traveling aboard commercial air transports.

Avoiding disruptions to the U.S. aviation industry is a great concern to policy makers. Before the September 11 attacks, the aviation industry employed a million people and contributed approximately $300 billion to the U.S. economy. A typical day finds 12,000 flights transporting 1,800,000 passengers. The September 11 attacks caused many to feel vulnerable, to question the safety of air travel, and to reassess the wisdom of having their spouse, parents, or children travel via the nation's airlines. The result was devastating to the industry. Airlines, already suffering from an economic downturn, saw their ridership and revenues plummet, and their losses rapidly escalate. To protect this vital industry from collapse, Congress provided billions of dollars to the industry and created the Transportation Security Administration to take over responsibility for passenger and baggage screening at the nation's commercial airports. For their part, the airlines replaced or reinforced previously-flimsy cockpit doors. These measures helped reassure a jittery public that air travel was again safe.

While these new security measures have reduced the likelihood that passengers will successfully smuggle weapons or explosives aboard aircraft, they will not prevent a determined MANPADS-armed terrorist from carrying out a catastrophic attack against a passenger aircraft. This threat was first revealed to much of the traveling public on Thanksgiving morning, when al Qaeda terrorists armed with four Russian-designed and manufactured SA–7 missiles unleashed two of them against a Boeing 757, operated by Israel's Arkia Airlines, as it departed from Mombasa, Kenya. The fact that a passenger transport aircraft filled with vacationing tourists might fall victim to missile-armed terrorists was shocking to many people. It should not have been.

Since the 1970s, MANPADS have successfully attacked at least 43 civil aircraft with 30 of these resulting in aircraft "kills." Nearly 1,000 passengers and crew have died in these attacks. Perhaps the lack of broad public knowledge of the threat is explained by the fact that most MANPADS attacks have occurred in parts of the world that are "off the radar screen" for most Americans —often in areas of significant political unrest—and few of the lost aircraft or victims had ties to the United States. In a post-September 11 world, MANPADS in the possession of terrorist, criminal, and sub-national groups that wish the United States ill pose an increased threat to civil aircraft operating in our national airspace. Chief among these groups is al Qaeda. Well funded, with a virulent hatred of the United States and a demonstrated history of attacking U.S. interests around the globe and within our own borders, al Qaeda has shown the capability of acquiring massive quantities of MANPADS. As of August of 2002, operations in Afghanistan resulted in the capture of over 5,000 of these short-range air defense missiles.

The attack in Mombasa illustrates that the capture of this enormous cache of MANPADS did not strip al Qaeda of all its shoulder-fired missiles. Luckily, that attack failed. Whether the failure was the result of the limitations of the equipment itself, or because of operator error—such as failure to lead the aircraft, or a failure to take into account the position of environmental IR sources —is unknown. Nevertheless, members of the group that destroyed the World Trade Center's Twin Towers and badly damaged the Pentagon were able to acquire multiple MANPADS, transport them, and then plan and carry out an attack on a civil air transport. Al Qaeda has a history of learning from their errors and we should not expect them to make the same mistakes next time. The smuggling of MANPADS is not simply an overseas problem. The U.S. Customs Service has already disrupted a sophisticated smuggling ring that had ready access to newly-produced MANPADS, obtained falsified end-user certificates from a co-conspiring ministry of defense official in a Baltic country, and set up a complex plan to smuggle the missiles into U.S. territory. Unlike the undercover law-enforcement operations that periodically come to light in which people are caught trying to purchase Stinger missiles, this case, centered in Miami, involved arms dealers who had the missiles and were willing to sell them.

The prospect of such an attack within the United States is chilling. Whether or not a domestic MANPADS attack results in an aircraft kill, the effects on the aviation industry and the economy as a whole likely would be devastating. The grounding of aircraft after the September 11 attacks was of limited duration and when aircraft started flying again, officials were able to restore passenger confidence with the federalizing of screeners and the implementation of more rigorous passenger and baggage screening procedures. Still, the industry lost billions of dollars, as did other air-travel-dependent industries, such as tourism. Unlike the situation after the September 11 attacks, should a MANPADS attack occur, there are few confidence-building security improvements that could be implemented quickly to again restore confidence in the security of the civil aviation system.

In the days and weeks after the Mombasa attack, there were numerous calls from within Congress and outside the government to protect US airliners from similar attacks. First came suggestions to implement perimeter patrols around airports to prevent terrorists from launching a MANPADS attack. Others called for installing flare systems to coax missiles away from targeted aircraft. The problem with these various calls to "do something" is that quickly-implemented solutions may only give the appearance of protection without imparting a significant degree of actual protection from loss. What the various proposed solutions have in common is a lack of recognition that simple and inexpensive solutions for protecting aircraft from MANPADS attacks may not be as effective as they first seem.

The proposal to implement perimeter patrols to protect against MANPADS attacks is illustrative of the problems with the post-Mombasa proposals. Although highly visible, implementing patrols around the over 450 airports with commercial service in the United States would require massive numbers of personnel. Even if one were to assign as many as 700 security personnel to the task at each airport—a total of 315,000 security personnel nationwide—their ability to prevent a MANPADS attack would be limited and the annual cost would be astronomical. If one assumes a "low-ball" total salary and benefit cost per person of just $30,000, the annual expenses would exceed $9 billion. Further, this cost estimate ignores the expense of equipping and maintaining the operations of these personnel.

Since commercial aircraft are at or below 10,000 feet for 40 or 50 or more miles before they land, just to protect airliners from older-generation MANPADS, perimeter patrols would need to cover an area of about 100 square miles for each approach corridor—slightly less for take-off routes, but still a substantial geographic zone. If one takes into account the capabilities of more advanced MANPAD systems, perimeter patrols will need to patrol the areas in which aircraft are below 12,000 to 15,000 feet—an even larger geographic region. Dividing the available personnel to protect both take-off and landing corridors (even ignoring the additional reduction in the available forces that would occur when taking into account the need to account for days off and in certain circumstances dividing the force to cover two work shifts), the number of personnel per square mile within the zone of susceptibility drops precipitously. The ability of such forces to provide adequate protection is doubtful. Even going so far as to incorporate patrol helicopters with snipers onboard is unlikely to prevent all but the least effective terrorist from successfully launching a MANPADS attack. At the same time, it will increase the potential for mid-air collisions. That said, instituting improved patrols in a limited area around the airport grounds is not unwise; they would reduce the possibility of a number of types of terrorist actions, from attacks with RPG's, light anti-tank weapons, and large caliber firearms. Perimeter patrols just cannot be expected to provide cost effective or dependable protection from MANPADS.

Likewise, a number of other non-technical/engineering solutions, which have proven effective in reducing military aircraft susceptibility—such as making use of unpredictable take-off and landing times, flying in tactical formations, using formation splits, and utilizing lights out procedures—are not likely to prove practical for the airlines. This turns the focus towards technical/engineering solutions. Heretofore, the loudest calls for technical solutions to the threat have largely focused on susceptibility reduction.

For a variety of technical and political reasons the installation of either flares or other pyrophoric susceptibility-reduction systems, such as BOL–IR, has significant disadvantages. Flares have the drawback of triggering fires when they land on combustible materials. It is difficult to imagine residents and businesses in take-off and landing corridors tolerating aircraft dropping flares as a routine part of commercial aircraft operations. Additionally, the sight of airliners spewing flames is unlikely to raise the comfort level of already-jittery travelers. The limited time that systems like Comet can operate and the limited number of times that they can be deployed and retracted before requiring servicing decrease the attractiveness of a mass deployment of these devices in the civil transport fleet. Beyond these issues, while reasonably effective at protecting aircraft from less sophisticated MANPADS, the emergence of MANPADS with two-color seekers and programmed with sophisticated counter-countermeasure algorithms capable of discriminating between these systems and the target aircraft, would appear to recommend a different solution.

Directed infrared countermeasures systems may be a viable alternative for airliners. Rather than simply providing a second bright IR source in an attempt to draw an approaching missile away from a targeted aircraft, DIRCM systems use beams of light, produced by a variety of means such as flashlamps or lasers, to exploit knowledge about the design of reticle-scan MANPADS seekers to defeat their homing mechanisms. In many MANPADS, a reticle within the seeker causes pulses of light from the target aircraft to "shine" on the missile's infrared detector. The IR detector senses the IR radiation and sends an electric signal to the guidance package, which determines the target location and allows the missile track the target aircraft's location and movement through the sky. By shining a modulated light towards the seeker, an IRCM system provides the infrared detector with extra "false" data, which deceives or "jams" the missile, causing it to miss its intended victim.

Northrop Grumman's Nemesis system is a widely-utilized flashlamp-based DIRCM system. Despite the advantages that DIRCM systems have over flares, these systems have limitations that have prompted a move towards laser-based systems, such as the Navy's TADIRCM system and the Air Force's new LAIRCM system. LAIRCM builds upon the NEMESIS platform but replaces the flashlamp source of IR radiation with a laser source. The current unit cost of an installed LAIRCM system is approximately $3 million. While pricey in absolute terms, this amounts to about 1.5 percent of the cost of a $200 million Boeing 747–400 and 5 percent of the cost of a Boeing 737. Another laser DIRCM system just recently offered for sale outside Israel is RAFAEL's Britening system. The unit cost of an installed Britening is approximately $1.5 million, somewhat higher if more than four UV launch detectors are necessary.

Laser-equipped DIRCM systems seem to offer commercial aviation the prospect of obtaining a high degree of protection, at a reasonable cost. Using the figure of $3 million per aircraft, the cost of equipping the U.S. commercial air fleet with the best currently-available protection from IR missiles would be around $18 billion. This is less than the amount pledged to the State of New York in the aftermath of the September 11 attacks. Further, if one uses the lower cost of the Britening system, or if LAIRCM's costs came down as a result of the efficiencies of scale arising out of increased production numbers, the cost of implementing state-of-the-art IRCM across the civil aviation fleet likely would be comparable to that of deploying ineffective airport perimeter patrols.

That said, implementing a laser-based DIRCM system, based on current technology, may not be a long-term solution. With the movement away from reticle-scan seekers and emergence of scanning focal plane array seekers and staring focal plane array seekers, the cat and mouse game being played between MANPADS developers and IRCM designers continues. Just as viruses mutate in response to immune system responses, so too MANPADS seeker design has responded to the development of countermeasures. The evolving nature of seeker technology is creating significant challenges to IRCM system designers. Even sophisticated IRCM systems that protect today may be ineffective against tomorrow's threat. Whereas providing protection against first- or second-generation MANPADS might deter "garden-variety" terrorists equipped with SA–7s from launching an attack against the U.S. civil transport fleet, it is unlikely to provide sufficient protection from a well-financed and determined terrorist adversary, such as al Qaeda. For those with the money, there are a number of black-market arms dealers with the capability of supplying sophisticated weapons including more advanced MANPADS. In the final analysis, it may prove to be more effective and less costly to allocate additional resources to bring on-line quickly new IRCM systems such as MEDUSA.

On February 5, Senator Barbara Boxer of California and Representative Steve Israel of New York introduced bills into their respective houses—S.311, and HR 580, the Commercial Airline Missile Defense Act (CAMDA)—requiring the installation of IRCM systems on all the jet aircraft operated by U.S. airlines. The bills call upon the Department of Transportation to evaluate, and then pay to acquire for the airlines, anti-missile systems that can identify a missile threat and disrupt the guidance system of the threatening missile. To reduce costs, turboprop aircraft are not covered by this proposed legislation. On March 20, the House Aviation Subcommittee met in closed session to hear from representatives of the intelligence community, the TSA, Department of Transportation, and industry representatives from both the United States and Israel to receive information concerning the scope of the threat to civil aviation from MANPADS. Immediately after the hearing the Subcommittee Chair and Ranking Member called on the Congress to appropriate at least $30 million for research and development and some limited deployment of anti-missile systems on airliners. Whether or not CAMDA becomes law or the proposed allocation of R&D monies is approved, the open acknowledgement of the existence of a TSA-led interagency task force looking into the MANPADS threat to civil aviation combined with the introduction of CAMDA and the Aviation Subcommittee's actions mark a watershed moment in the quest to address the MANPADS threat to airliners.

Although susceptibility-reduction measures such as the installation of IRCM systems on airliners would no doubt improve the survivability of those aircraft, experience has shown that vulnerability reduction should not be overlooked. Simply focusing on the susceptibility side of military aircraft was not sufficient, and many pilots owe their safe return from hostile environments to vulnerability reduction efforts. Since no IRCM system is likely to prove 100 percent effective against all current and emerging IR missile threats, it may be wise to direct additional attention towards reducing civil aircraft vulnerability to IR missiles. Regardless of the measures used on any particular aircraft design—whether relying on such familiar approaches such as dispersing redundant critical components around the aircraft, armoring hydraulic lines, installing self-sealing fuel lines, and installing strategically-placed fuel shut-off valves, or whether one looks towards fuel tank fire and explosion protection through the use of powder panels or other technology, adjusting fuel chemistry to reduce the chances of fire or explosion, improved turbine blade and disk debris containment, or even adopting explosive-resistant and lightweight fuselage materials—focusing additional resources on vulnerability reduction should be a priority. An additional benefit that comes from vulnerability reduction efforts is that they also provide a degree of protection against non-IR threats such as RF missiles, RPGs, high-caliber machine guns and sniper rifles, as well as from damage caused by explosives that might slip through the passenger and baggage screening process.

The efforts of the survivability community have resulted in the design of combat aircraft that are significantly more likely to avoid and survive MANPADS attacks. One notable example is the success of the F/A–18 hornet during Desert Storm. The time may have come to apply aggressively the lessons learned in the military context to the civil air fleet. This will not likely be cheap and will in all likelihood necessitate live-fire testing with an assortment of commercial aircraft of different sizes and different propulsion systems. Whether such tests are conducted on static aircraft or whether additional funding can be obtained to "drone" the test aircraft, to avoid conducting live-fire testing based on cost considerations would be shortsighted. Just as a small percentage of the cost of every car sold goes to pay for crash tests, live-fire testing of airliners could be funded via a small surcharge on each airline ticket sold. Regardless of the funding mechanism, arguments against such testing based on cost considerations are misplaced. If we as a nation fail to allocate sufficient resources to fully assess and address the problem posed by MANPADS, the economic repercussions we suffer as a result of a domestic MANPADS attack on a civil aircraft may be far more severe than anyone dare contemplate. ■

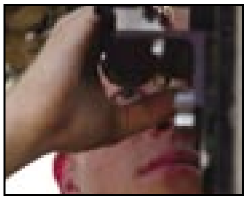
Paul J. Caffera is a writer based in Rochester, New York whose articles on terrorist threats to aviation have appeared in major newspapers around the world, in trade publications, and online. Among others, Paul's commentaries on terrorist threats to aviation have been heard on MSNBC, the Australian Broadcasting Company, the BBC, the Canadian Broadcasting Company, and public and commercial radio stations coast to coast. Paul holds a B.S. in Life Science from Kansas State University, a B.A. in History from Regents College (now Excelsior University), and a M.S. in Management from Central Michigan University.

American Institute of Aeronautics and Astronautics

Survivability Awards Call for Nominations

Nominations Due 1 October 2003

The American Institute of Aeronautics and Astronautics (AIAA) is accepting nominations for the prestigious Survivability Award. Established in 1993, this award is presented to an individual or a team to recognize outstanding achievement or contribution in design, analysis, implementation and/or education of survivability in an aerospace system. The biennial award will be presented in April 2004 at the Structures, Structural Dynamics and Materials Conference in Palm Springs, California. Nominations must be submitted by 1 October 2003. Past recipients of the award have included Mr. Dale Atkinson, Dr. Robert Ball, Mr. Nikolaos Caravasos, Mr. Jerry Wallick, and Mr. Michael Meyers. Forms can be obtained by accessing the following Web site: http://www.aiaa.org/, or contacting Aimée Petrognani, AIAA Honors and Awards Liaison, at 703.264.7623 or via E-mail at aimeep@aiaa.org. or Mr. Dennis Williams of the AIAA Survivability Technical Committee at 314.232.7955.



Aiding Aircraft Survivability

Coherent Electronic Attack

■ by Dr. Gregory Cowart and Mr. T. Christopher Moss

Lance Cpl. McCorkle aligns the antenna with the azimuth from an AN/TPN–22 (Tactical Precision Navigation Radar) through the use of a scope. The An/TPN–22 gives the controller information on a plane from 10 nautical miles out. U.S. Air Force photo by SSgt. Reynaldo Ramon.

