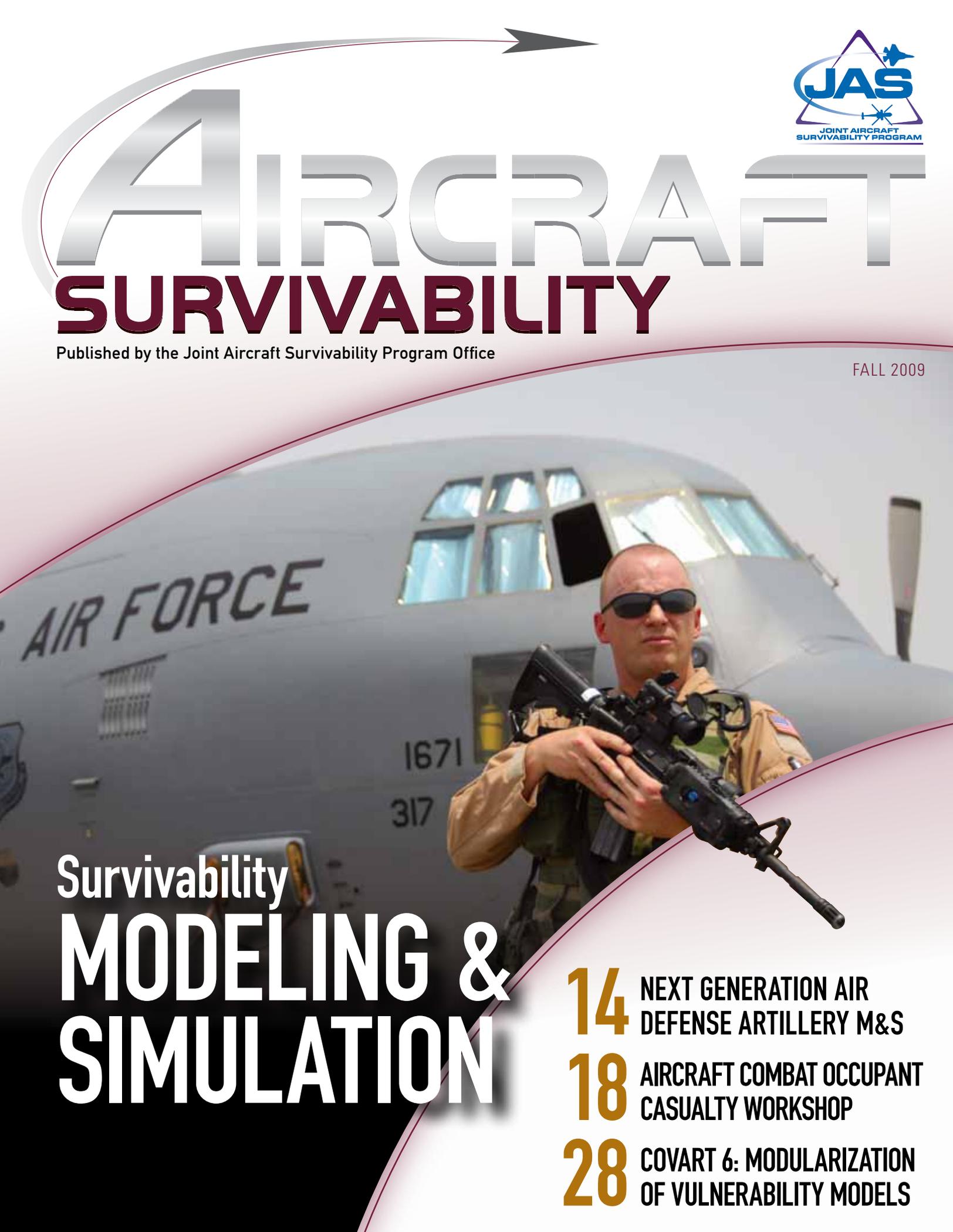


AIRCRAFT SURVIVABILITY

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Survivability

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JAS Program Office
200 12th Street South
Crystal Gateway #4, Suite 1103
Arlington, VA 22202

Views and comments are welcome and may be addressed to the:

Editor
Dennis Lindell

Assistant Editor
Dale B. Atkinson

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On the cover: US Air Force Tech. Sgt. James Seidel, assigned to 386th Expeditionary Security Forces Squadron, provides front security for a C-130 Hercules aircraft during a Fly Away Security Team (FAST) training exercise at an undisclosed air base in Southwest Asia. Photograph by USAF Tech. Sgt. Raheem Moore.

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14 Next Generation Air Defense Artillery Modeling and Simulation *by Jackie Koegler, Michael Bennett, and Christopher Vogel*

For the last six years, the National Ground Intelligence Center (NGIC) in Charlottesville, VA, has been developing a next generation air defense artillery (ADA) simulation using the Threat Modeling and Analysis Program (TMAP) methodology. This model, called the Air Defense Artillery Model (ADAM), offers analysts working on survivability studies new simulation features and fidelity never before available in previous models. ADAM will eventually replace a legacy ADA model, the Radar-Directed Gun System Simulation (RADGUNS), still in use. For survivability studies requiring evaluation of the ADA class of weapon systems, ADAM, with its ongoing enhancements and efficiencies, is a tool of choice. This article summarizes ADAM's capabilities and uses, its development status, and future plans for the tool.

18 Aircraft Combat Occupant Casualty Workshop *by Peggy Wagner, Philip Radlowski, Patrick Gillich, John Manion, and Barry Vincent*

In November 2007, the Director of Live Fire Test and Evaluation (LFT&E) in the office of the Secretary of Defense sent a memo to the Joint Aircraft Survivability Program Office, emphasizing the need to assess the survivability of the crew and passengers as a result of combat damage. The letter stated that "assessment of aircraft crew and passenger casualties to the point of safe return or egress is an important element of LFT&E." Current evaluation methodologies have historically focused on what happens to the aircraft in a combat event, with limited consideration of personnel casualties resulting from combat-induced aircraft losses.

22 SURVIAC—The Leader in the Survivability/Vulnerability Modeling Community

by Barry Vincent and Eric Schwartz

SURVIAC is a centralized information resource for all aspects of nonnuclear survivability, lethality, and mission effectiveness activities. SURVIAC provides information resources and analytical services to support scientists, engineers, analysts and program managers engaged in designing and improving weapon systems for the warfighter. In a tight time reaction environment, it is essential to make efficient use of credible models and simulations to support acquisition, test and evaluation, and warfighter operations. Thus, an important part of SURVIAC operations is distributing selected computer models to US government organizations and their contractors. The Joint Aircraft Survivability Program (JASP) and Joint Technical Coordinating Group for Munitions Effectiveness (JTTCG/ME) computer models entered into SURVIAC have been specifically designated by these government agencies as standard methodologies for wide use within DoD organizations. The resources and expertise available to SURVIAC in the survivability modeling arena is unmatched.

24 A SECAD Update

by Charles Frankenberger

The Survivable Engine Control Algorithm Development (SECAD) project has reached a significant milestone. As part of the JASP Turboshift SECAD project, General Electric has integrated SECAD algorithms with the T700-701E control software and loaded the algorithms into a full authority digital engine control (FADEC), bringing this technology one giant step closer to transition.

27 Excellence in Survivability—Patrick J. O’Connell

by Dale Atkinson

The JASP is pleased to recognize Mr. Patrick J. O’Connell for Excellence in Survivability. Pat is the Air Force deputy test director for the DoD Joint Live Fire Program (JLF) and the Aerospace Vehicle Survivability Facility (AVSF) Vulnerability Operations team lead for the Aerospace Survivability and Safety Flight at Wright-Patterson Air Force Base (AFB), Dayton, OH. He is also the Air Force Live Fire Test & Evaluation (LFT&E) lead engineer on the Joint Strike Fighter Program and other LFT&E programs.

28 COVART 6: Modularization of Vulnerability Models

by Tim Staley

Since computer-aided vulnerability and lethality (V/L) analysis began in the 1960s, several tools have developed to support the number of aircraft analyses performed across the DoD. Two of the most widely used of these tools are the Computation of Vulnerable Area Tool (COVART) and the Advanced Joint Effectiveness Model (AJEM)/Modular UNIX-based Vulnerability Estimation Suite (MUVES). COVART is the primary tool for Air Force and Navy fixed- and rotary-wing aircraft vulnerability analyses, with AJEM/MUVES supporting lethality and weapons effectiveness analysis and Army vulnerability analysis.

Mailing list additions, deletions, changes, and calendar items may be directed to:



SURVIAC Satellite Office

13200 Woodland Park Road
Suite 6047
Herndon, VA 20171

Promotional Director
Christina P. McNemar

Creative Director
Christina P. McNemar

Art Director
Donald Rowe

Technical Editor
Lindsay Marti

Newsletter Design
Tammy Black

Illustrations, Cover Design, Layout
Victoria Criddle
Michelle DePrenger
Lacey Olivares

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by Dennis Lindell

Chip Mumford

Please welcome Carey "Chip" Mumford to the Joint Aircraft Survivability Program Office (JASPO).

Chip is a retired US Air Force Colonel with 10 years of operational experience, seven years staff experience at the secretariat and unified command level, and 18 years in acquisition. He qualified as an instructor and evaluator pilot in the F-4 and F-16. He has flight experience in the Pacific and European Theaters, including a two-year exchange flying F-4s with the US Marine Corps. Chip is acquisition workforce certified Level 3 in systems engineering and program management. He was director of the F-22 engine program and propulsion System Program Office and supported the Training Systems program, B-2 System Program Office and Large Aircraft Infrared Countermeasures as a contractor.

Chip will take over as deputy program manager (DPM) for Vulnerability Reduction (VR). Matt Crouch, the current DPM for VR, will transition to DPM for Susceptibility Reduction (SR), and Robert Lyons (current DPM for SR) will become the JASPO Director of Operations. Mike Weisenbach will remain the Survivability Assessment

DPM and CAPT Branham will remain the JASPO Military DPM and JLF-Air Joint Test director.

To allow the DPMs to get familiar with their new subgroups (and vice versa), the transition will take place over the summer and be complete at the start of the new fiscal year (1 October). This will allow the JASPO staff to broaden its experience while minimizing the disruption to JASP and subgroup operation.

Please give Chip a warm welcome.

BRAWLER

Survivability/Vulnerability Information Analysis Center (SURVIAC) has begun distributing the newest classified and unclassified version of BRAWLER v7.1. These programs and their upgrades are funded by HQ USAF/A9 with administrative support provided by JASPO.

The new version of BRAWLER v7.1 model is an update from BRAWLER v7.0. This upgrade includes: enhancements to Frame-Based, Electronically Steered Array (ESA) modeling; dynamic radar cross-section (RCS) modeling of weapons bay doors and afterburners; integration of the National Air and Space Intelligence Center's air-to-air missile models; incorporation of HELCOMES Directed Energy code; criteria for passing and assessing weapons-quality track information; and new tools for plotting, post-processing, and trajectories for data visualization.

BRAWLER simulates air-to-air combat between multiple flights of aircraft in both the visual and beyond-visual-range arenas. This simulation of flight-versus-flight air combat is considered to render realistic behaviors of military fighter pilots. BRAWLER incorporates value-driven and information-oriented principles in its structure to provide a Monte Carlo, event-driven simulation of air combat between multiple flights of

aircraft with real-world stochastic features. The user decides the pilot's decision process, including—

- ▶ Missions and tactical doctrines
- ▶ Aggressiveness
- ▶ Perceived capability of the enemy
- ▶ Reaction time
- ▶ Quality of the decisions made

Supported Platforms—

- ▶ Linux
- ▶ SGI
- ▶ SUN

You can obtain the new versions of BRAWLER v7.1 from SURVIAC.

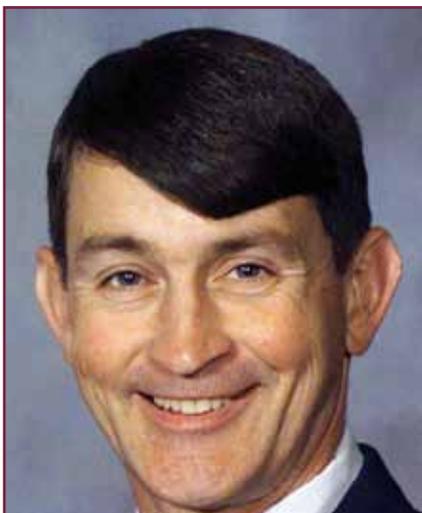
Vulnerability Toolkit

SURVIAC has begun distributing the newest version of the Vulnerability Toolkit. These programs and their upgrades were funded by JASPO and developed by Aeronautical Systems Center/ENDA (ASC/ENDA).

The new version includes significant updates to the Computation of Vulnerable Area Tool (COVART) and the Fast Shotline Generator (FASTGEN). COVART 6.0 is modular in nature and includes several new libraries (.dll or .so) as part of the release, including the FASTGEN 6.0 Ray Tracing library.

The COVART 6.0 computer program is a method for determining the vulnerable areas of targets damaged by impacting single kinetic-energy penetrators, shaped charge jet penetrators (SCJ), and high-explosive (HE) threats (including Man-Portable Air Defense Systems and proximity-fuzed warheads).

The COVART 6.0 program builds upon the restructuring of the code that occurred under prior development efforts by integrating ray tracing capabilities and updated penetration equations. COVART is written in a "modular" form, utilizing loadable libraries to separate program functionalities. While the structure of COVART 6.0 differs significantly from COVART 4, most of the input file formats as well as threat and damage capabilities are identical to COVART 4



Chip Mumford

and still utilize keywords. The COVART 6.0 computer program is written in the FORTRAN 90 language.

COVART requires data generated by tracing shotlines through a geometric description of the target. COVART 6.0 program integrates separate ray tracing modules for FASTGEN and BRL-CAD (librt), the two most common geometry formats in the Department of Defense, and processes these targets natively. This integration of ray tracing functionality into COVART has streamlined the analysis process, especially for HE threats.

Features added in COVART6 include—

- Penetration equations for shaped charge jets
- Updated penetration equations for fragments and projectiles
- Separate Pklh definitions from Pcdlh
- Front-face fire AIRGAP Pk tables
- Increased number of kill levels (from 6 to 15)
- Increased number of items in a multiply vulnerable group or system (from 8 to 24)
- Improved shotline trace

- 22 Software Change Requests (SCRs) addressed

The loadable libraries included with COVART 6.0 (in addition to the main COVART program) are—

- Ray Tracing
 - FASTGEN 6.0
 - BRL-CAD 7.12.4
- Penetration
 - ProjPen 2.2 (projectiles)
 - FATEPEN 3.2.18.1 (fragments)
 - FragPen (JTCCG/ME Fragment Penetration Equations)
 - SCJ (Fireman-Pugh shaped charge jet methodology)
- Damage
- Fault Tree

FASTGEN 6.0 traces the path of a projectile's shotline through a target composed of three-dimensional database objects called components. The set of components encountered along a shotline is arranged in the order of encounter, and this sequenced set is called a line of sight. FASTGEN is used to develop line of sight data for other software, such as COVART.

With the release of COVART 6.0, the FASTGEN ray tracing functionality has been made available directly to COVART as a shared object library. The ray generation functionality previously performed by the standalone FASTGEN program has been placed in a FORTRAN 90 module and made available from within COVART as callable subroutines. This allows for easy integration of other ray tracing libraries into COVART in addition to FASTGEN. Other modifications to FASTGEN include run time improvements due to more efficient target handling through voxelization.

You can obtain the new version of the Vulnerability Toolkit from SURVIAC.

JCAT Corner by CAPT Kenneth Branham, USN

They say all good things must come to an end. CDR Tim "TJ" Johnson, USN, is completing the last month of his deployment to Iraq. In theater, CDR Johnson serves two functions: the Joint Combat Assessment Team (JCAT) Officer in Charge (OIC) (FWD)/LNO and the Surface-to-Air-Fire (SAFIRE) manager. He eagerly anticipates passing the torch to LtCol Joerg Walter, USAF; after a brief transition period with CDR Allen Miller, USN. LtCol Walter will be the first Air Force officer to assume the role as the JCAT LNO at Multi-National Corps-Iraq (MNC-I).

