

# AIRCRAFT SURVIVABILITY

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## Modeling and Simulation Credibility



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Photo by SSgt. David Nolan

## Director's Notes

**T**he Pyramids, the Colossus of Rhodes, the Statue of Zeus at Olympia, and Modeling and Simulation (M&S) are all considered wonders of the world. Well, maybe M&S is not actually a wonder of the world, but it should be. Everyone constantly claims how wonderful it is and yet no one can really explain what it is or how it works.

Modeling and simulation is probably one of today's most misunderstood tools that we use in aircraft design. Its utility is rated somewhere between the ultimate tools capable of easily designing an entire aircraft and support systems, to a necessary evil that must be included in the design process to satisfy the technology junkies of the 21st Century. Some model managers claim that their code can leap tall building in a single bound or lasso the sun and control the universe. While others think that money spent on M&S development would be better spent on building a bridge to the moon. The truth is, M&S capabilities are somewhere near the middle. Modeling and simulation can be a great tool, but a model's limitations and assets need to be well understood for it to help rather than hinder the design process. Furthermore, a designer must remember that M&S is a tool that provides input into the organically based (human) decision process. Software cannot make decisions for us, but models can provide very good inputs into the decision making process.

The Joint Technical Coordinating Group on Aircraft Survivability (JTTCG/AS) sponsors the development and maintenance of a number of aircraft survivability models including ESAMS, AJEM, RADGUNS, and ALARM. We have worked hard over the years to make sure that each model is the most capable and beneficial to the analyst by incorporating the most recent updates and maintaining the latest version in the Survivability/Vulnerability Information Analysis Center (SURVIAC) for distribution to anyone. Although we have come a long way in developing capable models, there are still many issues that exist for the M&S community.

This newsletter issue focuses on many of the great uses of M&S in aircraft survivability design and the issues surrounding them. One of the articles, "The M&S Credibility Workshop II," was written by our Survivability Assessment Subgroup Chairman, Mr. Ron Ketcham. He describes one of the biggest issues in M&S—model credibility. Making a model is easy, but making one that is accurate, efficient, and reliable is a whole other story. The JTTCG/AS has spent a lot of time and money on refining many of the models used in aircraft design so that aircraft designers and program offices are comfortable using these models as a part of their decision processes. If we can make models credible and reusable, we can save a tremendous amount of precious resources, both financial and human, that can be applied to other issues in the design field.

Another issue facing the M&S community is how to transition from legacy code to next generation models. Just look at all the

heartburn JMASS is causing. It is obvious that we have the need and the technology to produce more capable, cost efficient codes that can replace multiple, older, and less capable codes. But how to do this is the problem. I liken the transition from legacy codes to next generation models to a young Tarzan swinging through the jungle. At some point, Tarzan grabs hold of the next vine that doesn't look steady, so he clings to the vine behind him. He needs to continue going forward to make progress through the jungle but hanging on to these two vines paralyzes him. What should Tarzan do? During a briefing to senior DOT&E leadership, I asked this same question. The answer was easy. "Just cut the old vine." That wasn't the answer I expected but it made the point. We need to find a more efficient way to speed up the transition from legacy code to newer more capable models while not losing any capabilities. Money is a finite resource, and we cannot afford to support and upgrade existing models while developing more advanced ones. There is not enough money to go around. Add in spiraling costs and production delays in most software acquisitions, and it is understandable why senior decision-makers become impatient with current efforts at model development. One of the articles in this newsletter focuses on the Advanced Joint Effectiveness Model (AJEM) development, which is a joint effort between the JTTCG/AS, JTTCG/ME, and the ARL. Although we have made some good progress in the AJEM development, the JTTCG/AS has learned firsthand all the headaches that accompany any model transition.

When I first got to this job, I received the M&S tutorial—fire hose style. I was secretly taken to a dark basement office in some building at Wright-Patterson AFB, where toothpicks were used to keep my eyes open, and I was briefed for hours on end about all the different models and what they were used for. Now I have an appreciation for how M&S works and why we need so many different models. I am nowhere near being an M&S expert but I now know enough to understand that M&S has its place in this world. The trick is using models correctly by providing the appropriate documentation and code validation and verification to aid, not inhibit, the decision-making process. To this end, the JTTCG/AS is committed to insure that the decision-makers have the best tools available.



LCDR Andrew (Andy) Cibula (USN)  
Director, JTTCG/AS Central Office



# The M&S Credibility Workshop II

## Planning for the Credible Employment of M&S in Acquisition

■ by Mr. Ron Ketcham

The second workshop for the promotion of modeling and simulation (M&S) credibility was held at the Silver Legacy Hotel in Reno, Nevada on 5–7 March 2002. This workshop, titled “Planning for the Credible Employment of M&S in Acquisition,” was sponsored by the Joint Technical Coordinating Group for Aircraft Survivability (JTTCG/AS). The M&S Credibility Workshop was facilitated by the Joint Accreditation Support Activity (JASA), and endorsed by the Defense Modeling and Simulation Office (DMSO) and the National Defense Industry Association (NDIA). Approximately 125 persons, representing a broad spectrum of Government and industry, attended the workshop.

### Planning for the Workshop: The WEAC

The second workshop (WS II) on M&S credibility, was a true outgrowth of the first workshop held in February 2001. During the first workshop (WS I), many of the problems and issues plaguing M&S credibility were addressed and documented. The goal for WS II was to concentrate on identifying solutions and then follow up the workshop with a plan, or roadmap, to start the long process of seeking to implement these solutions.

After the initial workshop (*Aircraft Survivability, Fall 2001*) JASA decided to expand participation in the planning process by creating a steering committee with membership from throughout the Department of Defense (DoD). The goal was to broaden the perspective of the workshop and enhance the probability of success by reaching out to the various M&S stakeholders. This committee



Rear Admiral Robert E. Besal delivering workshop keynote on “An Appropriate Role for M&S in Operational Test: One Tester’s Perspective.”

was created in late summer of 2001 and was named the Workshop Executive Advisory Committee (WEAC, pronounced Wee-Ack). The membership of the WEAC included—

- Ron Ketcham, Chairman (JASA)
- Bob Cook (SAF/AQI)
- Doug Fraedrich (NRL)
- Frank Gray (AFOTEC)
- Brian Hall (OPTEVFOR)
- John Haug (ATEC)
- Hans Mair (IDA—in support of OSD)
- Debra Ridgeway (AMSO)
- Jim Sebolka (Barcroft Group)
- Jack Sheehan (DOT&E, C3I & Strategic Systems)
- Tracy Sheppard (University of Texas, Austin—in support of OSD)
- Ron Thompson (JTTCG/ME Central Office)
- Mike Weisenbach (JTTCG/AS)
- Simone Youngblood (DMSO)
- Kathy Russell, Workshop Coordinator (JASA)

The WEAC met several times between the two workshops to define the objectives and processes of WS II, drafted and published a call for papers, selected and invited special presenters and the keynote speaker, and set the final agenda. WEAC

members also served as chairmen of five sessions of WS II. Special mention goes to the participation of DMSO in the planning and preparation of WS II. Ms. Simone Youngblood, the DMSO Verification, Validation and Accreditation (VV&A) Technical Director, hosted and facilitated WEAC meetings at DMSO headquarters. She has also assumed an even greater role in the post workshop efforts by taking the lead in documenting what was learned at WS II and developing a roadmap to promote more credible employment of M&S.

### The Workshop

Although WS II did not officially begin until Tuesday, 5 March 2002, early arrivals were able to attend two tutorials held on Monday. Over half of the WS II attendees took advantage of these events. The initial tutorial was “The Statistics of Validation” presented by Dr. Alan Breiter, recently retired from the Center for Naval Analysis (CNA). Michelle Kilikauskas, JASA Director, also presented a tutorial on VV&A.

The workshop sponsors had a more visible presence and impact at WS II. The first day began with an opening presentation by the JTTCG/AS Central Office. LCDR Andy Cibula, Director of the JTTCG/AS Central Office, began by detailing the function and structure of the JTTCG/AS. He described the historical role that the JTTCG/AS has had with M&S. The JTTCG/AS currently has a major role in model development, with such efforts as AJEM (the Advanced Joint Endgame Model). It also plays a pivotal role in M&S support through Survivability/Vulnerability Information Analysis Center (SURVIAC), which in addition to being a repository of M&S used in survivability, also sponsors user group meetings to promote community involvement in the management and direction of M&S tools by the appropriate subject matter experts (SMEs). The JTTCG/AS has also promoted M&S credibility with the creation of JASA and other efforts such as the ESAMS Cooperative Assessment Team (ECAT). ESAMS is a group of subject matter experts using open-air test range data to com-



From Left to Right: Col Phil Faye (ESC/CX), LCDR Andy Cibula (JTTCG/AS), Ron Thompson (JTTCG/ME), Col Kevin Greaney (MDA), Chad Holvenstot (SAIC), Edmond Levy (Northrop Grumman), David Blancett (Northrop Grumman), Maj Steven Bishop (USF PO).

pare with ESAMS outputs for validation purposes. But there are concerns within DOT&E and the JTTCG/AS regarding the rising costs of M&S support. The JTTCG/AS needs to reevaluate the role they have in M&S management and support. LCDR Cibula asked the conference attendees “who is in charge of M&S within the DoD?” He asked, “what was the role of DMSO and who should be sponsoring this Workshop?” He also said that, “there needs to be a plan for the long-range support of M&S.” Finally, he asked, “what was going to be the product of the workshop?”

At his luncheon address later that day, former LFT&E Director James O’Byron answered some of the issues raised about the role of DMSO. He stated, “there are differing perceptions of DMSO’s roles.” He added that the role and size of the DMSO staff is not clearly understood throughout DoD. DMSO does not have the people to take on M&S in the manner desired by many—but not all. Finally, he challenged the audience with the statement that you should “get busy solving your own problems, do not look for OSD or DMSO to solve your problems.”

These issues were further addressed on the second day of WS II by Robert “Wojo” Wojciechowski, DOT&E staff assistant to the Live Fire Test

(LFT&E) office. He began by stressing that the workshop needs to have a product. The product needs to focus beyond the problems, beyond the possible solutions, and place aim at actual fixes. He also raised the issue of who in DoD should be sponsoring this workshop.

Wojo also identified many of the T&E community concerns with M&S—

- M&S often does not provide the information that helps to answer the key programmatic issues.
- There are few, if any, early V&V opportunities.
- There are no tests conducted to generate data needed for model inputs.
- M&S is used too late.
- Model predictions are often made using different M&S tools and are not comparable.
- There is a lack of a model-test-model approach.
- Poor model documentation often does not provide the information required to assist the user in determining M&S credibility.

- There are difficulties and limitations in correlating M&S results with test results.
- Proprietary M&S often prevents a credible V&V effort.
- M&S tools are modified for each program, thereby making past V&V information less useful.
- “Building block” approach is used for testing but not M&S applications.

He ended his brief with some clear recommendations for improving M&S employment in test and evaluation (T&E). The M&S community should be included in the TEMP process to ensure that M&S is used appropriately. Improve the quality of the M&S documentation to include assumptions and limitations, and clearly define the intended applications for the model or simulation. Finally, ensure that the program has supplied resources for M&S early enough to enable testing to provide M&S inputs and data for V&V, to provide for the development of any new features required by the program, and finally to fund M&S VV&A efforts.

The keynote speaker, Rear Admiral Robert E. Besal (COMOPTEVFOR) also addressed the question of the role of M&S in T&E during his remarks (the memorandum was signed by the four heads of the OTA organizations expressing their concerns about the appropriate role of M&S in OT&E.) They were concerned that with the pressure to reduce acquisition time and costs, that model results may sometimes be substituted for test results. RADM Besal and the other signatories felt that while there was an appropriate role for M&S in OT&E, it is essential that—

*operational testing should continue to be the primary basis for OT&E [in order to] ensure that the real system, in the real environment, with the real operator, can accomplish its operational task.*

He also expressed concern that the resources were not being made avail-

able to address credibility concerns in a timely manner for OT&E.

The rest of the briefs were divided into the five Workshop sessions. These sessions were—

- **Programmatic Issues that Impact Effective Planning for Credible M&S (Chairperson: Mr. Mike Weisenbach, JTCG/AS)**—This session examined current acquisition practices and how they impact the ability to plan for the employment of credible M&S in survivability and lethality.
- **Effective Planning that Promotes Credible Utilization of M&S in T&E (Chairperson: Mr. Tracy Sheppard University of Texas, Austin)**—During WS I, the T&E community specified a solid requirement that M&S employed in support of T&E must be credible. This session focused on how the T&E community effectively plans for the usage of M&S and how their credibility concerns were, or were not, being addressed.
- **Software Development and Management Processes that Promote M&S Credibility, Chairperson: Mr. Douglas Fraedrich—Naval Research Laboratory (NRL).** This session examined the available infrastructure for development and maintenance of M&S is often extremely limited. This significantly impacts the ability to properly VV&A M&S utilized in survivability and lethality.
- **V&V—Addressing the Technical Issues (Validity, Interoperability, and Reuse) (Chairperson: Ms. Simone Youngblood, DMSO)**—This session looked at technical issues and innovation that had impact on M&S credibility.
- **Planning for the Transition of Legacy Models to New Model Developments (Chairperson: Ms. Simone Youngblood, DMSO)**—The survivability and lethality communities are facing a major M&S tool transition

with the employment of the new models (e.g., AJEM, JMASS, JSIMS, JWARS) to replace some current legacy models. This session allowed the user community to address credibility concerns with regard to this transition.

### Post Workshop Efforts

The critical post WS II follow-up activities of the WEAC began at the workshop. The WEAC, joined by other interested attendees, met at the end of each day’s briefings to create a daily summary of the key points raised during the daily briefs, panels, and open discussions. This was a key resource in developing the workshop out brief.

Special mention goes to Mr. Jim Hollenbach, President, Simulation Strategies, Inc. Mr. Hollenbach, a former Navy Captain and Director of DMSO, formed a working group of WS II attendees, exclusive of the WEAC membership, to meet after hours to address some of the issues being raised at WS II. His working group reported their findings on the final day. One of the key concerns raised by this working group was that the focus of the WS II might be too broad to be effective. They felt a better approach would be to form smaller workshops with a narrower focus. Speakers and attendees would also be more selective to address the specific issue in a more substantive way.

Mr. Hollenbach has joined the WEAC in developing the WS II out brief and roadmap. This effort, led by Simone Youngblood of DMSO, is intended to analyze and digest the briefs, panels, open discussions, and summary slides generated at WS II to identify commonality in issues and observations. It also will focus on possible resolution identified at WS II and in the post workshop efforts. This out brief will form the basis for the roadmap on what and how the WEAC will seek to address these concerns. ♦



After Hours: The Workshop generated enthusiasm that lasted well after the daily briefs. This photo was taken at about 6:00 p.m. after the second session on Wednesday 6 March, 2002. It depicts multiple workgroups discussing workshop issues after hours.

Mr. Ron Ketcham has a B.A. degree from Transylvania University (Lexington, Kentucky) in Economics, and a M.S. in Economics and Industrial Engineering from Iowa State University. He began his career at the Naval Weapons Center at China Lake in 1982 as a warfare analyst (Air-to-Air and Strike Warfare) for the Weapons Planning Group. In 1987, he took over as Project Manager for the Analysts' WorkBench (AWB). During this period he did work in the area of Software Development, Software Development Process Improvements, and VV&A. In the early, 1990s Ron served on a DON committee that drafted initial Navy M&S VV&A policies. In 1997, Ron joined JASA and took over as Accreditation Lead for the Joint

Strike Fighter (JSF). He is currently head of the System Survivability Integration Branch at the Naval Air Warfare Center Weapons Division (NAWCWD Code 418100D). He is also the Chairman of the Survivability Assessment Subgroup for the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS).



LCDR Andy Cibula, Director of the JTCG/AS Central Office

CDs of all workshop presentations, out brief, and other WS II related documents can be obtained by contacting—

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# Modeling and Simulation Credibility

■ by Mr. Ron Ketcham and Ms. Simone Youngblood

**T**he Modeling and Simulation (M&S) Credibility Workshop II (WS II), “Planning for Credible Employment of M&S in Acquisition” (March 2002) provided attendees from Government and industry with an excellent opportunity to exchange ideas and lessons learned for enhancing the quality of M&S results throughout the Department of Defense (DoD). WS II also provided attendees a venue for building networks of M&S professionals in the survivability, lethality, and mission effectiveness disciplines. However, the benefits of WS II were not limited to the actual event. It was always envisioned that WS II would begin a process to identify obstacles

(and solutions) to the credible application of M&S, and the ultimate goal of the workshop was to define a roadmap to implement process and practice improvements that mitigate, or even eliminate, these obstacles.