This article presents a look at the trend in threat radar development, discusses why coherency in electronic attack (EA) is desirable, and gives an overview of some current areas of research. We begin with an often-cited definition of coherency—

"Two or more harmonic oscillations of the form v(t)=V0 sin (wt + Ø) are termed coherent over the interval t… if the phase shift between them is constant over the interval t…. More generally for radars the signals are considered to be coherent if their phase structure is linked and the relationship of the linkage is known." [1]

The above definition is from the radar point of view. Such familiar radar types as pulse-Doppler, pulse compression, frequency agile, phase coded and any imaging radar [synthetic aperture radar (SAR), and inverse synthetic aperture radar (ISAR) technology, for example] are coherent systems. Coherency brings higher energy on target, adaptive management of radiated power, increased range resolution, improved clutter rejection, enhanced targeting and tracking, and increased anti-jam margin. From the EA perspective, a good working definition of coherent jamming is any modulation scheme that passes energy through the radar frequency (RF) filtering/matching process into the intermediate frequency (IF) stage of the radar. The effectiveness of the coherent jamming is directly related to how much of the jamming signal gets downconverted into IF. Thus for coherent jamming, the key idea in attacking a radar system is knowing the phase structure of that radar signal or class of radar signals.

Threat and threat direction

Figure 1 depicts the threat trend. In the mid 1960s the threat was pulse radars such as the Flat Face and Low Blow of the SA–3 surface-to-air missile system. [2] These radars had minimal anti-jamming capabilities. Shortly after the introduction of the SA–3, the SA–6 Straight Flush continuous wave (CW) illuminator was introduced. [3] In the 1980s, fully coherent surveillance and targeting radars appeared such as the SA–12 Bill Board and Grill Pan radars. Bill Board used post-detection integration and sidelobe suppression to negate the effects of jamming. [4] Additional anti-jamming capability arrived in the 1990s with the introduction of radars such as the Giraffe 75. Electronic protection (EP) used by radars introduced in the 1980s and later included coherent pulse Doppler, frequency hopping, pulse compression, polarimetric jammer nulling, and low sidelobes. The future trend appears to be toward imaging target-tracking radars using ISAR. From the advent of the SA–6, most new radars are coherent and it is the coherency that affords these radars their anti-jamming capability.

Coherency and benefits

The most efficient EA signals for use against coherent radars are those that use the radar waveforms to generate countermeasure (CM) techniques. If you present a radar with what it wants to see in time (range), frequency (velocity), and polarization the radar will have a difficult time rejecting the jamming.

Three of the ways that coherent EA waveforms can be generated are—

1. Direct digital synthesis (DDS) using a priori knowl-

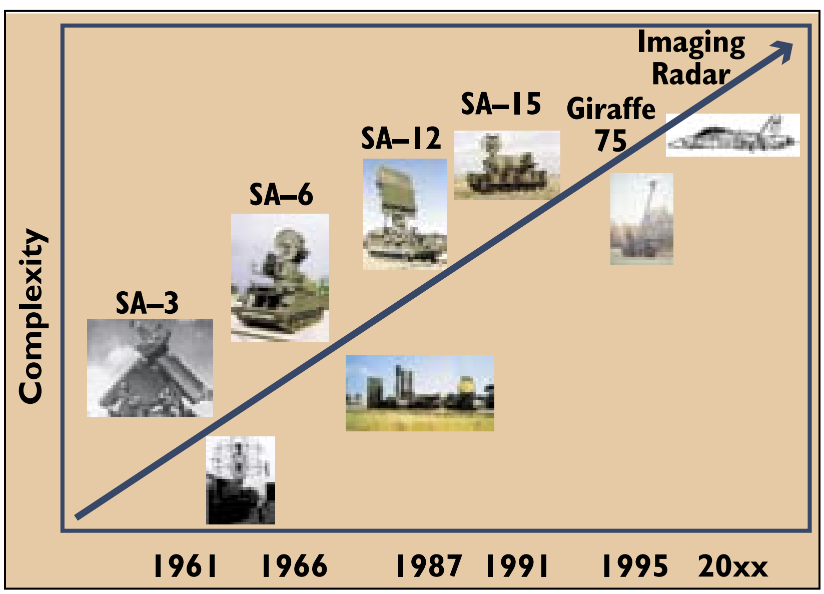


Figure 1. A view of the threat technology trend.

edge of the signal of the victim radar,

2. Measuring the radar waveform and setting on a DDS,

3. Using a repeater type jammer

A DDS system using given knowledge of the phase structure of the radar signal can generate coherent EA waveforms. It has the advantage that a receiver is not required with obvious implications for jammer size, weight and cost. As an EP technique, radars will use frequency or pulse compression agilities to expand the required jamming signal bandwidth. Often the jammer bandwidth necessary to successfully negate radar agilities is so large that insufficient jam-to-signal ratios will occur unless the jammer resorts to significant increases in transmitter power. Thus a receiver may be added to a DDS based system to attempt to track radar frequency movement in order to focus jammer energy into effective frequency subbands. As mentioned, using the radar waveform to generate the EA waveform is the most efficient coherent jamming method so the repeater jammer is a very attractive technology. Agilities are automatically handled if the repeater has sufficient bandwidth, as is usually the case. However, since the repeater continuously receives and transmits at a given frequency in the band of operation, isolation becomes the critical technical issue.

It is sometimes advantageous to rebroadcast the jamming waveform to make the EA appear as something from other than a point source. For DDS based systems it is a simple matter to repeat the EA. However, receiver based CM systems must either capture and then replay the signal or recirculate the signal and tap off the RF at appropriate intervals. The former process is implemented in digital radio frequency memory (DRFM) devices, while the second technique is based on tapped delay lines which may use acoustic, microwave or optical technologies. Most on-going research and emerging self-protection jamming systems are DRFM based.

Coherent jammers whether DDS, DRFM, or delay-line take full advantage of the signal processing of the radar. The two major gains are in pulse compression and pre-detection integration where the phase of the radar return is important. Pulse compression gain is often 20 dB (decibel) and pre-detection integration gain can be of the same magnitude. Non-coherent waveforms therefore must have additional 40 dB transmit power to make up the difference. Sidelobe jamming using any jamming technique, coherent or non-coherent must make up the difference between mainlobe and sidelobe levels with transmit power. With well-designed antennas, this can be as much as 40 dB or more. While this may seem great, it should be considered in the context of the type of radar being jammed. For example, surveillance radars are designed to detect small targets at long ranges so they have a significant dynamic range on receive. Here a positive J/S (jam-to-signal ration) may not be necessary to disrupt accurate surveillance through sidelobe jamming.

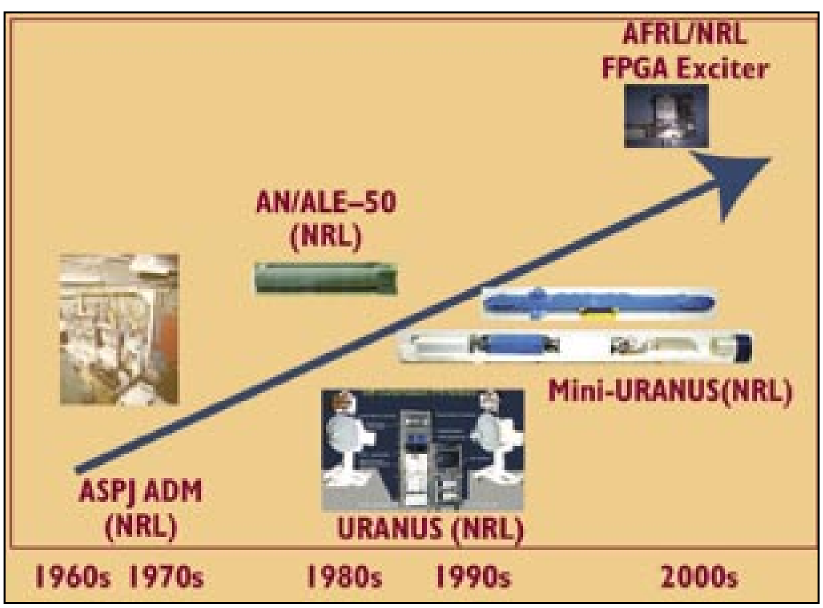


Figure 2. Technologies developed in airborne coherent EA.

Current research

The Naval Research Laboratory is seeking to develop EA waveforms that mimic target returns in time, frequency and polarization to the fidelity of the radars. Obviously imaging radars with a one meter resolution require significantly more fidelity in the jamming waveforms than do surveillance radars with 300 meter resolutions, however both types are better jammed with an RF image of the appropriate fidelity. Originally large heavy DRFMs were used to generate coherent EA. These devices use considerable power and are quite bulky and complex. Advances in programmable logic devices, in particular field programmable gate arrays (FPGAs), allow DRFM capability to be delivered in a device the size of your hand. Frequency and range modulations can be added to the jamming signal by the FPGA as well. Figure 2 depicts the progression in coherent jamming as illustrated primarily by NRL devices. In the 1970s, NRL, with Westinghouse, built the advanced development model for the AN/ALQ–165. The AN/ALE 50 towed repeater decoy was also in development at that time. In the late 1980s the Universal Radar Nulling System (URANUS) imaging radar jammer test bed was built and demonstrated using analog delay lines. A smaller version of the URANUS, the DRFM based Mini-URANUS, was developed to demonstrate coherent jamming against coherent surveillance and target tracking radars. In cooperation with the Air Force Research Laboratory (AFRL), a version of the Mini-URANUS based on FPGA technology is in development.

This FPGA jammer will be suited for small stand-in jammers. AFRL is also sponsoring the development of a Lightweight Modular Support Jammer (LMSJ) that will be a fully coherent DDS/DRFM based jammer whose receiver, transmitter and all intervening control, memory, and modulator logic will be in the pod. LMSJ will give an end-to-end, self-contained, jamming capability in a single pod suitable for mounting on multiple platforms.

Stand-in jamming (SIJ)

One result of the Airborne Electronic Attack Analysis of Alternatives is the recognition of the value of stand-in jammers on unmanned aerial vehicles (UAVs). These jammers could be hosted on slow loitering small UAVs, forward fired from an attacking aircraft as commanded by the pilot cued from on-board or off-board sources, or delivered by another, larger UAV such as a UCAV. A network of stand-in jammers could be developed using all three types of UAVs. For close-in EA, the UAV size is limited since avoiding detection is important, or at least presenting such a small acoustic, radar or optical signature that effective surface to air attack is difficult. Limiting the vehicle size means the available prime power to operate the jammer is limited also, hence the jammer transmitter power needs to be low. This power requirement necessitates coherency for the jammer. For robustness and flexibility, the jammer should have a DRFM based exciter to generate effective modulation schemes. Because of their small size, programmability and remarkable functionality, FPGAs are ideal technologies for this application.

As important as the emerging DRFM and FPGA based hardware, is the research into software control of jammers. Network centric warfare is predicated on adaptive sensors and affectors. In the EA domain, especially when envisioning many stand-in jammers acting in concert, jamming efficiency and effectiveness will hinge on the ability of individual stand-in jammers to respond to a changing RF environment. Artificial intelligence (AI) techniques are being brought to bear on jammer control as well as UAV autopilots. Efforts are underway to demonstrate the use of genetic programming to optimally place and control stand-in jammers for a given mission. The goal is to have the jammers not only respond to the changing environment, such as a pop-up threat or unexpected radar sites, but to do so in a near optimal fashion.

Conclusion

The next frontier for EA is the stand-in jammer. UAVs of all sizes are being developed that can house EA payloads. To overcome the processing gains that modern coherent radars achieve, we believe that coherent jamming, as opposed to simple noise sources, will be needed for effective stand-in jamming missions. The convergence of UAV development, digital memory and programmable logic devices, and advanced command and control algorithms provide the opportunity to inject coherent jamming into the electronic battlespace. Fully coherent jamming is the best method for radar soft-kill and thus enhancing attack aircraft survivability. ■

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T. Christopher Moss heads research on coherent countermeasure systems and integrated countermeasure systems. At the Aerospace Electronic Warfare Systems Branch, Tactical Electronic Warfare Division, Naval Research Laboratory, Washington, DC, he has worked in airborne EA for twenty-two years formulating, investigating, and demonstrating EA concepts. Mr. Moss is the current chairman of the RF Countermeasures Committee (RFCM) of the Technical Panel for Electronic Warfare (TPEW) and is a member of the NATO SCI–140 on Vulnerabilities of Imaging Radars to EA. He earned a BSEE from Syracuse University 1981. For more information, please contact him at—

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Directed Infrared Countermeasures for Tactical Aircraft

■ by Mr. Kenneth A. Sarkady and Dr. Hugo A. Romero

Shoulder-fired surface-to-air missiles (SAMs) are widely proliferated, inexpensive, and easy to conceal. In its annual report to Congress, the State Department reports the sale of 758 SAM systems to Near-East nations alone over the three-year period 1998–2001. A burgeoning market has now emerged making these weapons systems available to numerous insurgency and terrorist organizations. In November 2002, for instance, al-Qaida claimed responsibility for firing two SA–7 SAMs at an Israeli civilian aircraft during take-off in Kenya. More than any other, this incident raised concern throughout the Western world about the safety of civilian air travel. By contrast, military aircraft have long been susceptible to infrared (IR) guided SAMs and air-to-air missiles (AAMs). Results of a worldwide survey, shown in Figure 1, indicate that these missiles are responsible for well over 50 percent of all military aircraft losses. These three factors (i.e., their availability, price, and record of performance) make IR SAMs and AAMs an emerging weapon of choice.

TADIRCM

Over the years, the U.S. Navy has sponsored the development of a number of key technologies needed to provide Navy tactical aircraft and Marine Corps fixed and rotary wing platforms with covert, highly effective protection against even the most advanced IR-guided SAMs and AAMs. Sponsored by the Office of Naval Research and NAVAIR, the Naval Research Laboratory (NRL) has successfully assembled these technologies into the Tactical Aircraft Directed Infrared Countermeasures (TADIRCM) system. The system uses a suite of two-color IR sensors to passively detect the afterburning signature of a threat missile plume. Judicious choice of the operating wavelengths and system optics allows for the detection of these missiles' boost ignition signature well beyond their maximum kinematic launch range, even if operating in severe (measured) urban clutter conditions. An onboard digital processor provides the system with the capability to autonomously cue a directed jamming system that can establish a precision track on the approaching missile using a high-resolution IR camera. A modulated laser beam is then used to create false targets in the missile seeker causing optical breaklock (OBL) of the targeted platform. The use of an on-board laser provides for essentially unlimited platform protection. This constitutes an extremely desirable capability as the protection currently available to Navy platforms is severely limited by the number of countermeasure assets that can be carried on-board.

Live Fire Testing of the TADIRCM system

The TADIRCM system components are shown in Figure 2(a). These components were installed on an aircraft pod mounted on a QF–4 drone aircraft as is illustrated in Figure 2(b). System performance was tested on the QF–4 beginning in the spring of 2001 and culminated in November 2001 resulting in OBL in each one of an advanced SAM and AAM fired against the QF–4. The ability of the TADIRCM system to rapidly declare the onset of boost ignition resulted in very large miss distances in each of these live-fire exercises.

Confidence in the capabilities of the TADIRCM system was established in a number of intermediate tests conducted at the Navy's weapons test range in China Lake, California. To begin with, the ability of the system to reliably declare a threat missile was conducted (frequently) with the help the of the Optical Beam Evaluation and Wander (OBEWAN) instrument. This instrument generates an IR signature whose intensity, spectral content, and temporal properties closely resemble NRL's large database of exploited threat missile signatures. For this portion of the test, the OBEWAN signature needed to correspond only to that seen in the missiles' boost motor ignition phase.

Testing of the TADIRCM system then focused on evaluating its ability to deliver laser beam energy at the desired target while in-flight on a tactical platform. To this end, a number of seekers of the two selected live-fire missiles were placed in the vicinity of the OBEWAN instrument. Flying in a racetrack pattern, TADIRCM was repeatedly stimulated and the OBEWAN instrument was used to measure the on-target spatial and temporal properties of the laser beam. Simultaneously, the missile seeker electronics were monitored to determine OBL of the QF–4 target. This portion of system testing was very successful resulting in OBL of all tested seekers in every pass of the QF–4. In all cases, OBL was measured to occur on very fast time scales. This portion of the test also confirmed the favorable power levels and spatial properties of the laser beam at all launch ranges of tactical interest.

At this point, all checks of system performance were successfully achieved and testing proceeded by firing one advanced SAM and AAM at the drone QF–4. In each case, the missiles were equipped with special telemetry packages that monitored the internal state of the missiles' seeker electronics. Timelines for all of the system events (missile launch, missile threat declaration, time to slew and establish track by the fine pointer-tracker, time to deliver laser energy, and time to OBL) were carefully monitored and cross-correlated. In each case, system performance was excellent and corresponded closely to that established in all preliminary tests of the TADIRCM system. The ability to rapidly declare the onset of boost motor ignition resulted in timelines for laser energy on target prior to the missile achieving a guided proportional navigation flight pattern. Hence, the miss distances in each of these tests well exceeded those needed for aircraft self-protection. In the case of the AAM, this test constitutes the first time that such a threat has been successfully countered in a live-fire scenario. For completeness, we present in Figure 3 a brief graphic illustration of a TADIRCM live-fire engagement.