Recently, CDR Johnson had the privilege to join VADM Debbink, COMNAVRESFOR, for lunch during the Admiral's visit to Iraq. CDR Johnson took to the opportunity to share with him what a valuable asset JCAT is in theater, providing on-sight engineering assessors and the ability to reach back to the broad survivability resources stateside. As explained, JCAT provides MNC-I and battlefield

commanders key tools to conduct aircraft battle damage assessments/ investigations and forensic analysis and provides important training to Combat Aviation Brigades (CAB). CDR Johnson also traveled with LTJG Keifer, USN, to Basra to provide training to the Naval Aviation Ambulance Detachment. This detachment is "one of a kind," comprised of personnel and hardware from four different squadrons brought together as one deploying detachment. Wearing his SAFIRE hat, CDR Johnson presented a brief on OIF SAFIRE trends at the MNC-I Monthly Aviation Conference at Camp Victory, Baghdad. All OIF JCAT personnel were able to attend: Balad Assessor; 2d Lt Dlugopoloski, USAF; and the Al Asad OIC, CDR Miller. CDR Johnson was instrumental in obtaining classification guidance from the Foreign Disclosure Office (FDO) in Baghdad to facilitate the releasing of future reports. CDR Johnson looks forward to redeploying and sharing his experiences in OIF with the survivability community.



CDR Johnson with VADM Debbink

Since February 2009, 2d Lt Dlugopolsky has been manning the JCAT office in Balad, mainly supporting the Army. Luckily, he has had very few assessments to complete due to the great work Army Aviation has been doing. In the meantime, he has been assisting in combining JCAT assessment data with that of the SAFIRE tracker and also working to create an all-encompassing threat system guide for both OIF and OEF.

Continued on page 26

Management of Modeling & Simulation

by Hugh Griffis

The fundamental need for successful investment in modeling and simulation (M&S) within the Department of Defense (DoD) is well documented and broadly recognized. More than a few efforts have been conducted to assess the then-current state, prevalent need, recognized gaps, and business practices for M&S. [1]



Figure 1 JAS Logo

Attempts in the 1990s to develop joint, monolithic simulations to meet multiple user requirements largely failed. [2] This is not news to those in the M&S community. However, heroic efforts by small groups of people have significantly advanced the state-of-the-art of legacy constructive survivability simulations.

As we transition into the second decade of the 21st Century, M&S will play an increasingly vital role in the DoD's ability to affordably equip the warfighter. [2] These challenges are embodied in the JASP slogan, "Survivability Enhancement Today and Beyond," (Figure 1). The incorporation of prior lessons learned and continued heroic efforts are required to break down M&S management barriers.

Usage of M&S

Modeling, simulation, and analysis (MS&A) activities provide the numerical underpinning for many weapon system acquisition decisions. These decisions require high quality and timely information from a broad spectrum of technical disciplines that

leverage M&S. These technical disciplines and M&S user communities conduct evaluations that span the entire weapon system life cycle—

- Experimentation
 - Long lead technology development
 - Immediate warfighter needs
- Warfighter
 - Day-to-day execution and planning
 - Capability assessment
- Intelligence assessments
 - Threat evaluations
- Acquisition
 - Capability assessments
 - Source selection evaluations
 - Requirements maturation
 - System design
 - Performance assessments
 - Cost, scheduling, risk evaluations

- Manufacturing processes
- Logistics assessments
- Test
 - Developmental test and evaluation
 - Operational test and evaluation
- Training and mission rehearsal
 - Operational usage of systems
- Education
 - Formal development

MS&A Background

The Analysis Hierarchy Survivability Pyramid (Figure 2) defines different levels of constructive simulations. Simulations at the bottom of the pyramid have a narrow scope and great depth, while simulations at the top of the pyramid have broad scope and limited depth.

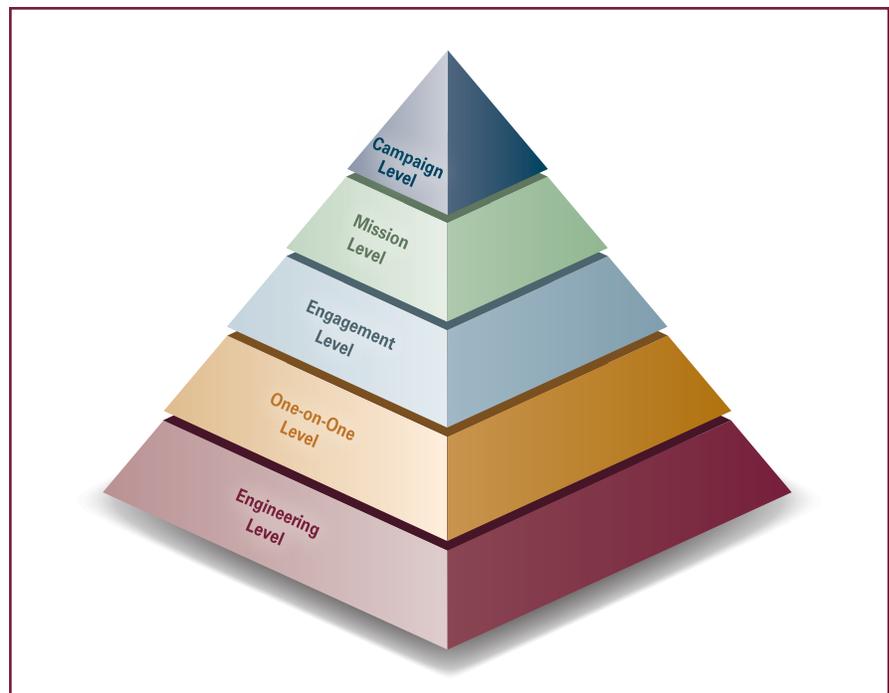


Figure 2 Survivability Pyramid

Pyramid Levels	Simulations
Campaign	Thunder
Mission	SUPPRESSOR
Engagement	Brawler
One-on-One	ESAMS (RF SAMS), MOSAIC (IR SAMS), RADGUNS (GUNS)
Engineering	FASTGEN/COVART (Vulnerability), BlueMax (Flight)

Constructive simulations typically run much “faster than real time,” a capability required to meet users’ analytical needs. The “faster than real time” capability implies that constructive simulation uses *simulated people* operating *simulated systems*.

Each simulation level emphasizes different analytical attributes. The proper calibration of upper level results with low level (higher detail) outcomes, enhancing analytical confidence in the upper level analysis results.

All Models Are Wrong

The corollary phrase to “all models are wrong” is “some models are useful.” Many of the current legacy survivability simulations that were initially developed three decades ago are still used today—indicating that these simulations are useful. Widely used, government managed and owned legacy survivability simulations are listed in Table 1. These survivability simulations support many hundreds of users across the country and have been leveraged by numerous weapon system programs across the DoD and beyond.

While the names of legacy simulations remain the same, these legacy simulations have evolved since their conception. Legacy simulations have implemented significant changes that provide greater breadth of analytical capability; enhanced technical robustness; and implemented modifications to reflect red and blue weapon systems advancements. Many of the legacy simulations are undergoing major updates for a variety of reasons. Simulations undergoing major changes are listed in Table 2.

In addition to the above legacy simulations, JASP has sponsored other software developments, which are listed in Table 3, Engineering Simulations.

M&S Availability

Government managed and owned survivability simulations are available to industry and government organizations. Descriptions of these simulations are available online at the JASP, SURVIAC, and Modeling & Simulation Information Analysis Center (MSIAC) websites. The DoD sponsors 19 Information Analysis Centers that encompass a diverse set of topics. Survivability M&S-related information and simulations are distributed by SURVIAC and MSIAC. In addition to websites that provide general information, several model managers have established online communities of practice.

Break Down M&S Barriers

While entire reports have been written on M&S barriers, the JASP has implemented and demonstrated a strategy to enhance M&S developments and user simulations.

Modules

A fundamental tenant of systems engineering is to divide work task content into smaller, manageable tasks. Simulations that are broad in scope and highly detailed have significantly higher developmental risk. Table 2 (see note section) highlights a major new trend. As computer speed and memory have increased, it is now feasible for higher

Legacy Simulations	New/Next Generation Simulations
Thunder	Storm
SUPPRESSOR6	SUPPRESSOR7 ^{1,2}
Brawler ⁷	Brawler ^{1,2}
JAAM3 ⁸	JAAM4 ^{1,2}
ESAMS ⁷	JSAMS ^{1,2,6}
MOSAIC3 ⁷	MOSAIC4 ^{1,2}
RADGUNS ^{7,9}	ADAM ⁵
COVART5 ⁷ & FASTGEN5 ⁷	COVART6 ^{3,4}
BLUEMAX ⁷	BLUEMAX6

¹ includes MATLAB-SIMULINK (TMAP, SIMS Like) flyout models

² includes BLUEMAX flight model

³ includes FATEPEN and PROJEN penetration modules

⁴ includes BRL-CAD LIBRT module

⁵ includes COVART6 model

⁶ includes SHAZAM3 model

⁷ Support by JASP

⁸ Support by JTCG/ME (Joint Technical Coordinating Groups for Munitions Effectiveness)

⁹ Support by Intelligence Agency

level simulations to incorporate discrete, stable, lower level simulations. These low level simulations are managed and controlled separately from the higher level simulation. This approach increases robustness while retaining acceptable developmental risk. Recent JASP and Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME)-funded projects have successfully demonstrated feasibility of modular development approach. While clearly the correct direction, this path induces several management issues—

Pyramid Levels	Simulations
Engineering	FPM (Fire Prediction), LS-Dyna (Threat-structural interaction)

- The DoD lacks well-written, functional modules with interface control documents that will support several different simulations.
- There is no centrally managed library of modules.
- There is no service infrastructural support to the module developer, to offset the needs of the user community.
- There are no controls to restrict upper level simulations from altering low levels simulations.

Verification & Validation

The quality of M&S needs to be appropriate for the decision they are supporting. The JASP has implemented policy that states JASP-sponsored hardware design and test projects will be coordinated with the appropriate JASP M&S point of contact. The JASP design, test, and M&S communities are coordinating on projects and test requirements. Test data is being collected to generate critical information to support M&S verification and validation (V&V). While this is the correct direction, this policy introduces several management issues—

- Hardware design, test, and M&S functions required additional funding to coordinate project and test planning.
- Collecting the additional data results in increased costs.
- The cycle time to collect test data, author test reports, conduct comparison of test and simulations, and author a V&V report results in several years of continued support.

Trained Workforce

Limited resources have been applied against critical analytical capabilities. As a direct result, legacy survivability simulations usability and documentation have suffered. While the M&S community required a trained workforce, [2] due to a lack of usability, many survivability simulations are overly difficult to effectively use. Current training initiatives include—

- The JASP sponsors two Joint Modeler Users Meetings and formal survivability training at the Navy's Post Graduate School. See JASP website for details.
- SURVIAC provides training courses for a selected set of JASP-supported survivability simulations.
- M&S model managers provide periodic training materials and courses.

- Given the availability of tools for building graphical user interfaces (GUI), the cost to develop user friendly simulations is much less today than in the past. However, prior to developing a GUI, the simulation needs to be well documented. Some projects are working toward more user friendly simulations.

Resources

Legacy survivability simulations exist because for many years, the government has sponsored the evolution and sustainment of these simulations. The evolution of M&S capabilities depends upon resources provided to the model manager. Typically, M&S sponsors come in three forms: 1) Weapon system programs, 2) Service infrastructure, and 3) Investment programs such as the JASP and JTTCG/ME. M&S user advocacy for resources enables the model managers to provide users with better services and simulations. Enhanced relationships with M&S users to obtain advocacy is vital for the accelerated growth of M&S.

1. **Weapon system programs:** Service weapon system programs provide sporadic, but significant funding support across the entire suite of survivability simulations. In general, weapon system programs provide resources to address specific, near-term program needs.
2. **Service infrastructure:** Service corporate funding is very limited. Many survivability simulations attain no service infrastructure funding.
3. **Investment programs:** DoD investment programs, such as the JASP and JTTCG/ME, sponsor survivability M&S projects across several levels of the analysis hierarchy, including Engagement, One-on-One, and Engineering. While JASP M&S funding is limited, this critical funding enables code fixes, day-to-day configuration control, and user support. On occasion, JASP also provides funds to address long-term sustainment issues.

Summary

Today's weapon system programs spend significant resources on M&S. Enhanced M&S capabilities are expected to reduce evaluation time, improve the information provided to decision makers, improve weapon system effectiveness, and reduce overall weapon system cost and risk.

The JASP M&S management strategy is to remove M&S barriers by implementing processes for long-term support of survivability M&S. The JASP has implemented and demonstrated a strategy that is enabling enhanced M&S development. While this process will take time to demonstrate its full value, these specific management processes have already provided benefits. The Joint Aircraft Survivability community believes that elements of this management strategy and its processes are applicable across all M&S communities. ■

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1. Metrics for M&S Investments
2. 2009 Vision for United States Air Force M&S

Survivability Models and Simulations: Past, Present, and Future

by David Hall and Ronald Ketcham

A major responsibility of the JASP Survivability Assessment Subgroup is to foster and support the development of common and/or standard survivability assessment methodologies for use by the all of the military services and industry. Thus, the objective of the Subgroup is to support the Joint Survivability Community (JSC) with common survivability trade-study analysis tools (models and simulations, databases, credibility information) that meet their individual requirements for capability, accuracy, and usability.

The Specter of M&S Past

In the 1980s and 1990s, the (then) Joint Technical Coordinating Group for Aircraft Survivability (JTTCG/AS) Survivability Methodology Subgroup and its seven committees (Susceptibility, Vulnerability, Advanced Threats, Gun Threats, Surface-to-Air Missile Threats, Air-to-Air Threats, and Methodology Integration) leveraged service modeling and simulation (M&S) and database developments with the “vision” of establishing—

“An accepted Joint Service methodology for conducting air weapon system survivability analysis, using a flexible and efficient computational environment, based on a set of credible modeling components.”

During that period, the Subgroup had five major focus areas: M&S credibility (Verification, Validation and Accreditation [VV&A]); transition to a new modeling architecture (Joint Modeling and Simulation System [J-MASS]); a new physics-based ballistic vulnerability simulation (Advanced Joint Effectiveness Model [AJEM]); development of an Integrated Survivability Assessment (ISA) process; and improved and coordinated survivability M&S management.

(1) In the early 1990s, the Susceptibility Model Assessment with Range Test (SMART) project was funded by the Office of the Secretary of Defense (OSD) to develop a cost-effective VV&A process and demonstrate it on five high-priority survivability M&S (Enhanced Surface-To-Air Missile

Simulation [ESAMS], Radar-Directed Gun System Simulation [RADGUNS], Advance Low-Altitude Radar Model [ALARM], BRAWLER, and Trajectory Analysis Program [TRAP]). One of the primary achievements of the SMART program was to define the attributes that define M&S credibility: capability, accuracy, and usability. Those attributes are documented in the Joint Accreditation Support Activity (JASA) Accreditation Support Package (ASP). Based on the successful completion of SMART, the JTTCG/AS established JASA to support system acquisition programs with M&S credibility issues, and to assess, improve, and document the credibility of the survivability models available through SURVIAC.

(2) Also early in the 1990s, the J-MASS architecture was being developed by the Air Force and the Intelligence Community. J-MASS was envisioned as a joint architecture for creating new engagement-level models, and proponents advocated expanding the use of J-MASS to mission-level assessment tools as well. Causing perhaps the most upheaval in the tri-service survivability analysis community of any development at the time or since, J-MASS had the potential to completely modify the way that the community did business. The Subgroup made attempts to identify and support ways to integrate J-MASS models into simulations and to leverage existing Joint Service infrastructures to address the long-term distribution and configuration management of J-MASS simulations. The JTTCG/AS became a member of the OSD J-MASS implementation team and the Senior Steering Group for J-MASS. The

Subgroup also developed common environment algorithms for ALARM, ESAMS, and RADGUNS, with the goal of them becoming accepted as the algorithms of choice for J-MASS models of the environment. This effort was successful in establishing the “BEARD” common algorithm set (BlueMax, ESAMS, ALARM, RADGUNS, Digital Integrated Modeling Environment). These common algorithms were included in each of those models as part of the SURVIAC M&S set; they were also included in some of the J-MASS models that actually reached fruition. The BEARD algorithms were added to all of these tools; however, they were only added as options. JTTCG/AS pushed the effort to develop the standard algorithms, but backed away from requiring them to be implemented as true standards.