In order to accomplish that goal, the Workshop Executive Advisory Committee (WEAC) immediately following WSII began sifting through the workshop presentations, panel discussion notes, and attendee comments to pull out common observations, and themes, and document recommended solutions to . Over a period of several meetings these were discussed and prioritized by members of the WEAC. The roadmap is being created from these prioritized lists to define how to

implement the recommendations from WS II. The WEAC also took into account the lessons learned from the initial M&S Credibility Workshop held in 2001 and the follow-up actions that resulted from that event to further enhance the probability of success. The results of WS II was presented to the Defense Modeling and Simulation Office (DMSO) VV&A Technical Working Group (TWG) in August 2002. An overview of the findings to date is presented in this article. The results and the roadmap were not yet complete as of this writing, so only preliminary results are presented here.

Issue/Observation	Resolution
<ul style="list-style-type: none"> <li>• Mission Context required to convert (observable) performance into understanding of (tangible) survivability, and (non-observable) Effectiveness. (SS #1, pg 1)</li> <li>• Validation and Accreditation anchored to often ill defined purpose. Understanding how purpose and outcomes affect decision can provide essential information. (SS#1, pg 1)</li> <li>• “You must have a good understanding of the intended purpose of the M&amp;S” (SS #1, pg 2)</li> <li>• “Operational context is key,” V&amp;V must be anchored to purpose (Hollenbach, pg 4)</li> <li>• Need to anchor across fidelity (Greaney)—maps to aggregation/de-aggregation issue raised by Hollenbach</li> <li>• User (application) requirements are essentials to successfully implement V&amp;V and ultimately achieving accreditation (Meyer)</li> <li>• “You don’t give a combat mission to the equipment, you give it to the warfighter.” (Rice)</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Theoretical</b>—“Focus” necessary to wisely invest finite VV&amp;A resources, VV&amp;A benchmark to “Purpose” “Purpose” is implicit, is often subjective across disparate stakeholders Perhaps wargaming decision “outcomes” would add explicit, objective structure to “purpose” thereby providing “focus” to VV&amp;A “Focus” will shift based on Acquisition stage: basic research; concept formulation; risk reduction; down select; full rate production (Sheehan, Summary Slide #1, pg 2)</li> <li>• <b>Education</b>—Train people to build robust requirements</li> </ul>

Figure 1. Impact of Mission Context on Requirements (names in parenthesis refer to the presenter from whose presentation the comment was drawn).

Issue/Observation	Resolution
<ul style="list-style-type: none"> <li>• Sensitivity analysis is invaluable for both model ND data accuracy requirements (Fraedrich)</li> <li>• Understanding the impact of parameter sensitivity for each type of test/analysis under consideration is vital (Shepherd, pg. 15)</li> <li>• Analysis of the impact of input parameter fidelity and input parameter absolute accuracy on engagement outcome is <b>REQUIRED</b> to enable credible IRCM effectiveness assessment. (Hatfield, pg. 10)</li> <li>• Sensitivity analysis enables V&amp;V to be focused on the critical issues, the high risk factors identified in the risk assessment (Fraedrich).</li> </ul>	<ul style="list-style-type: none"> <li>• Implementation—The high fidelity physics-based modeling approach structures and supports sensitivity analysis, focuses and maximizes value of experiments and tests.</li> <li>• Education— <ul style="list-style-type: none"> <li>– Training in statistical analysis</li> <li>– Training to avoid operator errors</li> <li>– Documentation <ul style="list-style-type: none"> <li>Formal manuals (technical, procedural, user, tutorial) and release notes</li> </ul> </li> <li>– On-call tech support</li> <li>– Users group</li> </ul> </li> <li>• Conclusion—There needs to be a better understanding of the mathematical underpinnings of sensitivity analysis and how it is applied to M&amp;S assessment.</li> </ul>

Figure 2. The Importance of Sensitivity Analysis to the Assessment of Simulation Credibility

### Workshop Accomplishments

To date, the workshop and follow-on WEAC efforts have resulted in the following accomplishments—

- Captured key issues
- Shared practical approaches to VV&A challenges
- Shared demonstrated and proposed solutions
- Workshop attendees synergistically derived solutions
- Synthesized proposed approaches

The important issues for M&S credibility were captured during the workshop, particularly common challenges that were identified by numerous attendees from multiple organizations. For each of these issues, the observations from multiple presenters, panel members, and audience members were recorded and combined under a single heading for the issue being considered. The WEAC then developed “theoretical” and/or “implemented” solutions to the issue, along with conclusions, recommendations, and recommendations especially for education requirements as part of the solution. Examples of the issues, observations, conclusions, and recommendations are given in the “issues” section below.

### The Issues

The key issues that were captured at the workshop include—

- Impact of mission context on requirements definition
- Relationship between correlation and validation
- Defining accreditation (good enough) and how to achieve it
- Importance of sensitivity analysis to the assessment of simulation credibility
- Critical requirement to improve M&S documentation
- Appreciate the importance of configuration management
- Mapping M&S use to the Verification, Validation, and Accreditation (VV&A) spiral development process
- Discipline to the M&S/VV&A process

Examples of the substantiating information used to derive the key issues can be found in Figures 1 and 2.

While some of the key issues are well known to the M&S community, others are less recognizable but no less important. Two issues that are often identified as primary obstacles to the

credible use of M&S are the lack of well articulated requirements and a limited understanding of the intended use and associated mission. Throughout the duration of the workshop, several presenters highlighted the pitfalls associated with ill-defined or vague user requirements. It was noted that to effectively and efficiently validate and accredit a model or simulation, you must clearly understand and document the intended use of the model and the requirements of the user’s application. The acceptability criteria, which flow from the M&S requirements, will be the criteria used to accredit. Clearly defined user requirements will focus any necessary V&V activity, thereby making the accreditation process more affordable and practical. Figure 1 (see page 8) illustrates the WEAC findings associated with this issue.

When it comes to M&S credibility, several presenters raised the question of defining “good enough,” identifying it as a critical factor in establishing the required levels of V&V. While in most cases, it is unrealistic to expect something to be validated 100%, it is essential that the user balances the risks being assumed in using the results of the M&S for a specific application against the cost of accumulating V&V evidence. A quote from WS I “Balancing the cost of knowing against the risk of assuming,” really cuts to the heart of the matter.

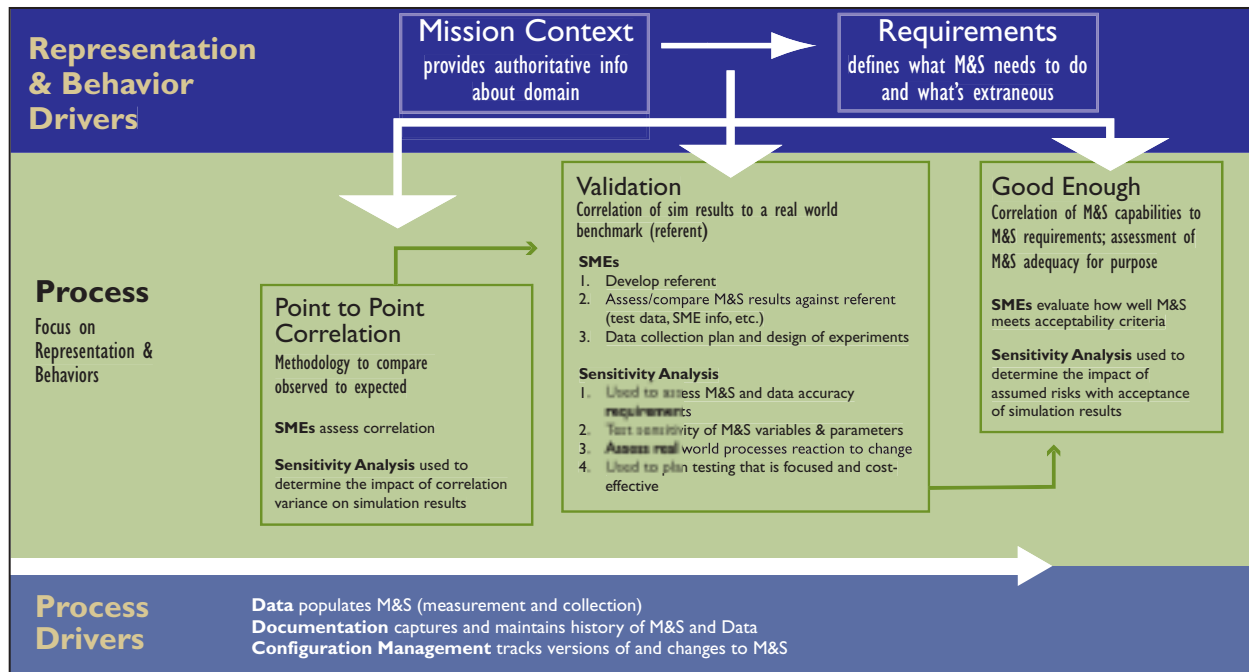


Figure 3. Conceptual Framework for Relating Issues

Multiple references were made to the employment of subject matter experts (SMEs) in defining “good enough” for a particular intended use. It is appropriate in some instances (i.e., when evaluating the representation of future systems) for the SME to play a key role in assessing credibility when relevant validation data may not exist. However, it should be noted that the qualitative nature of SME assessment would not be appropriate in all cases. Some instances may require a more quantitative evaluation. One such quantitative assessment, sensitivity analysis, was mentioned quite often in the course of the workshop. Sensitivity analysis used to support the establishment of M&S credibility can provide a wealth of information about the model or simulation as well as information of great value to SME assessments. Figure 2 (see page 9) is another illustration of the WSII output to date that lists the observations and recommendations from the WEAC with respect to sensitivity analysis.

There was considerable focus during the workshop on the elements of good model management and documentation, and the impact these processes have on enhanced M&S credibility. The value of requirements

management has already been addressed. However, good configuration management (CM) is also an essential part of the equation. Several presenters highlighted that the positive relationship between model management processes and the quality of model results demonstrates the value of applying the capabilities maturity model (CMM) to support the establishment of M&S credibility by evaluating the quality of a simulation’s underlying software development process.

Another common thread running through the workshop briefings and panel discussions was the need to find more mechanisms to share information and experiences. This is especially important for cash-poor programs that would benefit from capitalizing on or leveraging the V&V efforts of others. Forums such as this workshop and individual model user group meetings facilitate this exchange of information. Good documentation by model developers will also assist in a program’s reuse of legacy models, providing information on previous V&V results that could serve as the foundation for new V&V activities. DOT&E stressed the need to improve model documentation, especially in identifying limitations and assumptions, as important to reducing the

cost and time associated in V&V efforts.

While each of the key issues discussed above stands alone, they are all related. Figure 3 demonstrates the relationship among these key technical issues. The diagram has three levels. The first level is focused on the definition of the Mission Context from which the Requirements are defined. These two items, Mission Context and Requirements, will drive the required representations and behaviors. The second level presents the process through which the representations and behaviors will be assessed for credibility. The third level shows the key process drivers [e.g., data, documentation, and configuration management (CM)], which play a critical role in the assessment and execution process. Under the concepts of Point to Point Correlation, Validation, and Good Enough, the role that SMEs and Sensitivity Analysis would play has been emphasized. However, these are not the only activities that will take place as these processes are implemented. The arrows accompanying the process drivers (data, documentation, and CM) indicate that they impact the whole assessment process. They also apply to the definition of the Mission Context and Requirements.

## The Future of the WEAC and the M&S Credibility Workshops

During Workshop II, both DOT&E and the JTCG/AS raised questions regarding the role and sponsorship of the M&S Credibility Workshops. While they were the primary sponsors for the first two workshops, it was emphasized that in order to procure their continued sponsorship, Workshop II must result in a product of real value. In response to that challenge, the WEAC is working to develop two products: The WS II outline and an associated map which identifies post-Workshop II activities. Additionally, the WEAC is working to establish partnerships with other organizations that have vested interests in M&S credibility (e.g., DMSO, the Service Offices). These partnerships will serve to facilitate implementation of the activities identified in the roadmap.

Finally, numerous comments from attendees regarding the valuable role that follow-on M&S credibility workshops was addressed. With the importance placed on M&S in the systems acquisition process, this type of forum is vital by providing a mechanism for the exchange of ideas and lessons learned among professionals in the field. However, the WEAC has recognized that changes should be made to increase the value of the workshops. As mentioned above, the WEAC recognizes the importance given to education in the solutions promoted at WS II. Therefore, the WEAC has proposed that any follow-on activity focus on these education requirements in M&S credibility.

While education was always one of the objectives of the workshop, members of the WEAC are considering specific proposals that will increase the focus on VV&A related training. These proposals include conducting smaller and more focused seminars and providing mechanisms for writing, publishing and disseminating white papers, and articles on M&S credibility topics, such as—

- Configuration management

- Requirements management
- Model documentation
- Risk assessments and mitigation
- Sensitivity analysis

Therefore, while the M&S Credibility Workshop II has ended, the forward progress continues. The WEAC is moving ahead with the ideas gleaned from the presenters and panels in Reno. A roadmap to more credible M&S is being developed and partnerships are being formed to increase the likelihood of its success. ♦

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*Ms. Simone Youngblood is a member of the Principal Professional Staff at the Johns Hopkins University Applied Physics Laboratory (JHU/APL). For the past five and a half years, Ms. Youngblood has served as the DoD VV&A focal point in her position as DMSO's VV&A Technical Director. Leveraging an extensive background in simulation development, modification and application, Ms. Youngblood has been active in the VV&A community for the past 10 years. She contributed to the development of Service and DoD policy and guidance. She has also led or supported a variety of VV&A efforts. From 1997 to the present, Ms. Youngblood has served as the chair of the SIW VV&A Forum. Ms. Youngblood is also active in the Society for Computer Simulation and the Military Operations Research Society. Ms. Youngblood has a B.A. in Mathematics as well as a B.S. and an M.S. in Computer Science.*



# A Warfighter's Perspective

## on Aircraft Survivability

■ by Major Robert W. Mann, (USAF)

**S**cientific results cannot be used effectively by soldiers who have no understanding of them, and scientists cannot produce results useful for warfare without an understanding of the operations.

—Dr Theodore Von Karman, Chairman, Scientific Advisory Group, 1944

*“Five seconds, bomb doors—open, three, two, one, internals are going, internals are gone, externals are going, whomp, externals are gone, bomb doors—closed, pilot, come right to heading 164, known SA-2 site 2 o’clock 25 miles. What was that whomp?”* So went the first combat sortie of a young (and certainly less gray) Lieutenant Mann in the hostile skies of Iraq. Survivability engineers by definition care about aircraft survivability, but trust me, at that point I really cared about aircraft survivability.

But, back to that unexpected *whomp*...as we dropped our full load of 24 CBU-87 combined effects munitions they prematurely func-

tioned, filling the air with 4,848 armor piercing, fragmenting, and incendiary BLU-97 submunitions. We had dodged SA-2 missiles and 100 mm anti-aircraft fire on the way to the target only to take hits from our own weapons detonating close below the aircraft. The Republican Guard’s Medina Division would keep its tanks another day.

Operators have two goals in mind when they plan a combat mission. First and always, plan to accomplish the mission. The mission is paramount, be it iron and fire on the heads of bad guys, supplies to an airfield, or passing gas to other aircraft. Second, plan to survive. Crews need to return an aircraft and crew that can fly the next mission. In summary, the products of the mission planner are live crews and dead targets. In this, aviators and those working on aircraft survivability improvements share a common goal, although we pursue it in different ways.

Combat mission planners focus almost entirely on decreasing the sus-



Figure 2. CBU-87 deploying its BLU-97 submunitions.

ceptibility of their aircraft. It might seem like common sense but avoiding a hit is always the goal. Especially since one of the critical components of that aircraft is a warm pink body, very often belonging to the person that planned the mission. As Dr. Bob Ball, the guru of aircraft survivability education notes in his classic text, “When penetrated, crew members tend to lose their ability to function.” Indeed!