Conclusions and future direction

The Navy has successfully tested TADIRCM in a live-fire environment on a QF–4 drone aircraft. TADIRCM has been shown to detect SAM and AAM IR-guided missiles well beyond their maximum kinematic launch range. The system was also shown to be capable of delivering the required jamming laser energy while in-flight on a tactical platform, resulting in optical break lock on very fast time scales. The results gathered in this test have engendered a great deal of interest to establish a production program for this system. Current planning calls for the production of several pod units to be delivered to the Fleet in order to establish configurational and operational procedures for this electronic warfare system.

At present, upgrades envisioned for this system include coupling to the Digital Terrain Elevation Database (so as to enable rapid, autonomous

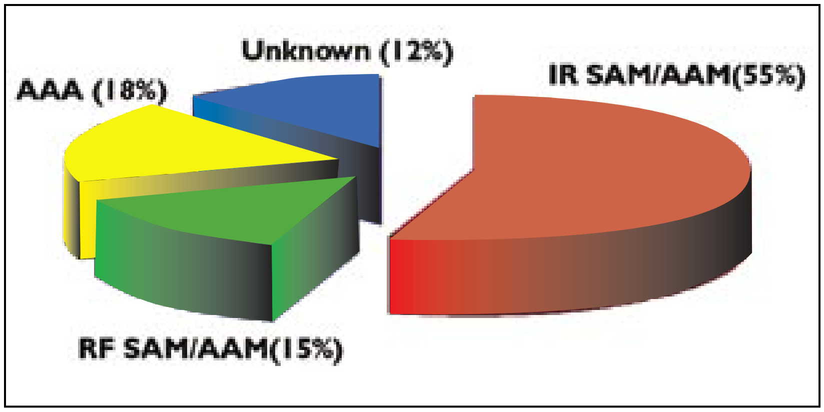

Figure 1. Survey of worldwide military aircraft losses (1991–1998).

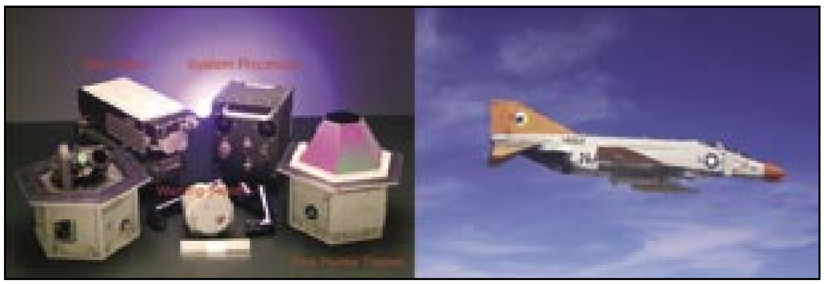

Figure 2. (a) The TADIRCM system components; (b) TADIRCM installed on a pod on the drone QF–4.

Figure 3. The chase plane view of TADIRCM at work. Note the missiles' dive trajectory effected shortly after jamming.

retaliatory action) and evaluation of the fine pointer tracker for IR search and track functions. ■

Kenneth A. Sarkady is the TADIRCM project engineer since the early 1990's. Hugo A. Romero, D. Merritt Cordray, James G. Lynn, and Roger M. Mabe are NRL staff scientists responsible for developing the system software, supporting hardware development activities, and planning and executing system testing. Keith Strothers, Joseph A. Schlupf, and Richard C. Cellucci provide contractor support to the project.

Army Advanced Infrared Countermeasure Flares

■ by Mr. Robert J. Ritchie

Pictured above—Navy HH–60 helicopter shoots flares in reaction to a simulated attack from the ground during the Desert Rescue excercise, June 26, 2002. Photo by SSGT. D. Myles Culen, 1st Combat Camera

The U.S. Army has recently Type Classified Standard two new Infrared (IR) Countermeasure Flares to enhance aircraft survivability against the most advanced IR guided missiles in the field. The new decoys, designated as the M211 and M212 Aircraft Countermeasure Flares, were developed under the Advanced Infrared Countermeasure Munition (AIRCMM) Program as a part of the Suite of Integrated Infrared Countermeasures (SIIRCM).

The M211 and M212 Aircraft Countermeasure Flares will supplement the M206 Aircraft Countermeasure Flare (see Figure 1) currently utilized by Army Aircraft and will provide protection against advanced air-to-air and surface-to-air IR weapon systems. The AIRCMM solution as it is referred to consists of using these three flares in a timing and sequence that has been optimized, through flight testing and computer simulations, to decoy the threats. The advances in these weapons such as development of improved counter-countermeasure techniques and decoy rejection capabilities, have made it necessary to continuously develop new countermeasures to maximize the survivability of aircraft and crews in their designated mission environment.

Simple improvement of the existing M206 was considered but found to be ineffective since a new decoy configuration and chemical composition are required to attain similarity between the aircraft signature and the flare signature. Testing on rotary-wing platforms (MH–60 and MH–47) has shown dramatic increases in effectiveness against modern, multi-spectral missile threats when compared to standard U.S. Army M206 flares used alone.

The new countermeasures were designed to be compatible with standard Army and Air Force dispensers that use 1x1x8 inch decoys, as well as the Improved Countermeasures Dispenser (ICMD) being developed for the Advanced Threat Infrared Countermeasure (ATIRCM) Program. A programmable dispenser, such as the ALE–47 system or ICMD, is required to use the optimized dispenser pattern developed in the AIRCMM program. The AIRCMM solution will be used on the Black Hawk, Chinook and Apache Aircraft.

Background

The program has its roots in an Army and JASPO funded Tech Base program to demonstrate feasibility of IR compositions that are spectrally matched to aircraft signatures. This research demonstrated the use of new formulations and technologies for spectrally matched decoys. This effort then transitioned to the Project Manager for Aircraft Survivability Equipment, now Product Manager for Infrared Countermeasures (PM–IRCM), for the Demonstration-Validation, and then Engineering Manufacturing Development phase.

The AIRCMM development program was managed and funded by PM–IRCM located in Huntsville, Alabama. The U.S. Army Armament Research, Development and Engineering Center (ARDEC), is the materiel developer and technical advisor to the design contractor jointly with PM–IRCM. Both AIRCMM and ATIRCM are improvement programs for ASE systems being developed under the SIIRCM Program. The AIRCMM is the countermeasure munition that will be used in the ATIRCM package.

The flare development effort benefited from the Office of the Test Director (OTD), Center for Countermeasures (CCM) IR Band IV test program that allowed flight-testing of prototypes against the most advanced captive IR guided threat systems. This series of tests, along with computer modeling, allowed for an iterative development of the decoys. The computer simulation used in the decoy development was the Digital Seeker and Missile Seeker (DISAMS) developed by Georgia Tech Research Institute (GTRI). This program allowed the flare designers to evaluate changes in individual decoy parameters, as well as the timing and sequencing of the new decoys. These developments were then tested in captive IR seeker tests from aircraft to confirm the results. Modeling analysis included an optimization analysis of dispenser orientation. This led to changing the dispenser angle on Army Helicopters that demonstrated increased effectiveness in field trials.

Figure 3 shows the Advanced Infrared Countermeasure Munition decoying five infrared missile seekers. The circles and crosses represent the Infrared seeker track points. An MH–47E Helicopter is dispensing the decoys.

Decoy descriptions

The M211 Aircraft Countermeasure Flare is a Special Material (SM) decoy flare produced to fit within the standard M206 1x1x8 inch form factor. SM is a high surface area metal foil which rapidly oxidizes when exposed to oxygen. The rapid oxidation of the material produces an extended cloud which emits infrared energy. The M211 is produced by Alloy Surfaces Company, Chester Township, Pennsylvania.

The M212 is a spectrally matched decoy flare that also fits within the standard M206 flare form factor. It has a weighted forward closure that improves the aerodynamics of the decoy. The pyrotechnic composition has been optimized to provide a match to IR signature of the aircraft. The M212 is produced by ATK Thiokol Propulsion, Brigham City, Utah.

Deployment and use

The AIRCMM solution has been utilized in the field on MH–47 and MH–60 Helicopters by the160th Special Operations Aviation Regiment since early 2000. Most recently the M211 and M212 flares were used to protect those aircraft during combat operations in Afghanistan. The aircrews reported the countermeasures were effective in defeating multiple missiles fired at them.

An urgent material release of the flares was completed in January 2003 to the 101st Airborne Division. They will be used to support Operation Enduring Freedom efforts and follow-on missions related to that.

The Air Force has adopted the AIRCMM solution for use on the HH–60 Combat Search and Rescue helicopters and were first used during Operation Northern Watch. The HH–60 dispensers have been upgraded and reoriented to the optimized angle. The AF has also begun use of the M211 Flare on C–130 Transports as well as AFSOC AC–130 Spectre Gun Ships.

Future efforts

The technologies developed for aircraft countermeasures have the potential to protect ground vehicles from smart weapons. Concepts are being explored to adapt these countermeasures to protect the Brigade Combat Team Stryker Vehicle and the Future Combat System.

As the threat evolves, so will the development of improved countermeasures and techniques to protect aircraft and its crew. Research is underway to counter the next generation of IR guided missiles with imaging seekers. ■

Robert Ritchie is an Engineer employed at the U.S. Army Tank-Automotive and Armaments Command (TACOM) Armament Research, Development and Engineering Center (ARDEC) located at Picatinny Arsenal, New Jersey. He holds a B.E. degree in Chemical Engineering from Stevens Institute of Technology. He has been working in the expendable decoy area for 15 years and is currently the Project Leader for the Advanced Infrared Countermeasure Munition (AIRCMM) Program. He also is a member of the JASPO Susceptibility Subgroup and the JDL–TPEW EO/IR Expendables committee.

Figure 1. AIRCMM Solution.

Figure 2. Chinook launching countermeasure flares.

Figure 3. IR Seekers being decoyed by AIRCMM countermeasures.

Dr. Kristina Langer

Young Engineers in Survivability

by Mr. Dale B. Atkinson

The Joint Aircraft Survivability Program Office (formerly the JTCG/AS) is pleased to recognize Dr. Kristina Langer as our latest Young Engineer in Survivability. Kristina is one of the bright young engineers in the Air Force Research Laboratory who has greatly contributed to the Joint Aircraft Survivability Program and the survivability design discipline as a whole.

After graduating summa cum laude with a B.S. in Civil Engineering from Ohio State in 1987, Kristina took a job as a structural engineer with Korda/Nemeth Engineering in Columbus, Ohio, where she designed reinforced concrete, structural steel, masonry, and wood support systems for commercial, institutional, and government facilities. During this time, Kristina participated in projects from the conceptual architectural phase through final construction, which was great experience. Kristina was selected as an Air Force Office of Scientific Research Summer Research Fellow in the summer of 1990, which introduced her to the R&D organizations at Wright-Patterson Air Force base in Dayton, Ohio. Kristina continued to work on her masters during this time period and graduated from Ohio State with a Masters in Civil Engineering in 1991.

Following graduation, Kristina took a job with the Air Force Research Laboratory, where she worked in the Aircraft Survivability and Safety Branch doing research on structural damage mechanisms associated with catastrophic failure. She developed and conducted an experimental research program to study ballistic impact effects on laminated composite panels. As one of the Air Force's brightest young engineers, Kristina was selected for the Air Force Palace Knight Program in 1991. The Palace Knight Program provides a fellowship that allows a person to conduct research while continuing to work towards a Ph.D. Under this program, Kristina developed a nonlinear finite element program to study steady-state crack propagation in finite deformation elastic materials and quantified dynamic crack propagation phenomena, including crack surface roughening, and nonlinear stress localizations, using perturbation techniques and finite element analysis. Kristina received her Ph.D. in Mechanical Engineering from Stanford University in 1998.

After graduation, Kristina returned to the Air Force Research Laboratory where she extended her finite element research to address aircraft damage resulting from high-speed missile impacts. As part of this initiative, she helped to plan, coordinate, and conduct the JTCG/AS-sponsored National MANPADS Workshop, the first ever U.S.-wide meeting of aircraft vulnerability experts specifically convened to address the MANPADS threat. During this time, she attended the Air Force Air Command and Staff College Seminar Program, graduating in June 1999, and the Air Force Squadron Officers School Civilian In-Residence Program, where she graduated with academic and writing honors in May 1999.

In August 1999, she became an Aerospace Engineer in the 46th Test Wing Aerospace Survivability and Safety Flight at Wright-Patterson AFB, Ohio, where she became a project engineer for survivability RDT&E programs to increase aircraft survivability against IR missiles, particularly Man Portable Air Defense Systems (MANPADS), and other anti-aircraft threats. Recognizing that an effective response to MANPADS would require the development of effective Joint Tactics, Techniques, and Procedures (JTTPs) in addition to technical hardware solutions, Dr. Langer was instrumental in conceiving, establishing, and gaining approval for the Joint Aircraft Survivability to MANPADS (JASMAN) Joint Test & Evaluation (JT&E) Feasibility Study sponsored by the Office of the Secretary of Defense. As the JASMAN Program Technical Director, Dr. Langer recognized that they needed to obtain Warfighter's inputs in planning and conducting the program in order for this program to be successful. As a result, she established and chaired the JASMAN Joint Warfighter Advisory Group (JWAG), which included pilots from all the major Service Commands and became a very effective group.

I personally observed Dr. Langer's interactions with the Warfighters at some of the JWAG meetings, and she obtained outstanding interest and support from these warfighters from all the Services. The yearlong JASMAN JT&E Feasibility Study successfully demonstrated the necessity and feasibility of evaluating and improving tactics, techniques, and procedures against MANPADS and had wide Warfighter support from all the Services. However, due to limited resources in the JT&E Program, JASMAN was not approved to continue as a three year Joint Test & Evaluation Program as proposed.

The recent terrorist use of MANPADS against an Israeli commercial aircraft in Kenya has renewed interest in a variation of the JASMAN program. Even though she changed jobs since the JASMAN JT&E Feasibility was completed, Dr. Langer continues to support and advocate this important program. (Editors Note: see related article co-authored by Dr. Langer on page 32 in this issue)

In July 2002, Dr. Langer moved back to the Air Force Research Laboratory where she is leading a team addressing structural integrity issues of low observable (LO) systems, with emphasis on exhaust washed structures. The goal of this program is to better understand the dynamic response of low observables (LO) applicable structural systems subjected to intense thermo-acoustic-vibrational loading, and to use this information to maintain susceptibility reduction (stealth) features without negative impacts to sustainability. This R&D involves nonlinear dynamic finite element analysis, thermal analysis, and combined thermo-acoustic-mechanical testing. Dr. Langer is also technical lead on an R&D effort to employ state-of-the-art finite analysis techniques to better understand ballistic impact, multiple impact damage, and blast phenomena, focused on the impact resistance of newly engineered hybrid composite structures. She is also the Team Lead for the Lean Certification of Aerospace Vehicles (LCAV) program whose goal is to develop integrated tools and techniques that will reduce costs and time associated with flight certification. Included in this effort are survivability related certification issues such as ballistic impact tolerance, LO, and fire protection issues.

In addition to the areas noted above, Dr. Langer has contributed to the survivability design discipline in a number of other ways. She has published a number of survivability related reports and made many presentations at symposiums, workshops, seminars, and other meetings which helped disseminate the results of her survivability research to the survivability community and the overall acquisition community. Dr. Langer was also one of the people who conducted a peer review of the second edition of Dr. Ball's *Survivability Textbook* last year, and according to Dr. Ball, "she did an absolutely outstanding job of finding bugs that no one else had found." The *Survivability Textbook* is being published by the American Institute of Aeronautics and Astronautics (AIAA) and will be out in the next few months.

Dr. Langer has been married to Keith Langer, a software engineer in Dayton, Ohio, since 1997. She is a volunteer at the world class Air Force Museum in Dayton, manning the 8th Air Force Control Tower and Nissen Hut several times a month, and also serving as a museum tour guide. It is with great pleasure that we honor Dr. Kristina Langer as our latest Young Engineer in Survivability.

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



Aim-Point Biasing

A Balanced Counter-MANPADS Concept

■ by Dr. David. J. Barrett, Mr. Greg J. Czarnecki, Mr. Nick Calapodas, Dr. Kristina Langer, and Mr. James Childress

In recent military conflicts, the highly mobile, hard-to-detect, and difficult-to-counter Man-Portable Air Defense System (MANPADS) threat has proven capable of generating numerous aircraft kills. Shoulder-launched MANPADS rank as one of the most effective and economical antiaircraft weapon systems in existence today. Rotorcraft are particularly at risk due to their slow speed and low altitude operations.