There was a general concern expressed in the late 1990s that too many resources were being focused on the development of architectures for future DoD M&S developments for training and testing. Resources were being redirected that could have been applied to ensuring that the M&S that were being used in development and test and evaluation (T&E) were credible and adequate to the job. The feeling was that while a joint modeling architecture may have been a laudable long-term goal, there were immediate and near-term needs that were not being met for research, development, test, and evaluation support across the board. And, of course, the J-MASS architecture and the few J-MASS models that were eventually available never caught on with the community.

(3) In another M&S initiative, the JTCG/AS, in cooperation with the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) and the Army Research Laboratory (ARL), developed a new physics-based simulation to assess the ballistic vulnerability of a wide range of targets as well as the lethality of many types of munitions. AJEM was a long-term effort of the vulnerability community to develop a new generation vulnerability methodology. AJEM was intended for entry into SURVIAC and it is in use within the JTCG/ME and by a number of Army programs; however, it has not gained complete acceptance by the aircraft survivability community, it has not been entered into SURVIAC, and JASP has dropped support for its development. Thus, even today we have a situation where we have a divided user community using two different tools (AJEM and Computation of Vulnerable Areas and Repair Times [COVART]) to do essentially the same task, spreading available M&S infrastructure dollars even thinner. An often stated reason for this split in the vulnerability M&S user community is the perception that AJEM development is managed by the Army solely for Army interests.

(4) During this time period, JASP focused its vision on developing an integrated survivability assessment (ISA) capability; a true ISA would allow for tradeoffs between all aspects of survivability design, including the effects of off-board assets (support aircraft, such as Suppression of Enemy Air Defense assets, stand-off jammers, fighter support, decoys) as well as all on-board aircraft assets. In order to address this ISA issue, the JTCG/AS held a series of workshops in the late 1990s to evaluate DoD customer needs for an ISA capability and the potential for current ongoing initiatives to satisfy those needs. There was significant participation from all service operational testing organizations, as well as the Director of Operational Test & Evaluation, and participation from industry and the system development community in all the services. The ISA Workshops developed a list of requirements for the JTCG/AS to pursue, including the credibility of engagement-level simulations (including calculation of probability of kill – Pk), mission level survivability modeling, and the inclusion of mission effectiveness and cost

assessment in the analysis process. The JASP program has since lost its focus on ISA capability development.

(5) The Subgroup also attempted to make some inroads into improving the configuration management of the M&S supported by SURVIAC. Figure 1 illustrates the general situation at the time: each of the M&S in SURVIAC was managed by a different agency within a service, and funding for maintenance and improvements was hit or miss depending on the budget of the managing agency and the JTCG/AS budget available to support the model. At the same time, the J-MASS initiative was draining resources away from the service model managers to support even minimal model maintenance. As a partial response to this situation, the Subgroup instituted the JASP Model User Meetings (JMUM), which bring together users of the most widely used models in SURVIAC twice yearly for coordinated user and configuration control board (CCB) meetings. While these meetings do not provide complete coordination of M&S development and management, they are at least a step in the right direction, and JASP continues to support them.

A September 1999 report of the Defense Science Board (DSB) Task Force on Test and Evaluation pointed out the need for increased investment and emphasis in all of these areas. The DSB report presented

numerous observations and recommendations that were particularly relevant when considering the role of JASP in the area of M&S, such as—

“Clearly, a better coordinated and more disciplined process is needed for the development and use of models and simulations, and for their VV&A.”

“Much of the extensive investment in M&S by DoD seems to emphasize model architecture, interfaces, graphical displays, and code writing at the expense of conceptual model development and basic data collection.”

Perhaps the most significant and most relevant finding of the DSB Task Force was that *“The lack of up-front funding is often a critical problem in M&S.”* With respect to the recommendations in the 1999 DSB report, it appears that, in actuality, DoD has stepped backward from where we were in the 1980s: for example, JASA is no longer part of JASP to support VV&A, and less funding in present-year dollars is going toward improvements in M&S technical capabilities than was the case earlier.

The Ghost of M&S Present

While M&S usage is widespread throughout the Joint Survivability Community, JASP is facing decreasing DoD investment in M&S in real dollars. Many of our primary tools lack proper configuration management and V&V

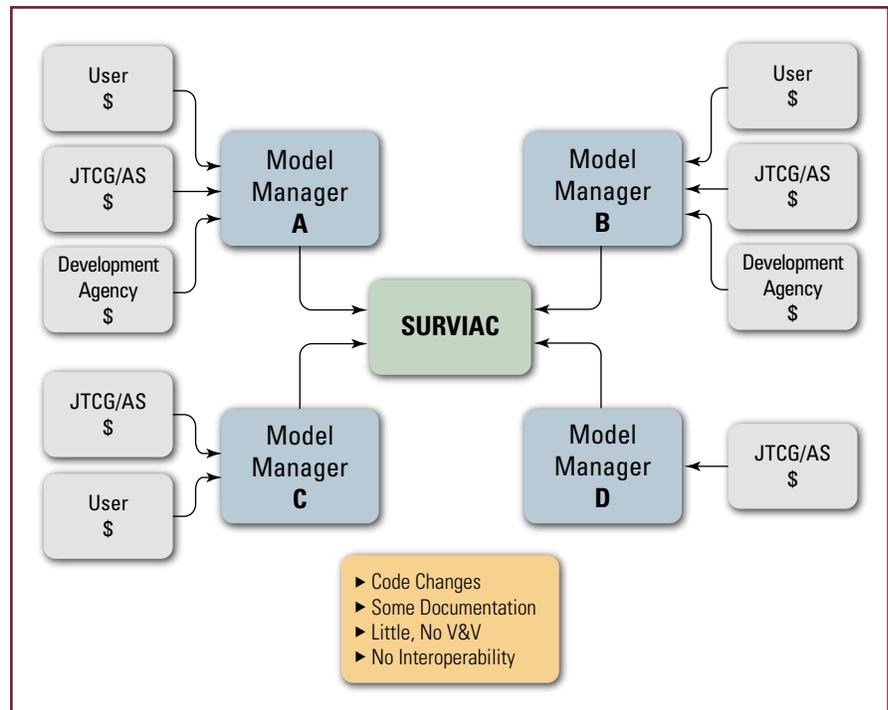


Figure 1 General Electric T700-701

data. Many have undergone regular and extensive code changes to fix bugs or enhance capabilities, but their documentation has not kept up. What limited and insufficient dollars there are to address these problems are spread out inefficiently when user communities are split, using multiple models that essentially do the same function because of disagreements related to ownership and management. The millions of dollars lost on the investment in J-MASS was a costly lesson in the pitfall of not having requirements for M&S defined by users who are working directly with aircraft acquisition programs. There were insufficient incentives for the JSC to transition from its existing tools to a new environment that produced very little substantive improvements. The M&S that were (and still are) being used to support acquisition never really recovered from the loss of their funding sources within the Services to these larger DoD initiatives. This has resulted in a lack of institutionalized support for maintenance and improvement of these joint-use models within the DoD.

JASP has been funding M&S-related efforts for many years to counter some of these problems, investing two to three million dollars annually in support of M&S tools. JASP historically has been reluctant to take a leadership role over the M&S tools employed by the survivability users of M&S; however, around 2002, this position gradually began to change. JASP began to recognize that there is no one better suited for the job of managing the M&S tools used by the JSC—for the interests of all users, services, and programs. Therefore, the joint membership of the Survivability Assessment Subgroup began to gradually assume a leadership role in managing and promoting the capabilities of what has become known as the JASP M&S toolset. This toolset includes such widely used models as ESAMS, COVART, Fast Shotline Generator, ALARM, and Fire Prediction Model (FPM). JASP was the logical choice for taking this role for several reasons—

- ▶ JASP is the representative of the aircraft survivability technical community. JASP M&S toolset users are the key component of its membership.
- ▶ JASP provides technical coordination of activities within this community as its primary function. JASP is charged with bringing the JSC together periodically to identify its require-

ments and ensure that these requirements are addressed in the management of the JASP M&S toolset.

- ▶ JASP already has the relevant connections and liaisons throughout the community that are required to provide this leadership.
- ▶ JASP's goal is to promote user-driven requirements as opposed to other organizations that would mandate their own requirements. JASP membership collectively has the direct knowledge and understanding of user's requirements: the Survivability Assessment Subgroup membership consists of the survivability analysts supporting almost all air system acquisition programs.
- ▶ JASP already has much of the required infrastructure to execute this role. The Subgroup meets routinely to identify, prioritize, and fund projects that maintain and advance our M&S capabilities, and JASP sponsors the biannual JMUM to facilitate user dialogue in these matters. JASP funds SURVIAC for model management, distribution, and configuration management support. As creator of JASA for VV&A related support, JASP still has retained the corporate knowledge and the expertise to promote M&S credibility.

Table 1 shows the current JASP M&S program.

The Spirit of M&S Yet to Be

For JASP, the question now before us is how we define good management practices and how we use limited funding to promote these practices across the entire toolset. Table 2 illustrates some of the cultural, institutional, and programmatic issues that inhibit good M&S management practice today.

JASP has realized that no individual acquisition program could sufficiently fund the required M&S management to maintain long-term M&S tool set credibility, even though all acquisition programs rely heavily on it. There have been proposals to centrally fund these needs in the past, but they came at the cost of taking M&S program requirements out of the hands of those best suited to define them—the user community that works directly with the programs to meet their requirements. JASP feels there is a need for a governance approach that addresses the following fundamental principle—

While funding should come from a central source that establishes and enforces standards and practices for demonstrating M&S credibility in the most cost-effective manner feasible, specific technical requirements for the actual M&S implementation must come from the members of the user community that is closest to and best understands their domains.

This principle redirects the impact of the “golden rule” to promote M&S credibility. Recognize that if you want M&S developers and users to adhere to good M&S management practices that promote M&S credibility, they must be funded to do so. Specific programs do not have the incentive to fund M&S; the funds they do provide are to support their specific requirements. Unlike those programs, JASP's objective is to develop and maintain a capable, accurate, and usable toolset available to all users across all services at all times. To meet this objective, JASP needs to be the provider of M&S infrastructure funds: “He who has the gold makes the rules.”

In the Fall 2004 issue of the Aircraft Survivability journal, the Survivability Assessment Subgroup published a Strategic Plan for managing and promoting the credibility of the JASP M&S toolset. This plan was further refined in 2007 as the JASP M&S Governance Approach (Figure 2). While JASP recognizes that full implementation of the Strategic Plan and JASP governance solution is still beyond their current available resources, it is desired that current funds be utilized as much as possible to move the JASP toolset in this direction on an incremental basis.

Under this approach, JASP would become the central source of funding that would require model managers, developers, and model users to practice M&S management polices that promote M&S credibility. These practices will—

- ▶ Ensure proper establishment and execution of required M&S infrastructure (Configuration Management [CM], V&V, Accreditation support)
- ▶ Promote collaboration between services/programs/users
- ▶ Promote development and implementation of cost saving standards
- ▶ Reach and maintain acceptable levels of M&S credibility

The ultimate goal is to reduce the M&S cost burden on individual programs and yet improve M&S credibility to address

Table 1 Current JASP M&S Program

Project	JASP Objective
SURVIAC Model Management Support	CM System Support, JMUM operations, Model repository, help desks
Passive Covert Radar ECM	New capability
Red on Blue Mission Analysis Methodology Support	Cooperation with JTCG/ME to support warfighter. Also promotes methodology enhancements and standardizations between survivability and lethality M&S
ESAMS CCB Activities	Improvements to CCB process making it on-going and tri-service
Vulnerability M&S Enhancements and Studies	Fixes, new capabilities, and V&V
TMAP Missile Models in MOSAIC and ESAMS	Improving integration of new intel threat models into standard IR and RF engagement tools
ADAM + Technical Support	New gun model to replace RADGUNS. This investment is being made to ensure the developer works closely with current RADGUNS users
MOSAIC ASP	Preliminary credibility documentation step necessary for entry into SURVIAC
Ongoing Threat Database Development	Data credibility documentation effort
IIR Multi-spectral Acquisition/Tracker Models	New capability
COVART Enhancements	Fixes new capabilities and V&V
AC Occupant Survivability	To assess current M&S credibility to address new mandated requirement
Geometry Conversions to CAT	Add data to tool to support JCAT
Combined Plate Testing	Data collection and validation effort
Rotorcraft Power Loss Flight Model	New capability
FPM Enhancements	Model improvements
Improved DRFM in Brawler	Model improvements
HRAM Model Validation Data	Data collection and validation effort
Vulnerability Data Base Assessment Tool (VDAT)	Tool to promote COVART credibility. Reduces errors
Stand Alone Fuze Model	Model Improvements
MANPADS Threat Model Development—Blast	Data collection and validation effort
MANPADS Threat Model Development—Frag and Debris	Data collection and validation effort
Credibility of MANPADS Hit Point Predictions	Data collection and validation effort

requirements by basing the JASP M&S program on user needs from all services and system acquisition programs.

The fundamental principle stated previously also recognizes that the user community that has direct contact with air system acquisition programs will be most capable of identifying and prioritizing those programs' M&S requirements. They will be the best suited to address the contesting, and sometimes conflicting, needs of multiple programs and services.

It is worth highlighting the key role SURVIAC plays in executing this plan—

- ▶ They provide standardized, web-based CM data bases available to all the users of all models. This is a very cost-efficient way of handling CM because incremental costs for each additional model are negligible.
- ▶ They prepare for and host the JMUM and CCB meetings, which are key user gatherings that coordinate M&S requirements across the country.
- ▶ They provide a repository for all JASP models in SURVIAC. Any member of government, industry, and academia can get the latest releases of all of the JASP M&S tools and support documentation by contacting SURVIAC.
- ▶ They provide help desk and training services for key JASP models.

The Moral of the M&S Story

JASP has supported the development, maintenance, and credibility of survivability M&S over the years, in spite of limited funds and the vicissitudes of external influences. DoD initiatives come and go, but JASP's focus has been and remains on the requirements of the acquisition community for a credible, usable, and effective survivability M&S toolset.

As stated before and is worth reemphasizing, JASP does not have sufficient resources to fully implement the JASP Governance Approach for all M&S currently in the toolset; however, JASP is using current funds to make incremental improvements. JASP prospects for even maintaining the current credibility levels in the M&S tool set are precarious. These are very dynamic models, which require continuous support for model and documentation maintenance, verification and validation, database and pedigree updates, incorporation of new and updated Threat Model and Analysis

Table 2 Sources of Problems with M&S in DoD

Cultural Problems	<ul style="list-style-type: none"> ▶ “M&S is not our product.” Acquisition program’s objective is to develop its system, not to maintain M&S for the wider community. ▶ “Not invented here.” Promotes duplication and multiplies the cost burden for the acquisition community.
Institutional Problems	<ul style="list-style-type: none"> ▶ “Nobody’s in charge.” There is no recognized M&S authority. ▶ “Who do I believe?” Competitive and counterproductive marketing by individual service activities to system acquisition programs promotes local interests over community interests. ▶ “The Golden Rule.” As applied today is counterproductive to effective and efficient management of broadly used M&S tools.
Programmatic Problems	<ul style="list-style-type: none"> ▶ “Not in my budget.” Individual programs are not motivated to support M&S beyond their immediate requirements. ▶ “Not my problem.” Lack of funds for long-term strategic M&S investments. ▶ “Late to need.” Broadly used models must contend with a highly dynamic state of evolving requirements.