I wonder to what degree the engineers working to improve aircraft survivability know how aircrews work to reduce susceptibility, and vice versa? It would be pretty difficult to keep up with even one specific aircraft. Operators never stop changing tactics, techniques, and procedures. As a flyer, I believe that it is extremely important that as we change our tactics, we take into account whatever survivability measures have been built into the aircraft. We certainly don’t want to develop a new threat avoidance measure that negates other aspects of our survivability, but of course, that street runs both ways.

Survivability enhancements that we can’t or won’t use because they are at odds with how we employ the aircraft are not very useful. As an example, I once heard a survivability engineer



Photo by: MSGT Greg Kobashigawa

Figure 1. A B-52 returns from its bombing mission in support of the USCENTCOM execution of Operation Enduring Freedom, March 23, 2002.

state with conviction that aircrews operate stupidly by not simply dropping flares preemptively in anticipation of a MANPADS launch. His organization had designed flares thinking that we would use them that way. They were not aware of several problems with this idea. First, most aircrew will never use flares preemptively at night because they will highlight the aircraft to a myriad of other threats. Second, because many aircraft have a limited number of flares, they cannot be used on every pass. Third, preemptive flaring could very well exhaust the entire flare load, leaving no flares available for reactive use (i.e., after a shot has been fired).

So with all that said, what is the point? Speaking as an aviator, I believe that it is vitally important that the engineering community know what we do, and that we in turn, know why and what they have done to our aircraft. A large amount of the readers of this newsletter most likely follow the traditional breakdown of the aircraft survivability discipline into susceptibility and vulnerability components. I would hold that a vital third component—one that intricately intertwines conventional survivability—is the operator. It is the operator that ultimately takes the work of the rest and goes into harms' way.

For example, consider aircraft vulnerability. In many cases, the various vulnerability reduction features that have been built into or added onto the aircraft are nearly transparent to the operator. Most of the time this is not a problem—vulnerability reduction measures tend to be passive in nature, requiring little to no interaction with the aircrew. But in a combat situation, especially after a shot has been fired, knowledge and understanding of these features could literally mean the difference between death and a really good “there I was” story for the bar. Just about every aircraft flown has something called a “last ditch” maneuver that is initiated when a hit is imminent. In this situation, wouldn't it be useful for the crew to know which parts of the aircraft are better able to withstand a hit, or which systems are disabled or destroyed after a hit in a particular location? And



Photo by SSgt. Phil Schmitt

Figure 3. Three B-52G Stratofortress aircraft leave clouds of exhaust behind as they take off in formation.

wouldn't it be equally useful for the vulnerability reduction engineers to have some knowledge about how the aircraft is employed during those last critical 3–5 seconds when the threat is inbound to the aircraft?

When going into “Indian country” operators put a lot of faith into the work that the two survivability communities have accomplished. While aircraft survivability has most definitely improved since the enormous attrition rates of Vietnam and earlier conflicts, it would certainly lead to a better product if engineers and operators sought out each other and cooperated on issues before mixing it up with the bad guys. An engineer working on aircraft survivability that never talks to an operator is missing out on a deep well of information that could make his or her work more useful in the field. Survivability programs need to be collaborative efforts between engineers and warfighters. Operators would better understand the protective measures and tools that are on the aircraft, and engineers would better understand what operators intend to do with their efforts in combat. ♦

*It is not sensible for the ones who specialize at the other end, to have such disregard for each other. (They don't actually, but people say they do.)*

—Dr Richard Feynman, Nobel Prize Winning Physicist, raconteur, bongo player

Major Robert W. Mann is a B-52 Instructor Radar Navigator and Weapons Officer with over 3,000 hours in the B-52G, B-52H, RF-4C, T-43, E-3A, and T-37 including 125 combat hours. He took part in Desert Storm, Allied Force, and is currently deployed in support of operation Enduring Freedom. He has a B.A. in History from The Citadel, an M.S. in Management from Embry-Riddle University, and an M.S. in Military Operational Arts and Sciences from The Air University. He may be reached at [robert.mann@b2.wpafb.af.mil](mailto:robert.mann@b2.wpafb.af.mil).



Photo by: Staff SGT Shane Cuomo

Figure 4. An Air Force munitions specialist from the 28th Air Expeditionary Wing changes the configuration of a B-52 external bomb rack from Joint Direct Attack Munitions to conventional munitions, November 28, 2001, during Operation Enduring Freedom.



The PUSH for an

# Advanced Joint Effectiveness Model (AJEM)

by Mr. Doug McCown, Mr. Ron Thompson, and Mr. Michael R. Weisenbach

In the early 1990s, the Anti-air Working Group of the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) identified the need for a new anti-air effectiveness model. In 1993, a group led by Mr. Bruce Nofrey of the Naval Air Warfare Center, Weapons Division at Port Mugu, California, and Mr. Tom Wasmund of the Naval Surface Warfare Center, Dahlgren, Virginia (both now retired) proposed this development to the Defense Modeling and Simulation Office (DMSO). DMSO encouraged the development of the Advanced Joint Effectiveness Model (AJEM) but stipulated that it made use of the Modular UNIX™-based Vulnerability Estimation Suite (MUVES) environment developed by the Army Research Laboratory (ARL). At the same time, the

JTCG/ME received critical support for AJEM development from the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS). These coordinated efforts resulted in the 1997 publication of the *Software Requirements Specification for the AJEM*. With the incorporation of MUVES, AJEM now possessed the potential to become the standard tool of the Department of Defense (DoD) for evaluating the vulnerability of aircraft, missiles, and ground-mobile targets, as well as the lethality and effectiveness of munitions.

Spiraling in on the goal to convert that potential to reality, there have been four releases of AJEM.

- September 2000 AJEM 1.0— Provided basic functionality

- August 2001 AJEM 1.1— Improved functionality, included MUVES upgrades and Encounter Visualization (EVT)
- November 2001 AJEM 1.2— Addressed user identified deficiencies
- June 2002 AJEM 2.0— Provided upgrades to the Graphical User Interface and included BRL-CAD™ 6.0

As shown in Figure 1, the vulnerability and lethality (V/L) processes currently employed by the survivability and lethality communities can involve a variety of tools in a variety of combinations. These tools can be sorted into three basic functions: target geometry, vulnerability assessment, and endgame. AJEM is

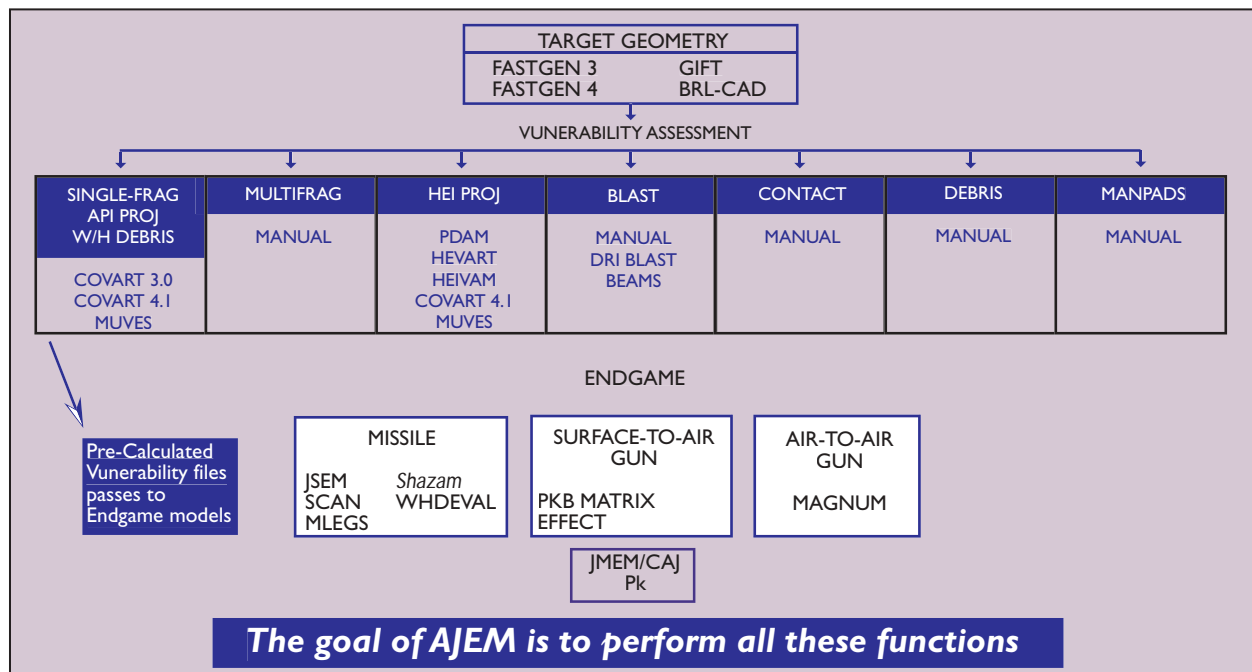


Figure 1. Common Vulnerability/Lethality Processes and Tools

designed to perform all of these functions in a single software package.

Making AJEM the standard DoD tool to perform all of these vulnerability and lethality functions is going to take a bit of a PUSH. That PUSH has taken the form of FY02 and 03 investments in—

- Production reliability
- Usability
- Suitability definitions, and
- Handling Verification, Validation and Accreditation (VV&A) issues.

AJEM is intended to be a production analysis tool. AJEM production reliability means a broad spectrum of users should be able to employ AJEM reliably, rapidly, and repetitively. AJEM has to meet the needs of this broad spectrum of users if it is going to be the standard tool for these applications.

That ushers in the second component of the PUSH—usability. For usability, AJEM documentation will be continuously maintained to ensure accuracy and clarity. Example applications for common AJEM applications will be provided (i.e., LFT&E, missile flight test analyses, design trades for

aircraft, and warhead applications are being considered). Also, the JTCG/ME and JTCG/AS have sponsored several introductory training courses to address analysts' AJEM usability issues. We are focusing in FY02 and 03 on fully supporting the AJEM user community by way of a solid foundation of support for several production analyses that will demonstrate both AJEM usability and capability. This support has and will help new users with their specific AJEM applications.

The third component of this PUSH is suitability. AJEM and its underlying structure, Modular UNIX™-based Vulnerability Estimation Suite (MUVES), has been shown by ARL to be suitable for a variety of ground-mobile V/L applications. The JTCG/AS and JTCG/ME are currently engaged in establishing and demonstrating the suitability of AJEM for the needs of the air target community through the above mentioned Production Analyses, and through the development of air target specific test cases. The ARL has significantly improved the suitability of AJEM for air targets by incorporating FASTGEN geometric modeling primitives into BRL-CAD™ 6.0.

The final element in the PUSH for AJEM is in handling VV&A. This

VV&A process is being accomplished in accordance with, *Procedures for Accreditation of Software by the JTCG/ME (61 JTCG/ME-1-7)*. The AJEM VV&A process is also in accord with the JTCG/AS process as developed by the joint accreditation support activity (JASA). The expected result is the preparation of one or more Accreditation Support Packages (ASP) for AJEM. These AJEM ASPs will be based both on results of current efforts as well as on a great deal of existing information. Current efforts include comparisons of AJEM results with those developed using the computation of vulnerability and repair times (COVART) model, which is the current standard analysis tool. These comparisons are being conducted for both ground-mobile and high performance fixed wing aircraft targets.

Existing AJEM documentation consists primarily of the new MUVES ASP-1 and analyst manual. While the MUVES makes up a significant portion of the AJEM product, the existence of MUVES verification and validation doesn't get AJEM completely off the hook. Figure 2 highlights (dark outlined boxes) ASP issues that are unique to AJEM.

The ASP will be submitted to an AJEM Model Review Committee

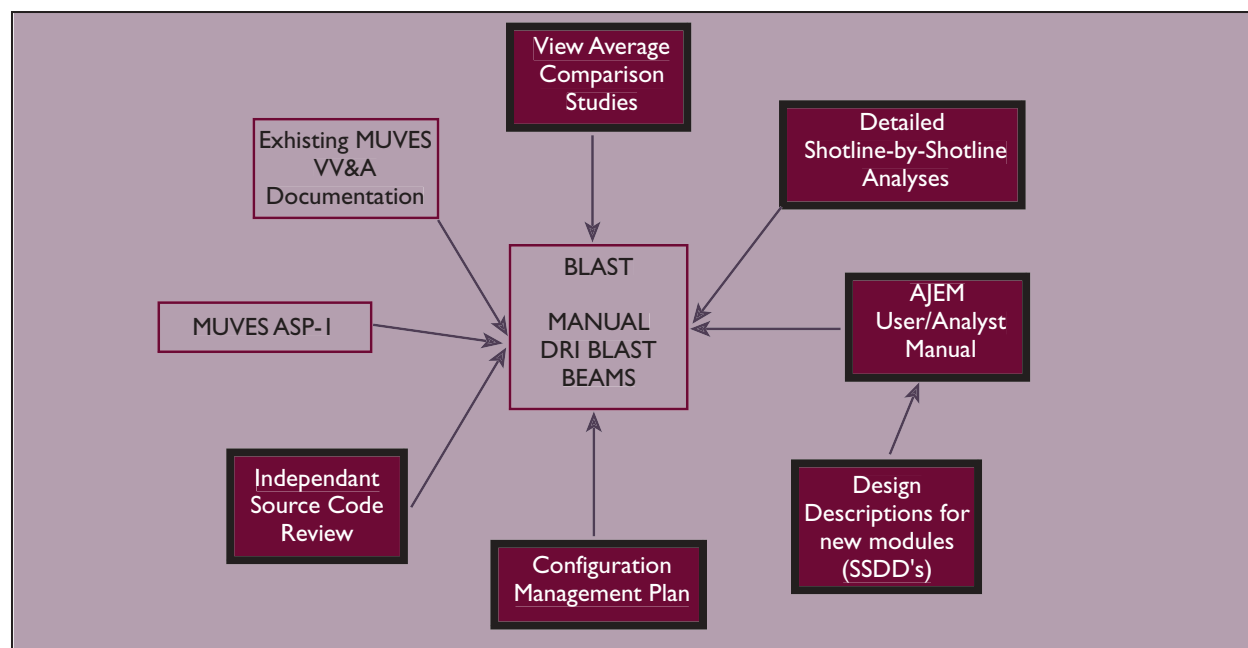


Figure 2. Accreditation Support Package (ASP) Issues



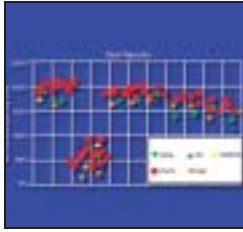
(MRC) that is currently being planned for FY03. The objective of the MRC will be to make an AJEM accreditation recommendation concerning the use of AJEM by the JTCG/ME to develop estimates for munitions effectiveness [Joint Munitions Effectiveness Manuals (JMEM)]. The MRC will have the responsibility to make sure that AJEM is applicable and sufficiently credible for the JMEM application. In this process, the MRC will use the AJEM ASP, along with information on the AJEM software configuration control process, and AJEM management support structure. Our intent is then to make the ASP, along with other pertinent accreditation documentation available as a resource for others with a need to accredit AJEM for their own specific applications. The JTCG/AS develops ASP documents for the major M&S supported by that organization and distributes them to users through the Survivability/Vulnerability Information Analysis Center (SURVIAC). AJEM will become one of those M&S supported by the JTCG/AS, as well as the JTCG/ME.