While the DoD and industry focus has been on high-tech susceptibility reduction measures such as active countermeasures and infrared suppression, these techniques are often costly and afforded to only a fraction of the fleet. And while flare countermeasures are low-cost and more widely distributed, they typically offer only short-duration protection against the MANPADS threat. Conversely, the vulnerability community has focused on damage resistance/tolerance associated with small randomly placed projectiles. The prospect of consistently surviving damage from a directed MANPADS missile hit is challenging indeed. To develop an economical approach to improving aircraft survivability against MANPADS, the JASPO has invested in four efforts that are collectively referred to as the MANPADS Aim-Point Biasing Thrust.

The JASPO MANPADS Aim-Point Biasing Thrust strikes a cost-effective balance between susceptibility and vulnerability reduction. Modeling and simulation (M&S) tools are used to develop this balance. The thrust is geared for legacy military and commercial aircraft and assumes that: 1) large IR signatures allow MANPADS lock-ons beyond the missile's kinematic range, 2) inadequate IR countermeasures are available for long duration protection, and 3) the probability of kill is high, should a hit occur on a flight-critical system (see Figure 1).

With the goal of drawing incoming missiles away from critical systems and toward the aircraft's least-vulnerable area (see Figure 2), aim-point biasing requires subtle modification of the aircraft's signature (a susceptibility issue) in order to reduce vulnerability. Concept viability hinges on satisfactory answers to the following four JASPO questions—

1. Do MANPADS hit-points significantly affect the probability of kill (PK)?
2. Can hit-points be predicted with confidence in order to design a decoy system that biases hit locations toward least-vulnerable areas?
3. Can an aim-point biasing "field kit" be designed that is lightweight, low in cost, and does not significantly increase the aircraft's overall signature?
4. Will a deployed aim-point biasing system be proven effective against the IR MANPADS threat?

PK as a function of hit location

To answer the first question posed by the Aim-Point Biasing Thrust, the JASPO investigated PKs as a function of MANPADS impact location. The scope included several rotorcraft types to substantiate the value of controlling MANPADS hit-points

Figure 1. MANPADS hits near flight-critical subsystems can prove disastrous.

Figure 2. MANPADS hits near least-vulnerable areas are survivable.

as a rotorcraft survivability mechanism. Three impact locations were assumed for each rotorcraft: 1) a thermally-driven impact location, 2) a least-vulnerable impact location, and 3) a standoff impact location. Vulnerability assessment results for the three impact locations identified a general trend that rotorcraft vulnerability to MANPADS decreases when impact depart from the thermally-driven location and proceeds toward a least vulnerable standoff location. These results established the value of pursuing development of an off-board IR decoy.

Hit-point prediction credibility

The JASPO next addressed the second question posed in the Thrust—whether hit-points can be predicted with confidence. M&S hit-point prediction methods were subjected to a cursory evaluation where modelers predicted hit-points on a three-part IR target board with a large measure of success, thus verifying the credibility of MANPADS fly-out/endgame M&S solutions for simple target configurations (see Figure 3).

Decoy system design

To address the third question in this Thrust, the feasibility of achieving an acceptable IR decoy design, the JASPO is sponsoring the design and prototyping of a low-cost/weight aim-point biasing "field kit" for countering IR MANPADS. The kit, called "Fixed IR and Enhanced Survivability (FIRES)," is a hybrid protection system that incorporates both susceptibility and vulnerability reduction components. Consisting of an IR decoy and localized aircraft hardening measures, FIRES is balanced and tuned for specific aircraft platforms via M&S. A detailed susceptibility analysis is required to insure that the IR decoy is the most attractive IR source on the air vehicle. An approaching missile can then be drawn to the location of the decoy. Other design goals include a total system weight of less than 20 pounds, field installation/removal times of less than eight hours, and a total per-unit cost of less than $40,000.

Two deployment options are currently under consideration. In its simplest form, the decoy would be directly mounted to the aircraft hull (using advanced bonding technology) at a pre-determined least-vulnerable location. While this configuration would not necessarily deter a MANPADS impact, it would improve the survivability of fixed-wing vehicles. The other deployment option, believed particularly suitable for rotorcraft application, considers that the decoy will be mounted on a standoff device, such as a fixed or deployable rod. In this configuration, the potential for air vehicle damage is greatly diminished. Each configuration will provide continuous protection in excess of 30 minutes with on-demand ability to mask/unmask. A prototype FIRES kit will be available for rotorcraft testing in late 2003.

Validation testing

Culmination of the MANPADS Hit-Point Biasing Thrust will be achieved by providing an answer to the final question of whether a hit-point biasing system can provide aircraft protection against the IR MANPADS threat. While decoy validation remains on-hold due to funding limitations, decoy effectiveness will be determined by: 1) missile attraction to the decoy as opposed to the rotorcraft, and 2) rotorcraft survival if the decoy is hit and the warhead detonates. Given an effective and validated decoy system, a follow-on rotorcraft test is proposed with the decoy removed. The purpose of this test—effectively a baseline for the first test—is to clearly and emphatically demonstrate the value of having a decoy system on-board. Once the FIRES decoy system is demonstrated effective, aim-point biasing can be considered for legacy air vehicles requiring economical MANPADS protection. ■

Figure 3. MANPADS fly-out into elevated IR target board for hit-point determination and validation of M&S solutions.

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Integrated Survivability Assessment

■ by Mr. David Hall

The operational test and evaluation (OT&E) community is required to perform an assessment of the effectiveness and suitability of air weapons systems from the standpoint, among others, of survivability. In addition, the OT&E community is required by law to perform live fire test and evaluation (LFT&E) of the vulnerability of covered air weapons systems. These two assessments are historically done separately, by different test communities, at different times, using different metrics. However, vulnerability of the system is a component of survivability, which makes an overall survivability assessment during OT&E difficult without incorporating the results of LFT&E. Combining LFT&E and OT&E issues in an integrated fashion for a true survivability assessment is critical to a valid OT&E program.

This article describes the results of a project that was conducted by SURVICE Engineering Company with support from Booz Allen Hamilton, Inc. for the Joint Aircraft Survivability Program Office (JASPO) at the request of the Director, Operational Test and Evaluation (DOT&E). The project's goals were to—

- Develop a "checklist" of survivability features and objectives that should be evaluated for any air vehicle system.
- Develop a hierarchy of metrics for survivability evaluations in combined OT&E and LFT&E; these metrics would be the means to evaluate the checklist.
- Describe an ISA process showing how those metrics could be measured today, making use of existing (JASPO) modeling and simulation (M&S) and tri-service test range assets.
- Identify deficiencies in and develop plans to improve the ISA process, the types and quality of test range data available to the process, and the M&S available to support the process.

What's a survivability checklist?

Survivability depends on susceptibility, vulnerability, personnel survivability and recoverability factors, the range and breadth of proposed missions, scenarios and threat levels, the availability of required support assets within those missions, and a definition of what level of survivability is "acceptable" for the platform. A checklist for DOT&E combined survivability assessments should help evaluate air weapons systems characteristics that relate to elements in the threat "kill chain," or the threat systems' ability to acquire, track, intercept and kill the air vehicle (see Figure 1, [1]). A generic checklist for use in survivability OT&E has been developed that describes various techniques for "breaking" the kill chain at each step in the process.

How do we measure systems using the checklist?

A set of metrics have been defined that measures the effectiveness or measures the performance of the system for the various elements of the survivability checklist. The numerical values for those metrics may be obtained via testing, modeling or a combination of the two. The primary ISA metrics are shown in Figure 2; additional supplementary metrics can be found in the body of the report describing the ISA process. [2]

These metrics were selected because they are measurable and testable at some level. Sensitivity analyses should be conducted for these met-

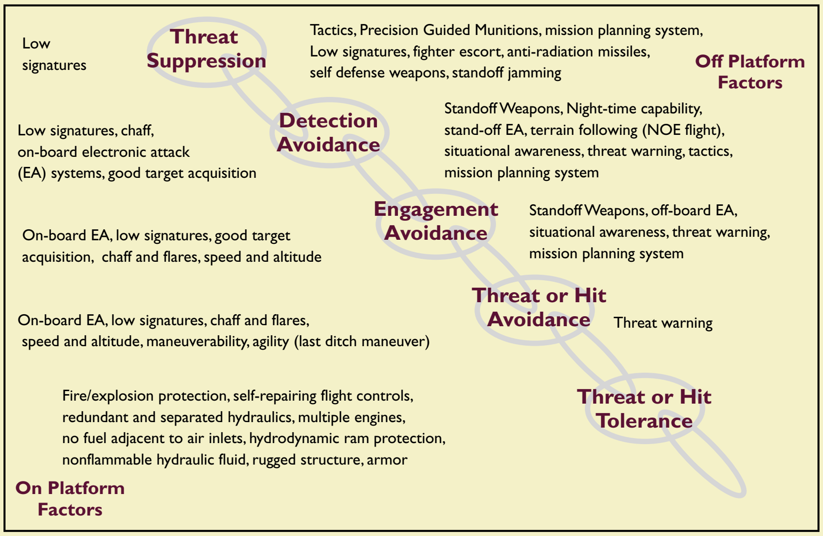

Figure 1. Threat "Kill Chain."

rics to determine how they vary with changes in air vehicle design parameters, threat parameters, and environmental factors (both natural and man-made). These sensitivity analyses will help determine those parameters which should be carefully measured during a test (those parameters that are driving factors in the value of the metric), as well as help to define the operational test matrix for the system under test. A cross-reference between the checklist and the metrics is shown in Table 1.

What's a vignette?

In order to evaluate a system against the checklist, it will be necessary to address the likely scenarios and missions for the system under test. No system can be evaluated under every condition, nor should it necessarily be expected to survive in every possible situation. What a combined survivability OT&E and LFT&E assessment needs to do, then, is to identify a minimum set of operationally significant situations in which to test the system's survivability. The assessment process can be simplified by the use of "vignettes"—a single mission portion of a campaign. A vignette is a two-sided situation that encompasses the air vehicle's employment conditions. It describes starting and ending conditions, the number of air vehicles involved and their relationships, tactics and operating conditions, targets and locations, natural and operational environments (terrain, weather, dust, smoke, etc.) and any other operationally significant factors. The vignette forms the basis of the integrated survivability assessment.

The list of vignettes that will be evaluated should be selected through negotiations between the system acquisition program office, the appropriate Service OT&E agencies,

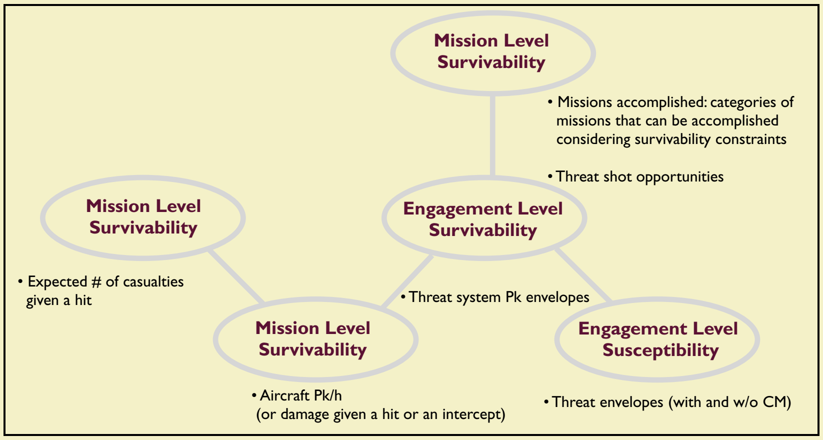

Figure 2 Primary Integrated Survivability Assessment (ISA) Metrics.

Links in the Threat Kill Chain	ISA Metrics	Potential Survivability Enhancement Features Along the Kill Chain
Mission Survivability Missions	Missions Accomplished; Robustness	All features combine to support mission-level survivability
Threat Suppression	Threat Shot Opportunities; Situational Awareness (number, timeliness and accuracy of threats detected)	Tactics, precision guided munitions, mission planning system, low signatures, fighter escort, anti-radiation missiles, self defense weapons
Detection Avoidance	Threat Detection & Acquisition Envelopes	Standoff weapons, night-time capability, on-board electronic attack (EA) systems, stand-off EA, low signatures, good target acquisition, terrain following (NOE flight), situational awareness, chaff, threat warning, tactics, mission planning system
Engagement Avoidance	Threat Tracking Envelopes; F-Pole, A-Pole, E-Pole; ECM Effectiveness	Standoff weapons, onboard EA, off-board EA, low signatures, good target acquisition, situational awareness, chaff and flares, threat warning, speed and altitude, mission planning system
Threat or Hit avoidance	Threat Intercept Envelopes; ECM/IRCM Effectiveness	On-board EA, low signatures, chaff and flares, threat warning, speed and altitude, maneuverability, agility (last ditch maneuver)
Threat or Hit Tolerance	Threat System Pk Envelopes; Aircraft Pk/h; Component Pk/h; VA; List of Vulnerable Components; Expected # of Casualties Given a Hit; Hit Locations on Aircraft	Fire/explosion protection, self-repairing flight controls, redundant and separated hydraulics, multiple engines, no fuel adjacent to air inlets, hydrodynamic ram protection, nonflammable hydraulic fluid, rugged structure, armor

Table 1. ISA Metrics and the ISA Checklist

		Somalia UrbanUrban	NEA Forest	SWA Desert	AFGHAN Mountains	Example weighting factors
Attack Helo Operations						
	CAS	X	X	X	**X**	10
	Battlefield Interdiction		**X**	X	X	10
	Air Combat		**X**	X		5
	Air Mobile Escort	**X**	X	X	X	10
	CSAR–Escort		**X**	X	X	5
AIR CAV						
	RECCE	X	**X**	X	X	30
	SCREEN	X	X	**X**	X	20
	Target Acq	X	**X**	X	X	10
Take Off/Landing		X	X	X	**X**	100
X = Most stressing Scenario for each Mission	Driving Factors	Close engagement range, hard to find bad guys	IADS, bad wx, hard to find bad guys, RF threats, MANPADS	Flat Terrain, Clear Weather, CB threat	High altitude, Terrain	

Table 2. Helicopter mission/scenario vignettes

and DOT&E. The vignette matrix provides a framework for developing the combined survivability OT&E and LFT&E strategy, since it identifies which test conditions will be evaluated during the OT&E program using the metrics in Table I. Test plans can be developed to maximize the number of vignettes tested, while minimizing the cost to the program. It also provides a roadmap for the use of M&S in support of combined OT&E and LFT&E. Several programs have taken a similar approach for not only OT&E test planning, but for developing requirements and evaluating compliance with specifications. Recent examples of these programs include the Joint Strike Fighter (JSF) and AIM-9X (for whom each launch condition represents a "mini-vignette."

Table I shows how the ISA metrics can be used within the checklist to evaluate survivability features of the system under test. The metric "missions accomplished" should be evaluated for all of the scenario vignettes that represent the mission space for the system under test. By evaluating the system in a wide variety of representative vignettes, the OT&E and LFT&E assessment can measure the "robustness" of the system under varying threat, scenario and mission conditions. The vignettes should not just represent the primary missions for the vehicle under test, but should also represent the variety of missions and combat situations that might be anticipated during the lifetime of the system.

Let's see an example

In order to examine the ISA process more fully, we evaluated several notional sample cases. In an attempt to "cover the waterfront," we selected three different types of aircraft, with correspondingly different types of missions to perform: a transport aircraft, a fixed-wing tactical aircraft, and a helicopter. The objective of these notional cases was to perform a "mental experiment" to see whether the metrics and the evaluation process we have proposed is suitable to evaluate the survivability (and vulnerability, in an LFT&E sense) of each of the aircraft types.

For these notional cases we postulated a number of potential hypothetical scenarios, and identified a set of missions that might be performed within each of those scenarios. The idea was to select a subset of the mission/scenario combinations to develop vignettes that sufficiently represent the mission space, stress the system's survivability features, and provide a selection scheme for test events, without placing an onerous burden on an OT&E program. We then described how the metrics in Table I would be evaluated using a combination of M&S and T&E resources. [2] A program might decide to use M&S to evaluate the complete set of vignettes that represent the entire mission/scenario space, and only test a small subset; the examples show how the program might go about deciding which subset to test (and which subset to model, if the entire set of vignettes is not evaluated).

For example, we identified a number of missions for a multi-purpose armed reconnaissance helicopter. We then selected scenarios that represented a cross-section of notional employment for such a platform. We picked a subset of the 36 possible mission/scenario combinations shown in Table 2 for evaluation by screening out redundant situations from a survivability standpoint. However, that screening process only eliminates 4 of the mission cases, leaving 32 vignettes with something unique about each of them. A real program may wish to spend more time sorting out which of those 32 combinations are really required for a complete assessment. In this case, the program may want to restrict its evaluation to those larger "bold X" boxes in the matrix that represent the most stressing scenario for each mission, which still leaves 9 vignettes to assess. And the program may want to argue that certain missions should be more highly weighted than others. Judicious test planning may allow the program to combine a number of vignettes into just a few test cases.