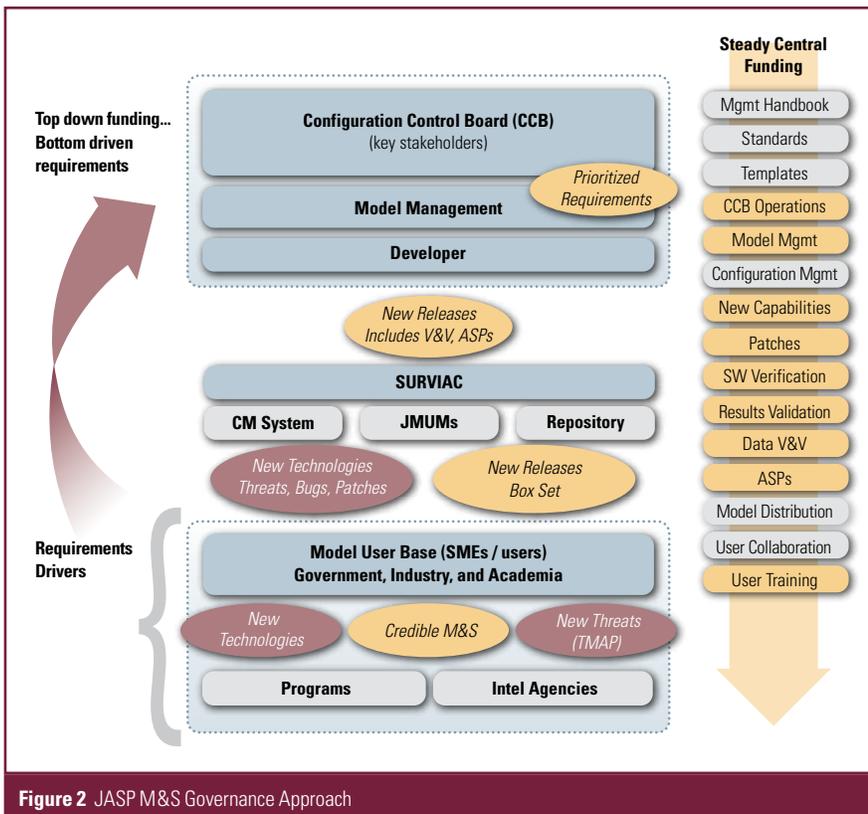


Figure 2 JASP M&S Governance Approach

Program (TMAP) threat models, CCB and CM operations, and even requirements for brand new capabilities. JASP cannot keep up at this pace with current levels of funding. It is falling more and more behind. This means the M&S tools used to support critical decision making with regard to aircraft survivability will have less evidence of credibility to support their usage, which may increase the probability of providing programs with the wrong answers.

The only solution is to find a method to increase funding for M&S infrastructure support. There have been proposals in the past to find this money, and JASP should be looking at all possible sources for a plus up; however, it needs to be emphasized that spending money alone will not guarantee that these funds will be spent effectively and efficiently. That is why JASP believes that the proposed JASP M&S Governance Approach is essential. ■

Next Generation Air Defense Artillery Modeling and Simulation

by Jackie Kogler, Michael Bennett, and Christopher Vogel

For the last six years, the National Ground Intelligence Center (NGIC) in Charlottesville, VA, has been developing a next generation air defense artillery (ADA) simulation using the Threat Modeling and Analysis Program (TMAP) methodology. [1] This model, called the Air Defense Artillery Model (ADAM), offers analysts working on survivability studies new simulation features and fidelity never before available in previous models. ADAM will eventually replace a legacy ADA model, the Radar-Directed Gun System Simulation (RADGUNS), still in use. For survivability studies requiring evaluation of the ADA class of weapon systems, ADAM, with its ongoing enhancements and efficiencies, is a tool of choice. This article summarizes ADAM's capabilities and uses, its development status, and future plans for the tool.

History of the Threat Modeling and Analysis Program (TMAP)

TMAP was approved in 2000 by the Military Intelligence Board. This board funded the Service Intelligence Centers (SIC)—the Missile and Space Intelligence Center (MSIC), NGIC, the Office of Naval Intelligence (ONI), and the National Air and Space Intelligence Center (NASIC)—to conduct a proof of concept for a common approach to threat model development using the commercially available products MATLAB® and Simulink®. Since that time, TMAP has become the SIC standard, providing authoritative, validated threat data and models for the community to use. The TMAP community has also expanded to include several foreign partners.

TMAP is a scientific and technical intelligence methodology that directs SICs to employ a common approach to creating reusable tools and threat models for predictive analysis. Its goal is a common, consistent approach to producing models of threat systems that are reusable, interoperable, and extensible to meet diverse customer needs.

In years past, intelligence customers received paper documents describing the known intelligence of a foreign system; under TMAP, customers receive authoritative, fully documented threat models. They can then use these models alone for analyses or they can integrate them into existing simulations (as either Simulink or code-generated C/C++).

TMAP offers two added benefits: a common framework and SIC awareness of ongoing efforts. These benefits in turn promote reuse of analysis and threat modeling solutions. Each SIC coordinates model development to leverage existing code and to avoid duplication of effort amongst the centers.

ADAM Description

ADAM is a self-contained, time-based, end-to-end ADA tool for analyzing all aspects of ADA engagements. It enables analysts to evaluate the effectiveness of specific gun systems against aerial targets. ADAM can evaluate the effectiveness of different airborne target characteristics (*e.g.*, radar cross section [RCS], maneuvers, use of electronic countermeasures [ECM], *etc.*) against a specific ADA system. It simulates every component of an ADA system—from acquisition and track sensors (radar and/or electro-optic), track filters, and the fire control computer to guns, projectiles, missiles, pedestal and platform dynamics, and targets. It covers simple and complex environments for both electro-optic and radio frequency sensors, as well as target and jammer characterizations.

ADAM uses MSIC's Standard TMAP Interface and Model Structure (STIMS). The STIMS standard offers modular flexibility: components such as the fire control computer and gun can be extracted for use in hardware-in-the-loop simulations. This flexibility allows NGIC to support a single gun model so that a common validated threat

representation is available for customers, including analysts, open air test ranges, the Army Joint Research Analysis and Assessment Center, warfighters, and mission planners.

The model is completely parameter driven, and all weapon, target, and environment-specific data are read into the model at run time. This design allows a single tool to represent every foreign threat ADA system—from a human-operated, 12.7-mm DShK small caliber anti-aircraft machine gun shooting point-detonating rounds to the fully automated, most advanced air defense artillery (ADA) systems shooting counter-precision guided munition (PGM) projectiles. ADAM can also represent closed-loop tracking for close-in weapons systems (CIWS) and active protection system-equipped weapons that engage extremely close targets with projectiles having novel burst patterns.

ADAM Advantages Over RADGUNS

One design requirement for ADAM was replacing the legacy RADGUNS. ADAM does so by incorporating many features not available in RADGUNS. For example, it has selectable earth models: flat, round, or WGS-84. It also has optional environment effects for processing clutter, multipath, and diffraction using both digital terrain elevation data (DTED) and land cover data. Unlike RADGUNS, ADAM can simulate one-on-one and few-on-few engagements and supports target ECM. ADAM also simulates various airburst

Table 1 RADGUNS 2.4.1 and Beta Edition of ADAM Comparison

Feature	RADGUNS 2.4.1	ADAM Beta Edition
Institutional Problems	11 canned flight paths types and BLUEMAX profiles	Reads BLUEMAX natively; graphical user interface offers constant velocity (additional profile types to be added)
Engagements	One-on-one engagements	One fire control computer with three guns
Languages	Fortran 77/90	MATLAB, Simulink, DSP, Stateflow, C++, and some legacy Ada
Operating Systems	Windows, Linux, Solaris	Windows
Gun Systems	54 gun systems (several not verified)	7 currently available gun systems for test
Modern Systems Support	No support for modern systems	Supports CIWS, modern ADA systems, and Air Burst munitions
Preplanning Tools	No preplanning tools	Provides tools to view the run matrix before executing runs
Visualization Outputs	IVIEW-format output for use with visualization tools	Hybrid Integration and Visualization Engine (HIVE) output planned for future release
Measures of Effectiveness	Ph, Pk	Ph/miss distance, Computation of Vulnerable Area Tool (COVART) integration underway
Electronic Countermeasures	Limited ECM	Advanced ECM (<i>e.g.</i> , pulse-level responses, side lobes, range gate walkoff, <i>etc.</i>)
Environments	No terrain	Supports DTED

and fusing schemes; it supports precision-guided munitions targets and traditional aircraft.

ADAM uses industry-standard PRODAS®-generated flyout tables for calculating the firing solution and modeling the projectile simulation. To ensure some backward compatibility, ADAM supports the standards set in RADGUNS, including support for BLUEMAX model flight profiles, RCS data files, and presented/vulnerable area (.pva) file formats. Table 1 compares RADGUNS to the beta edition of ADAM.

ADAM Enhancements

To support ADAM and the growing modeling and simulation needs of the intelligence community, the Joint Aircraft Survivability Program Office (JASPO) is funding an effort through the Survivability/Vulnerability Information Analysis Center (SURVIAC) to build a new graphical user interface (GUI) for ADAM that will provide additional analysis tools. The goal of this effort is to create an interface that analysts who are not experts in MATLAB and Simulink can use for their simulations. As part of these enhancements, ADAM is being integrated with the Computation of

Vulnerable Area Tool (COVART) endgame model to provide probability of kill (Pk) calculation capabilities.

ADAM Graphical User Interface

The initial version of the ADAM GUI allows for easy modification of the most commonly used engagement parameters. The GUI can run the ADAM model in either its interpretive edition (native MATLAB® or Simulink®) or its

compiled code edition. Figure 1 shows the main interface GUI with its parameter category section buttons along the left-hand side.

ADAM supports the following parameter categories—

- **Run Options:** The run options enable users to set up basic simulation characteristics such as simulation duration. They also contain an

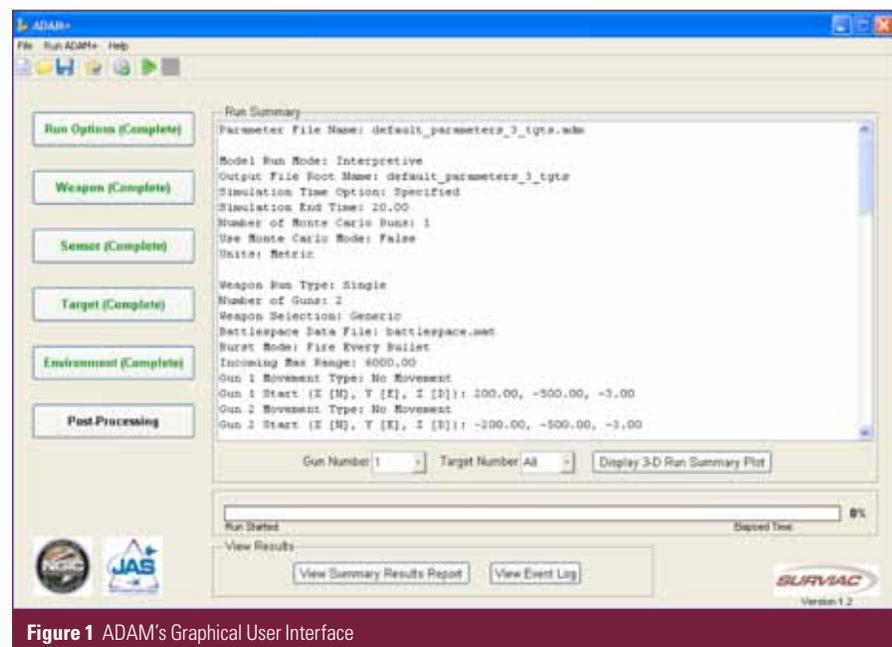


Figure 1 ADAM's Graphical User Interface

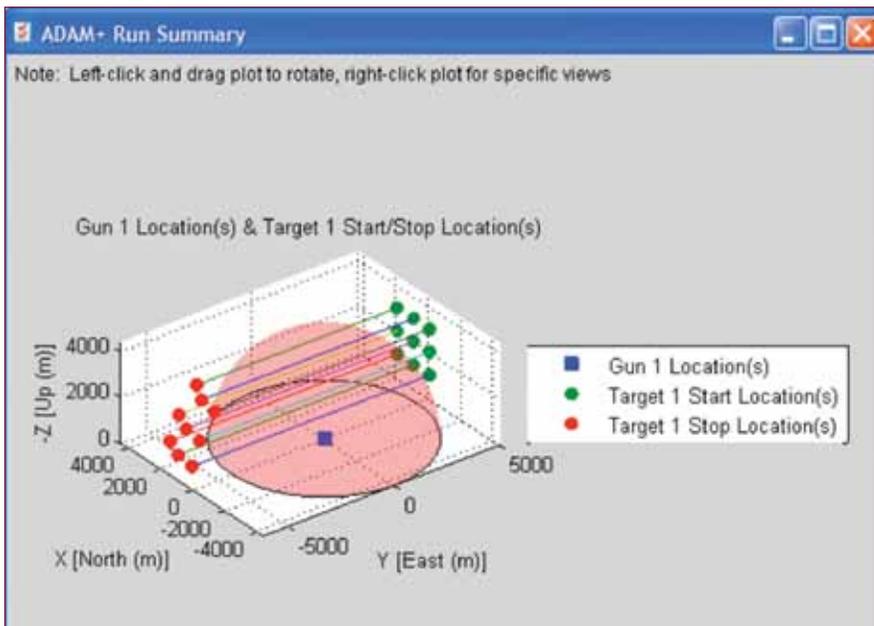


Figure 2 3-D Run Summary Plot Shows the Grid of ADAM Runs to Be Executed

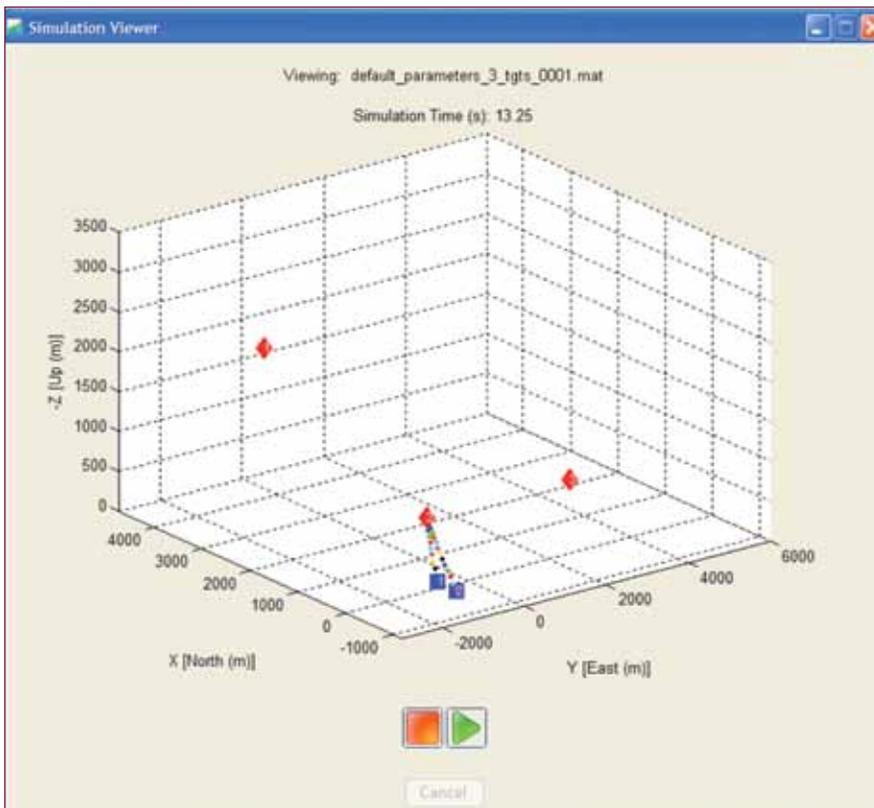


Figure 3 Simulation Viewer

each sensor type. In addition, there are options to specify electro-optical sensors and radio frequency sensors.

- ▶ **Target:** The target section enables analysts to set up a matrix of runs and to specify the target type, number of targets, target location/target movement, electro-optical signature, presented area, and RCS options.
- ▶ **Environment:** The environment section has earth properties, clutter, multipath, and diffraction options and visibility parameters.

The GUI also features support for visualizing a run matrix. Figure 2 depicts a 3-D run summary plot, which graphically represents the ADAM simulations queued to run. This example of a notional gun system illustrates a single weapon and a uniform grid of target runs. The dome displays the effective range of the ADA system.