To learn more about AJEM or provide us with valuable feedback to help us improve the quality of the AJEM product, visit our Web site at <http://www.ajem.com> ♦

*Mr. Doug McCown was appointed AJEM model manager in November of 2001. He received his B.S. in Systems Science from the University of West Florida. He has been involved in the JTCG/ME for 15 years. He has 19 years of experience in vulnerability, lethality, testing, technology development, and weapon system development. Most of this work has been for air-to-air weapon systems. He has been the principal maintainer of the missile lethality code, Shazam, at Eglin Air Force Base, delivering Wright-Patterson their first copy in 1986. He may be reached at 850.882.9585, or [mccown@eglin.af.mil](mailto:mccown@eglin.af.mil).*

*In September 2001, Mr Ronald A. Thompson joined the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) Program Office at Aberdeen Proving Ground, Maryland. He is the Anti-Air Technical Program Manager, AJEM coordinator and Contracting Officers Technical Representative. Prior work since 1983 at the Army Materiel Systems Analysis Activity (AMSAA) was in ground combat vehicle system development, methodology development, test and evaluation, and live fire. Mr. Thompson has a B.S. in Mechanical Engineering from the University of Maryland, is a Registered Professional Engineer and has an M.S. in Technical Management from the Johns Hopkins University.*

*Mr. Weisenbach is currently the Air Force civilian representative in the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) Central Office. He has been in the Central Office since May 2000. His duties include providing oversight and direction to the Survivability Assessment Subgroup. Prior to his current assignment, Mr. Weisenbach spent 14 years at the Aeronautical Systems Center, Wright-Patterson AFB, Ohio, in the Mission Analysis and Engineering Directorates. He supported the survivability and effectiveness analyses of conceptual designs ranging from advanced tactical transports to cruise missile defense systems, and also served as the F-22 Live Fire Test Engineer for 12 months. He is a 1984 graduate of the University of Notre Dame with a B.S. in Aerospace Engineering. He can be reached at 703.607.3509, ext.18, [weisenbachm@navair.navy.mil](mailto:weisenbachm@navair.navy.mil)*



# Successful Correlation of M&S to Live Fire Test Results

for the U.S. Army's SIIRCM Program

■ by Mr. James Hatfield III, Dr. Mike Neer, and Ms. Julie Locker

**W**ith the war on terrorism, there is a new urgency to develop and field self protection systems for U.S. Army aircraft. The U.S. Army's Suite of Integrated Infrared Countermeasures (SIIRCM) has completed a successful integrated test program in CY2001–CY2002 and is currently entering into production for fielding on the MH-47 Chinook helicopter. The SIIRCM system is developed and managed by the U.S. Army's Program Manager for Aviation Electronic Systems located at Redstone Arsenal, Alabama. The system is designed to provide aircraft defensive countermeasures for defeating incoming heat-seeking missile threats to U.S. Army attack, utility, cargo, and special operations aircraft. The SIIRCM system components include the Advanced Threat Infrared

Countermeasures (ATIRCM), Common Missile Warning System (CMWS), and the Advanced Infrared Countermeasure Munitions (AIRCMM) (see Figure 1). The U.S. Army's current IRCM configuration for the fleet helicopter consists of the Countermeasures Set (AN/ALQ-144A) for the AH-64 Apache and the UH/MH-60 Blackhawk, and the AN/ALQ-156 missile approach detector and M-130 flare/chaff dispenser for the CH/MH-47 Chinook.

The SIIRCM program is a simulation based acquisition program. Obviously, live missiles cannot be fired at manned aircraft. Therefore, senior Department of Defense (DoD) management must make production decisions without ever firing missiles at the aircraft they are trying to protect. Models and simulations are used to overcome test limitations and

supplement system performance test data. One of the early uses of modeling and simulation (M&S) in the SIIRCM program was to make pre-test predictions in support of test plan optimization, risk reduction, range safety analyses, and on-site quick look analysis.

The most important use of M&S has been to supplement limited open air range test results in evaluating key system performance measures such as probability of declaration, probability of countermeasure, and false alarm rate. Another major testing requirement supplemented by M&S is the ability to test system hardware and software modifications. As the system goes through the development and test cycle, problems are found and corrected leading to the need for regression testing. Repeating open-air tests can be cost prohibitive, so



Figure 1. SIIRCM System Components

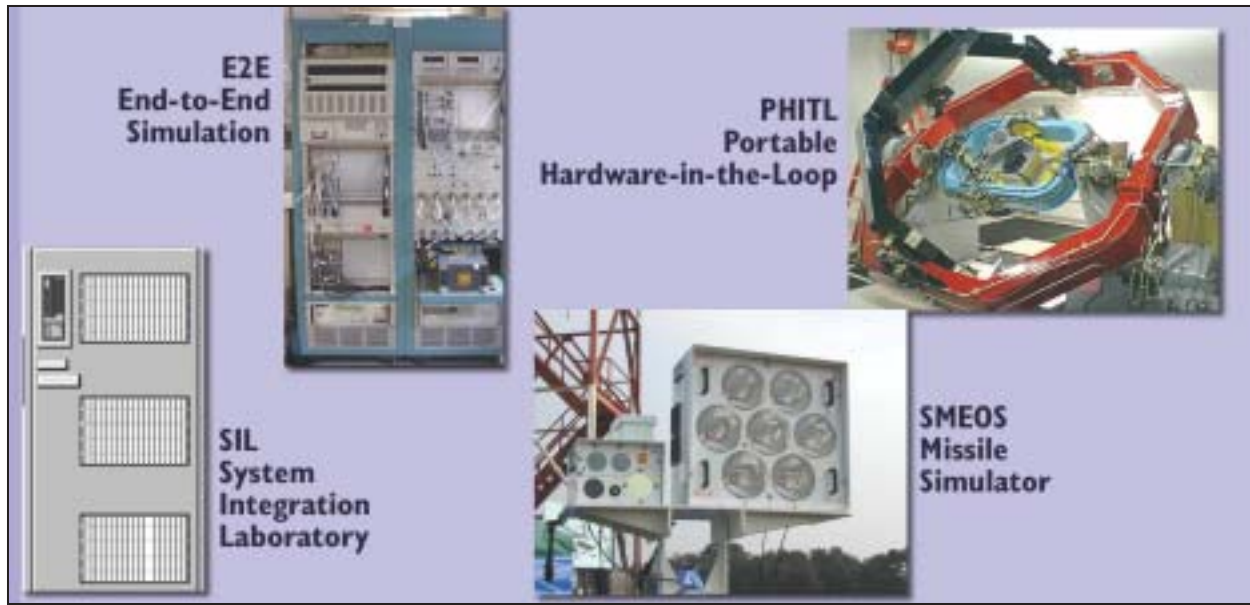


Figure 2. SIIRCM Simulation Tools

modeling and simulations are often the only affordable way to test system upgrades.

Specific M&S tools, were developed to meet program requirements (see Figure 2).

A full digital simulation called the End to End Model (E2E) was required to determine the system false alarm rate, probability of declaration, and probability of countermeasure. Once accredited this model could produce the thousands of simulated missiles and potential false alarm sources (PFAS) needed to achieve the confidence levels required.

A simulation tool was also required to illuminate the test aircraft with missile radiation so system performance could be determined when the system is installed on actual aircraft. To satisfy this requirement a ground based missile simulator called Super Multi-Role Electro-optical Simulator (SMEOS) was developed which allows testing of the SIIRCM system during tactical flight profiles by simulating missiles from various ranges, directions, and in different weather conditions. The SMEOS has collimated ultraviolet (UV) and infrared (IR) output beams each of which are programmed with either irradiance data from actual missile tests or irradiance predictions from the E2E

model. SMEOS also has an IR radiometer to detect jam energy from the ATIRCM laser. SMEOS has a video camera for verification of target tracking and witness sensors to monitor beam output.

A simulation tool was also needed to test the system under stressing conditions in which the CMWS could be exposed to an almost unlimited number of simultaneous missile and PFAS sources. The System Integration Lab (SIL) satisfied this requirement. The SIL contains an actual CMWS Electronic Control Unit (ECU) with simulated UV sensor inputs produced by the E2E model. The SIL produces INS data for input to the ECU simulating the aircraft 1553 data.

The last simulation tool needed to fulfill M&S requirements was a Portable Hardware in the Loop (PHITL) facility which has the capability to test CMWS performance during stressing aircraft maneuvers including snap rolls. The PHITL contains 3 CMWS sensors and an ECU mounted on the inner three axes of a five axis flight motion simulator. The inner three axes simulate aircraft roll, pitch, and heading while the outer two axes simulate missile angular motion (azimuth and elevation) relative to the aircraft. A MEON missile simulator (hand held version of SMEOS) was mounted on an opti-

cal bench on the outer two axes to produce UV missile irradiance on the sensors. A collimating mirror was used to eliminate parallax.

The SIIRCM system successfully completed all test requirements in CY 2001–CY 2002 including the following open air range tests: Developmental Test Potential False Alarm Source Test (DTPFAS), Captive Seeker Test, Sled Test, Cable Target Missile Firing (CTMF-1), and Dynamic Target Missile Firing Test (DTMF). The purpose of the DTPFAS test was to measure system performance in the presence of PFAS sources and to measure PFAS UV and IR source signatures for inclusion in the E2E model. PFAS sources tested and characterized included a wide variety of battlefield and non-battle field sources of UV and IR radiation. The purpose of the captive seeker test was to test the ability of an airborne installed SIIRCM system to defeat ground deployed missile seeker heads with the ATIRCM Jam Head and AIIRCM Flares. The purpose of the sled test was to demonstrate that an airborne installed SIIRCM system could track and put jam energy on a missile moving down a sled track. The purpose of the CTMF-1 test was to demonstrate that a SIIRCM system mounted on an unmanned cable car at the WSMR Aerial Cable Range could defeat live missiles. The purpose of the DTMF test was to demonstrate that

the CMWS missile warning receiver, mounted on an unmanned drone QF-4 aircraft, could detect and declare live missiles in time for them to be defeated by dispensed flares.

A comparison of the four simulation tools to CTMF-1 test results is shown in Figure 3.

During the CTMF-1 test, 11 missiles were fired at the SIIRCM system while installed on a pod approximately 700 feet in the air. The pod was attached to a cable trolley which allowed the pod to be moving for some missile firings and static for others. An IR heat source hung below the pod as a target for the missiles. The trial numbers of the 11 missile firings are shown along the bottom axis of Figure 3. The vertical axis is the warning time (time until missile impact) when the CMWS system declared the incoming missile and initiated a countermeasure (jammer and/or flare). The warning time has been normalized to avoid classification problems. The four simulation tools compare very well to the actual test data. Input irradiances to the SMEOS and PHITL were obtained from a UV radiometer on board the cable car. Radiometer data was not obtained for trials 1 and 11b. SMEOS simulations were accomplished on site at the CTMF-1 test

but only attempted for trials 5 and 6. PHITL simulations were each repeated 24 times to assess the variability in system performance due to naturally occurring photon (Poisson) noise. Input irradiances for the SIL and E2E Model were predicted by the E2E. The problem which caused the E2E Model not to declare on trials 5 and 6 is currently being investigated.

In summary, the simulation tools have proved successful in meeting program goals for evaluation of the SIIRCM system under varying conditions. The primary difficulties lie in keeping simulation tools updated to reflect system hardware and software changes. No one tool was able to meet all of the SIIRCM program's M&S requirements. Correlation is critical for the success of validation and accreditation efforts. Acquisition programs utilizing simulation tools require discipline, control, and formal configuration management. ♦

Mr. James Hatfield III is the Chief, IRCM Technical Branch & Chief Systems Engineer for the U.S. Army's IRCM Program. He is responsible for planning, programming, scheduling, budgeting, and direction for overall technical issues for electronics equipment onto rotary and fixed wing aircraft. Mr. Hatfield has over 15 years experience within the U.S. Army providing test and simulation support and has

been providing support to the SIIRCM program since 1998 as lead for all Developmental and Operational test events and more recently, as Chief Systems Engineer. He may be reached at jimhatfield@peoavn.redstone.army.mil.

Dr. Mike Neer is President of Neer, Inc. located in Belle Meade, New Jersey. He is the original author of the Organics Under Simulated Interstellar Conditions (OSIC) UV Atmospheric Propagation Model, a primary author of the Tactical Missile Signatures Measurements Standard Handbook, and has over 25 years of experience in IRCM modeling and testing. He is currently providing test and signature measurement support to the SIIRCM program. He received his Ph.D. in Aeronautical and Astronautical Engineering from the Ohio State University. He may be reached at mike@neerinc.com

Ms. Julie Locker is Division Chief for Software Engineering and Test at Morgan Research Corporation in Huntsville, Alabama. Ms. Locker is currently the contractor test and engineering lead for PM Aviation Electronic Systems supporting the U.S. Army's SIIRCM program. Ms. Locker has a Bachelor's degree in Mechanical Engineering from Georgia Institute of Technology. She may be reached at JLocker@morganres.com.

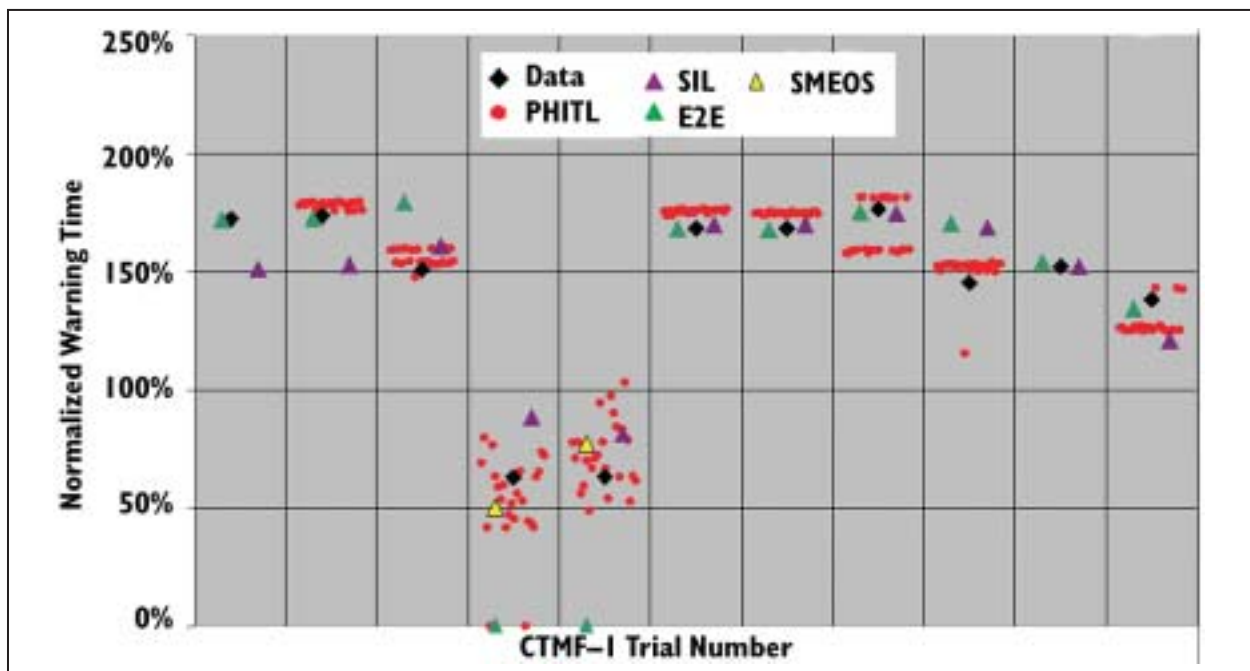


Figure 3 CTMF-1 Test Results



## Credibility Assessment of

# MANPADS Hit-Point Predictions

■ by Mr. Greg Czarnecki, and Mr. Al Boyd (Defense Intelligence Agency/Missile & Space Intelligence Center)

**A**ircraft vulnerability reduction features are typically distributed throughout the vehicle based on expectations of random hits from Anti-Aircraft Artillery (AAA) and missile warhead fragments. Until recently, direct surface-to-air missile (SAM) hits were considered kills and received little vulnerability attention. Results from Desert Storm changed this mindset. While several classes of aircraft hit by shoulder-launched man portable air defense system(s) (MANPADS) survived with frequency, others did not. The deciding factor involved a combination of missile hit-points and their proximity to critical aircraft subsystems. Current MANPADS modeling and simulation (M&S) efforts have been designed for the purpose of advancing susceptibility reduction measures. These simulations commonly terminate with a report of infrared (IR) countermeasure effectiveness. The capability of MANPADS M&S to accurately predict hit-point locations for vulnerability assessment requires further investigation.

Acknowledging the importance of hit-point prediction, the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) launched a MANPADS Impact Point Assessment project to assess the ability of current MANPADS M&S to accurately predict hit-points on complex IR targets. This effort is led by Greg Czarnecki (46th Test Wing) and Al Boyd (Defense Intelligence Agency/Missile & Space Intelligence Center, [DIA/MSIC]). The project uses a model-test-model approach. Organizations providing M&S support consist of MSIC (Redstone Arsenal, Alabama); the Army Research Laboratory-White Sands Missile Range (ARL-WSMR); the

Threat Systems Management Office (TSMO, Redstone Arsenal, Alabama); the Naval Air Warfare Center (NAWC T-SPII, China Lake, California); the 46th Test Wing (46TW GWEF, Eglin AFB, Florida); the Air Force Information Warfare Center (AFIWC, Lackland AFB,

Texas); the Air Force Research Laboratory (AFRL/SN, WPAFB, Ohio); and the Air Force Electronic Warfare Evaluation Simulator (AFEWES, Fort Worth, Texas). Each participating organization brings a unique and diverse set of M&S solution methodologies to the table.