The driving factors in each scenario identify those issues that should be addressed in the test and analysis program for each vignette in that scenario. For each vignette, there should be a number of tactical variations that are evaluated to determine the effects on survivability of assumptions about threat density, location, tactics, blue resources available, etc. That is, each vignette is comprised of at least several, and possibly many tactical situations that may stress the system under test.

So where are we?

The process [2] for conducting an integrated survivability assessment of these vignettes makes maximum use of the existing test facilities and modeling and simulation resources available through the Joint Services. Based on the three notional examples (transport, TACAIR, helicopter) and upon examination and analysis of known M&S and test range limitations [3], a number of deficiencies in our ability to perform an integrated survivability assessment were identified. [2] For each deficiency we identified the impact on our ability to assess system survivability, and some mitigating actions that should be taken to remove or reduce the impact of that deficiency. These mitigating actions should form the basis of a plan to improve the ISA process, and should become the core of a plan of action for DOT&E and JASPO funding.

The status of this project was briefed to the JASPO Principal Member Steering Group and to Mr. Larry Miller, DOT&E/LFT at their January meeting. Mr. Miller commented that—

1. The ISA process needs to provide a strategy for integrating LFT&E lessons learned into acquisition programs during design, PDR and CDR, as well as support OT&E.

2. The Test and Evaluation Master Plan (TEMP) as we know it may be going away, so we need to ensure that the ISA process applies to new ways of doing T&E business.

3. We need to package the ISA process in such a way that Service OT&E activities will pick it up and use it.

4. We need to consider how spiral development is or is not supported by the ISA process.

5. We need to get Program Managers involved in development of the ISA process, and we will need to get requirements for ISA into RFPs.

What's next?

Follow-on activities needed (in FY03) include—

- Brief the Service OT&E agencies and DOT&E on the proposed ISA process and follow-on activities

- Develop detailed plans to mitigate the deficiencies identified in the ISA process, including—

  – M&S improvements (which will be coordinated with the Program Plan for the JASPO Survivability Assessment Subgroup)

  – Range Capabilities improvements [Conduct detailed assessments of test range capabilities to support ISA requirements, expanding on the initial studies described in this report; Coordinate required improvements with the ongoing DOT&E test range improvement process (CTEIP)]

- As a means to develop potential funding sources for required improvements, the JASPO should identify potential Program Objectives Memorandum (POM) Plus-Up requirements & opportunities, and develop issue papers to staff in the POM process.

The JASPO and DOT&E should take steps to institutionalize the ISA process for use by OT&E and LFT&E programs. As a first step, JASPO should select and negotiate with an example aircraft system to exercise the complete ISA process as a demonstration. Detailed procedures manuals should be written as reference material to support TEMP development. ■

David Hall currently serves as Manager of the Ridgecrest Operations of SURVICE Engineering Company, providing support to the Air Weapon Systems Survivability Support Contract from NAWCWD. Prior to retiring from Civil Service in January 2002, he served as the Chairman of the Methodology Subgroup in the JASPO and as Chief Analyst and Head of the Analysis Branches in the Survivability Division at China Lake, California. He holds B.S. and M.A. degrees in Mathematics from California State University at Long Beach, California.

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Improving Aircraft Survivability

to Shoulder-Fired Missiles

■ by Mr. Greg Czarnecki, Dr. Kristina Langer, and Mr. Jeff Wuich

Shoulder-fired surface to air missiles (a.k.a. man-portable air defense systems (MANPADS)) are in the possession of every major terrorist organization worldwide, yet the ability of U.S. military and commercial aircraft to survive this threat remains limited, particularly during take-off and landing. MANPADS are well known within military circles and are generally mitigated by flying high, or not flying at all. Airfield operations remain a point of concern. Terrorism, and the near-catastrophic MANPADS encounters with an Israeli commercial aircraft (Kenya, 28 November 2002), forced this threat into public light. Should any commercial aircraft encounter MANPADS over domestic soil, the result would likely prove catastrophic to the airline industry and to our nation's economy. A comprehensive, uniform, and proven set of aircraft-MANPADS survivability solutions is needed. Such is the goal of the proposed Joint Aircraft Survivability to MANPADS–Airfield Operations (JASMAN–AO) program. The objective of JASMAN–AO is to improve the survivability of come-as-you-are aircraft via non-hardware tactics, techniques, and procedures (TTPs). JASMAN–AO will consider each aircraft's available suite of survivability equipment, or lack thereof, and optimize survivability through a prescription of complimentary TTPs.

JASMAN–AO is a proposed follow-on to the recently completed JASMAN Joint Feasibility study (JFS)—a 15–month Joint Test and Evaluation (JT&E) effort led by the 46th Test Wing at Wright-Patterson AFB. Sponsored by the Office of the Secretary of Defense (OSD) and the Federal Aviation Administration (FAA), the JASMAN JFS successfully demonstrated the necessity and feasibility of evaluating and improving aircraft-MANPADS TTPs by generating YES answers to the following questions—

- Do major Service and joint Commands perceive a need to evaluate/improve the effectiveness of counter-MANPADS aircraft survivability TTPs under realistic conditions?
- Can a credible plan-of-action be established to evaluate/improve counter-MANPADS aircraft survivability TTPs?
- Are selected heavy-aircraft counter-MANPADS TTPs suitable for adaptation to commercial aviation?

With necessity and feasibility firmly established, JASMAN–AO now seeks to apply the JASMAN JFS plan-of-action to airfield environments. And while JASMAN–AO remains unfunded, this effort is poised to produce perhaps the nearest term and lowest cost means of improving military and commercial aircraft survivability to MANPADS. The JASMAN–AO team will work closely with its Joint Warfighter Advisory Group (consisting of aircraft operators and tactics developers) to consider each aircraft's suite of infrared countermeasure (IRCM) hardware while developing a complimentary set of TTPs. JASMAN–AO will—

1. Quantify the effectiveness of existing counter-MANPADS takeoff and landing procedures at major military and civilian airfields
2. Develop and quantify the effectiveness of safer alternative procedures, and
3. Identify deficiencies to support development and incorporation of new IRCM hardware.

JASMAN–AO will apply a well-established military infrastructure of test ranges, test aircraft, modeling and simulation (M&S) capabilities, and associated talent to assess and improve the survivability of come-as-you-are military and civil aircraft. Initial assessments will involve the TTPs of heavy military aircraft during takeoff and landing operations. Selected military TTPs will be assessed, and modified as appropriate, for potential application to commercial aircraft. Government-owned commercial aircraft will later be included for a more-direct assessment of TTP effectiveness on civil systems.

A model-test-model approach will be used to conduct the JASMAN–AO evaluation of TTP effectiveness. Digital and hardware-in-the-loop (HITL) M&S will generate initial estimates of time in the launch envelope (TLE), number of potential launches (NL), and number of hits (NH) for a nominal threat lay-down. Engagement scenarios of merit will then be selected for field testing under realistic conditions. TIme Space Position Information (TSPI) instrumented aircraft will fly through simulated threat fields consisting of Seeker Test Vans (STVs), Portable Air Defense Simulators (PADS), and Smokey SAMs (small rockets that generate visual and electro-optical queues) to generate actual measures of TLE and NL. Field test results associated with

PADS "launches" and aircraft time-position will then get handed back to HITL modelers to complete missile fly-outs under exact test conditions to generate more precise estimates of NH. HITL simulations will also be used to estimate hit locations. Because impact locations dictate aircraft survival, endgame missile approach vectors and hit locations will be fed into aircraft vulnerability assessment models for a determination of probability of kill, given a hit (PK/H). Using this model-test-model approach, JASMAN–AO will yield a toolbox of proven-effective TTPs, each ranked according to TLE, NL, NH, and PK/H metrics, and each designed to compliment and enhance the effectiveness of existing-hardware IRCM solutions.

All decisions concerning TTP selection will be left to major Commands and Homeland Security. As such, major Commands and Homeland Security will provide the "bridge" to achieving workable aircraft-survivability solutions by adopting a suitable set of TTPs in tune with that organization's threat-dependent CONOPS plan.

In summary, JASMAN–AO offers a proposed near-term, low-cost approach for improving heavy military and commercial aircraft survivability to terrorist missile threats. The approach involves blending TTPs with come-as-you-are aircraft hardware. JASMAN–AO will, for the first time, produce a well-coordinated, comprehensive, and uniform set of takeoff and landing procedures for aircraft protection both at home and abroad. The JASMAN–AO toolbox of proven-effective TTP solutions will be made available to major Commands and homeland security for consideration during generation of CONOPS plans. Adoption of these solutions will significantly reduce the potential for loss-of-life and dire effects on our nation's economy. ■

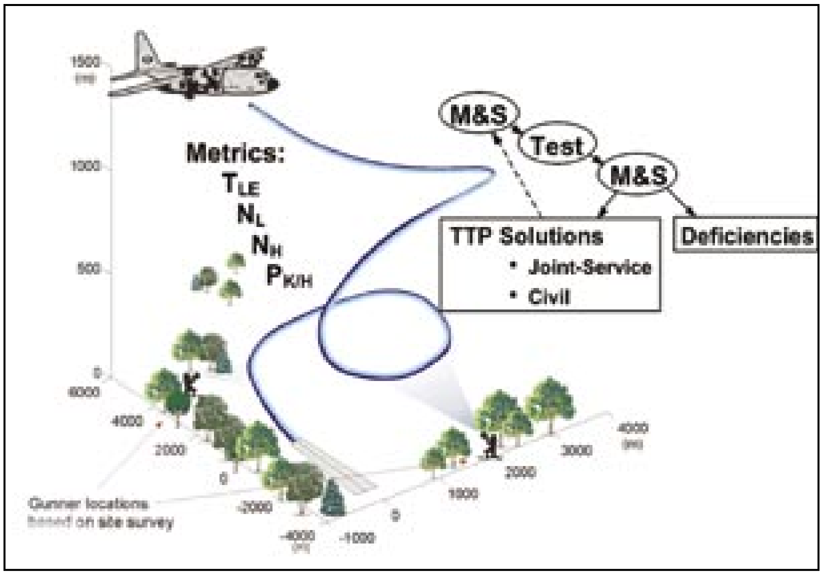

Figure 1. JASMAN–AO evaluation and improvement of TTP effectiveness.

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Joint Services Surrogate Seeker Development

■ by Mr. Matthew C. Lawrence

Countermeasure (CM) developers are constantly in need of representative seeker hardware to evaluate the effectiveness of their latest devices and techniques. Unfortunately, missile developers make every effort to protect emerging seeker technology to avoid exploitation by foes. While these efforts by both communities are justifiable, it has long been recognized that productive interaction between these groups can provide systems that are more robust than would be possible otherwise.

While this interaction would occur in a perfect world, reality typically proves differently. Exposing vulnerabilities of emerging technology before it is given a chance to mature can cause needed research and development to go unfunded for both missile and CM developers. Also, detailed design information on emerging threat system hardware is often lacking. This is particularly the case with imaging infrared (IIR) seeker technology. Compounding the issue is the flexibility available in reconfiguring the signal processing of an IIR seeker. Drastic variations in seeker performance can be obtained with little or no modification of seeker hardware and only minor changes to the software.

For CM developers, a solution to these problems is to build IIR surrogate seeker hardware that is flexible enough to be configured to represent emerging threat technology. This will allow multiple seeker configurations to be tested while also providing the ability to fine tune the surrogate seeker fidelity as more intelligence information is obtained. This also removes the political sensitivities of exposing the vulnerabilities of specific developmental missile systems. Missile and CM developers from all services benefit from technical interaction and exchange of technology.

Background

A recent example of the successful interaction of missile and CM developers was with the design and implementation of the Foreign Imaging Infrared Surrogate Seeker Threat (FIIRSST). FIIRSST was designed and integrated by the Missile Guidance Directorate of the Aviation and Missile Research, Development and Engineering Center (AMRDEC), U.S. Army Aviation and Missile Command (AMCOM) at Redstone Arsenal. Design specifications and operational requirements were defined by countermeasure developers at the Survivability and Lethality Analysis Directorate, Army Research Laboratory at White Sands Missile Range and the Directed Energy Directorate, Air Force Research Laboratory at Kirtland Air Force Base with input from the Air Force Research Laboratory at Wright-Patterson Air Force Base and the Naval Research Laboratory (NRL) in Washington, DC.

FIIRSST was implemented to represent the state-of-the-art capability in a small diameter IIR surface-to-air missile. All system design parameters were specified to be compatible with a three inch diameter, short range, air defense missile. Capabilities required to effectively test against conventional expendable CMs, laser jammers and damage class lasers were incorporated. Flexibility was provided through the ability to replace in the field, the detector, the dewar, the optics, the seeker dome or the processing algorithms with very little down-time. A picture of the FIIRSST gimbal showing the replaceable optics and dewars is shown in Figure 1. A picture of the FIIRSST system with all associated electronics is shown in Figure 2.

Joint Services Surrogate Seeker

Dr. Frank Barone of NRL approached AMCOM AMRDEC with the intent to build a Joint Services Surrogate Seeker under the auspices of the Joint Aircraft Survivability Program Office's Susceptibility Reduction subgroup. The Joint Services Surrogate Seeker (JSSS) would be specified and designed to emulate emerging air-to-air threat seeker technology. Experience gained through integrating FIIRSST would be leveraged as much as possible to mitigate risk and cost in the JSSS.

Early in the design phase FIIRSST and several other laboratory seekers

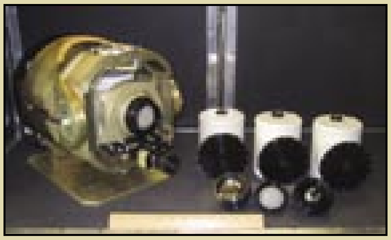

Figure 1: FIIRSST Gimbal, Optics and Dewars

Figure 2: FIIRSST System

were evaluated to determine their capability to provide a high fidelity air-to-air surrogate. None were suitable without extensive modification. However, it did become clear that specifying the same gimbal and sensor control electronics as used in FIIRSST would have a very positive impact on reducing system cost and lowering integration risk. There was also added benefit in keeping the same signal processing environment.

The JSSS effort (Project: S–1–04, technical lead: Richard Moore, NRL) started with the detailed design of the surrogate seeker and the integration of the signal processing electronics. The signal processing electronics, utilizing a quad MPC7410 PowerPC board with an MPC8240 PowerPC core, will be configured to operate in either a stand alone mode for hardware-in–the-loop environments or the normal closed loop seeker mode. The software environment will be based on a commercial real-time operating system to ease the process of developing and testing the tracking algorithms.

The twelve inch diameter, rate stabilized gimbal used in the FIIRSST system will also be used in the JSSS. Although the large diameter gimbal was not mandatory, it provided a low risk platform with known performance and interfaces. The large payload of the gimbal will alleviate much of the packaging constraints and keep the system cost in check. Either single or dual torque motors can be used on each gimbal axis to ensure adequate torque is available for the oversized payload. Since the dewar and detector interface electronics need not be miniaturized, a design approach was taken that will provide the ability to replace or switch the detector if the need arises. The oversized gimbal also permits a more flexible approach to implementing the real-time nonuniformity correction (NUC) hardware. Packaging and size constraints would not prohibit the future incorporation of a different NUC technology if the need arose. The optics for the JSSS will be based on an air frame diameter suitable for air-to-air missile applications.

The sensor electronics are based on a commercial product. The design is portable and rugged and provides the ability to control a majority of the state-of-the-art infrared focal plane arrays currently available. A disk array based digital recorder is included in the system. The baseline detector to be incorporated into the JSSS will be a midwave infrared InSb focal plane array. A closed cycle cryo-cooler will be integrated with the detector to provide low maintenance, reliable operation.

Summary

JSSS will provide the Joint Services CM development community with a high fidelity, imaging infrared, air-to-air surrogate missile seeker. Although the JSSS is a high fidelity surrogate, flexibility has not been sacrificed. The use of commercial hardware and software for the image processing and algorithm development environment will make it easy to integrate and maintain tracking algorithms. The commercial sensor control electronics can be reconfigured with very little effort to operate a wide range of focal plane array detectors. The use of an oversized gimbal will keep modification and upgrade options open for the NUC hardware and the optics.

The JSSS program also provides a very cost effective approach to developing and maintaining a surrogate seeker. Use of commercial products will allow future upgrades, particularly in the signal processing area, at a very reasonable cost. The use of a previously developed gimbal will keep non-recurring expenses to a minimum. Using an oversized gimbal will also keep miniaturization and packaging cost low.