The new GUI also provides post-processing utilities, including a results file, metrics, and simulation viewing options. A simulation viewer (see Figure 3) can depict a simple animation of a simulation run with all gun, weapon, and projectile locations throughout the simulation.

Computation of Vulnerable Area Tool (COVART) Interface

The new GUI offers another feature: an interface to COVART so that all ADAM ballistic information (*e.g.*, projectile profile, impact angle, striking velocity, *etc.*) and aircraft orientation information can be fed directly into COVART 6.0. This capability allows analysts to generate improved probability of hit (Ph) calculations using an actual aircraft geometry versus just an ellipsoidal target, to generate and view hit locations on the aircraft geometry, and to calculate both shot and engagement Pk.

The distribution version of ADAM will include 11 sample geometries and a complete F-4 sample target input to provide a complete example for endgame analysis. Figure 4 depicts a sample geometry included with ADAM along with the projectile impact point locations.

Current Development Status and Future Plans

The beta edition of ADAM was released through SURVIAC in May 2009 to five beta sites. These sites tested several aspects of the model, including the new GUI. Software change requests are being tracked from these sites, and NGIC is

automatic feature to compute the simulation end time (stop time) based on when all targets are out of range of a weapon system. Monte Carlo run parameters are also included among the run options in this section.

- ▶ **Weapon:** The weapon section includes single or multiple run options, weapon selection, the number of guns, gun location, and gun movement. Multiple

run options include specifying uniform gun locations (a grid of runs) or arbitrary locations. The gun movement options are no movement or constant velocity. Table and 3-D plot run summary options are also available for analysts to verify their settings.

- ▶ **Sensor:** Similar to the weapon section, the sensor section includes sensor location and movement options for

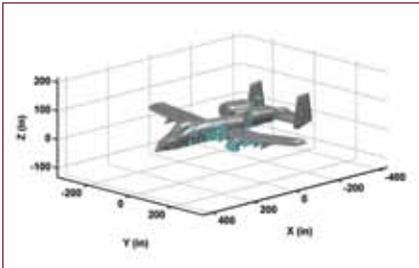


Figure 4 FASTGEN Geometry Rendered via ADAM GUI with Engagement Hit Locations

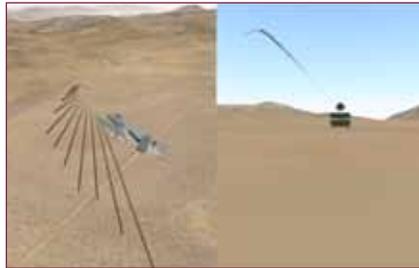


Figure 5 Prototype HIVE Visualization of ADAM Scenario

responding to each request with model fixes as required. SURVIAC has fixed all GUI-related requests, and NGIC is continuing work toward an initial community release.

Additional enhancements to ADAM are also being considered, including bundling a complete visualization package with the distribution that would be controlled through the ADAM GUI. This Hybrid Integration and Visualization Engine

(HIVE) would allow analysts to “play back” any ADAM run and visualize a complete engagement (see Figure 5).

Once ADAM exceeds all current RADGUNS capabilities and is approved by JASPO and NGIC, SURVIAC will begin distributing and supporting ADAM and will archive RADGUNS. At that time, analysts can turn to ADAM for their survivability evaluations. ■

References

1. NGIC is the authoritative source for ADA intelligence information.



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Aircraft Combat Occupant Casualty Workshop

by Peggy Wagner, Philip Radlowski, Patrick Gillich, John Manion, and Barry Vincent

In November 2007, the Director of Live Fire Test and Evaluation (LFT&E) in the office of the Secretary of Defense sent a memo to the Joint Aircraft Survivability Program Office, emphasizing the need to assess the survivability of the crew and passengers as a result of combat damage. The letter stated that “assessment of aircraft crew and passenger casualties to the point of safe return or egress is an important element of LFT&E.” Current evaluation methodologies have historically focused on what happens to the aircraft in a combat event, with limited consideration of personnel casualties resulting from combat-induced aircraft losses. Aircrew and occupants are being injured and fatally wounded due to combat related in-flight escape and crash events. A methodology to predict these injuries and/or fatalities needs to be incorporated into the survivability evaluation methodologies.

Survivability equipment needs to earn its way into the design of an aircraft. The first step is to be able to assess the personnel survivability features of the design. Once an evaluation method is in place, then more stringent requirements can be placed on the aircraft design. An evaluation method also facilitates design trade studies to further increase capability. Future Test and Evaluation Master Plans for aircraft acquisition programs will contain requirements to evaluate the impact of aircraft vulnerability on the crew and passengers. Current vulnerability assessments provide only a portion of the necessary information.

The JASP has begun a project to incorporate crew and passenger casualty assessments into aircraft survivability evaluations. The initiative is being executed through JASP project M-08-09 “Aircraft Combat Occupant Casualty” from FY 2008 to FY 2011 and has tri-service involvement. The goal of the project is to include aircraft occupant casualty reduction as a vulnerability design consideration in the acquisition process.

The first portion of the project involves researching the current agencies that gather or produce data that could feed the crew and passengers survivability assessments. A JASP-sponsored Aircraft Combat Occupant Casualty Workshop was held 13 to 15 January 2009. The

objective of the workshop was to assess state-of-the-art casualty data and discuss current casualty metrics, evaluation techniques, and methodologies. Vulnerability test and evaluation representatives from the three services participated in the workshop. Additionally, there were several other government organizations that presented their perspectives and capabilities related to passenger survivability analysis and test. These organizations included the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA-Langley), the National Transportation Safety Board (NTSB), the National Highway Traffic Safety Administration, and DoD safety centers and aeromedical experts. Several analytical frameworks and test techniques for evaluating combat casualties from initial ballistic aircraft penetration through a safe landing and egress were proposed by aircraft survivability experts from within all the Services. The information received at the workshop forms a strong basis for starting to develop both short- and long-term Joint Service assessment methodologies through the JASP.

The workshop revealed there is a substantial amount of work being done in the field. The briefings and the discussions were focused on four main topics—data gathering, existing analysis and testing capabilities, non-DoD government agency efforts, and DoD undertakings.

Data Gathering

There are several organizations and agencies responsible for collecting and analyzing data related to the occupant survivability in aircraft. SURVIAC presented an overview of the potential data sources for casualty data that needs to be investigated, the models and methodologies that can be used and or expanded to assess occupant casualties, and four scenarios that will be tested out once the methodologies have been refined. A review of the findings and recommendations from the 2008 National Defense Industrial Association Casualty Workshop were covered, and discussions followed centering on the current kill chain assessed for typical survivability analyses. A survivability analyses does not typically consider casualties to crew and passengers as a result of the return flight, crash landing, and/or egress. These three factors could contribute significantly to the number of casualties resulting from hostile threats.

The safety centers from the three services function as a data repository for aircraft mishaps. While these incidents are not analogous to combat incidents, they do offer insight as to casualties resulting from the return flight, crash landings, and egress. The Naval Safety Center presented “Naval Aviation Mishap Investigations.” The purpose of the safety center is to investigate and understand why an incident happened so that steps can be taken to prevent a reoccurrence. A Safety

Investigation Report is developed and includes the official causal factors of the mishap, which can be human-related or material-related. For each causal factor, the safety center identifies at least one recommendation to prevent recurrence of the mishap. The data collected and reported by the safety centers may be useful when correlating personnel injury/fatalities with aircraft damage. The direct use of the data may not be feasible because certain parameters of an incident may be unknown, but it will provide insight into the type of casualties associated with a type of incident.

The data collected by a DoD safety center can have restrictions on its releasability for use by other organizations, including other DoD organizations. The Readiness Programming & Assessment Office of the Under Secretary of Defense briefed the releasability processes for this information. The briefing describes safety privilege data that is information protected by military and civilian courts and is used for safety purposes only. The privileged data is not used for legal, punitive, or administrative purposes. The purpose of having privileged data is to overcome an individual's reluctance to reveal complete and candid information. The briefing also discusses classified data and human use data. All three types of data are protected and require steps to access the data and re-release.

In addition to non-combat safety incident data, there is a smaller amount of combat survivability data that has been collected and studied. Most of the data is from recent operations. The Institute for Defense Analyses (IDA) presented the results of the Aircraft Combat Casualty Study. This study looked at Operation Enduring Freedom/Operation Iraqi Freedom combat data between 2002 and 2008. The study identified injuries and fatalities per incident, aircraft type, weapon type, aircraft system lost, crew position, and aircraft maneuvers. Recommendations from this study were to develop better methodologies to capture combat loss data and to develop methodologies to assist LFT&E efforts in assessing crew and passenger casualties. Both of the recommendations correlate with the overall goal of the Crew and Passenger Survivability (CAPS) analysis.

The Joint Combat Assessment Team (JCAT) also presented "Combat Forensics for the Warfighter." The JCAT collects incident data involving threats against US aircraft. The primary reason for

collecting incident data is to understand the types of threats and tactics that the enemy uses to shoot down US aircraft. The safety centers are not able to collect this type of data because mishaps do not involve threats. The briefing also detailed how the JCAT data is maintained in the Combat Damage Incident Reporting System. The type of data collected by the JCAT could be expanded in order to benefit the crew casualty analysis process.

Existing Analysis and Testing Capabilities

There are several DoD organizations currently working in the field of personnel survivability. Similar to existing aircraft vulnerability assessments, they provide significant amount of data for a portion of the assessment but cannot answer the entire question. The Army Research Laboratory (ARL)/Survivability Lethality Analysis Directorate presented "An Overview of Wound Ballistics, the Operational Requirements-based Casualty Assessment (ORCA) Model and its Military Applications." The history of wound ballistics and a description of the different damage mechanisms (fragments, blast, thermal, *etc.*) evaluated within the code to assess crew casualty were outlined. The results from the code include injury/medical metrics that define the severity of the injury and if the soldier can perform his or her specific task. The severity of injury is ranked from minor, which are superficial wounds, up to maximal, which is nearly unsurvivable.

AMSRD-ARL-SL-BD presented the US Army Aviation Analysis methodology. Current crew vulnerability assessment by ARL uses the Modular UNIX-based Vulnerability Estimation Suite (MUVES) code; crew vulnerability modeling in the future will use ORCA. The DESCENT code is a rotorcraft flight model that characterizes a hard or crash landing by calculating the impact velocity and identifying a resultant kill category for input into MUVES. The current limitations of DESCENT will need to be greatly improved before it can be used for crew casualty analysis. The kill category in DESCENT is directly related to the structural capacity of the airframe. It currently does not consider personnel survival; however, future efforts may allow for the resultant impact velocities to be fed into another dynamic modeling code that will calculate the impact forces onto an occupant. If the forces on an occupant are known, then injury/incapacitation could be calculated.

The US Army Medical Research and Materiel Command presented the "DoD Medical Research Program for the Prevention, Mitigation, and Treatment of Blast Injuries." The objective of the program is to provide a coordinated research effort to understand and address blast injuries on personnel, identify preventative techniques, improve treatments, and allow soldiers to return to duty. A key accomplishment of the program is the establishment of the Joint Trauma Analysis and Prevention of Injury in Combat (JTAPIC) program. The JTAPIC program provides a method for agencies to work together to form better assessments of the crew survivability problems and allow for better understanding of the vulnerabilities. JTAPIC also allows different organizations (*e.g.*, medical community, materiel community, operational/intelligence community, customers) to meet regularly and share data and ideas and reduce the time it takes to come up with new solutions to problems. The operational concept of JTAPIC is to look at the cause of an incident, what the effects were (*e.g.*, individual, individual's clothing and equipment, vehicle) to develop improved tactics, techniques, and procedures. Also discussed were new techniques developed to collect data from soldier helmets to help understand the impact loadings of a soldier with a traumatic brain injury.

The work that is being performed by the JTAPIC group can help to identify what injuries are occurring in the field and can be used to help characterize personnel injuries from hard or crash landings.

The Air Force Research Laboratory Human Effectiveness Directorate presented "Injury Models and Survivability Related Projects." The Human Effectiveness Directorate is responsible for providing injury assessments for most modern Air Force ejection systems, for developing ejection test mannequins, and for continuing to define human injury limits and criteria. The directorate maintains a man-rated horizontal impact accelerator and a vertical deceleration tower used to test equipment and to define the human responses to different loading environments. Using numerous models and testing, the directorate can define ejection/impact injury criteria for aircraft equipment to prevent personnel injuries due to G loads. Also presented was an overview of the Collaborative Biomechanics Data Network website,

which contains large amounts of data that can be used to understand forces and impacts on humans. Another model used by the Human Effectiveness directorate is the Burn Simulation (BURNSIM) model, which calculates heat transfer through fabrics and can predict burn depth, time to pain, time to threshold blister, and max temperature. The BURNSIM is available to all DoD and contractors and will be incorporated into ORCA.

The Naval Air Systems Command (NAVAIR) presented “Navy Human Effectiveness Dynamic Modeling.” Discussion topics included the Dynamic Test Facility and the capabilities of the facility, which include an ejection tower, horizontal accelerometer, wind blast facility, and a virtual test facility. NAVAIR has worked to reverse engineer the crush of an aircraft from crash photos and an estimate of the descent rate. Kinematic modeling can be used for all sorts of survivability issues with numerous models existing that simulate the human body response to given impact conditions. Models can simulate what happens to an aircraft if the ballistic damage and the aircraft response are known. The missing pieces are the landing/crash conditions and the crash acceleration pulse. The structural models of the aircraft also need to be improved. By comparison, the automotive industry has higher fidelity automobile models with one million to two million element models for determining how the automobile will crumple. In the rotorcraft industry, the model only had about 10,000 elements used for NASA Structural Analysis.

Non-DoD Government Agency Efforts

In addition to the DoD organizations, several other government agencies are actively working personnel survivability in automobiles and aircraft. The Human Injury Research Division, Office of Vehicle Safety Research presented “Occupant Injury Research at National Highway Traffic Safety Administration (NHTSA): Process, Regulation, Tools.” The primary mission of the NHTSA is to perform testing and research to advance the scientific knowledge in impact biomechanics to enhance motor vehicle occupant safety. Each aspect of a crash timeline (crash prevention, severity reduction, injury mitigation, and medical attention) is researched/modeled/tested and standards are devised. Numerous Federal Motor Vehicle Safety Standards have been adopted as a result of the analyses and studies performed by the

NHTSA. Recent major accomplishments include new frontal dummy injury criteria, side impact dummy injury criteria, and lower extremity criteria. All injury criteria are published on the <http://www.regulations.gov> website. All NHTSA crash tests performed since 1982 are also available to the public *via* the NHTSA website. The testing and M&S performed by the NHTSA are very similar to the testing and modeling needed to understand the human response in an aircraft crash. These same tools and procedures could be used to support the CAPS methodology.

The FAA presented the FAA Crashworthiness Program. The goal of the FAA crashworthiness is to reduce or prevent crash related injuries/fatalities. The FAA Crashworthiness Program focuses on the regulator process and research initiatives. The regulator process evaluates current regulatory standards and design deficiencies. Research initiatives develop technical data for enhanced aircraft crashworthiness. The six major research areas in the FAA crashworthiness program include: aircraft structures, cabin interiors, occupant protection, crash environment, fuel systems, and analytical modeling. Some elements of crashworthy aircraft system design were discussed and impact characteristics were identified. Of note, approximately 60% of fatalities are due to thermal injuries, and the remaining 40% of fatalities are due to impact injuries.

NTSB presented “NTSB Aviation Survival Factors Investigations.” The NTSB was established by Congress in 1967 to investigate and determine the causes of accidents in all modes of transportation. The Board issues recommendations to the FAA and/or industry to improve survivability. Also discussed was the Survival Factors Group, which is a part of the NTSB Go-Team and assists regional investigators. This group documents damage to structure (*e.g.*, cabin, exits, floor); conducts interviews of passengers, crew, aircraft rescue and fire fighting personnel, witnesses, and training personnel; and gather data for FAA on evacuation and escape, and personnel injuries and/or fatalities. The NTSB is able to collect significant amounts of data after the accident. This information is critical to understanding the effects on the crew and passengers. The methodologies developed to assess CAPS need to be able to adapt to new

information as crash investigations continue and analysts further understand why injuries/fatalities occur.