Figure 1. Three-part IR Target Board



Figure 2. MANPADS fly-out into suspended target board for hit-point determination.

These methodologies range from digital solutions to various hardware-in-the-loop (HITL) simulations.

The MANPADS Impact Point Assessment project consists of three phases—

- Baseline Assessment (FY01)
- Collaborative M&S Study (FY02)
- Final Exam (FY03)

Phase I used selected M&S hit-point prediction methods to design and subsequently predict the results of a live fire test using simple target boards. Shown in Figure 1 (see page 16), IR target boards, consisting of three horizontally-aligned subtargets with 1 meter spacings, were fabricated for use as targets. Figure 2 shows a MANPADS launch at a target board. M&S hit-point predictions were compared with the actual tests results.

In Phase II, the M&S team is participating in a collaborative M&S study. This M&S study will examine a specific set of C-130/MANPADS engagement scenarios. The Phase II study will culminate in documentation of the MANPADS M&S capabilities for providing hit-point locations. Factors determining hit-point include the M&S ability to represent various target signatures, the diversity of MANPADS used, and complexity of using simulations to predict hit-points as opposed to only assessing IR countermeasures. Because

each M&S solution employs different methods for generating a aircraft's signature and for representing MANPADS, the project will use a well-defined series of MANPADS-aircraft engagement scenarios to compare the various M&S methods.

In Phase III, the M&S team will design a series of complex IR target boards for final M&S evaluation. The target boards will be fabricated and subjected to a new series of MANPADS live fire tests. Test results will be compared to M&S hit-point predictions. Given successful demonstration of endgame solution credibility, the vulnerability community will be able to use the capability of MANPADS fly-out M&S to—

1. Significantly decrease the number of views/shotlines necessary for MANPADS-aircraft vulnerability assessments.
2. Select meaningful MANPADS-aircraft hit points for live fire testing.
3. Point toward areas in need of vulnerability reduction attention.

Hit-point prediction capability will be established by the JTCCG/AS as an essential element of aircraft vulnerability reduction. ♦

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*Mr. Al Boyd received his B.S. in Applied Physics from the Georgia Institute of Technology and a M.S. in Engineering Management from the University of Alabama, Huntsville. He is a civilian with the Defense Intelligence Agency, Missile and Space Intelligence Center, Office for Defensive Weapons, where he leads a team that develops EO/IR SAM simulations. He may be reached at [wab@msic.dia.mil](mailto:wab@msic.dia.mil).*

## 2002 Threat Warheads and Effects Seminar

■ by Major Mark Carteaux and Lt Col Anthony Brindisi

**T**he shriek of Man Portable Air Defense Systems (MANPADS) and the thudding of large caliber machine guns told the story—the fourth Threat Warheads and Effects Seminar had come to town. This year, from 29 April to 3 May 2002, the Joint Services Air Defense Lethality Team (JSADLT) brought their Joint Technical Coordinating Group for Aircraft Survivability (JTCG/AS) sponsored Threat Warheads and Effects Seminar to the Hurlburt Base Theater at Hurlburt AFB, Florida. Time was split between Hurlburt AFB and Eglin AFB for the various briefings, live fire demonstrations, and capabilities tours. As always, the seminar's principal objective is to improve the warfighter's understanding of threat warheads and their effects to U.S. combat operations.

The seminar is structured around multimedia training, integrating threat lethality information, imagery, hardware from threat exploitation and live fire testing, and actual combat engagements. It covers the threat weapons systems from small arms through the latest Russian surface-to-air missile systems. The technical portion of the seminar is a collaborative effort between the Joint Services Air Defense Lethality Team, Defense Intelligence Agencies, 46th Test Wing, Air Force Special Operations School, and Federal Aviation Administration (FAA). The Missile and Space Intelligence Center (MSIC) provided numerous outstanding technical threat briefings by senior analysts and an eye popping MANPADS hardware display. The National Ground Intelligence Center (NGIC) provided an attention-grabbing briefing on Air Defense Artillery to include the Skyshield Air Defense System, which is designed to counter both air-

craft and a wide range of air delivered munitions. This year, the seminar added the Air Force Research Laboratory (AFRL) Human Effectiveness Directorate who led a session on the low power laser threat; and responding to the Army's experiences in the war on terrorism, an introduction to Rocket Propelled Grenades (RPGs). Air Force Special Operations School conducted the Small Arms live fire demonstrations at their Hurlburt AFB range, and at Eglin AFB the

MANPADS live fire demonstrations were held at its B-75 Range complex.

As shown in Figure 1, this Stinger live fire shot was at a C-130 Wing section approximately 5000 feet downrange. Note the missile homing in on the target—a direct hit. After the seminar concluded, many attendees were treated to highly informative Chicken Little threat systems' capabilities tour, a 46th Test Wing's capabilities overview, the Guided Weapon's Evaluation Facility tour, the McKinley Climactic Hangar



Figure 1. MANPADS Launch



Figure 2. MANPADS Homecoming in on C-130 Wing Box.

tour, and the Test Site A-22 (Guns) tour.

The two live fire demonstrations provided a unique experience to the attendees. The demonstrations were split over two days, with the small arms demo on Tuesday, 30 April 2002, and the MANPADS and RPG demonstrations held on Wednesday, 1 May 2002. Air Force Special Operations sharpshooters demonstrated the effectiveness of small arms (from 5.56 mm rifles to 14.5 mm heavy machine guns) on numerous aircraft components and personnel protective equipment. This particular demonstration always changes how conference attendees view the small arms threat. The SHORAD office (Stinger Systems Program Office) demonstrated the MANPADS threat. A total of six Stingers were fired against targets ranging from intense infrared signature sources on a plywood background to a portion of a C-130 wing and two Kiowa helicopters. Unfortunately, one Stinger malfunctioned causing this portion of the live fire demonstration to be concluded before the RPGs could be fired.

146 personnel attended this year's seminar from all three Services and industry. Specifically represented were Air Combat Command, Air Education Training Command, Air Mobility Command, Air Force Special Operations Command, the Intelligence Schoolhouse, the Office of Naval Intelligence, China Lake Naval Air Warfare Center, U.S. Army Evaluation Center, and the Army's Special Operations Group. A wide cross section of the Military was represented with personnel from the headquarters level through operational combat squadrons including flight crews, intelligence officers, Aircraft Battle Damage Repair Specialists, fighters, bombers, transporters, tankers, and rescue groups from Active Duty, Guard, and Reserve.

The common thread throughout the seminar is the emphasis on what type of damage to U.S. combat aircraft occurs when one is hit by threat weapons systems and how, by careful documentation and analysis of all

aspects of successful combat engagements, we can learn to more completely protect our combat aircrews and make our aircraft less vulnerable to enemy fire. This data can also serve to reduce the vulnerability of future weapons systems. All new Military aircraft acquisition programs have design-to-requirements

that reduce the susceptibility and vulnerability of these future aircraft. Many more airmen have been able to return to friendly territory due to the emphasis on collecting the threat induced aircraft damage or lost aircraft data, then redirecting the intelligence information back to designers and manufacturers, as well as war



Figure 3. SMSgt Walter Briefing Small Arms Live Fire Demo



Figure 4. Stinger Shot Hitting First Target



Figure 5. Audience for MANPADS Live Fire Demos

planners, operators, maintainers, and intelligence personnel. This would not have been possible without the teams of highly trained and experienced military and civilian personnel who support and recognize the need for combat data collection and assessment efforts.

The JTCG/AS, a long time supporter and user of combat data, recognized the team's value to all the Services and sponsors many of the Team's efforts. Under the JTCG/AS mentorship, bridges were built between all three Services in order to develop a tri-Service combat data collection capability. Currently, the team is made up of reservists from Air Force Material Command's 46th Test Wing Aerospace Survivability Flight at Wright Patterson AFB, Ohio; Naval Air Systems Command, Patuxent River, Maryland; Office of Naval Intelligence/SPEAR, Washington D.C.; Naval Air Warfare Center, China Lake, California; and the Army's Aberdeen Test Center. The teaming between the components is growing and a true "purple" capability is emerging, providing a strong and diverse combat data collection force.

Today, the Joint Service Air Defenses Lethality Team continues its vital mission. This program provides expertise on the lethality of threat air defense systems against U.S. Army, U.S. Navy, and U.S. Air Force aircraft by combining information from threat exploitation, live fire test, and combat data collection. The mission is to enhance the warfighter preparedness for threat damage to aircraft. This team accomplishes its mission through three separate, yet interrelated projects—

- "Battle Damage Data Collection" of combat data
- "MANPADS Live Fire Evaluation" guidance and participation in survivability S&T and live fire testing
- "Threat Warheads and Effects" peacetime training to the warfighter (intelligence, tactics, and logistics)

The first two projects are certainly important to further our analysis capabilities, understand the lethality of threat projectiles and missiles, and compile complete records for detailed analyses, all of which populates the Survivability/Vulnerability Information Analysis Center (SURVIAC) database. However, it is through the archives contained in this database and the knowledge gained through these first two projects that the Threat Warheads and Effects training program has evolved. The primary training objectives for the JSADLT has been to provide the warfighter an understanding of the lethality of threat projectiles and missiles. There are a number of classes of threats due to concentration of the projectiles and the severity of the damage. The team provides an eye opening, threat effects experience of the various kinds of damage (penetration, explosion, and collateral) that could truly ruin a warfighters whole day even from "small arms" fire. Other learning objectives are to train combat data collectors for effective acquisition of intelligence data from an incident, best practices for obtaining the observations and accounts from the pilot's perspective and/or their wingman's perspective, and efficient collection procedures of the vehicle damage (to include photos and the HUD video), the maintenance reports generated (AFTO 97), and if possible interviews with the crew chief and other maintenance personnel. Still, the biggest challenge is how to best integrate any and all information gathered to accurately reconstruct the incident. Lastly, the team must convey the criticality of recognizing the "signature" of the various threat warheads on the damaged vehicles. This truly is not a simple task and should not be taken lightly. A combat data collector must know where to look for damage based on initial assessments of the vehicle, with the intent to reconstruct the events that lead up to the event, while still keeping in mind for his safety and the safety of others that there is a possibility of the presence of unexploded ordinance (UXO) still remaining in or on the vehicle. The JSADLT training program effectively administers a real, and most often sobering portrayal of the threat effects from small arms fire, anti-aircraft artillery fire (AAA), and

man portable air defense systems (MANPADS). It is very important to the team that they maintain a very active presence with the warfighter community and continues to interface with them to provide the latest and greatest threats that may be or could be employed by an adversary. ♦

*For additional details on the Threat Warheads and Effects (TW&E) Seminars, please contact Maj Mark Carteau, USAFR, at mark.carteau@wpafb.af.mil. As a reservist for the 46th Test Wing at Wright Patterson AFB, Ohio, Maj Carteau was the 2002 TW&Es Seminar Chairman responsible for the planning and execution of the Joint Technical Coordinating Group on Aircraft Survivability sponsored Joint Service Air Defense Lethality Team premier training event. He has a B.S. degree in Aeronautical Engineering from Purdue University and a M.S. degree from Embry Riddle Aeronautical University. Maj Carteau has over 17 years of U.S. Air Force active duty, U.S. Air National Guard, U.S. Air Force Reserve, and Civilian (Lockheed Martin and Government Service) experience as an Aerospace Engineer and Aircraft Maintenance Officer. He currently works on developing advanced materials and structural components and on improving Supportability features of both RCS and IR signature reduction technologies. As a member of the JSADLT, Maj Carteau is responsible for coordinating and integrating the efforts of the U.S. Navy into the joint service team.*

*For additional details on the training opportunities available from/with the Joint Service Air Defense Lethality Team, please contact the team leader, Lt Col Anthony Brindisi, USAFR, at anthony.brindisi@wpafb.af.mil. Lt Col Anthony Brindisi is the senior reservist for the 46th Test Wing at Wright Patterson AFB, Ohio. He has a B.S. degree from Parks College of Aeronautical Technology and holds an M.S. from the University of Southern California. In his civilian life, Tony has over 20 years of aircraft susceptibility reduction experience, primarily as a Low Observable engineer working both in industry and for the Government. Having been active in performing combat data collection and analysis during Operation Allied Force, he now leads the Joint Service Air Defense Lethality Team, coordinating efforts with the U.S. Army, U.S. Navy, and U.S. Air Force to perform combat data collection.*



# Dry Bay Fire Model Enhancements

## Meeting the Difficulty

■ by Mr. Martin L. Lentz, Mr. Andrew Pascal, and Mr. Michael R. Weisenbach

**F**ire onboard an aircraft is often a deadly scenario. Unfortunately, dry bays—compartments or internal volumes located between the exterior surface of a vehicle and its internal structures—may contain fluid lines (fuel, hydraulic, etc.), hot bleed-air ducts, electrical wire bundles, and intervening clutter (structures, boxes, etc.) that are especially vulnerable to fire. Examples of dry bays common to many aircraft include wing leading edge bays, landing gear wheel wells, avionics equipment bays, and engine accessory bays.

In the mid-to-late 1980s, although a great deal of time and resources had been spent designing and evaluating tradeoffs in fuel system protection relative to risk reduction, performance, weight, and cost, no robust accepted model existed for predicting fires in aircraft. The Joint Technical Coordinating Group for Aircraft Survivability (JTCG/AS)—recognizing how all Military services would benefit from a physics-based, validated, standard fire prediction model—became involved with the Dry Bay Fire Model (DBFM) in the early 1990s.

This article focuses on the continuing development of the DBFM to help predict fires in Department of Defense (DoD) vehicles. The model has evolved each year, growing in physical capabilities, while retaining its original objective—to provide a fast running, easy-to-use, and credible accurate model applicable to a wide range of target threat, impact, and environmental conditions. Enhancement and validation are ongoing and under sponsorship of the JTCG/AS.

### DBFM's Present Configuration

The DBFM simulates the events occurring during the penetration of a single threat through a vehicle (fixed-wing aircraft, helicopter, or wheeled/tracked) dry bay and impacting a flammable liquid filled container, either a fuel tank or fuel or hydraulic line. The simulation currently addresses the principle phenomenology of contained fires: liquid spray ignition, fire initiation, fire growth, and fire sustainment.

The DBFM uses basic physics, supplemented by empirical data, and several simplifying assumptions to address the several distinct stages of a dry bay fire. These stages include—

- 1. Initial Threat Impact:** Ballistic penetration with changes in velocity, mass, and direction.
- 2. Ignition Source:** Armor penetrating incendiary (API) jacket striping, fragment adiabatic shear “plugging” and fragment breakup, High Explosive Incendiary (HEI) bursting, electrical wire sparking, and Shaped Charge plasma jetting.
- 3. Fuel Tank Impact:** Hole size and crack growth based on shock pressure and impulse and cavity pressure and duration. Droplet sizes depend on fluid pressure and hole size. Determines fluid mass flow for both spray and steady state leaking. Looks at droplet penetration into the bay and droplet size based on Sauter Mean Diameter (SMD).
- 4. Fire Ignition:** Droplet vaporization in the spray involves simultaneous heat transfer by conduction and convection and mass vapor transfer to the hot gas cloud by convection and diffusion. Determines probability of ignition for threat type.
- 5. Fire Sustainment:** Applies conservation equations for mass, species, momentum, and energy to a multi-cell, 3-dimensional, dual grid system. Processes accomplished within each cell are: forced convection from ventilation inlet and exit and damage hole(s), buoyancy in density differences by dry bay height, diffusion, vaporization using convective mass transfer coefficient, liquid fuel characteristics, flow velocity within dry bay, and vapor temperature above surface, and radiation based on average temperature. Outputs of this stage are cell temperature, oxygen content, and fuel vapor content time histories.
- 6. Fire Suppression:** No capability in current model. Army has requested this enhancement for FY03 and the approach will follow previous work in droplet transport, gaseous agent flame interaction, and water mist quenching accomplished under the Next Generation Halon Replacement Program (NGP) funded by OSD/SERDUP.
- 7. Fire Migration:** Estimates steady state flow of fuel from the tank due to piezometric head using Bernoulli's equation. Liquid poring out of a container will spread along the floor and be contained by structure

barriers and the bay walls. Once the flow has reached the barrier height, it will be allowed to flow over and spread to next barrier. The model supports 10 bay barriers.