Most importantly, JSSS will provide a high fidelity surrogate that is more than just a point design. While much can be gained through the analysis and testing of a point design, more can be learned by having a flexible surrogate that can be configured to emulate multiple emerging technologies. It has been demonstrated that minor changes in the tracking algorithms alone can cause drastic performance differences in an imaging missile system. The flexibility inherent to a point design imaging threat system will be greatly exceeded by the JSSS. This will provide a tool that can be used by countermeasure and missile developers alike to advance the understanding of both how to defeat imaging infrared threat systems and how to harden systems against future CM technologies setting up a "win-win" situation for the U.S. Joint Services. ■

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New Infrared Signature Measurement Capability

at Patuxent River, Maryland

■ by Mr. Michael Falco

The Patuxent River Infrared Signature Measurement (PRISM) facility at NAVAIR's Atlantic Test Ranges (ATR), Patuxent River, Maryland conducts dynamic, surface-to-air and surface-to-surface infrared signature measurements of fixed wing aircraft, rotary wing aircraft, missiles, UAVs, and engines. The PRISM system is completely mobile and designed to be operated either locally at NAWCADPAX or remotely anywhere in the world for extended periods of time. When located at NAWCAD, the integrated ATR facilities can provide additional telemetry, tracking, and range control.

Background

The Atlantic Test Ranges (ATR) located at Patuxent River NAWCAD is the site of several world-class signature measurement facilities. ATR has the capability to dynamically measure the radar cross-section, threat communications, and EW systems of dynamic, full-scale targets. To compliment this world-class capability, an infrared (IR) signature measurement program was developed.

The IR measurement program began with a two week long demonstration/evaluation (DemVal) test in June 1998 to determine the feasibility of making surface-to-air IR signature measurements at the Patuxent River NAWCAD, located in Southern Maryland. Several fixed and rotary wing vehicles were measured using borrowed equipment and donated vehicle flight time. The DemVal test was a success and definitively showed that IR signature measurements were not only feasible, but also extremely convenient considering the host of vehicles regularly available at a large test facility such as Pax River.

As a result of the successful DemVal, a four-year Improvement & Modernization (I&M) program was awarded in FY00 to design and develop a surface-to-air infrared signature measurement facility. The entire design was performed in-house by Navy engineers and technicians. Now, with less than a year remaining on the I&M program, the IR facility is almost complete and has already participated in several full scale signature measurement flight tests.

PRISM system

The PRISM system is capable of signature measurements in the short wave (1.8μm–2.4μm), mid-wave (3.0μm–5.0μm), and long wave (8.0μm–12μm) infrared bands for both moving and stationary targets. By combining ATR TSPI, TM, GPS, and weather assets with a suite of state-of-the-art infrared spectrometers and imagers, the PRISM system can measure the IR signature of any helicopter, fixed wing, UAV, UCAV, missile or engine in several IR bands chosen by the customer.

The two major components of the PRISM system are the data acquisition trailer and the Kineto Tracking Mount (KTM) (see Figure 1). The data acquisition trailer is an environmentally controlled, 48' trailer. The trailer contains four rooms: a data acquisition room, a customer observation room, a lab/equipment room, and a galley. The data acquisition room accommodates the Test Director, the KTM controller and up to four acquisition workstations (see Figure 2). The customer room has a 42" split screen flat panel display to view testing real time as well as a separate entrance to the outside for

Figure 1: PRISM trailer and KTM.

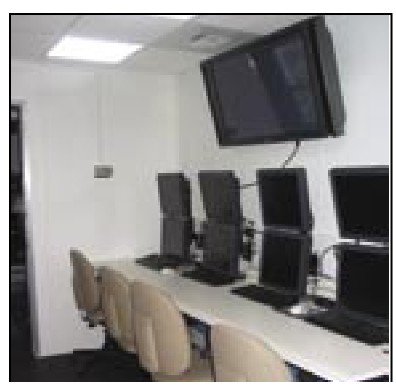


Figure 2: Trailer workstations include dual monitors and 43" plasma display.

customer convenience. The trailer requires a three-phase 480V circuit, which can be provided by either shore power or the PRISM generator. The trailer is mobile and can be towed by a standard semi-tractor.

The PRISM KTM is a remotely operated, high precision tracker with a payload of up to 900 pounds. It accommodates all PRISM IR cameras, spectrometer, laser range finder, and video cameras. The goal of the development program is to allow the KTM to be remotely operated up to 500' from the trailer.

PRISM instruments

SWIR Imager
320x256 InSb FPA
Band: 1.8µm–2.4µm
Pixel size: 30µm
Max frame rate: 338 Hz

MWIR #1 Imager
640x512 InSb FPA
Band: 3µm–5µm
Pixel size: 24µm
Max frame rate: 92 Hz

MWIR #2 Imager
640x512 InSb FPA
Band: 3µm–5µm
Pixel size: 24µm
Max frame rate: 92 Hz

MWIR #3 Imager
640x512 InSb FPA
Band: 3µm–5µm
Pixel size: 24µm
Max frame rate: 92 Hz

LWIR Imager
640x512 HgCdTe FPA
Band: 3µm–5µm
Pixel size: 24µm
Max frame rate: 92 Hz

Long Wave Microbolometer
320x240 FPA
Band: 7.5µm–13µm
Pixel size: 52µm
Max frame rate: 60 Hz

Bomem MR–254
Spectroradiometer
InSb/MCT detectors
1.7µm–12µm
30 scans/sec @ 4cm–1 resolution

Data products

IR signature measurements produce two kinds of IR data, spectral and image. Spectral data describes the infrared energy in terms of intensity vs. wavelength. Spectral data is crucial towards understanding the effects a particular type of material may have on the IR signature of a target. Image data, by comparison, describes the infrared signature spatially. The PRISM system can provide spectral data from 1.7µm through 12µm, and image data in crucial bands from 1.8µm to 12µm.

The PRISM team is capable of acquiring, processing, analyzing and storing all levels of classified data, from unclassified to Top Secret. The data acquisition trailer has a 360º field of view security oversight camera mounted on it's roof, secure external doors with tinted windows and blinds, and a GSA approved safe. Additionally, post test data processing and storage can be handled in the certified PRISM SCIF facility located at the ATR.

Future developments

Future plans for the PRISM system include automated target tracking, improved system acquisition/processing software and incorporating a real time telemetry/TSPI link to Patuxent River test assets.

Summary

The U.S. Navy is developing the Patuxent River Infrared Signature Measurement facility at the Atlantic Test Ranges in Patuxent River, Maryland. Once complete in FY03, the system will support dynamic, surface-to-air and surface-to-surface infrared signature measurements of fixed wing aircraft, rotary wing aircraft, missiles, and UAV's. The PRISM system provides the customer with both image and spectral infrared data in the short-, mid-, and long-wave bands. The PRISM system is completely mobile and designed to be operated autonomously at remote sites.

For further information contact Mike Falco at 301.342.0143 and falcomf@navair.navy.mil. ■

Mike Falco is the PRISM Team lead and the Program Manager of the Multispectral Signature Measurement Program. Prior to that, he was involved in the design and testing of antennas and low observable components/vehicles in both the RF and IR technology disciplines. Mr. Falco has a B.S. in Electrical Engineering from Villanova University. He may be reached at falcomf@navair.navy.mil.

Figure 3. PRISM midwave and shortwave imagers.

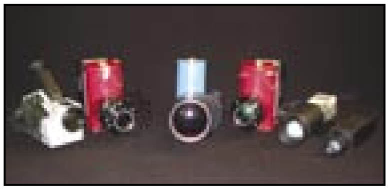


Figure 4. PRISM lens assortment from 25mm to 550mm.

Figure 5. Midwave image—MD state police helicopter over tree line.

Super-Lightweight Thermal Insulation

for Rotorcraft

■ by Mr. Malcolm Dinning

The principal threat to low altitude tactical aircraft is the infrared (IR) guided man portable air defense systems (MANPADS). The rapid pace of improvements in detector materials and the increasing sensitivity of both cooled and un-cooled seeker systems has allowed these threats to detect and lock-on to even modest thermal signature sources, such as engine, transmission and avionics bays. The use of insulative materials to inhibit this heat transfer to the airframe outer skin is the most obvious solution, but the weight of these parasitic treatments directly reduces payload capability. The Aviation Applied Technology Directorate of the Army Aviation and Missile Command, along with the Aircraft Electronic Systems Division of the Communications and Electronics Command and the Joint Aircraft Survivability Program Office (JASPO, formerly JTCG/AS) initiated a program that developed and demonstrated a super-lightweight insulation system that reduces areal density by 50 percent relative to the best currently available commercial-off-the-shelf (COTS) insulation blanket systems. This work was done under contract to Aspen Systems and Bell Helicopter. This program focused on the use and optimization of aerogels as a high performance insulation material, encapsulated in innovative, lightweight packaging. The aerogel blanket insulation system, with a weight of only 5 pounds, demonstrated a 40 percent reduction in aircraft IR signature during flight demonstrations on an Army OH–58D Kiowa.

Gel materials are a network of solid structures suspended in a fluid. Jello is a familiar example of a gel, made of sugar and calcium structures suspended in water. Aerogels are formed when the liquid base is removed from the gel through a "drying" process, but drying gels without destroying the lightweight solid structure is difficult. The solid structures trap liquid droplets, and the droplets in turn, cling to the structural cells via surface tension. If the gel is dried by traditional means of heating the fluid to its boiling point, the stress from fluid surface tension will collapse the cell structure as it shrinks, turning the dried gel to powder. Research in the mid-1930s discovered that a more effective method of removing the fluid was to bring the fluid to its critical point, the temperature and pressure at which the fluid essentially "boils" from the inside out, eliminating surface tension stresses. However, this drying process required an autoclave and took several weeks to completely remove the fluid. Much of the aerogel research since the 1930s has focused on developing sol/gel systems that allow more efficient drying, which directly relates to mate-

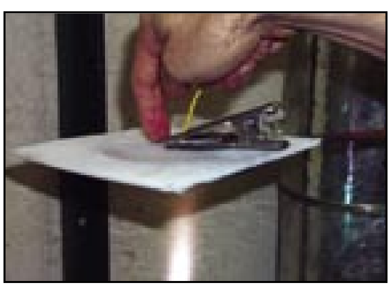


Figure 1. Aerogel blanket material.

Figure 3. Core peel test specimen.

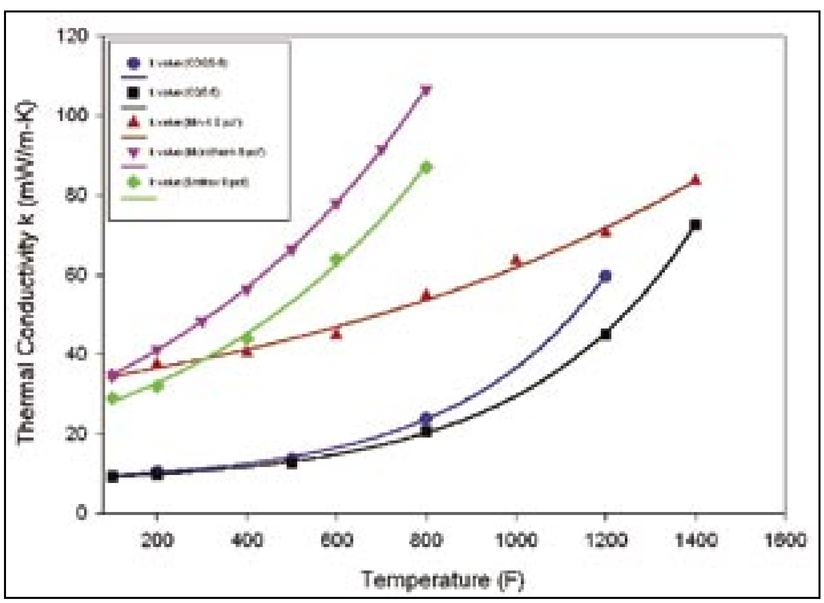


Figure 2. Thermal conductivity of insulative materials.

rial cost. One of the most promising applications of aerogels is for thermal insulation. Developing aerogels around silica materials, with their inherently low thermal conductivity, produces a very lightweight structure that has exceptional insulation characteristics. Figure 1 illustrates the effectiveness of silica-based aerogels. Subjected to long-term heating by a torch, a small sample of aerogel reduces heat flux through it to the point that one can safely touch the insulator for an extended period.

The Super-Lightweight Thermal Insulation program further optimized sol/gel chemistry to produce aerogels that were better suited to application in a semi-flexible blanket system operating in a moderate 250–600°F environment, typical of engine bays and exhaust ejector assemblies. Encapsulation, or packaging, to withstand the rigors of normal flight line operations, including exposure to jet propellant, hydraulic fluid, oil, and water was developed. Recognizing the inherent encapsulation benefit of existing structural honeycomb materials on many aircraft today, aerogels were developed that could be added to core as a granular material. Finally, a set of blankets were fabricated and installed on an Army Kiowa aircraft for flight demonstration.

Silicon dioxide aerogel, in bulk monolithic form, is very brittle. While very strong in compression, it has a low modulus in bending and shear. In order to utilize this material in a semi-flexible blanket, small-scale reinforcing elements must be added to the solution prior to gelation, much like rebar is used to reinforce concrete. Micro fractures will occur when the material is subjected to bending and shear stress, but the reinforcing elements will maintain continuity of the macro system. Polydimethylsiloxane (PDMS) polymers were selected as the reinforcing material and experimentation was conducted to determine optimum doping levels. However, during inspection of these reinforced aerogels cast into a bat fiber blanket, it was discovered that the amount of PDMS fibers needed to provide sufficient toughness in flexure also interfered with the bonding of the aerogel to the batting during the drying process. This resulted in decoupling of the aerogel from the macro fibers and a significant loss of blanket mechanical performance. At the same time, opacification agents were being investigated to reduce radiative transfer through the aerogel material itself.

Because silica-based aerogels have such low density, they are inherently transparent. At temperatures above 200°F, radiation through the aerogel becomes a dominant thermal transport mechanism (see Figure 2). The aerogel must be doped with opacifying agents to decrease the aerogel's transparency. Small amounts of carbon micro-fibers (3–5 percent) were added to minimize radiative thermal transfer, and in so doing, were found to also behave as reinforcing elements. While not as efficient as the longer strand polymers, the addition of carbon micro-fibers allowed for a reduction in the amount of PDMS doping required to meet blanket mechanicals and still maintain good bonding with the batting fiber system of the blanket mat. Surfactants must be added to insure a homogeneous distribution of carbon and polymer elements within the gel solution, but each additional additive also has the potential to interfere with the formation of a high quality aerogel structure during gelation, adversely affecting the insulative performance of the resulting aerogel. Final sol/gel optimization produced a very efficient insulator material tailored for 250–600ºF applications.

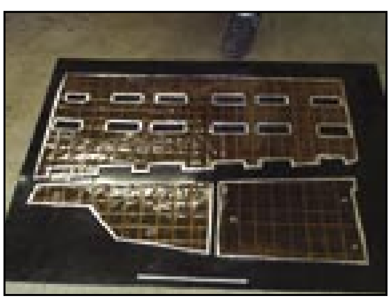


Figure 4. Kiowa blanket kit (airframe side).

Figure 5. Kiowa blanket kit (hot side).

Protecting the aerogel from mechanical and environmental damage was a significant challenge for this program. Existing composite honeycomb aircraft structures meet many of these packaging requirements and because the structure is rigid, also eliminate the need for polymer reinforcement. The core material is not optimized for thermal conductivity, but the low surface area across the core structure minimizes its impact. Monolithic aerogel is granulized to provide better packing efficiency within the core cell structure. A sealant layer is applied to the filled honeycomb to prevent aerogel powder from interfering with the core/skin bonding process. The structural honeycomb part is then bagged and autoclaved per the normal cure cycle. Measurements before and after the core bonding indicate no degradation in thermal performance. Mechanical testing of the core/skin bond strength demonstrated that failure occurred in the core itself (see Figure 3), rather than at the bond line, indicating no impact of the aerogels on structural performance. Thermal performance is less than an equivalent blanket system but does not incur the added packaging weight of a blanket.

Blanket encapsulation must prevent environmental damage to the aerogel fiber blanket, which is largely driven by fluid incursion into the blanket batting. Most silicon-based aerogels are hydrophilic, that is they absorb water, which significantly increases its thermal conductivity. Aerogels developed for this program were designed to be hydrophobic, or resistant to water absorption, but fluid in and around the blanket will still impact system thermal performance. Kapton film was selected as an effective fluid barrier that is also lightweight. Kapton is susceptible to puncture during routine flight line maintenance and so a tougher material was desired for the exposed side of the blanket system. As the exposed side is facing the internal heat source, a radiative barrier, or reflective surface would further improve thermal performance. Thin gauge stainless steel film, textured to improve mechanical performance, was selected as the exposed blanket side facing material. The prototype blanket edges were reinforced with metal film (Figures 4 and 5) but the production design will have Kapton reinforced edges. Measurements demonstrated desired thermal performance with a 50 percent reduction in weight, or areal density.