NASA presented an “Overview of Research Performed at the Landing and Impact Research (LandIR) Facility.” The facility can perform full-scale crash testing of systems up to 64,000 pounds into concrete and also has a hydro impact basin to test water impacts. The testing performed at the LandIR facility supports analyses for numerous survivability-related efforts, such as dynamic impact and landing simulations. The goal of many of these tests and simulations is to understand crash characteristics and to support future aircraft designs with improved crash performance and onboard crew/occupant safety equipment. Additional testing performed at the LandIR facility supports material characterization used for input into simulations. Other discussion topics included NASA’s Crash Simulation Research focused on crashworthy design. Crashworthy design is defined as a system that maintains a livable volume, limits the decelerations transmitted to the occupants, mitigates post-crash fire, and allows for safe egress. An example program described was the Subsonic Rotary Wing Rotorcraft Crashworthiness Program. The objective of this program is to develop a structural concept for improved energy absorption and to demonstrate its capability. Focused on multi-terrain impact simulations, human occupant simulation and injury prediction, and system integrated helicopter crash simulation and model validation studies. This program could be very helpful for future CAPS analysis methodologies.

IDA presented “Space Station and Crew Survivability Following Orbital Debris Penetration.” Within this program, a risk assessment was performed to assess a crew loss given an orbital debris penetration of the space station. The presentation showed that crew and passenger end effects can be predicted on the space station given adequate input data. The space station survivability analysis process could be leveraged in the development of an aircraft personnel casualty assessment resulting from threat damage.

DoD Undertakings

The Air Force and Navy briefed two notional methodologies developed for CAPS analysis as a part of the JASP project. The goal of the methodologies will be to include aircraft occupant casualty reduction as a vulnerability design consideration in the acquisition process. Current codes such as Computation of Vulnerable Area Tool and Advanced Joint Effectiveness Model are used to assess the vulnerability of both fixed and rotary wing aircraft. These codes can be leveraged as they describe the state of the aircraft after threat impact. Additional steps will need to be implemented to facilitate analyses beyond current capabilities. External data from sources such as personnel survivability models, aircraft databases, and external analyses will need to be incorporated in the assessments. Appropriate metrics for the crew and passenger assessments need to be established. The metrics will allow designers to see the impact of certain design features on the personnel survivability.

The JASP project is not the only effort to assess or improve personnel survivability in vehicles. The Aviation Applied Technology Directorate presented the ongoing Aircrew Survivability Technologies program. The purpose of this program is to reduce aircraft and crew vulnerability to ballistic and crash events for current and future generation Army rotary wing aircraft. The objective of the program is to develop new rotorcraft crashworthiness criteria and to develop a design guide for future rotary wing aircraft and a methodology to evaluate crashworthy design. Also described was the future (2012 to 2015) Aircrew Survivability Technologies program. The purpose of the future program is to advance aircraft and crew vulnerability reduction technologies for current and future generation Army rotary wing aircraft, building on technologies developed under the current program. The overall payoff from this program will be a reduction in serious injuries and fatalities from conventional and non-conventional threat weapons.

Key Decisions and Findings

The Aircraft Combat Occupant Casualty Workshop involved experts from several government agencies to discuss crew and passenger casualties as a result of combat damage. The briefings by the various

agencies showed that significant capability to assess portions of the crew and passenger survivability already exists. Additional data sources from DoD and non-DoD organizations will be pursued in an effort to collect additional data and analysis methodologies.

The JASP-sponsored Aircraft Combat Occupant Casualty project was conceived to address the topic of crew and passenger survivability as a result of combat damage. A key deliverable for this project will be a draft state of the art report (SOAR), which will contain the CAPS data collection roadmap when it is combined with other efforts being pursued by JASP for the next several years. The SOAR will identify and document gaps in the existing data where improved or further capability is needed. The project will also provide a methodology to assess the personnel survivability from combat damage. The methodology will leverage existing data, processes, and codes and include the effects of in-flight threat effects, landing/crashing, and egress. The crew and passenger assessment methodology will allow for existing and future aircraft designs to evaluate personnel survivability. The Air Force and Navy will coordinate and develop methodologies applicable to fixed wing and rotary wing aircraft. Coordination is necessary to ensure the resulting methodologies overlap in common areas but differ due to the design and operational differences between a fixed and rotary wing aircraft. The methodologies will significantly leverage existing data and modeling and simulation capabilities. Aircraft vulnerability codes likely will be used as a starting point and then heavily rely on external data to influence the development of analysis inputs. The methodology development and testing process will also aid in identifying data voids. Once the performance of a design is known, efforts and design changes can be made to improve survivability. This methodology will provide a way to assess casualties and ultimately influence design in acquisition. For additional information, please contact the authors. ■

SURVIAC—The Leader in the Survivability/Vulnerability Modeling Community

by Barry Vincent and Eric Schwartz

SURVIAC is a centralized information resource for all aspects of nonnuclear survivability, lethality, and mission effectiveness activities. SURVIAC provides information resources and analytical services to support scientists, engineers, analysts and program managers engaged in designing and improving weapon systems for the warfighter. In a tight time reaction environment, it is essential to make efficient use of credible models and simulations to support acquisition, test and evaluation, and warfighter operations.

Thus, an important part of SURVIAC operations is distributing selected computer models to US government organizations and their contractors. The Joint Aircraft Survivability Program (JASP) and the Joint Technical Coordinating Group for Munitions Effectiveness (JTTCG/ME) computer models entered into SURVIAC have been specifically designated by these government agencies as standard methodologies for wide use within DoD organizations. The resources and expertise available through SURVIAC in the survivability modeling arena is unmatched.

SURVIAC conducts many activities to support modeling and simulation. The SURVIAC library contains a large number of models. SURVIAC services these models by maintaining, distributing, and updating them. SURVIAC also supports the model user community by providing expertise, training, and user meetings. Furthermore, SURVIAC supports the developers of models by providing configuration management support and assisting in the development of models. In addition to modeling support, SURVIAC is a major user of the models in its library and from elsewhere for analysis support. SURVIAC can be a one-stop shop for survivability and vulnerability modeling needs.

SURVIAC Models

The models in the repository have not been developed solely by SURVIAC, but typically are products of other government agencies, JASP, and JTTCG/ME. SURVIAC provides the DoD community with comprehensive survivability and lethality modeling services that include model distribution and expert technical support. SURVIAC's

involvement in modeling support involves active support for current models as well as introduction of new models in the survivability and lethality topic areas.

SURVIAC provides a range of model information to help users solve their problems. SURVIAC can discuss key aspects of the user's problem and then offer informed advice on selection of models to address the user's issues. SURVIAC maintains models that address engagement functions such as detection, track, launch and guidance, and endgame analysis. The 14 models currently in SURVIAC's inventory can be applied to analyze the following—

- Aircraft flight path generation
- Warhead-Target fragment interactions
- Air-to-air and surface-to-air missiles
- Radar detection
- Air defense artillery
- Endgame analysis
- Advanced threats
- Air combat

If users have modeling questions on subject areas beyond the survivability and lethality domain, such as logistics or cost, SURVIAC will refer the users to the appropriate DoD agency for those models. The models currently in the SURVIAC library include the following—

- Airborne Radar Detection Model (AIRADE)
- Advanced Low Altitude Radar Model (ALARM)
- BLUEMAX – Variable Airspeed Flight Path Generator
- BRAWLER – Air-to-Air Combat Simulation
- Ballistic Research Laboratory Computer-Aided Design Package (BRL-CAD)

- Computation of Vulnerable Area Tool (COVART)
- Directed RF Energy Assessment Model (DREAM)
- Enhanced Surface-to-Air Missile Simulation (ESAMS)
- Fast Shotline Generator (FASTGEN)
- Fast Air Target Encounter Penetration Program (FATEPEN)
- IVIEW 2000 – Graphical User Interface for Output Simulation
- Joint Service Endgame Model (JSEM)
- Low Energy Laser Weapons Simulation (LELAWS)
- Radar-Directed Gun System Simulation (RADGUNS)

Model Distribution

Model requesters can contact SURVIAC by telephone, letter, email, fax, or visit. Each request should specify the computer and operating systems on which the model will execute as well as the desired media. All requesters will receive a memorandum of agreement (MOA), which they must complete and return to SURVIAC; it must be on file before any software can be released. Copies of the MOA are available on the SURVIAC website. The requestor must sign this statement. For contractors, it also must be signed by the government contracting agent to certify need to know. Documentation comes on the same CD as the model. Models and documentation are made available to government agencies free of charge. In the past, a charge of \$500 was required from all non-government users for each model requested. At the SURVIAC Technical Coordinating Group meeting held February 2009, it was decided that the model distribution fee of \$500 for contractors will be suspended starting

1 July 2009. This will be revisited after one year to assess the effects on the SURVIAC core operations.

Model User Support

Part of SURVIAC's charter is to provide support to users through inquiries. A user can contact SURVIAC and receive support on questions regarding the model they are using.

Subject Matter Experts

SURVIAC's analysts provide additional value-added support on these models by responding to requests and carrying out in-depth analysis for special studies and tasks. In addition, SURVIAC maintains a network of subject matter experts in government, industry, and academia to draw upon to answer technical questions and support special studies.

Training

SURVIAC hosts training classes on the various models in its library. The registered users of the model are notified of upcoming courses. The location and cost of the courses vary depending on the model involved and the number of attendees.

User Meetings

SURVIAC personnel works closely with JASPO to carry out two JASP Model User Meetings (JMUM) yearly. The summer JMUM meeting is usually held at the United States Air Force Academy in Colorado Springs, Colorado, and the winter JMUM is usually held at Nellis Air Force Base, NV. The JASP-sponsored models include the following—

- ALARM
- BLUEMAX – Flight Path Generator
- COVART
- DREAM
- ESAMS
- FASTGEN
- RADGUNS

JMUM is an excellent networking event for JASP, SURVIAC, and other models users. Participants from various DoD services as well as DoD contractors attend the meeting to gain insight on current JASP models. The meeting is intended to be an informative meeting for anyone with interest in the JMUM model suite and promotes open discussions on hardware and software issues related to each of the JMUM models.

Configuration Management Support

The Software Change Request (SCR) reporting tool is a web application developed to track SCRs for models. The system has several user roles that can be customized for each model. It supports

model managers, developers, configuration control board members (CCB), and general users. In order to access the system, the user must apply for an account and request access for the models they use. Once the application is received and approved, users can create/update/view SCRs, download model updates, and view reports. The model managers and CCB members can use advanced features, such as voting on changes and updating the status of current SCRs.

The major benefit of the system is the improved communication between model users. Users are able to look for known problems and solutions in the database instead of submitting a request. Some solutions may be able to be resolved without the effort of the model management team. Users can also obtain updates directly from the website instead of having to wait to receive the CDs. Decisions can be made more quickly on submitted SCRs using the online voting system. Overall, the increased communication and knowledge sharing allows problems with models to be resolved more rapidly.

Model Development

SURVIAC has a team of subject matter experts who specialize in model development and analysis. This group of developers has modified and maintained existing models such as RADGUNS and ESAMS. They have also integrated models together and provided visualization capabilities of models. In addition, the group of experts has developed models for Threat Model and Analysis Program (TMAP) and integrated TMAP models into other survivability models. The subject matter experts available to SURVIAC have very broad and deep skills in model development.

Analysis

Another primary modeling function at SURVIAC is analysis work. SURVIAC analysts have conducted numerous survivability and vulnerability studies for all milestones in the procurement process. They also have conducted analysis for many future concepts, weapon system modifications, and mission planning. In addition to the models with the SURVIAC library, SURVIAC analysts have used other models such as Winfire, Suppressor, and TMAP models in their analysis. The SURVIAC analysts that conduct the studies leverage this experience to provide support to users and input for model maintenance and development.

Model Submission

The process for entering a new model into SURVIAC and the standards to which candidate models will be assessed is well defined. These procedures apply to all models that are candidates for SURVIAC entry, and are intended (1) to define the standard approval process to be followed; (2) to provide guidance to model proponents wishing to enter a model into SURVIAC; and (3) to ensure that model standards are achieved and maintained for the SURVIAC models.

Candidate models for SURVIAC are to be assessed relative to nine criteria in the three basic areas of capability, accuracy, and usability. In each of these criteria, a minimum standard has been established to qualify for entry into SURVIAC for each of the two model categories. These standards should be used by model developers as a guide for their efforts if their ultimate objective is SURVIAC entry. Prospective model users can also expect that any model obtained from SURVIAC meets these standards.

Conclusion

Survivability of weapons systems is key in today's defense environment. New lethal threats and asymmetric threat innovations have made protection against, and reduction of, weapon system losses critical to maintaining our defensive forces. At the same time, concern and sensitivity to any of our own losses or casualties have never been higher. The survivability/vulnerability community must apply lessons learned from combat and tests to improve future system design, performance capability, and survivability against anticipated lethal and non-lethal threats. The challenge for the survivability professional is to glean insights from combat and test data, find leading-edge technology solutions, and apply approved state-of-the-art methodologies. Helping to meet that challenge is why the DoD created SURVIAC. ■

A SECAD Update

by Charles Frankenberger

The Survivable Engine Control Algorithm Development (SECAD) project has reached a significant milestone. As part of the JASP Turboshaft SECAD project, General Electric has integrated SECAD algorithms with the T700-701E control software and loaded the algorithms into a full authority digital engine control (FADEC), bringing this technology one giant step closer to transition.



General Electric T700-701



T700-701E FADEC

After five years of development with the F414-GE-400, two years of National Aeronautics and Space Administration-funded development using Large High Bypass Commercial Engines (CF6-80C2L1F), and a year of work with small turboshaft engines (T700-701E), SECAD algorithms now reside in a FADEC.

The goal of the SECAD project has been to provide the pilot with early detection of engine damage, and to provide residual power for as long as possible. Over the years, the SECAD methodology has proven to be very successful in providing real-time engine damage detection, and a capability to restore a part of the performance loss to a damaged engine. The methodology has been successful using existing engine sensors, the number of which varies widely across engine types. This presented the biggest challenge to the Turboshaft SECAD team.

Under the Turboshaft SECAD program, the SECAD methodology was applied to a T700-701E small turboshaft engine. The traditional damage scenarios were applied, including compressor damage (Figure 1), combustor damage, and turbine damage. Turbine damage was separated into gas generator turbine and power turbine categories. The SECAD damage detection algorithm uses engine sensor data that passes through a predefined engine damage estimator to determine if engine damage has occurred and, if so, the type of damage. Identification of the damage type is necessary so the algorithms can correctly apply the appropriate damage mitigation scheme. Early analysis in the Turboshaft SECAD project indicated that due to the limited number of engine sensors, damage classification would need to be reduced. It became difficult to resolve differences between compressor damage and gas generator turbine damage. Mitigation techniques were investigated for each of these damage cases, and due to the limited number of control variables, the mitigation technique was

similar for these damage types. These damage categories were merged in the final damage detection algorithm.