8. **Damage Accumulation:** Current model does not address thermal damage due to heat flux or structural burn through. Heat flux will a measurable variable by the end of 2002.

9. **Vehicle Response:** Accounts for all subsystem and system damage due to various damage and failure mechanisms. This enhancement will be looked at after heat flux improvements have been validated.

The DBFM requires users to describe the—

- **Dry bay**—Including the dimensions; material; ventilation air velocity and inlet and exit sizes; and the number, size, and location of structural barriers present.
- **Fuel container**—Such as tank, fuel line, or hydraulic line. For each container type, the model requires fuel level and volume, tank material, or line diameter and pressure.
- **Dry bay clutter**—Can also be described to simulate structure, internal components, and multiple dry bays.

As Figure 1 shows, the amount of detail required can be extensive depending on the complexity of the user's dry bay. Dry bay configurations are not all rectangular parallelepipeds or a single bay as seen in Figure 2.

The complexity of the dry bay geometry and the need to incorporate and use existing vehicle geometry descriptions in the DBFM has been debated for close to 10 years. The survivability/vulnerability community uses two distinct types of geometries to describe aircraft and ground vehicles. The aircraft industry uses a form of Finite Element grid similar to NAS-TRAN called FASTGEN, and the Army uses for its ground vehicles a

solid geometry method entitled, BRL-CAD. Both methods have advantages and challenges, but the automatic processing of required dimension data for the DBFM by either method remains a desired, currently unmet enhancement.

A sustained fire, commonly called a diffusion flame, is where the reactants are initially separated and are brought together and burn in a narrow strip separating them. In dry bay fires, the vaporization of the liquid pool supplies fuel vapor, and air found initially in the dry bay is replenished by ventilation air entering the bay. To simulate the reacting flow, the DBFM uses the principles of local conservation of mass, momentum, species, and energy. Solutions are obtained on a numerical grid of elementary control volumes that fill the entire dry bay. This approach ensures local balances in the many small control volumes, subject only to the particular boundary conditions. To improve computational efficiency and reduce model run-time, the DBFM uses a multi-cell, three-dimensional dual grid system—a diffusion and convection grid. Within the diffusion grid, the simulation of fire is performed by the solution of the conservation equations of mass, momentum, species, and energy. Because convective currents work over much larger distance scales than the process of diffusion and combustion, the conservation of momentum (i.e., the convective mass and energy flow) is performed in the convective grid and the results superimposed into the diffusion grid by the prorating of flow seen. In this manner, the user can achieve accuracy and reduce model run-times by performing the conservation of momentum in a larger grid, reflecting the large distance scales of convection and performing the remaining calculations in a smaller grid, reflecting the smaller distance scales of diffusion and combustion.

The convection grid cell must be larger or equal to the diffusion cell size and the diffusion cell must be an even divisor of the convective cell size. As an example, for a 6 inch convective cell, diffusion cell sizes of 6, 3, 2, or 1 inch are permissible. Fractional sizes, such as 0.5, 0.25, or 0.1 are also

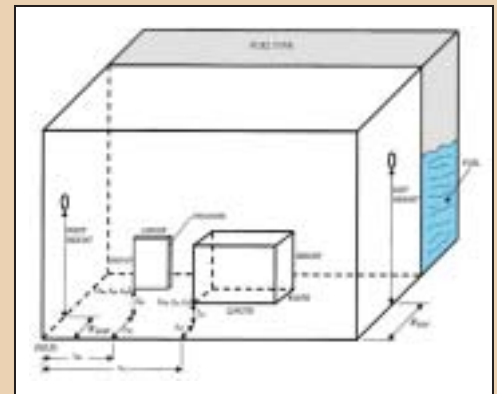


Figure 1. Dry Bay Description

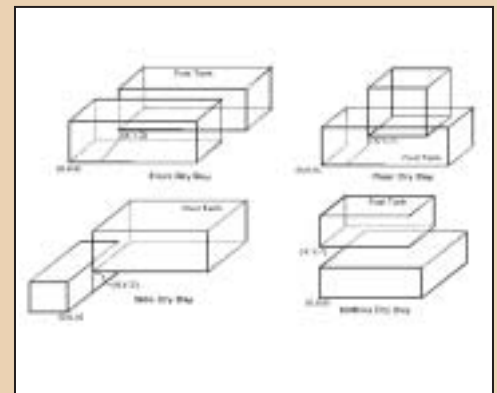


Figure 2. Configurations

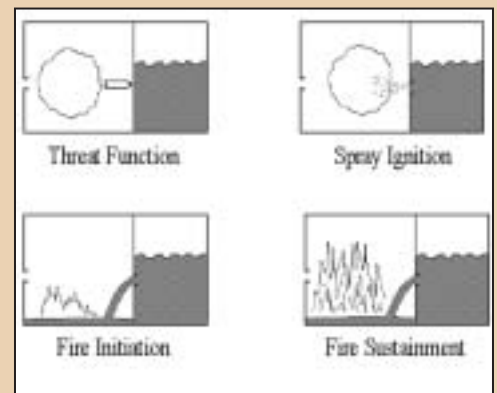


Figure 3. Fire Initiation Sequence

allowed. When selecting a convective cell size, the number of cells will reflect the dry bay dimensions. The number of cells is the rounded integer of the ratio of the dry bay dimensions and cell size. Thus, if the dry bay length is 3.75 feet and the convection cell size is 6 inches, the simulation will run with 8 cells (i.e., the model assumes the bay is 48 inches long). If more accurate simulation is required, a 3 inch cell width must be used. In that case, 15 cells will exactly fill the dry bay dimension.

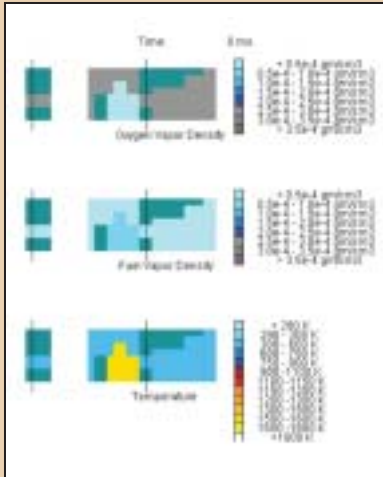


Figure 4. Dry Bay Time Zero

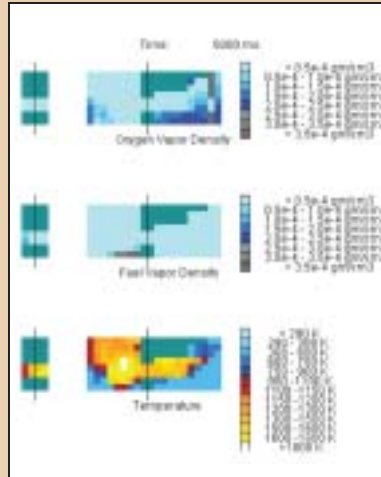


Figure 5. Dry Bay at 5 Seconds

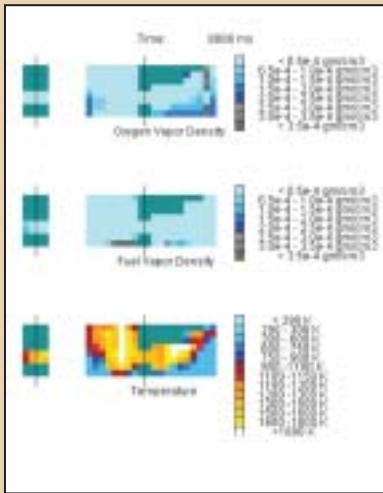


Figure 6. Dry Bay at 8 Seconds

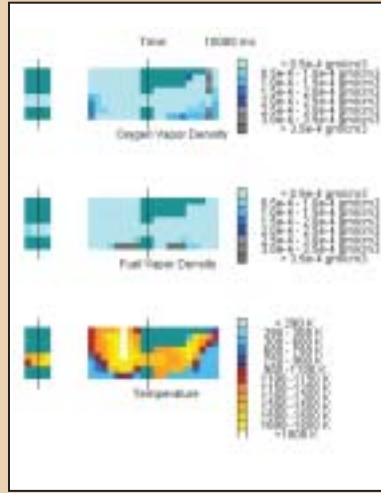


Figure 7. Dry Bay at 10 Seconds

The motion of fluid within the bay is described by the Eulerian approach where the composition, velocity, and state of the fluid everywhere in the bay at all instants is determined. To derive the Eulerian equations of motion, a stationary coordinate system is chosen and fluid is observed entering and exiting a volume of arbitrary shape and size. This control volume is found within the fluid and is at rest with respect to the coordinate system. In the DBFM, the volume is a cube (cell) whose length is user-specified.

To achieve its fast run-times, DBFM uses several simplifying assumptions, including—

- Fluid flow is modeled using Bernoulli's equation that drives flow by pressure differences

between cells. Streamlines with curvature, recirculation zones, and eddies are not explicitly modeled. Having said that, recirculation zones are seen to occur. Contributing to the development of recirculation zones is the fact that viscous effects along the wall of the dry bay are included in the simulation

- Fuel and air are assumed perfectly mixed within each cell. Turbulence is not simulated. Complete (i.e., no soot is formed) and perfect combustion (i.e., combustion products are limited to CO<sub>2</sub> and H<sub>2</sub>O) of fuel and air is assumed.
- Radiation is treated by emission alone, utilizing an "effective" emissivity.

### Sample Case

Based on the current version of the model (DBFM 3.2) a typical aircraft dry bay run for a cluttered dry bay or two separate bays connected by a small opening (see Figure 4).

The clutter in the bay is shown as greenish blue. One piece is seen on the left and represents a simple black box (avionics). On the upper right, clutter represents structure in a scalloped pattern. In the center, more clutter splits the dry bay into two separate compartments. Ventilation flow enters into the left bay and exists the right bay. Flow between bays occurs through a narrow slit in the center clutter. The threat impact is in the left bay perpendicular to the paper. Fuel is free to flow over the bottom center clutter from the left bay into the right one.

The figure also shows the dry bay at time zero. Ignition has occurred and the model is initialized with hot combustion gases (1,500–1,600K) in the left bay. The cross section indicates the slit between the compartments.

Figure 5 shows the dry bay 5 seconds after ignition. Fire is burning in the left bay and hot gases are seen migrating into the right bay. Figure 6 shows the dry bay 8 seconds after ignition. A sustained fire is burning in the left bay, while the temperature in right bay is climbing due to the migrating of hot gases following the airflow from the left to right bay. In the fuel vapor density plot (center) there is some vaporization of the liquid pool starting. Figure 7 is the dry bay at 10 seconds where a fire has been initiated in the right bay from vaporized fuel igniting. The oxygen concentration in the left bay (top plot) is continuously diminishing. Figure 8 (see page 28) shows the dry bay 20 seconds after ignition. The fire in the right bay is starting to self extinguish due to a lack of oxygen while the fire in the left bay is reaching peak temperatures. Fresh air only enters in the left bay through the vent inlet and the damage hole from the threat penetration. The fire in the left bay is consuming the majority of the new oxygen and very little is migrating through the slit into the right bay.

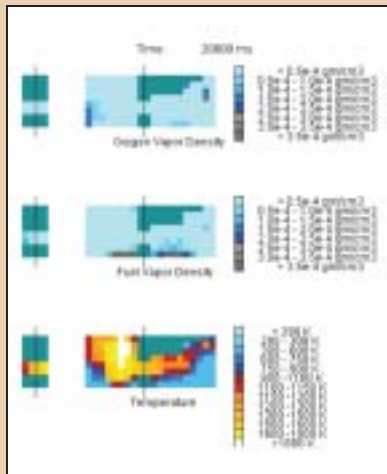


Figure 8. Dry Bay at 20 Seconds

If the model were to continue, the plots would show the right bay temperature continuing to cool down while the left bay would continue to burn until no fuel was left.

### Model Validation

Several efforts are directed at accomplishing DBFM's ongoing verification and validation. The Joint Strike Fighter (JSF) program office is funding an effort to verify the current methodology in the DBFM and to build a suite of test cases for future model verification. A sensitivity study is ongoing with results planned to be published in late 2002.

A separate program—funded by the OSD/DOT&E/LFT&E office and called Survivability and Safety Initiative for Aircraft (SSAI)—was to design, fabricate, and test a dry bay fire simulator, and use the data generated to validate fire models for DoD. This program, which started in 1997 and ended in 2001 involved all three Military Services and SANDIA National Labs. Under guidance of a group of fire modelers from the services and SANDIA, a dry bay test fixture was designed, instrumented, and constructed at the Aerospace Survivability and Safety Flight at Wright-Patterson AFB, Ohio. Figure 10 shows the fixture in the airflow facility. Over a two-year period, 96 baseline and mixing tests were performed.

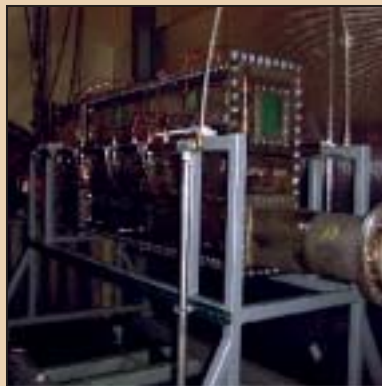


Figure 9. SSAI Dry Bay Simulator

This test data is being used to validate the DBFM. Temperature data has been compared and a test report is under review. Heat flux data will be examined in late 2002. The DBFM is continuously being used to predict fire probability in ongoing live fire tests for all new vehicle development and joint live fire tests programs of existing aircraft in the inventory. All problems and lack of capability due to physics or databases are reported to the DBFM Configuration and Control Board (CCB), which meet twice each year. The board and model manager decide where resources will be applied to enhance the model during the next coming year. The CCB is one of the responsibilities of the JTCCG/AS.

The JTCCG/AS is sponsoring an additional validation effort starting in 2002 titled the Dry Bay Fire Ignition Phase Validation and Experimentation program. It will address the possible different types of ignitions within the dry bay such as convective vs. radiation heating of the fuel pool, hot gas cloud expansion to touch the pool or the steady flow from the damage hole in the tank, or the secondary droplet ignition from a front face splash. This test simulation will strive to show visualization and instrumentation to define the method or methods of ignition that occur in a ballistic impacted dry bay. Results are planned for release in early 2004.

### Conclusions

The DBFM is a model under continuing development for the application of fire prediction in DoD vehicles. The model is a tool requested, used,

and improved by a coordinated group of survivability/vulnerability experts. The model's applications do not require it to be 100% accurate, only credible as defined by its users. That is the purpose and direction of its continued enhancement. ♦

*Mr. Martin L. Lentz is the Technology Branch Chief for the Aerospace Survivability and Safety Flight of the Munitions Test Division of the 46th Test Wing. He serves as the Co-Chairman of the JTCCG/AS Survivability Assessment Subgroup, a working member of the JTCCG/ME, and the COTR for SURVIAC. Mr. Lentz has a B.S. in Industrial Engineering from Louisiana Tech University and a M.S. in Computer Science from Wright State University. He can be reached at 937.255.6302, ext. 241.*

*Mr. Andrew Pascal received his M.B.A. from the University of New Mexico and a B.A. from New York University. He has been involved with the vulnerability community for over 30 years, performed numerous vulnerability assessments, and participated in both JLF and LFT test programs. He is authored Dry Bay Fire Model and the Ullage Explosion Model. He may be reached at 505.281.7522.*



# The JSF LFT&E Program

■ by Mr. James Rhoads

**L**ockheed Martin's Joint Strike Fighter (JSF) is a covered system as defined by the Live Fire Test (LFT) Law. With this requirement, Lockheed Martin was required to develop a process that would not only identify the vulnerabilities of the aircraft, but would also provide a methodology for defining the Live Fire Test and Evaluation (LFT&E) plan. Lockheed Martin has pioneered a process that combines the vulnerability design process, with modeling and simulation (M&S) to produce an in-depth LFT program that covers many issues and the spectrum of conventional and non-conventional threats.