As a final demonstration of the performance of the blanket system, a set of blankets was fabricated for application to the OH–58D Kiowa aircraft (Figure 6) and installed in March 2002 (Figure 7). The aircraft was tested in conjunction with a new IR suppressor for the aircraft that eliminated hot gas impingement on the airframe, leaving engine bay radiation from the cowling structure as the primary IR signature source. While the system is planned to be fielded with lightweight Velcro-type fasteners, the test aircraft used mechanical fasteners to minimize safety-of-flight concerns. Velcro allows for a more complete sealing of the blanket insulator to the airframe and minimizes hot gas paths to the airframe skin. The mechanical fasteners used for this flight test consisted of bonded threaded studs. Holes in the blanket were protected with metal grommets. The aircraft was tested with and without the blankets and the IR signature was measured spectrally with a Bomem M254 radiometer and was imaged with a Santa Barbara SBF125 256x320 focal plane array (Figure 8 and 9). The reduced data showed a 40 percent reduction in Band IV aircraft signature. Thermocouple data inside the engine bay indicated no increase in operating temps with the blankets installed. The exhaust system of the Kiowa is designed to pump a high volume of cooling air through the engine bay and thus, the heat normally radiated through the aircraft structure was convected through the engine exhaust suppressor. Remaining signature sources visible in the thermal images are the engine bleed air port, upstream of the engine bay doors, and the oil cooling inlet screen in the lower portion of the aft cowling structure. There sources are being addressed as part of a production plan for the Kiowa IR suppressor. The blanket system weight is 0.25 pounds per square foot, as installed on the Kiowa, and total system weight (less mechanical fasteners) is approximately five pounds. The Kiowa PM has selected the aerogel blanket system to complement the IR suppressor as part of an upgrade program for the Kiowa fleet. Production is funded to begin in FY07.

This work could not have been successful without the dedicated efforts of George Gould, Project Manager from Aspen Aerogels, and Kendal Goodman from Bell Helicopter. In addition, Dan Bullock, Aspen Aerogels; Kang Lee, Aspen Systems; and Steve Webster, Bell Helicopter provided key organizational support.

This program is an element of a three part JASPO co-funded program, that includes high temperature aerogels applied directly to F–16 exhaust hot metal components, managed by Dr. Leonard Truett, U.S. Air Force, WPAFB, and another high temp application applied to Cobra helicopter hot metal components, managed by Mr. Leo Budd, NAVAIR, China Lake. ■

Malcolm Dinning is the Signatures Technology Team Lead at the Army's Aviation Applied Technology Directorate, Fort Eustis, Virginia. Mr. Dinning is responsible for directing S&T and customer funded efforts to reduce rotorcraft signatures and assess the susceptibility of Army aircraft to current and anticipated threat weapons and sensors. Mr. Dinning has a B.S. in Aeronautical Engineering from California Polytechnic, San Luis Obispo. He may be reached at mdinning@aatd.eustis.army.mil.

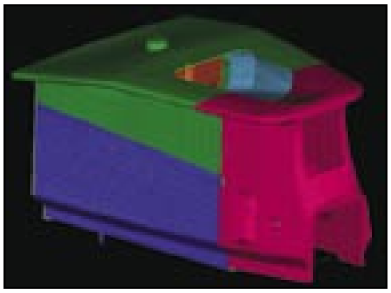


Figure 6. Kiowa engine cowling structure.

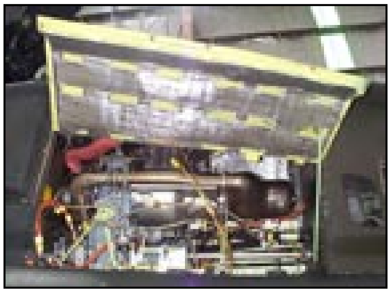


Figure 7. Aerogel blanket kit installed.

Figure 8. IR imagery of Kiowa without blanket kit.

Figure 9. IR imagery of Kiowa with blanket kit.

Evolving and Asymmetric Threats

in Military Aviation

■ by Mr. Howard Seguine and Mr. Charles Burgess

The fact that the U.S. is likely to face asymmetric and evolving threats in the post-Cold War world, where military adversaries cannot hope to compete with the U.S. directly, is becoming increasingly recognized. The Gulf War, operations in the Balkans and in Somalia demonstrated that adversaries will use various means to degrade or deny advantages in virtually all areas outlined in Joint Vision 2020, including information dominance, dominant maneuver, and precision engagement. This changing environment underlines the need to understand the following relative to evolving threats—

- Environment definitions or weapon effects
- Typical expected targets and defenses.
- When these threats likely will become viable.
- Expected delivery means and knowledge/skills needed for same.

Perspective

In its simplest form, an asymmetric threat can be seen as the introduction of any weapon, tactic, method of delivery or strategy outside the conventional form of engaging in conflicts. Asymmetric and evolving threats have great implications for aircraft survivability. It is safe to assert that the susceptibility of aircraft to be subjected to various asymmetric and evolving threats only increases with time. This article—

1. Outlines some of those threats, with information the authors obtained from open sources, the Windows on Science Program, [1] and other direct liaison with foreign nationals.
2. Addresses some of the implications these threats have on aircraft survivability planning.
3. Offers recommendations to make the survivability community more aware of these threats.

Threat Environment	When Viable	Threat Environment	When Viable
Biological			
Antipersonnel/material	Now	Genetically altered organisms	15 years
Biota modification	Now		
Chemical			
Antipersonnel/material	Now	Smoke/obscurants	Now
Biota modification	Now	Super acids	5 years
Interhalogen oxidizers	Now		
Electric Guns			
Electric coil guns	5 years	Metal Storm (Australia)	10 years
Improved Conventional			
Platter (or disk) charges		Solid fuel-air	5 years
Reactive material	Now	Thermobaric	Now
Directed Energy			
Conducting aerosol	< 5 years	Particle beam	> 10 years
Laser	Now	Radio frequency	Now
High-Energy-Density Material			
Isomers	> 10 years	"Tailored" molecule HE	10 years
Metastable compounds	> 10 years		
Nuclear			
"Dirty" bomb	Now	Thermal/blast/radiation	Now
Electromagnetic pulse	Now		
Terrorism			
Denial of service	Now	Mass casualties/effects	Now
Weather Modification			
Local effects	> 10 years	Tailored effects	> 10 years

Figure 1. Examples of evolving threats.

Asymmetric or evolving threats can be broken into two different types—new uses of old technologies and emerging technologies. For example, one new use of an old technology is the "platter charge" (also called "disk charge" or "flying plate") which is a specially fabricated weapon that uses conventional explosive material placed on one side of a flat, dense disk such as a manhole cover. When the explosive is detonated, the disk is hurled at a very high rate of speed toward a target, in a plane parallel to the target to be impacted, and can penetrate several layers of highly reinforced or energy-absorbing material. A rule of thumb is about four pounds of explosive (such as C–4) is used for each pound of metal disk. Platter charges can punch holes in structures and aircraft from a quarter to half mile away, assuming they can be positioned that close.

Examples of emerging technologies include reactive materials, radio frequency weapons (RFW, also called high power microwave (HPM), or pulse power weapons), and interhalogen oxidizers. These weapons pose significant risks not only to aircraft survivability but also to airbases themselves as well as associated infrastructures such as telecommunications and power grids. To underline the threat potential of asymmetric and evolving threats, the Joint Requirements Oversight Council (JROC) last year singled out RFW/HPM as a significant threat. In a memo dated 14 January 2002, the JROC directed that the "Services conduct susceptibility testing, perform R&D, and provide protection for electronic systems and personnel against HPM" and the "Services consider development of tactics, techniques, and procedures for operations in HPM environments."

Threat environments

New threat environments are proliferating and will be of increasing concern to combat aircraft designers. Some of these environments are here now and others are in development. Table 1 (page 41) shows some of these threats. [2] Note that evolving threats are mixed with new applications of old technologies or threat environments such as platter charges.

Selected threats

Certain environments are of direct concern to combat aircraft and their supporting infrastructures, or will be within the foreseeable future. [3] These are discussed below.

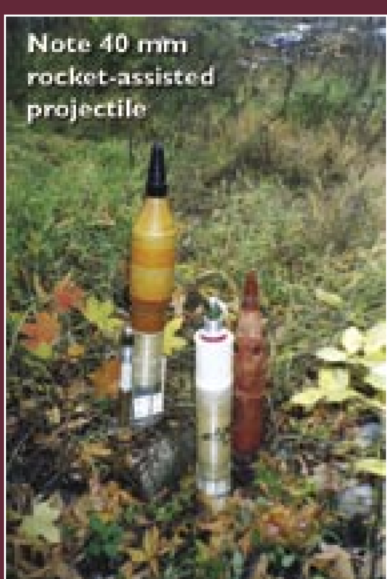


Figure 2. Claimed Russian RFWs

Radio Frequency Weapons (RFW)

What it is: Explosive- or electric-driven devices generating bursts of energy at microwave or lower frequencies sufficient to burn out/disrupt microelectronic systems/circuits/components/materials. RFWs operate at the speed of light, can be fired without any visible emanations, and are unaffected by gravity and atmospheric conditions.

When available: Now; Russia claims to have fielded a 40mm RAP and several other projectiles (see Figure 2).

Employment method: Same as any other ordnance payload: bombs, projectiles, submunitions, and man-emplaced.

Credibility of threat: Becoming increasingly high. Demonstrating the increasing international interesting was the creation of the Ordnance Working Group last summer by the International Pulsed Power Society. Representatives of over 20 nations hold membership in it. This alone should serve as a wake-up call to Department of Defense planners concerned with defensive approaches. Members of Congress were sufficiently concerned about the RFW threat that it sponsored a demonstration of commercial off-the-shelf radio frequency or high power microwave "weapon," in April 2001.

Lethality & range: Since research on RFWs began in the 1970's, there has been considerable progress in developing power sources, beam conditioners, and antennas for aiming the resulting energy. Compact, explosively driven RFWs can generate gigawatt-level pulses of a few nanoseconds duration. See Figure 3 for a proposed 25mm RFW. Pulsed power sources capable of producing terawatt energy levels are commercially available, which at a modest 10 percent extraction efficiency suggests the potential for microwave weapons transmitting pulses in excess of 100 gigawatts (billions of watts). RFW radii of effects are several meters to tens of meters and beyond.

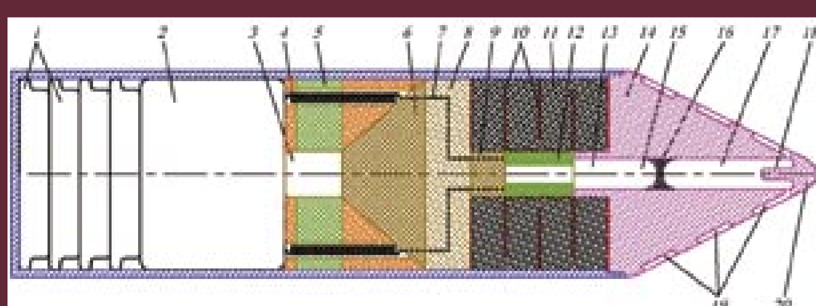


Figure 3. Proposed 25mm RFW projectile.

Typical Targets: Any unshielded or vulnerable microelectronic-based system; via front door or back door. [4] RFW targets are limited only by the imagination of the planner and operator.

Current & Potential Developers: Over 20 nations; including some that sell to nations and groups having interests inimical to those of the U.S. Other nations have developed powerful microwave devices, and the growing emphasis on network-centric operations may make U.S. forces uniquely vulnerable to their effects. [5] More appropriately, the introduction of digital technologies into every facet of national commerce and culture may make the U.S. national infrastructure and national security vulnerable to RFW aggression by our adversaries. The federal government has only recently begun to investigate the full range of RFW effects, in order to more fully grasp the danger they may pose to U.S. interests in the future.

Discussion: Military concepts have been discussed openly in other nations, such as those presented in several papers by Carlo Kopp, an Australian researcher at Monash University. Some of these are—

- "A Doctrine for the Use of Electromagnetic Pulse Bombs," Air Power Studies Centre, RAAF, Paper 15, available at http://www.csse.monash.edu.au/~carlo/archive/MILITARY/APSC/wp15-draft.pdf.

- "An Introduction to the Technical and Operational Aspects of the Electromagnetic Bomb," Air Power Studies Centre, RAAF, Paper 50, available at http://www.csse.monash.edu.au/~carlo/archive/MILITARY/APSC/wp50-draft.pdf.

Testing of RFW threat environments against aircraft systems has been done at the Naval Air Weapons Center, China Lake, and referred to in an earlier issue of Aircraft Survivability.

Laser weapons

What it is: The technology for high-energy lasers (HEL) is mature. HEL generates an intense beam of monochromatic, coherent light.

When available: Lasers are available now and according to the media and DoD announcements are capable of being employed in large aircraft for use in ballistic missile defense. Several approaches to laser design have been undertaken: chemical, solid-state, and free-electron lasers.

Figure 4. Tactical laser weapon system (artist concept).

Figure 5. Solid fuel-air explosive test.

- Chemical lasers use chemical reactions to excite atoms, and then "focus" the light into beams via mirrors.

- Solid state lasers use an intense light source to excite atoms in a rare-earth-based lasing rod such as synthetic ruby or sapphire; while of interest, they are relatively inefficient in terms of weapon relevance.

- Free-electron lasers use streams of electrons from a particle generator, or other source, that are passed through a linear array of electromagnets; varying the magnetic force allows the wavelength and duration of the beam to be altered. These systems are still in the early stages of research.

Employment method: Today, laser weapons are bulky and are not yet near the capabilities of being man portable. They need large antennas that must be trained mechanically and need large power supplies; therefore, large platforms are needed for laser weapons, for today's technologies. Figure 4 shows an artists depiction of the Tactical High-Energy Laser weapon system, which successfully shot down an incoming Katyusha rocket at White Sands Missile Range, June 2000.

Credibility of threat: Efforts continue, incrementally, to develop laser weapons that may be considered for tactical use.

Lethality & range: Assuming pointing accuracy, the lethality of lasers against any class of targets is determined by power level, wavelength, and optical dimensions. Atmospheric conditions, such as snow or battlefield smoke, degrade laser weapon effectiveness.

Typical Targets: Aircraft, structures, ballistic missiles, vehicles, and personnel may be considered to be targets for laser weapons

Current & Potential Developers: Multiple nations have laser weapon programs, e.g., the Tactical HEL system is a joint Israel-U.S. effort.

Highly energetic explosives

What it is: Explosive technologies that produce significantly greater energy than typical chemical explosives. These include thermobaric weapons, [6] solid fuel-air (SFAE) explosives, and reactive material. [7]

When available: Now

Employment method: Same as any other ordnance payload, e.g., air-delivered, projectiles, submunitions, and rocket-propelled grenade. Reactive material is a solid material with sufficient tensile strength that it could provide its own ballistic envelope or container.

Credibility of threat: High

- The Soviet Union fielded thermobaric weapons over 20 years ago, and Russia used them against rebels in Grozny, Chechnya, causing considerable devastation to buildings. Battelle Memorial Institute has in independent R&D program underway on solid thermobaric materials, based on perchlorates

- Reactive material and SFAE are being researched at multiple DoD commands, as well as within the private sector. Figure 5 is a Navy test of SFAE

Lethality: Thermobaric and SFAE weapons provide a long impulse. Reactive material, too, provides a longer impulse than conventional explosives.

Typical Targets:

- Thermobaric and SFAE weapons—would likely be most effective when detonated within hangars, control towers, and maintenance facilities

- Reactive material—may be used effectively against aircraft, missiles, and surface targets traditionally engaged by aircraft

Current & Potential Developers: Work in these weapon areas continues in Russia, the UK, and the U.S. Rosoboronexport (Russian state armament sales entity) offers several missile systems with thermobaric payloads for sale. In addition, Bulgaria and Poland are marketing rocket-propelled grenades with thermobaric payloads, and China is alleged to have received a license from Russia to design and sell thermobaric weapons.

Discussion: While the explosives above are in developmental stage, another class of far greater explosive capabilities, called high-energy-density materials (HEDM), may appear in 10–15 years. HEDM explosive output is expected to be about midway between explosive output, per unit volume, of today's conventional explosives and explosive output of same unit volume of fissile material—without the accompanying radiation and fission products. Research on HEDM continues in Russia and the U.S.

Implications

There are many asymmetric and evolving threats that have implications for aircraft survivability. Thus the threat environments listed in this article are illustrative only. However, planners and testers must begin to familiarize themselves with the various threat environments in order to prevent unnecessary loss of combat assets. However, before this can happen, OSD must provide leadership on this matter (e.g., provide guidance and priorities on the issues of asymmetric and evolving threats). In addition, the intelligence community must provide timely information on these subjects. DoD must direct the appropriate authorities to conduct assessment of the various threats and provide recommendations on how to mitigate these threats. If done late or not at all, planners and testers will remain unaware of potential threat environments the U.S. will face.