Through the use of GE's T700 performance models, the damage detection algorithms were tested. Damage levels were inserted in small, medium, and large levels to determine the algorithms performance. A damage indicator is used to identify component damage. Values above a predefined threshold will indicate damage of various types. Figure 2 shows a dot plot of the damage indicator for the various cases: no damage, gas generator damage, combustor damage, and power turbine damage. The blue bar in each graph represents the damage case under analysis. A damage indicator value is produced for each damage type. The strongest indication above threshold values flags damage of that type. Figure 2 represents thousands of computer runs used to understand the



Figure 1 Compressor Damage

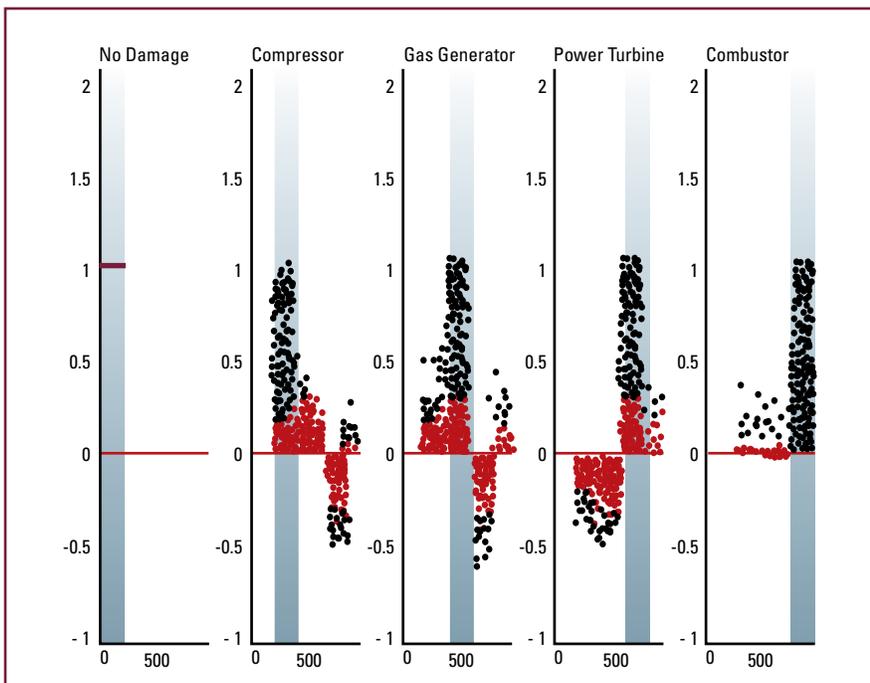


Figure 2 Damage Detection Analysis

damage condition slightly greater than 91% of the time, and provided an overall damage indication 96% of the time. This means that 96% of the time, an indication would be sent to the pilot when the engine is damaged. Five percent of those indications were attributed to the wrong damage condition.

To further evaluate the damage detection algorithms, data was provided from live fire testing conducted on a T700-401C. Although there were significant engine cycle differences between these two versions of the T700, there was sufficient fidelity in the algorithms to detect the changes in engine performance that would lead to successful engine damage detection.

The SECAD algorithms have been integrated with the T700-701E control software—a FIRST for SECAD—in preparation for bench testing at GE’s Lynn facility. Dry rig testing is expected to begin late March 2009 using a real-time engine simulator with the damage models injected through out the defined flight profile. Testing will help validate the SECAD logic and provide further insight to mitigation schemes possible with integrated multi-engine systems.

Test results will be presented to the T700 Product Directors Office to identify opportunities for transition. ■

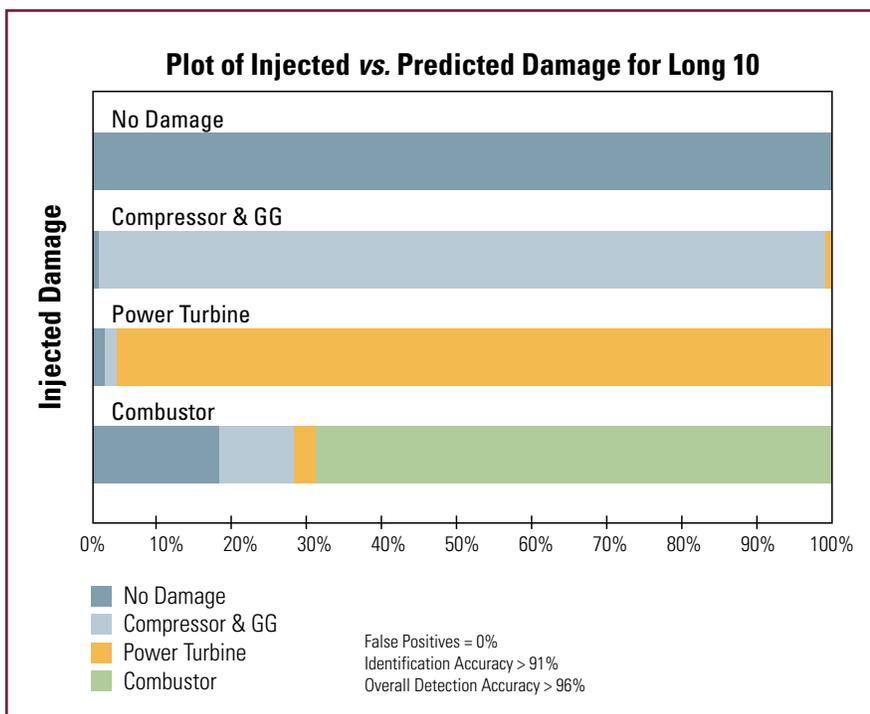


Figure 3 Damage Detection Performance

algorithm performance and optimize threshold values. Threshold values are key to producing detection algorithms that will correctly identify engine damage and not indicate damage on a non-damaged engine, termed a false positive. The data provided in Figure 2 shows the justification for combining compressor and gas generator turbine damage types due to limited engine sensor suite. For the compressor

damage case, there are many high-level damage indicator values in the gas generator column, and likewise for the gas generator data, there are many high level compressor values.

Damage detection algorithm performance is provided in Figure 3. The solid blue bar indicates that the goal of no false positives was achieved. For damage indication, the algorithms indicated the appropriate



CDR Kadowaki, JCAT OIC in Afghanistan, is currently busy developing procedures to function more efficiently in a coalition environment where the International Security Assistance Force is in command. With two primary airfields and a large number of Forward Operating Bases and Combat Outposts, communication has become more vital than ever to JCAT operations. Because aviation assets are scattered all over theater, the primary means for acquiring minor aircraft battle damage photos and information is through Voice over Secure Internet Protocol Router (SIPR) and SIPR email, and the connectivity can be very limited at times.

New Marine Corps squadrons are either receiving JCAT briefings in Al Asad prior to arriving in the OEF area of responsibility (AOR), or are receiving JCAT training soon after settling into the area. This will facilitate rapid data collection. Many personnel are already familiar with JCAT from previous deployments in Iraq and need little explanation regarding the importance of the data. Task Force aviation wings relocated within theater and the arrival of the 82nd CAB have significantly increased the number of US Army aviation assets in Kandahar. Like the arriving Marines, many Army personnel are familiar with JCAT and still have their "JCAT Squares," some personalized for their Brigade or Division.

CDR Kadowaki also spends time with Coalition S-2s (Intelligence) to assist with the validation of SAFIRE reports. JCAT has become a technical resource on threat weapon engagements for the Coalition intelligence community and a conduit to the Missile and Space Intelligence Center (MSIC) and the US Army's National Ground Intelligence

Center (NGIC). CDR Kadowaki has coordinated with NGIC and the FDO in Kandahar to put NGIC anti-aircraft artillery (AAA) videos on the North Atlantic Treaty Organization Mission Secret network to help with the accuracy and consistency of SAFIRE reporting.

Much is changing here in OEF, and many are learning that the OIF mindset does not work well in this theater. As many people here say to those just arriving: This is not Iraq.

2009 Threat Weapons and Effects Training Seminar

The Army component of JCAT is the Army Shoot Down Assessment Team, more commonly known as ASDAT. They were this year's host for the very successful Threat Weapons and Effects Seminar at Hurlburt Field/Eglin Air Force Base, FL, 21-23 April 2009. The seminar's title was ASIA RISING and focused on the United States Pacific Command (PACOM). The seminar is held annually and is a collaborative effort between the JCAT (sponsored by the Joint Aircraft Survivability Program Office [JASPO], Aeronautical Systems Center, Naval Air Systems Command, and the Army Research Laboratory), Defense Intelligence Agency (with support from the Missile and Space Intelligence Center), and other agencies. This year was another great success with 212 registered conference attendees for an auditorium that seats only 200 personnel.

The goal of the seminar is to provide not only intellectual stimulus but also practical, hands-on training on the lethality of threat air defense systems and the damage they can inflict on friendly aircraft. Information is drawn from threat exploitation, live fire testing, and combat experience to provide a complete picture on threat lethality. A hands-on experience is provided through the use of threat munitions/missiles, test articles, damaged aircraft hardware, and videos from various test activities and actual combat. There were some outstanding live fire demonstrations that included RPG shots and Stinger missiles. An old UH-1H carcass was used as the RPG target and was also hit by multiple small arms (5.56 mm, 7.62 mm and .50 cal). Target hit points were drive train, pilot armor, and the rotor system. For the Man-

Portable Air Defense Systems (MANPADS) (Stinger) shot, a wing from an actual MIG-29 was the target.

Experienced instructors provided current, relevant information briefs on threat system upgrades, proliferation, and lethality for countries of interest within the PACOM AOR. The briefs were very informative with detailed analysis supported by the MISC and NGIC/DIA. Other briefs included OEF and OIF incident briefings, asymmetric threats to aviation platforms, Navy and Marine Corp countermeasure efforts, Army countermeasure efforts, and threat small arms/heavy machine gun, AAA, MANPADS, and radio frequency missile systems.

The seminar is held every April and is classified secret/NOFORN. It is open to operations, intelligence, tactics, logistics, and engineering and analysis personnel. Be sure to watch for announcements beginning early next year for the 2010 seminar and an outstanding opportunity for some in-depth threat weapons training and professional development.

New ASDAT Team Lead

It is time to say goodbye to CW5 Len Eichhorn, USA, as the ASDAT team lead. He has done an outstanding job leading the fearless Army aviators in the JCAT/ASDAT mission. The new OIC for the Army component is CW5 Bobby Sebren, USA. Mr. Sebren joins the team from the Aviation Center's Directorate of Simulation, where he managed the Database Generation Facility for the Tactical Terrain Visualization System, Army Aviation's mission planning software application. ■

Excellence in Survivability— Patrick J. O’Connell

by Dale Atkinson

The JASP is pleased to recognize Mr. Patrick J. O’Connell for Excellence in Survivability. Pat is the Air Force deputy test director for the DoD Joint Live Fire Program (JLF) and the Aerospace Vehicle Survivability Facility (AVSF) Vulnerability Operations team lead for the Aerospace Survivability and Safety Flight at Wright-Patterson Air Force Base (AFB), Dayton, OH. He is also the Air Force Live Fire Test & Evaluation (LFT&E) lead engineer on the Joint Strike Fighter Program and other LFT&E programs. In 1984, Pat graduated from Parks College of Saint Louis University with a bachelor of science degree in aerospace engineering and later received a master of science degree in mechanical engineering from the University of Dayton in 1988.



From 1984 to 1989, Pat was the Air Force Battle Damage Repair (ABDR) technology project manager at Wright Labs as a lieutenant in the Air Force. In late 1989, he became the Air Force’s lead ABDR engineer in the ABDR Program Management Office at McClellan AFB, CA, and served in that role as an Air Force captain until 1995. In this role, he developed training plans and wartime deployment requirements that proved to be very effective in Desert Storm. He created and taught the one-week ABDR engineering course and authored a corresponding ABDR engineering handbook. After leaving the Air Force, Pat became a senior consultant at SURVIAC and provided support for the battle damage repair efforts on the B-1 Live Fire Test Program. He also authored a report entitled, “The Air Force’s ABDR Experience during Desert Storm,” which documented and cataloged each

aircraft battle damage incident that occurred during the first war with Iraq. In 1996, he joined NCI Information Systems where he worked until 2000. Among other efforts, he was the lead engineer for the Aircraft Battle Damage Assessment and Repair Technology Program, which was an Air Force advanced development program to create a portable aid for assessing and repairing battle damaged aircraft.

In late 2000, Pat joined the Aerospace Survivability and Safety Flight, where he has been responsible for numerous survivability technology and test efforts. He conceived, advocated, and acquired funding for a new thrust area to evaluate the vulnerability of unmanned aerial vehicles (UAV). This comprehensive program consisted of five JASP- and JLF-funded programs he coordinated across the three services. He and his tri-service counterparts developed a Predator A vulnerability model; evaluated the Predator B design for vulnerability reduction; accomplished vulnerability testing of UAV wings, components, and fuselage structures; and developed a UAV design guide to help reduce the vulnerability of future UAVs, which is paying off in new designs.

Working with his counterparts in the Army and Navy, Pat also developed and acquired funding for a comprehensive, four-year joint program to determine the vulnerability of attack helicopters to rocket propelled grenades (RPG). The results of the testing were fed back directly to the warfighter, which

allowed them to implement revised tactics to counter RPGs. This has directly benefited people in the field who are concerned about this very serious threat.

Pat was then appointed as the program engineer for the C-130 Avionics Modernization Program (AMP) LFT&E Program to lead the C-130 AMP LFT&E program. The primary effort involves the development of a C-130 system level vulnerability analysis to compare the vulnerability of the aircraft before and after the AMP modifications.

Pat is also the Air Force’s test lead for the Joint Strike Fighter LFT&E Program. The joint Air Force/Navy LFT&E program consists of over 20 major test projects over an eight-year period. Pat just finished accomplishing three test programs at the AVSF, including Electrostatic Hydraulic Actuator vulnerability testing, ballistic testing of materials for flash characterization, and determining the potential for fuel fires due to electrical arcing.

Pat is a member of the National Defense Industrial Association (NDIA) and has given presentations on many of these programs at the NDIA Combat Survivability Symposium held at the Naval Postgraduate School in Monterey, CA, over the years. Pat is also a prolific writer and has written numerous articles for the Aircraft Survivability

Continued on page 31

COVART 6: Modularization of Vulnerability Models

by Tim Staley

Since computer-aided vulnerability and lethality (V/L) analysis began in the 1960s, several tools have been developed to support the number of aircraft analyses performed across the DoD. Two of the most widely used of these tools are the Computation of Vulnerable Area Tool (COVART) and the Advanced Joint Effectiveness Model (AJEM)/Modular UNIX-based Vulnerability Estimation Suite (MUVES). COVART is the primary tool for Air Force and Navy fixed- and rotary-wing aircraft vulnerability analyses, with AJEM/MUVES supporting lethality and weapons effectiveness analysis and Army vulnerability analysis.

These tools play an increasingly important role in decision making for multi-billion-dollar acquisition and development programs by supporting combat effectiveness, vulnerability, lethality, and live fire test and evaluation (LFT&E), as well as aiding the warfighter through support of the

combatant commanders and the Joint Combat Assessment Team (JCAT). In addition to the prominent roles played by these tools, the complexity of the systems and damage mechanisms modeled has increased, likewise increasing the complexity of the models themselves.