As written in the previous issue by Mr. Hugh Griffis ("Vulnerability Design Discipline," *Aircraft Survivability*, Spring 2002), acqui-

sition reform introduced a performance based vulnerability requirement onto the JSF program. This has opened the trade space for the designer allowing Lockheed Martin to pursue new technologies to solve traditional vulnerability problems and to affordably support the vulnerability requirements while maintaining the balanced design approach for the overall air system. The traditional vulnerable area and time based kill levels have been replaced with engagement probability of kill (Pk/e) and mission oriented kill levels. In both instances, the new terminology and definitions provided a clearer understanding for senior management and easier design acceptance.

The Lockheed Martin process for performing a vulnerability assessment and the development of the

LFT&E plan is outlined in Figure 1. There are two loops to this process but both loops begin with the definition of the requirements in the bottom of the outer loop. Once the requirements are defined, trade studies are conducted to determine which design features best reduce the vulnerability of the aircraft and meet the balanced design approach. These trade studies require the development of a detailed geometric target description. Lockheed Martin initiated a process several years ago that extracted the geometric data from CATIA, ACAD, and NASTRAN databases to form very realistic target descriptions with minimal labor hours. A process that once took 6 months was reduced to weeks and at the same time increased the level of fidelity and accuracy of the target description.

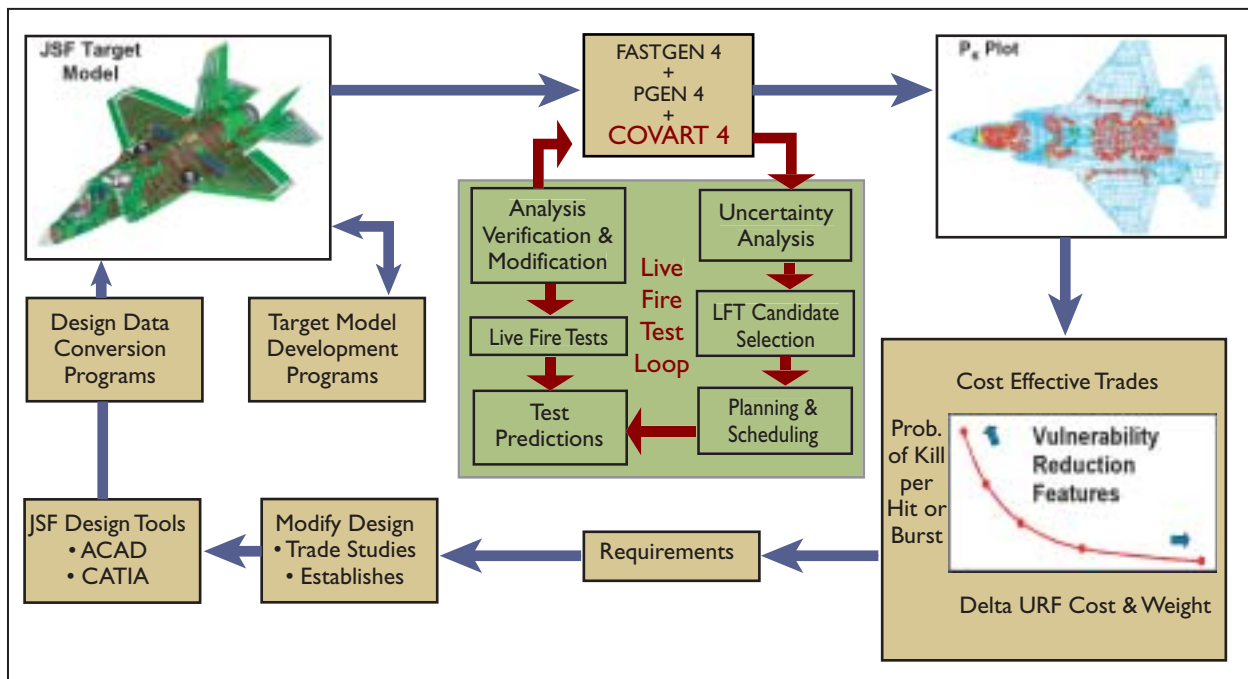
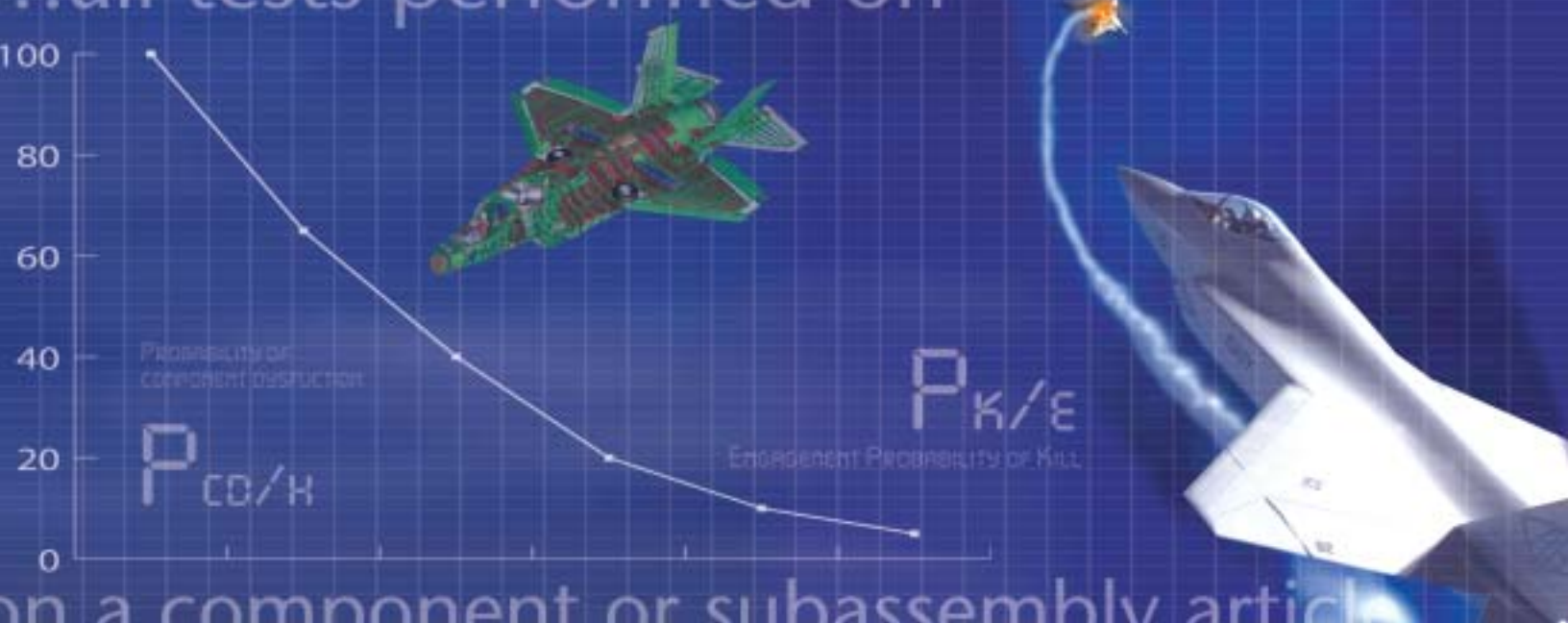


Figure 1. Lockheed Martin Vulnerability and LFT&E Design Process.



Lockheed Martin has implemented several unique M&S techniques to refine and enhance the vulnerability process. These include tracking the weight of the components within the target model, number of component and interferences, and the size of the target description file. Tracking the target model weight and matching to the real weights carried by the mass properties group insures proper shielding throughout the aircraft. An additional M&S enhancement included performing an uncertainty analysis on probability of component dysfunction given a hit (Pcd/h) tables. The Pcd/h table is the core to the current vulnerability analysis process used within COVART. Lockheed Martin asked the question “what happens if our Pcd/h tables are wrong?” A process was developed that essentially involved running the vulnerability assessment three times—

- The current baseline Pcd/h table,
- Setting the Pcd/h table to all 1.0 values,
- Setting the Pcd/h table to all 0.0 values.

The results of the sensitivity analysis were combined with additional LFT guidelines to prioritize and develop the overall LFT plan.

Some of the guidelines for developing the LFT plan included but were not limited to testing those things that were considered invulnerable but had little test data, unique components or materials that have no test data (Electro Hydraulic Actuators [EHAs] and lift fan drive shaft), the cost of

testing is cheaper than M&S, or those components that contributed more than 5% to the aircraft’s Pk/e. The number of tests and the test articles were assembled with the following common goal: all tests performed on a full-up test article must have an earlier test on a component or subassembly article. This goal was established to prevent surprises when testing is begun on the two aircraft that have been acquired for LFT (Navy drop test article and a Full-up Short Take Off and Vertical Landing [STOVL] variant). In addition to the traditional ballistic threats, the LFT plan covers directed energy threats (low power lasers and High Power Microwave [HPM]) as well as an extensive test series for chemical and biological threats. Also because the JSF will be using a 27 mm armor piercing projectile currently not fielded within the U.S. inventory, lethality testing will be performed to demonstrate the round and gun system can achieve the required ground target probability of kill.

The argument for using M&S versus testing was addressed while writing the extensive Live Fire Master Test Plan. The LFT plan contains numerous tests to develop data for M&S activities because there is a lack of confidence in current M&S activities or there are no models to address the specific vulnerability. For example, fire is the number one contributor to aircraft vulnerability, yet we have very simplistic fire prediction capabilities. The MANPADS threat does not have a defined modeling capability. Several tests have been performed on full-up legacy aircraft that have

shown common damage modes. Other vulnerability considerations such as spall from the aircraft canopy or fuel migration are lacking in modeling capability. Improvements in vulnerability engineering modeling and vulnerability system level modeling are possible and will be pursued. These are a sample of the M&S issues and these have been provided to the JSF M&S office along with the appropriate government M&S groups in order to improve the vulnerability M&S.

In summary, Lockheed Martin has developed a comprehensive LFT&E program for the JSF aircraft. The program benefits from an extensive use of CAD developed data for target descriptions, refinements of the vulnerability analysis process, scrutiny of the vulnerability M&S codes, and the desire to reduce risk for full up aircraft tests. Testing has already begun and will continue throughout the System Development and Demonstration phase of the program. ♦

*Mr. James Rhoads received his B.S. in Aerospace Engineering at Pennsylvania State University in 1990. He has been performing vulnerability assessments on aircraft since 1990 and joined Lockheed Martin in 1997. Currently, he is responsible for writing the JSF LFT Master Plan, leading several of the test programs as well as conducting analysis and trade studies. He has served on the American Institute of Aeronautics and Astronautics (AIAA) Survivability Technical Committee from 1996–2002. He may be reached at 610.354.2804.*



# Educating Warfighters and Acquisition Professionals

On the Fundamentals of Aircraft Survivability Combat through VTC

■ by CDR Mark Couch

**T**he current philosophy among the warfighters is that Military aircraft should not be designed for a single role or unique capability, but rather all Military aircraft should be used in multiple roles and have many capabilities. As these new aircraft are designed, acquisition professionals must consider more threats to these aircraft in order to ensure that these new aircraft survive in combat and complete their assigned missions. Additionally, all Services are seeing “mission creep” on all their legacy aircraft, mission creep defined as new roles and missions given to aircraft that they were not originally designed to perform. For example, the U.S. Air Force is considering using KC-135 tanker as an airborne relay to update target information for fighter and attack aircraft. How will this affect the combat survivability, the reliability, or the system safety of this aircraft? Will this aircraft become a high priority target? Will the aircraft be considered non-mission capable if the airborne link system is inoperable? Normal procedures for airborne refueling are to minimize electromagnetic transmissions to enhance system safety, but now transmissions will be required using some part of the electromagnetic spectrum.

So what do mission creep and multiple roles mean to the acquisition professional in regards to aircraft combat survivability? It means that focusing on a few small aspects of survivability, such as signature reduction or missile launch detection, are not enough to ensure our Military aircraft survive in combat. The warfighters and acquisition professionals must consider all aspects of aircraft combat survivability to include both vulnerability and susceptibility reduction

concepts. The question is how do the program offices accomplish this seemingly daunting task? Part of the answer is in the education of both the warfighters and the acquisition professionals. The Naval Postgraduate School offers the only course [Aircraft Combat Survivability, Reliability and System Safety Engineering (AA 4251)] in the country that takes a comprehensive look at aircraft combat survivability, including both vulnerability and susceptibility reduction concepts. Under the sponsorship of the JTTCG/AS, this course is now available via Virtual Teacher Center (VTC) to personnel at other Service/government facilities.

This course is designed to accommodate both warfighters and acquisition professionals and focuses on teaching the fundamentals of aircraft combat survivability without over-emphasizing any one particular attribute by using *The Fundamentals of Aircraft Survivability Analysis and Design, 2nd Edition*, by Dr. Robert E. Ball. The course begins defining the terms used in aircraft combat survivability. What does survivability mean? Vulnerability? Susceptibility? Others? Then, the students are introduced to the inherent probabilistic nature of aircraft combat survivability along with the requisite knowledge of probability theory needed to understand the problems associated with aircraft survivability. The course discusses measures of mission effectiveness and how survivability is enhanced through the six susceptibility reduction concepts (threat warning, noise jamming and deceiving, signature reduction [stealth], expendables, threat suppression, and tactics) and six vulnerability reduction concepts (component redundancy with separation, component location, passive damage sup-

pression, active damage suppression, component shielding, and component elimination or replacement).

Next, students are introduced to the roles and missions of aircraft and the air defense threats. Threat characteristics are identified and the damage processes and mechanisms are discussed. Since most threat weapons use some portion of the electromagnetic spectrum, students are introduced to the physics of radar and infrared radiation to give them a basic understanding of the phenomena. Some specific threat weapons from various countries (U.S., allies and potential adversaries) are introduced to give the student an appreciation for the numbers, types, and modes of operation of air defense weapons that could be brought to bear against an aircraft, either fixed-wing or rotary-wing. One student who took the course in the winter of 2002 said,

*...the text and course were some of the best unclassified sources for aircraft roles and missions and air defense threats*

that she had seen.

Finally, the course addresses more detailed quantification of aircraft combat survivability to the analysis and design of Military aircraft. In this portion, the student learns how to conduct fault tree analyses and damage mode effects analyses in order to determine the critical components on an aircraft. With this methodology, the vulnerability of an aircraft can be quantified so that trade studies can be made on various vulnerability reduction features. Similarly, quantification of the susceptibility of an aircraft is made to

look at various susceptibility reduction concepts. Finally, the vulnerability and susceptibility portions are combined to quantify the survivability of an aircraft against a specific threat in the given encounter conditions.

In order to give the students an appreciation for breadth of the aircraft combat survivability discipline and how it influences other parts of the design process, segues are made into the reliability and system safety disciplines. Students are shown how these three disciplines complement each other in the design process and methodologies learned in one discipline can easily be applied to another. It is this part of the course that bridges the operational requirements of the warfighter with the maintenance requirements of the acquisition professional. The goals of the aircraft combat survivability discipline are—

1. The early identification and successful incorporation of those specific survivability enhancement features that increase the combat cost effectiveness of the aircraft as a weapon system.
2. In those circumstances where the damage will eventually lead to and aircraft kill, the survivability enhancement features should allow a graceful degradation of the system capabilities, giving the crew a chance to depart the aircraft over friendly territory.

Course AA 4251 was originally developed for in-resident Naval Postgraduate Students (NPS) students to provide them with knowledge of aircraft combat survivability and how it relates to system safety engineering and reliability engineering. The concept of delivering the course on a continual basis to non-resident students came from a meeting in November 2001 with RADM Heely, (Air 4.0), Dr. Bob Ball, Mr. Ken Goff (Head, Survivability Engineering Division, Air 4.1.8), LCDR Andy Cibula (JTCG/AS), and CDR Mark Couch (course instructor) to discuss the future of the NPS survivability program. In this meeting, concerns about educating young,

newly hired engineers at Patuxent River and other U.S. Navy facilities were expressed, and it was decided that the use Virtual Teacher Center (VTC) technology would be the best way to reach these groups. It was decided that JTCG/AS would sponsor the VTC portion of the course for winter quarter 2002 and to make the course available to any interested DoD activity. Three sites decided to participate: two from NAVAIR (Patuxent River and China Lake) and the JSF Program office in Crystal City. A total of 31 students took the course including the 5 in-resident students from NPS. The VTC portion of the course was taught concurrently with the in-resident portion to minimize costs and maximize interaction between NPS students and civilian engineers.