Conclusions

Requirement writers and commodity managers, program managers, their integrating contractors, and test and evaluation planners could use hypothetical threat environment definitions [8] that: (1) give ranges of pertinent parameters and expected qualitative and quantitative characteristics, and (2) neither confirm nor deny sensitive or special access programs underway in the U.S. These could well be based on information gained through normal, routine liaison with foreign nationals.

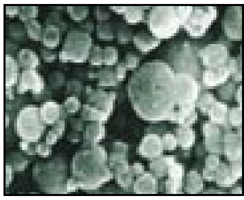
In addition to the hypothetical threat definition above, an evolving threats catalog would be valuable to DoD, especially if it includes an estimated timeframe for when each threat environment would become a threat. ■

Howard Seguine is Director of Asymmetric Threats Assessment & Response Center, of Decisive Analtyics Corp. He is a co-author of Jane's Unconventional Weapons Response Handbook. He has over 40 years experience in the nuclear weapons program, many of which included adversarial analyses of the nuclear weapons complex and command and control processes and facilities. He also adapted some of the nuclear weapons adversarial analysis and participated in a special antiterrorist vulnerability assessment of one of the nation's largest water authorities. He may be reached at howard.seguine@dac.us.

Charles Burgess is a researcher in and founding member of the Asymmetric Threats Assessment & Response Center, of Decisive Analtyics Corp. He is experienced in analyses of weapons of mass destruction, ballistic missile proliferation, infrastructure vulnerabilities to asymmetric threats, and future U.S. defense planning priorities. He was Coordinating Editor at Jane's Publications Group, specializing in emerging threat technologies. He may be reached at charles.burgess@dac.us.

References

1. Nunn-Lugar-Domenici initiative
2. The authors have created an evolving threats catalog that describes weapon effects, when the threat weapons is expected to be viable, typical targets and defenses, and expected ease of use and skills needed by an adversary to employ the weapons.
3. "Directed-Energy Weapons: Technologies, Applications, and Implications," The Lexington Institute, February 2003, page 15
4. "Front door" is an intended electromagnetic energy path, such as an antenna and its lead; "back door" is an unintended entry point for electromagnetic energy, such as apertures and power cabling
5. "Directed-Energy Weapons: Technologies, Applications, and Implications," The Lexington Institute, February 2003, page 15
6. In its original Russian formulation, thermobaric material was a liquid explosive with a large amount of aluminum or magnesium chips
7. Small aluminum particles coated with Teflon; stoichiometrically balanced so that upon detonation all the aluminum is converted to aluminum fluoride
8. Similar to the Design Basis Threat (DBT) Department of Energy uses for certain planning functions



Improved Infrared Countermeasures

with Ultrafine Aluminum

■ by Dr. Robert Shortridge and Dr. Caroline Wilharm

Decoy flares are a key element in aircraft survivability against an increasingly sophisticated and widely proliferated arsenal of infrared-guided MANPADS, and other surface-to-air and air-to-air missile threats. Over the years, it has been a challenge to package a sufficiently intense infrared emitter in the relatively small space aboard a fighter aircraft that is available for decoy flare countermeasures. This is particularly evident when one considers that a large number of flares may be required to protect the aircraft during a lengthy mission, in an area that is well protected with infrared guided missiles.

Before the advent of IR guided missiles with both spectral and kinematic discriminating capabilities, one did not have to worry about the spectral distribution and the trajectory (relative to the aircraft) of the decoy flare countermeasure. Unfortunately, that is not case today. There are many missiles in the field today that employ increasingly sophisticated counter-countermeasure (CCM) capabilities, by which they can exploit the differences between the spectral signature of the aircraft and that of the flare. They can also exploit the differences between the trajectory of the aircraft target and the flare in order to maintain track on the aircraft.

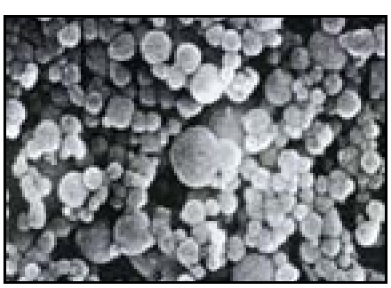


Figure 1. Field emission electron micrograph of ALEX.

These infrared guided missiles are well within the budget of the many terrorist groups in the world today, so the threat against both military fighter, bomber, and transport aircraft, as well as civilian aircraft, is becoming increasingly formidable. This is why we have endeavored to produce increasingly effective decoy flare countermeasures for aircraft self-protection. Such countermeasures will be a valuable asset—not only for our war fighters throughout the world, but for homeland security as well.

One way to make a flare more effective in decoying threat missiles is to increase its peak output intensity. One means of doing this is to increase the burn rate of the flare while maintaining the total energy output. Another means is to increase the combustion temperature of the flare, because the intensity of both black body radiation and the specific emission from combustion product species, such as hot carbon dioxide, increase rapidly with increasing combustion temperature.

The emission intensity from a pyrotechnic device depends upon how many molecules of fuel and oxidizer can react to release energy within a given time. Since the reacting molecules are located at the surfaces of the pyrotechnic ingredients, the greater the available surface area of the fuel and oxidizer, the greater the resulting emission intensity. Since smaller particles within a given volume usually have greater total surface area, the use of reactants with the smallest possible particle size would be expected to help increase emission intensity. For example, two equal smaller spheres will have approximately 26 percent more surface area than one larger sphere with the combined volume of the two smaller ones.

Fortunately for the flare designer, worldwide interest in the field of nanotechnology has grown to high levels over the last several years. In fact, the recent 29th International Pyrotechnics Seminar, held in July 2002 at Westminster, Colorado, devoted an entire session to the use of nanomaterials in the fields of pyrotechnics, explosives, and propellants. Accordingly, we have been working to develop new decoy flare countermeasure compositions that contain ultrafine aluminum as one of the pyrotechnic fuels. Specifically, we have conducted a number of laboratory scale studies in which Electro-Exploded Aluminum (ALEX) from the Argonide Corporation has been incorporated into a number of conventional formulations containing magnesium, Teflon, and Viton copolymer binder. Research has also been done on compositions that use alternate fuels and oxidizers, known as "spectrally balanced" compositions, which produce infrared spectral emissions that more closely match typical aircraft spectral signatures. This work was initiated during 1999 under support from the Office of Naval Research and is on-going from FY01 to the present under JASPO support.

Figure 1 shows a Field Emission Electron Micrograph of ALEX powder. ALEX has nanometer scale diameters, averaging approximately 200 nm, and this translates into specific surface areas of from 10–14 meters^2/gram. Conventional micron sized aluminum or magnesium have particle sizes ranging from about 20 to 100 microns and specific surface areas less than 1 meter^2/gram. Hence, it is not surprising that the burn rate of a conventional MTV pyrotechnic formulation significantly increased when ALEX was substituted for a portion of the atomized magnesium fuel, as illustrated in Figure 2.

Varying amounts of ALEX were substituted for magnesium during the course of our studies. Also, the overall fuel to oxidizer ratio was varied during this investigation. Although all ALEX containing compositions exhibited some increase in burn rate relative to the corresponding MTV composition without ALEX, it was evident that only the fuel rich compositions, similar to those in use in today's flares, burned fast enough to be considered for air countermeasure applications.

When ALEX was added to spectrally balanced flare formulations produced by both the conventional coacervation coating (or shock gel) process with the non-energetic Viton binder, and a cast cure process based upon the energetic curable binder Glycidyl Azide Polymer (GAP), increased burn rates compared with the non-ALEX-containing analogues were observed. An additional benefit from the ALEX-containing compositions was a higher spectral color ratio. This is defined as the ratio of radiant emission intensity in two routinely measured infrared bands. In general, the higher the color ratio, the better the match between the infrared signature of the aircraft and that of the decoy flare.

These initial studies involved linear burn rate (LBR) testing of 15-gram pellets of composition. Testing was conducted statically in our Photometric Tunnel, and infrared intensity versus time data was collected in two infrared bands. In addition, infrared spectral data was collected for many of the spectrally balanced formulations using a rapid scanning BOMEM Fourier Transform Infrared (FTIR) interferometer spectrometer. Analysis of the resulting test data led to the selection of the most promising formulations as candidates for scale up from laboratory to concept scale using the MJU–38/B flare form factor, 1.42 inches diameter by 5.8 inches long. In this manner, three MTV/ALEX formulations and three cast cured spectrally balanced (CCSB)/ALEX formulations were selected for scale-up.

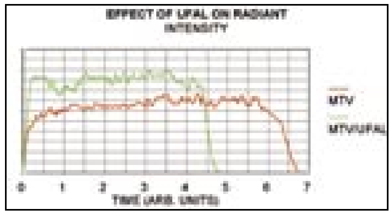


Figure 2. Radiant intensity plot of MTV and MTV/ALEX compositions.

It is well known that ALEX, as well as the pyrotechnic compositions made from it, have exceedingly high ignition sensitivity to electrostatic stimuli, less than 10 millijoules, making them very prone to unintended initiation. Indeed, when we used the analytical tool of Scanning Electron Microscopy (SEM) with the back scattering electron (BSE) and elemental mapping options to view various MTV/ALEX compositions, we found that there was incomplete coverage of the ALEX and magnesium fuels by the Viton binder. However, we found that by performing a separate step of pre-coating the ALEX fuel with a portion of the Viton binder before mixing it with the remaining ingredients was very useful in significantly reducing its electrostatic sensitivity, as well as the sensitivity of the MTV/ALEX compositions made from it. Furthermore, this reduction in electrostatic sensitivity was achieved without significantly reducing the burn rate of the compositions. Because of this process safety benefit, it is planned to use this Viton pre-coated ALEX during the scale up from laboratory to concept scale of both the MTV/ALEX and CCSB/ALEX compositions.

In addition, we also looked into the possibility of pre-coating the magnesium fuel with a portion of the Viton binder in addition to the ALEX fuel. Scanning electron microscopy and ignition sensitivity testing were performed on the composition with both fuels pre-coated with Viton, and the results showed no significant improvement in ignition sensitivity compared with the composition in which only the ALEX was pre-coated.

We plan to continue with the fabrication of the concept scale MTV/ALEX and CCSB/ALEX flare candles in the MJU–38/B size form factor. The test units will be burned statically in the Photometric Tunnel, as well as in a simulated dynamic environment at the Windstream Facility (see Figure 3). This facility simulates the dynamic high wind shear environment that a flare would be exposed to subsequent to launch from a high-speed aircraft. We will record radiant and spectral power in the infrared bands of interest and compare these to reference MTV units without ALEX. Promising ALEX-containing flares will then be studied further, and hopefully will eventually be evaluated in various flare deployment strategies at captive seeker flight tests. ■

Figure 3. Crane Windstream facility.

Dr. Robert Shortridge received his B.S. in Chemistry from Loyola University of Los Angeles, and his Ph.D. in Physical Chemistry from the University of California at Irvine. He has been involved with pyrotechnic research and development, as well as testing and simulation, since 1982. He has authored/co-authored a number of papers presented at the International Pyrotechnic Seminars as well as the Military Sensing Symposia on Infrared Countermeasures. He may be reached at shortridge_robert@crane.navy.mil.

Dr. Caroline Wilharm received her B.S.E. in Chemical Engineering from the University of Iowa, and holds a Ph.D. in Chemical Engineering from Iowa State University. She has been involved with pyrotechnic research, development, and modeling since 1999. She may be reached at wilharm_c@crane.navy.mil.

The authors gratefully acknowledge funding of this project from JASPO, the Office of Naval Research (ONR), and the former Electronic Warfare Advanced Technology (EWAT) Program. We also thank Dr. Bernard E. Douda, Senior Scientist for Pyrotechnics, Ordnance Engineering Directorate, for his review of this article and his support and encouragement during the course of this project.

NDIA's Combat Survivability Division Presents

Annual Survivability Awards

The National Defense Industrial Association's (NDIA) Combat Survivability Awards for Leadership and Technical Achievement were presented to Dr. Steven L. Messervy and Mr. Paul W. Martin, respectively, at the Aircraft Survivability 2002 Symposium. These awards, presented annually at the symposium, recognize individuals or teams demonstrating superior performance across the entire spectrum of survivability, including susceptibility reduction, vulnerability reduction, and related modeling and simulation. In addition to these annual awards, the NDIA Combat Survivability Award for Lifetime Achievement was presented to Mr. John J. (Jack) Welch, Jr.

Leadership Award

This award is presented an individual who has made major contributions to enhancing combat survivability. The emphasis of this award is on demonstrated superior leadership of a continuing nature. Dr. Messervy, Project Manager, Aviation Electronic Systems, Army Program Executive Office, Aviation, Redstone Arsenal, Alabama was the 2002 Leadership Award recipient. He was directly responsible for planning, developing, and fielding all U.S. Army aircraft survivability equipment (ASE). As an effective advocate for aircraft survivability programs, Dr. Messervy tirelessly pushed for increased awareness and funding for all areas of electronic warfare, and he garnered industry, congressional and internal Army support for critical ASE systems. His efforts have been essential to Army modernization efforts as it seeks to enhance combat survivability to meet the challenging threats that now populate the hazardous low altitude battlespace where Army aircraft must fly during wartime. Here, for example, Dr. Messervy spearheaded efforts of a quick-reaction task force charged with developing and fielding ASE designed to counter man portable infrared surface-to-air missile systems. He also led development and implementation of a unified ASE modernization plan, which complements both the Army Aviation Modernization Plan and overall Army transformation planning. Because of Dr. Messervy's demonstrated exceptional leadership in a key technical field, the combat survivability of Army aircraft has been significantly enhanced and the Army better positioned than before to prevail in any future conflict.

Technical Achievement Award

This award is presented to a person or team who has made a significant technical contribution to any aspect of survivability. Individuals at any level of experience are eligible for this award. Mr. Paul W. Martin, Senior Vice President, Government and Advanced Programs, Sikorsky Aircraft Cor-poration, Stratford, Connecticut, was the 2002 recipient. Throughout his career as an engineer and technical manager, Mr. Martin has been instrumental in the development and fielding of survivable military aircraft. In particular, he is credited with integrating stealth technology into the systems engineering discipline, ensuring that this revolutionary new technology was incorporated into the design of a front line weapon system, the F–117 stealth fighter, and not merely allowed to languish as an interesting technological curiosity. He has been instrumental in the transition of several generations of survivability enhancement technologies to meet threats of increasing sophistication, providing critical technical guidance for developments of the F–15, SR–71, F–117, F–22, UH–1N, CH–53, and RAH–66, as well as UAVs. Because of Mr. Martin's personal contributions to enhancing the combat survivability of numerous aircraft and related systems over the years, the United States is today well positioned to prevail in any future conflict.

Lifetime Achievement Award

This award is presented only when merited by the lifetime contributions of a noteworthy individual to the long-term enhancement of aircraft survivability and national security. The Combat Survivability Lifetime Achievement Award was presented to Mr. John J. Welch, Jr., Consultant, Bethesda, Maryland. During a lifetime of service to the U.S., Mr. Welch shepherded the development and fielding of effective air weapon systems that have proven their worth during combat operations. As Chief Scientist of the Air Force, and later as Assistant Secretary (Acquisition), he provided critical technical guidance and acquisition oversight for the U.S. Air Force, thereby ensuring the successful introduction of such systems as the Advanced Cruise Missile, F–22, B–2, and F–117. Importantly, he was influential in convincing others of the military worth of stealth technology as an effective survivability enhancement technique. Mr. Welch continues to serve the Air Force and the Department of Defense as an influential member of a number of independent advisory boards and committees. Because of Mr. Welch's personal contributions to enhancing the combat survivability of a wide range of aircraft and related systems over the years, the U.S. is today well positioned to prevail in any future conflict. ■

From left to right—D. Jerry Wallick, Chairman Awards Committee, Combat Survivability Division; Dr. Steven L. Messervy; Paul W. Martin; John J. Welch, Jr.; and RADM Robert H. Gormley, USN (Ret), Chairman, NDIA Combat Survivability Division.

Calendar of Events

JUN

17–20 Monterey, CA
Joint Aircraft Survivability (JAS) Model Users Meeting (JMUM)
eng_paul@bah.com
937.255.3828, ext. 273

23–26, Orlando, FL
AIAA Fluid Dynamics, Applied Aerodynamics, Thermophysics, Plasmadynamics & Lasers, and Computational Fluid Dynamics Conference
www.aiaa.org

JUL

14–17 Dayton, OH
International Air & Space Symposium and Expo in Celebration of 100 Years of Powered Flight
orkwis@uceng.uc.edu
aiaa2003@cs.wright.edu
http://www.daytonairshow.com/

15–17, Baltimore, MD
UAVSI 2003 30th Annual Symposium/Expo UAVSI
www.auvsi.org

AUG

11–14 Austin, TX
AIAA Guidance, Navigation, and Control; Atmospheric Flight Mechanics; and Modeling & Simulation Technologies
www.aiaa.org

19–20, Los Angeles, CA
Space & Air Protection Conference
www.crows.org

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

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