This complexity has served to reinforce the necessity of leveraging technical expertise as well as funding in the development and improvement of methodologies. Consistency in methodology is also critical, with various tools being used to support weapon systems in the various phases of

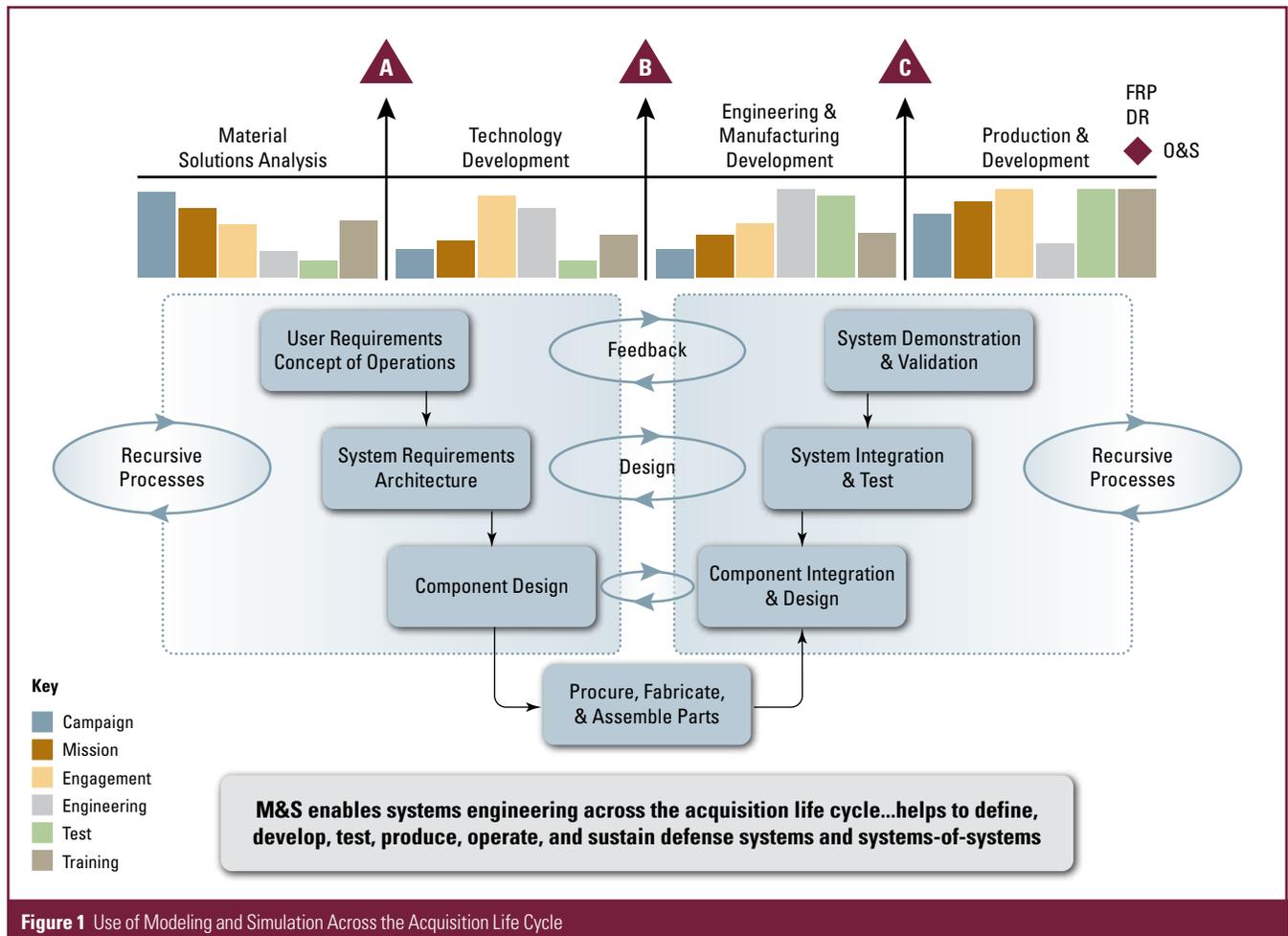


Figure 1 Use of Modeling and Simulation Across the Acquisition Life Cycle

their life cycles and the need to model both Red and Blue forces with equivalent levels of fidelity. But actually achieving this leveraging and consistency is not always easy.

One method to address this issue is the consolidation of models, with all investment going to the development of methodologies to support a single model, and thus inherently ensuring consistency. However, it has proven difficult to satisfy the needs of user groups like the V/L community, which have similar analysis domains but whose requirements are not homogeneous. Additionally, achieving the necessary level of user buy-in is also problematic, with issues such as how the model fits into the user's workflow, and the learning curve for complex, expert-driven models.

A large amount of data from disparate sources is required to populate the databases that drive these models, and a whole infrastructure of supporting tools and processes have been developed by the government and contractor organizations performing these analyses. No user expects a tool to be stagnant with no improvements in capabilities, but the addition and evolution of capabilities and methodologies must always be weighed against the impact on the analyst as well as the end consumer of the data generated by the models.

An alternative to a "one model for all" method is the sharing and reuse of discrete methodologies that can be incorporated into different tools to support different users and requirements. This allows leveraging development work and maintains consistency, while allowing for implementation in various tools that serve different customers or interests. There are two primary approaches to the implementation of this method, one of which can cause issues with the long-term supportability and reuse of the discrete methodologies.

One example of this approach is the use of a common set of JTTCG/ME penetration equations (*i.e.*, the Penetration Equation Handbook). While successful in many respects, it also serves to illustrate the shortcomings of a common methodology separately coded in multiple tools. The JTTCG/ME equations were hard-coded into both COVART and AJEM/MUVES, but as

the models matured and deficiencies were addressed, these changes did not always migrate from the version in one tool to another. Even when the same changes were made, they had to be implemented and tested independently.

Similarly, when the Fast Air Target Penetration (FATEPEN) equations for fragments were added to COVART 3.3 and MUVES in the mid-1990s, the FATEPEN source code was modified extensively in order for it to be integrated. As a result, there were multiple instantiations of the code that had to be maintained and configuration managed. This hard-coded approach of FATEPEN in COVART made it difficult (to the point that it never happened) to take advantage of the improvements made to FATEPEN in the years after its initial integration.

There was consensus within the community that this sharing and reuse of data was essential, but must be done in a manner that is more sustainable. This consensus was typified by an after-hours meeting held in conjunction with the summer Joint Model Users Meeting June 2004. The purpose of the meeting was to discuss the "future of vulnerability/lethality methodology." Based upon the results of that meeting and subsequent events, it could be said that the future was development of common, shared modules. Though there was significant debate as to what a "module" actually was, eventually there was agreement that a module should—

- Be limited in scope
- Have a defined interface
- Be able to be shared across multiple models
- Be able to be validated and verified (V&V) independent of any model in which it is integrated

While there was already ongoing work in this area—such as MUVES integration of FATEPEN 3 in a manner that did not require modification of the FATEPEN source—actual examples of sharing modules between tools was more the exception, rather than the rule.

COVART Modularization

Around this same time period, COVART was being modified extensively as part of the Vulnerability/Survivability Integrated Module Set (VSIMS) project in order to allow integration of advanced analysis capabilities. One of the core concepts of the VSIMS project was that each

particular function (such as penetration or air blast) should be a separate module. For COVART this entailed splitting the code into three modules based upon COVART's primary functions—

- Penetration
- Damage (Pk)
- Fault Tree

Though the exact method of modularization attempted in VSIMS (with each module as a separate executable) was abandoned, the overall goals and underlying concept of functional modules were carried forward with the development of COVART5.

With COVART5, instead of breaking COVART into three separate executables, each of COVART's functions were put into libraries (*.dll for Windows, *.so for UNIX/Linux) which were called by COVART. This approach allowed the main part of COVART to still handle input and output, while having separate modules handle the underlying methodology. Though the entire structure of COVART changed, the changes were not apparent to the user because the inputs and outputs remained unchanged from previous versions of the code, allowing input databases developed for COVART4 to be used with COVART5. Structurally, in addition to COVART main, COVART5 consisted of five libraries, three of which handled penetration calculations—

- FATEPEN 2 penetration equations
- JTTCG/ME Fragment penetration equations
- JTTCG/ME Projectile penetration equations (ProjPen)
- Damage
- Fault Tree

Though there were no new analysis capabilities or enhancements to the methodologies within the modules in COVART5, this laid the foundation for what was to come.

Up through COVART5, ray tracing had been performed separately from COVART, typically using either Fast Shotline Generator (FASTGEN) or Ballistic Research Laboratory Computer-Aided Design (BRL-CAD). Though this had the advantage of isolating COVART from changes to the ray tracer codes and allowed for processing multiple target formats as long as they could provide the properly formatted input, it had the distinct disadvantage of separating penetration and computation of damage from the

target geometry. Because the target geometry, shotline processing, and penetration computations are so intertwined, it only makes sense that these functions are brought together. In fact, this was already done with AJEM/MUVES and the BRL-CAD ray tracing library.

Ray tracing was brought into COVART proper through the use of libraries, like the ones developed under COVART5. In order to do this, significant changes were necessary to both FASTGEN and COVART. FASTGEN was broken into three primary pieces: (1) ray generation, (2) target handling, and (3) ray tracing.

The ray generation portion determines the location of the ray for parallel and diverging rays, including the Advanced Diverging Ray Mode (ADRAM). This part of FASTGEN was integrated into COVART proper, allowing the generation of rays and use of the ADRAM methodology for any ray tracer integrated into COVART.

Target handling and ray tracing were put into a single FASTGEN ray tracing library, very similar to BRL-CAD's librt library. In addition to the FASTGEN ray tracing library, COVART6 included librt for ray tracing of BRL-CAD targets. This allowed COVART to continue to be able to handle the two dominant target model formats without the need for time-consuming and error-prone target conversion from one format to another, and for the first time, allowed ADRAM threat databases to be used with BRL-CAD targets.

In addition to the integration of ray tracing functionality, some of the existing libraries for penetration were updated in COVART6. FATEPEN development had been proceeding more or less continuously in the nearly 15 years since FATEPEN 2 was implemented into COVART. As previously mentioned, part of this development included the creation of a library that could be called without modification. This, along with the developments as part of COVART5, made implementation of over a decade's worth of penetration equation developments into COVART a relatively simple task.

Though development of the JTCG/ME projectile penetration equations was not as active as FATEPEN, the need to address some long-standing issues with

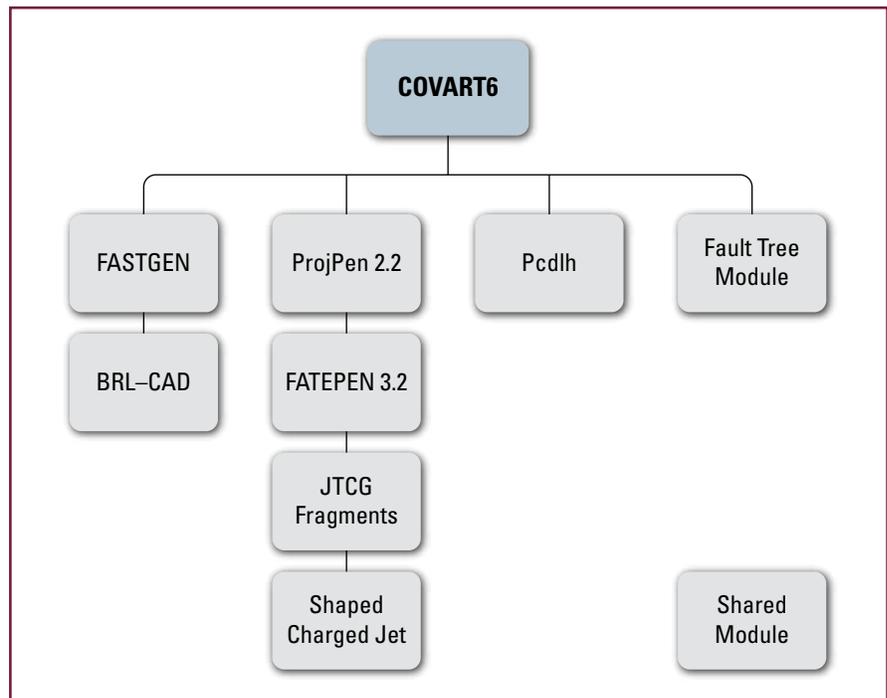


Figure 2 COVART6 Structure

these equations was recognized. With JASP and JTCG/ME funding, improvements were made to the projectile penetration equations as coded in ProjPen. Additionally, there was a JASP-funded effort to improve the incendiary functioning predictions to better correlate with test data. Because these modifications were made to the ProjPen module, updating COVART to use the new equations required only minor modifications. The updated ProjPen library will also be integrated into AJEM/MUVES.

As important as the improvements in methodologies and capabilities, with the release of COVART6, there is a degree of commonality across the V/L tools that did not exist before. Out of the eight modules in COVART6 shown below, three will be shared with at least one other V/L tool (shown in bold).

- ▶ Ray Tracing
 - FASTGEN
 - **BRL-CAD**
- ▶ Penetration
 - JTCG/ME Fragments
 - **FATEPEN 3.2.18**
 - **ProjPen 2.2**
 - Fireman Pugh Shaped Charge Jet (SCJ) Penetration
- ▶ Damage
- ▶ Fault Tree

Of the two penetration libraries in COVART6 that are not shared, the JTCG/ME fragment penetration library

is being retained for legacy purposes and will eventually be phased out. The Fireman-Pugh SCJ library for processing SCJ threats such as rocket propelled grenades (RPG) is based upon the methodology implemented in AJEM/MUVES, but is not actually a shared library at this point.

Just as with COVART5, a significant effort was made to limit the impact of code changes on the user and maintain backwards capability. Of the five main inputs into COVART (threat file, JTTYPE, header, MV and BASIC file) only the BASIC file is not backwards compatible using COVART6's integrated mode, due primarily to the integration of ray tracing, though changes were also made to make the analysis options more user friendly.

The development paths of COVART and AJEM/MUVES have demonstrated that sharing modules across multiple V/L tools is feasible and achieves the goals of leveraged development. The JASP modeling and simulation community has benefited from years of JTCG/ME and Navy funding through the integration of FATEPEN 3 into COVART6. The JTCG/ME will benefit from JASP funding of ProjPen through its integration into AJEM/MUVES. Perhaps just as important, COVART6 has been able to add additional capabilities and improved methodologies while minimizing the impact on the user.

That is not to say that the move toward common modules is not without obstacles. Configuration control not only takes on an even more important role, but also becomes increasingly difficult as the supported community becomes larger and more diverse. Care must be taken to address user needs while not unduly making changes that can have dramatic, and perhaps unforeseen, ripples across the tools utilizing a particular module. Along with this is the myth of “plug n’ play” modules. When a module is developed with a single application or tool in mind, a particular type of interface is developed. That interface may need to be changed to accommodate incorporation into other tools, and every time the interface changes, every tool utilizing that module must also

change. Even when an interface has not changed, if the underlying methodology causes differences in results, those differences must be fully explained and accepted by the community, and baselines used for testing of the higher level tools like COVART must be reset to account for this change.

Much has been done in the last five years to increase the amount of reuse and sharing of methodologies across the V/L community. The use of the FATEPEN 3 and librt libraries within COVART and the development of the ProjPen library have improved consistency and leveraged investment while allowing users to continue to use tools with which they are experienced and comfortable. Though progress has been made, there is still more that can be done. The community

should continue to work toward a collection of tools that fits the need of the user while using a more common underlying set of methodologies. ■

**Excellence in Survivability—
Patrick. J. O’Connell**
Continued from page 27

Journal, including excellent articles on the UAV and RPG programs to help get the word out.

Pat lives in Dayton, OH, and is married to Vivian with four children ages four to 18. He is active with the Boy Scouts of America; his oldest son just received his Eagle rank. Pat is an avid runner and has completed five marathons and

numerous half-marathons. He is also a pilot-in-training and a member of the FAI Flying Club in New Carlisle.

It is with great pleasure that the JASP honors Mr. Patrick O’Connell for his Excellence in Survivability contributions to the JASP, the survivability discipline, and the warfighter. ■

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Calendar of Events

NOV

NDIA Aircraft Survivability Symposium

3–6 November 2009
NPS Monterey, CA

AAAA ASE Symposium

9–11 November 2009
Nashville, TN

Soldier Equipment & Technology Expo

17–18 November 2009
Fort Bragg, NC

Helicon

17–19 November 2009
Huntsville, AL

JASP Winter JMUM

17–19 November 2009
Nellis AFB, NV

DEC

APR-39 Joint User's Conference

1–2 December 2009
Rolling Meadows, IL

GTRI Infrared Countermeasures Class

1–4 December 2009
Atlanta, GA

AAAA Unmanned Aircraft Symposium

9–11 December 2009
Arlington, VA

JAN

AUSA Aviation Symposium & Exhibition

5–7 January 2010
Arlington, VA

Mugu Crows EW Symposium 2010

26–27 January 2010
Pt. Mugu, CA

FEB

US Air Force T&E Days 2010

2–5 February 2010
Nashville, TN

Joseph P. Cribbins Aviation Product Symposium

10–11 February 2010
Huntsville, AL

AFA 2010 Air Warfare Symposium

18–19 February 2010
Orlando, FL

MAR

4th Annual Naval Expeditionary Forces Symposium and Expo 2010 (NavExFor)

1–3 March 2010
Virginia Beach, VA

NDIA 26th Annual National Test & Evaluation Conference

1–5 March 2010
San Diego, CA

Dixie Crow Symposium 35

21–25 March 2010
Warner Robins, GA

APR

SpecOps Warfighter EAST 2010

12–15 April 2010
Fayetteville, NC

51st AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference

12–15 April 2010
Nashville, TN

AAAA Annual Convention

14–18 April 2010
Fort Worth, TX

JCAT Threat Weapons & Effects Seminar

20–22 April 2010
Fort Walton Beach, FL

MAY

JASP Aircraft Combat Survivability Short Course

4–7 May 2010
NPS, Monterey, CA

SpecOps West 2010

10–12 May 2010
Ft. Lewis, WA

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