Some of the comments from the students were—

*Thanks to NPS (CDR Couch) and JTCG/AS for giving students at distant sites the opportunity to participate in the class and learn about such an important part of current and future naval weapon planning and development.*

*Excellent course! I was given a good introduction into ACS. Thank you.*

*A very worthwhile course.*

Due to the overwhelming success of the first course, a decision was made to offer the course again for the Summer quarter 2002. Electronic announcements were sent to all DoD activities involved with aircraft survivability (JTCG/AS mailing list). Seven sites decided to participate: three from NAVAIR (Pax River, China Lake, and Lakehurst), two from Aberdeen Proving Grounds, and one each from Quantico (supporting MCOTEA and MCCDC) and Wright Patterson AFB (supporting 46th OG, AFMC, and ASC). The course is again being taught concurrently with the in-resident students with a total of 91 students (12 at NPS). To demonstrate how survivability can be applied to systems engineering studies, the NPS students will be conducting survivability analyses for Expeditionary Warfare 2020 CONOPS project currently underway as part of the systems engineering inte-

gration (SEI) curriculum at NPS. CDR Bill Erhardt (SEI Team Leader) is taking AA 4251 and agreed to serve as team leader for the survivability project. The purpose of the survivability project is to show how conducting survivability analyses early in the design process can improve the overall design of the air vehicle. ♦

*CDR Mark Couch received a B.S. in Chemical Engineering and a B.S. in Chemistry in 1984 from Purdue University. After graduation, he reported to Aviation Officer Candidate School in Pensacola, Florida and was commissioned as an Ensign, and immediately reported to NAS Whiting Field to commence primary flight training. Upon completion of helicopter flight training, he reported to Helicopter Mine Countermeasures Squadron 14 (HM-14) and served in the Operations and Maintenance Departments. During this tour, the squadron was rapidly deployed to the Arabian Gulf to conduct mine countermeasures operations in support of Operation Earnest Will. After completion of this tour, he reported to U.S. Atlantic Fleet to serve as the Aide and Flag Lieutenant to the Deputy and Chief of Staff. In 1991, he reported to NPS to begin graduate studies in Aeronautical Engineering. He received a M.S. in Aeronautical Engineering (with distinction) in September 1993. His research was in the field of rotary-wing unsteady aerodynamics, and he co-authored two papers. After completing his studies, he reported to HM-14 again and served as the Aviation Safety Officer during a Class A mishap investigation. He later reported to the Helicopter Tactical Wing, U.S. Atlantic Fleet where he served as the Wing Operations Officer and Safety Officer. In 1997, he reported back to HM-14 for a third tour as the Operations Officer and Administrative Officer. In 1999, he reported to NPS where he serves in his present assignment as military faculty in the Department of Aeronautics and Astronautics. He currently teaches graduate-level courses in Aircraft Combat Survivability, Computational Methods, and Aircraft Fatigue. Additionally, he is pursuing his doctorate in Aeronautical Engineering concurrent with his military duties. CDR Couch has approximately 1500 flight hours in the T-34C, TH-57B/C, RH-53D, and MH-53E aircraft with 300 hours under tow. He has received four Navy Commendation Medals, a Navy Achievement Medal and four Battle "E" Awards.*



# Aircraft Combat Survivability, Reliability, and Systems Safety Engineering (AA 4251)

**DoD Engineers and Analysts: Are you interested in learning more about:**

Aircraft Combat Survivability | Reliability Engineering | Systems Safety Engineering

**T**he Naval Postgraduate School (NPS), under the sponsorship of the JTTCG/AS, offers a distance learning course in Aircraft Combat Survivability, Reliability, and Systems Safety Engineering (AA 4251). This course is offered via Virtual Teacher Center (VTC) and gives the practicing engineer or analyst the tools necessary to solve problems in these disciplines.

## Course Description

This course provides an understanding of the essential elements in the study of survivability, reliability, and systems safety engineering for military aircraft (fixed wing, rotary wing, and unmanned air vehicles). Also presents technologies for increasing survivability and method-

ologies for assessing the probability of survival in a hostile (non-nuclear) environment of anti-aircraft artillery (AAA) and surface-to-air missiles (SAM). Several in-depth studies of the survivability of fixed wing and rotary wing aircraft will give the student practical knowledge in the design of battle-ready military aircraft. An introduction to reliability and system safety engineering examines aircraft system and subsystem failure in a non-hostile environment. Safety analyses (hazard analysis, fault-tree analysis, and component redundancy design), safety criteria, and lifecycle considerations are presented with applications to aircraft maintenance, repair, and retirement strategies along with the mathematical foundations of statistical sampling, set theory, probability modeling, and probability distribution functions.

<b>Who:</b>	Aircraft survivability engineers, aircraft design engineers, modeling and simulation analysts, or anyone interested in aircraft survivability testing or design. Both new and experienced personnel can benefit from this course as it covers all aspects of aircraft survivability design from susceptibility reduction, vulnerability reduction, and modeling and simulation analysis. Students of the course usually include a mix of military officers with flight experience and aircraft engineers from all Services.
<b>When:</b>	Twice yearly, usually in the Summer (July–September) and Winter (January–March) quarters. Class meets twice weekly for 2 hours. Specific days and times are coordinated with curriculum requirements at the NPS. Special one-week course offerings are available upon request based upon the availability of the course instructor and the number of interested students.
<b>Where:</b>	In a VTC room near you! Exact locations TBD by demand. Sites previously served include: Paxtuxent River, China Lake, Wright Patterson AFB, Edwards AFB, Aberdeen Proving Ground, and several locations in the Washington, DC area.
<b>Registration:</b>	The Summer session for 2002 is closed to new applicants. If there is interest in future course participation, please fill out the course registration form and fax it to either the JTTCG/AS Central Office 703.604.1033 or the NPS Instructor at the address provided below.
<b>Fee:</b>	DoD employees (Military and civilian) – No cost. DoD-Contractors – \$1000. This course is sponsored by the Joint Technical Coordinating Group/Aircraft Survivability (JTTCG/AS). Each VTC site will bear the costs of connecting to the NPS VTC bridge.
<b>Instructor:</b>	CDR Mark Couch, NPS, Phone: 831.656.2944, Fax: 831.656.7884, E-mail: macouch@nps.navy.mil
<b>Prerequisites:</b>	B.S. in Engineering or Science. You'll be taught any graduate level math and physics that you'll need.
<b>Graduate Credit:</b>	Students may take this course for 4 graduate credit. Those interested in receiving graduate credit are required to take two exams and complete a project in aircraft combat survivability. The course may be taken as a non-credit course, no exams or projects are required.

## Registration Form

Name: \_\_\_\_\_ Organization: \_\_\_\_\_

Position/Code: \_\_\_\_\_ Telephone: \_\_\_\_\_

E-mail: \_\_\_\_\_ Type Aircraft Involved With or Flown: \_\_\_\_\_

Do you want to take the course for  Credit  Non-credit  Don't know yet

Other Information you want me to know: \_\_\_\_\_



## Mr. Jeffrey Wuich

Survivability/Vulnerability Information Analysis Center  
(SURVIAC)

### Young Engineers in Survivability

■ by Mr. Kevin Crosthwaite

**T**he JTCG/AS is pleased to recognize Mr. Jeffrey Wuich, an associate at Booz Allen Hamilton who supports the Survivability/Vulnerability Information Analysis Center (SURVIAC), as our second Young Engineer in Survivability. Jeff is one of SURVIAC's bright young engineers who is doing an outstanding job supporting the Joint Live Fire (JLF), Live Fire Test & Evaluation (LFT&E), and JTCG/AS programs as well as answering day-to-day survivability/vulnerability/lethality technical questions as a SURVIAC representative.

Jeff is the SURVIAC lead engineer responsible for supporting vulnerability and lethality testing conducted on U.S. Army, U.S. Navy, U.S. Air Force, and U.S. Marine Corps aircraft. He has over 10 years of professional experience evaluating new and existing aircraft to combat threats in support of a number of Joint Live Fire (JLF) and Live Fire Test and Evaluation (LFT&E) Programs. Jeff has authored numerous detailed test plans and final reports, aircraft battle damage and repair (ABDR) reports, and has assisted in developing LFT&E strategies, waiver packages, and alternative test plans required by congressional law. Aircraft (fixed-wing and rotary) he is familiar with include the A-10, AH-1S, AH-64, AV-8B, F-14, F-15, F-16, F/A-18, F-22, B-1, C-5, C-17, C-130, Comanche, CH-47, CH-53, Mi-24, MiG-23, MiG-29, and UH-60. Aircraft systems he is familiar with include avionics, crew station, flight controls, fuel systems, hydraulics, propulsion, and structures. Combat threats he is familiar with include armor piercing incendiary (API) projectiles, high explosive incendiary (HEI) projectiles, man-portable air defense systems (MANPADS), vehicle launched surface-to-air missiles (SAMs), and air-intercept missiles (AIMs). Damage mechanisms he is familiar with include projectile penetration and blast, spall, hydrodynamic ram, inlet ingestion, dry bay fire, and ullage explosion. Jeff provides outstanding administrative and technical support to the programs he supports.

Prior to working for Booz Allen in support of SURVIAC, Jeff served as an officer in the U.S. Air Force. Jeff served as an aerospace engineer and was assigned to the Wright Laboratories, Flight Dynamics Lab, Vehicle Subsystems Division, Survivability Enhancement Branch (now the 46 OG/OGM/OL-AC). Jeff was responsible for evaluating new aircraft configurations and materials to determine their vulnerability to combat threats. He also conceived,

planned, and conducted ballistic tests to discover and reduce aircraft vulnerability. Jeff served as the Program Manager for the F-16 portion of the \$3.5 million Joint Live Fire (JLF) Test Program where he was responsible for all vulnerability testing conducted on the USAF's F-16 Fighting Falcon. Jeff was also a member of the Combat Operations Assessment and Reporting Program (COARP) Team that was trained to collect data on U.S. aircraft that received combat damage during Operation Desert Storm. Although the COARP Team never made it in country, they did travel to each of the units to collect combat data (e.g., interview pilots and ABDR technicians and take photographs of damaged and repaired aircraft) upon their return from overseas. The U.S. Air Force has served him well as it helps him to fully understand each of the Services he works with on a daily basis as well as he is able to apply all that he learned from his Military career to his current career.

Currently, Jeff is the Data Manager for the Joint Live Fire – Aircraft Systems Program. He provides administrative and technical support to the U.S. Air Force, U.S. Army, U.S. Navy, Foreign Aircraft Deputy Test Director's, and the JLF/Air Joint Test Director. He assists in preparing annual JLF/Air Test Program proposals, Grey Book entries, and publication of JLF/Air detailed test plans and final reports. He manages current JLF/Air efforts including the Standard Characterization of Foreign Ammunition (SCOFA) and the JLF/LFT Information System. Jeff authored the Test Approach and Strategy for the JLF/Air U.S. 20 mm PGU-28/B SAPHEI vs. Foreign Fixed-Wing Aircraft effort. This effort proved to be “ground-breaking” for JLF/Air's role in supporting the Joint Munitions Effectiveness Manuals (JMEM's) for the warfighter. Jeff recently reported on the JLF Program in a well-written article entitled “The JLF Program” in the Winter 2001/2002 issue of the JTCG *Aircraft Survivability* newsletter and the SURVIAC Bulletin. Jeff is sometimes referred to as the “glue” behind the JLF/Air Program since he provides most of the grunt work required to keep the program organized, on schedule, and moving forward.

Jeff also supports the 46th Test Wing and the C-5 Reliability Enhancement and Re-engineering (RERP) Development System Office (DSO), both located at Wright-Patterson AFB, Ohio, with the C-5 Modernization LFT&E Program. Jeff supported the C-5 RERP DSO with

their LFT&E waiver package and alternative test plan. He is currently assisting the C-5 DSO and the 46 OG/OGM/OL-AC (the responsible test organization (RTO) for the Air Force) with each of the detailed test plans required for component and sub-system level test series. Jeff was a key support member for the C-17 and B-1 CMUP LFT&E Programs. The C-17 was the very first U.S. Air Force aircraft to undergo Live Fire Testing. His knowledge of completed LFT&E programs, the issues of concern and the history behind them, the various test organizations involved, the decision makers, and the politics sometimes involved with LFT&E make him a valuable asset to any program office.

Jeff is the SURVIAC point of contact for the FASTGEN, COVART, FATEPEN, BEAMS, WINFIRE, and ULLEX computer models. These models are funded by the JTCG/AS & JTCG/ME. Jeff assists in planning and conducting the Fire & Explosion and Penetration Models Configuration Control Board (CCB) meetings and is responsible for preparing and distributing the minutes. CCB meetings provide an open forum for people from the S/V/L community to present their program needs, findings from using the model, model deficiency reports, etc., in order to continuously enhance the capabilities and improve the accuracy of the models. Ultimately, these meetings provide guidance, planning, and future direction for the models. Jeff is responsible for documenting the progress made and plays a key role in making sure the aforementioned models keep improving.

Jeff received his B.S. in Aerospace Engineering (1988) from Iowa State University and his M.S. in Mechanical Engineering (1992) from the University of Dayton. He is a member of the National Defense Industrial Association (NDIA) and currently possesses a security clearance. Jeff is also a professional engineer (P.E.) registered in the state of Ohio (1995) and a certified energy manager (C.E.M.-1996) as recognized by the Association of Energy Engineers. He has over five years of energy management experience and has conducted over three-hundred energy surveys for various utility, commercial, and industrial clients. Jeff has been married for eight years to his fun and loving wife Julie. He has two children, Claire (age 5) and Luke (age 3) who provide him with hours of fun, love, and some of life's more interesting challenges. His hobbies and interests include boating, water-skiing, and snow-skiing. His stress relievers include running, weight-lifting, swimming, and hot-tubbing. It is with great pleasure that we present Mr. Jeffrey Wuich as the second person to receive the JTCG/AS Young Engineer in Survivability recognition.

◆  
*Mr. Kevin Crosthwaite is Director of the Survivability/Vulnerability Information Analysis Center (SURVIAC). He has worked on several technical analysis and test programs involving a wide variety of weapon systems. Mr. Crosthwaite has an M.S. in nuclear physics from Ohio State and is a licensed professional engineer. He serves on the ADPA Combat Survivability Executive board on the AIAA Survivability Technical Committee. He may be reached at 937.255.4840, DSN 785.480, or via E-mail at crosthwaite\_kevin@bah.com.*

# Aircraft Survivability Symposium

18-21 November 2002

“Combat Survivability: UAVs and Manned Aircraft”

Sponsored by—

- The National Defense Industrial Association (NDIA) and the Association for Unmanned Vehicle Systems International
- Naval Postgraduate School, Monterey, California

Goals of Symposium—

- To acquaint aircraft survivability professionals with the characteristics of current and planned UAV systems as well as operational concepts
- To bring the UAV community up-to-date on the survivability techniques and technologies embodied in manned aircraft for hit avoidance and damage mitigation.

For more information, visit  
[www.ndia.org](http://www.ndia.org) or call  
703.522.1820.

# Calendar of Events

## SEPT

### **8–13, Toronto, Canada**

23rd International Congress of the  
Aeronautical Sciences  
[www.AAIA.org](http://www.AAIA.org)

### **16–18, Huntsville, AL**

5th Conference on Aerospace  
Materials, Processes, and  
Environmental Technology  
(AMPET)  
[ampet.msfc.nasa.gov](http://ampet.msfc.nasa.gov)

## OCT

### **1–2, Panama City, FL**

40th Annual Air Targets, UAVs, and  
Range Operations  
[www.ndia.org](http://www.ndia.org)

### **29–1 Nov, Woburn, MA**

Aircraft Fires and Explosions due  
to Accidents, Combat, and  
Terrorist Attacks  
[www.blazetech.com/  
Course\\_Listings/course\\_listings.html](http://www.blazetech.com/Course_Listings/course_listings.html)

## NOV

### **4–8, Dayton, OH**

Aircraft Fire Protection/Mishap  
Investigation Course  
[members.aol.com/afp1fire/www.htm](http://members.aol.com/afp1fire/www.htm)

### **18–21, Monterey, CA**

Aircraft Survivability 2002—  
Combat Survivability: UAVs and  
Manned Aircraft  
[www.ndia.org](http://www.ndia.org)

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

SURVIAC, Washington Satellite Office  
Attn: Christina McNemar  
3190 Fairview Park Drive, 9th Floor  
Falls Church, VA 22042  
PHONE: 703.289.5464  
FAX: 703.289.5467

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