Reducing Aircraft Combat Casualties

by Dr. Joel Williamsen

Historically, aircraft combat survivability design metrics and evaluations have focused on what happens to the aircraft, with only limited consideration given to casualties generated during combat-induced aircraft damage or loss. Recognizing this, on 6 May the National Defense Industrial Association's (NDIA) Combat Survivability Division held its annual Aircraft Survivability Workshop at IDA on "Reducing Aircraft Combat Casualties," developing the topic in concert with the Director of Operational Testing and Evaluation (DOT&E) as an outgrowth from last year's NDIA workshop on aircraft vulnerability reduction, as well as from studies of recent air combat casualty data from Operations Enduring Freedom and Iraqi Freedom.

The objectives of this workshop were to identify critical needs (technologies, policies, analysis methods, and/or procedures) for understanding and reducing aircrew/passenger casualties during combat, and to explore advantages of better integrating combat survivability and safety communities to achieve this. Eighty-two participants from 28 government and industry organizations—including warfighters, aircraft designers and fabricators, program managers, and survivability and safety specialists—came together to study combat data, share information, and brainstorm ideas for ongoing or upcoming programs that could benefit aircraft crew and passenger combat survivability. The findings and recommendations from the workshop will be presented this summer to Mr. John Young, Under Secretary of Defense for Acquisition, Technology and Logistics, with copies to other Pentagon leaders. Copies of the report may be obtained from Mereidieth Geary at NDIA.

Summary of Findings

Combat and Mishap Casualty Data

Recent combat data indicate that—

- Most of the occupant injuries and fatalities appear to have occurred as a subsequent, indirect result of the crash—not as a result of direct threat effects wounding the occupants.
- A high percentage of helicopter shoot-down events are survivable. Even helicopter shoot-downs by man-portable air-defense systems (MANPADS) missiles are sometimes survivable. Aircraft having design features such as fire protection, energy absorbing seats, and the ability to maintain sufficient internal space for the crew/passengers after a crash from being injured by collapsing massive overhead components (*e.g.,* rotors and gearboxes) can make a significant difference in crash survival rates.
- Passengers make up a majority of aircraft occupant losses in Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF).
- Combat-related shoot-down assessments do not contain the same type of information normally developed during aircraft mishap/accident investigations. Data regarding the nature of the casualties (type of injury, condition of the aircraft at the time of crash, *etc.*) and those who are uninjured (numbers, locations, protective equipment, *etc.*) are not currently being gathered in theater, and are not available for dissemination to designers.

Injury data related to mishaps can be used to inform designers, but are not always readily available for use, or in a form that could guide the development of requirements. A study summarizing injuries related to DoD helicopter mishaps from 1985 to 2005 has recently been presented by Col Peter Mapes from Deputy Under Secretary of Defense Readiness/ Readiness Programming and Assessment [DUSD(R)/RP&A], but it does not include combat-related crash casualty data. It is possible that combat damage-induced crashes have differing and more debilitating on-board conditions prior to the crash than in non-combat related mishaps. These conditions might include an increased incident of fire, explosions/reactions of combustible materials and toxic fumes onboard the aircraft, more severe loss of control and power, and the presence of structural damage that reduces the aircraft's inherent crashworthiness. By closely analyzing the data retrieved from the combat-related crashes and establishing design requirements based on these data, some damage attenuating technologies such as fire extinguishers and more damage tolerant (soft) landing design features might more readily "buy their way" onto an aircraft.

Though all Services are committed to improving aircraft occupant survivability through (combat-related) vulnerability reduction and (peacetime) crash safety/ egress technologies, communication between these two related technical communities varies greatly from Service to Service. The Army rotary wing community has achieved the closest communication between the crash safety and combat-related vulnerability reduction personnel, since these organizations are co-located in the same organization at the branch level. In general, more communication between the safety and vulnerability reduction communities is needed, as is coordination of crashworthiness efforts across Services and civilian aviation agencies.

Needed: Design Focus on Casualties

Rotary wing aircraft have significantly increased their gross weight since the original airframes were tested for crashworthiness, and even then, some of the aircraft did not pass the existing standards. New standards are being developed that will include the effects of varying the type of terrain at impact (*i.e.*, grass, sand, and water); however, these standards are being developed without the benefit of combat-related crash and casualty data, as it is not available.

Aircraft survivability evaluations and vulnerability testing have historically focused on the loss of the aircraft or its mission, and not on occupant casualties. Although many of the steps taken to save the aircraft can also save the occupants, attention also should be paid to saving the occupants even when the aircraft is lost. Likewise, design features that are optimized to reduce aircraft losses (within constraints on cost, weight, and effectiveness) might not be optimal for reducing occupant casualties. For example, H-60 accident investigations showed that loss of power was the most frequent mechanical cause of Class A incidents (in which the resulting total cost of property damage is $1,000,000 or more; an aircraft is destroyed, missing, or abandoned; or an injury and/or occupational illness results in a fatality or permanent total disability), but that loss of control caused the greatest total number of casualties, because the crashes were worse.

New design improvements needed for reducing casualties will require the extension of current analysis methods or models and test procedures to explicitly address occupant casualties. In response to this need, in November 2007 DOT&E issued a directive to expand survivability assessments to include evaluation of casualties due to both direct and indirect damage effects (indirect effects including instances where the occupant is not directly injured by the threat but suffers subsequent injuries from bail out/ejections, secondary damage effects, forced landings, or crash impacts).

Consider Direct and Indirect Effects on Passengers and Crew

To fully address casualties, both analysis and test damage assessments would have to be expanded in scope to consider both direct and indirect effects. Current aircraft vulnerability analysis models are capable of estimating crew casualties from direct ballistic impacts, but casualties are not typically reported as outputs. The models do not address casualties from indirect effects such as crashes. Moreover, post-test damage assessments do not report any inferences regarding personnel casualties. Enhancements to vulnerability models will be required to address occupant casualties from indirect effects, accounting for safe escape from a damaged aircraft in flight, crash survival, and safe escape from a downed aircraft. Post-test damage assessments would need to include inferences as to what might have happened to the occupants, in order to make comparisons with model predicted outcomes to validate the models or analysis methods.

The new Joint Cargo Aircraft program will include a crew and passenger casualty (CAP-C) evaluation that considers a mix of inputs from probabilistic vulnerability models, threat vignettes, landing scenarios, and egress exercises to produce an evaluation of crew casualties from the point of threat encounter all the way to a safe landing. Such a mixed quantitative/qualitative evaluation strategy appears to be a viable alternative until more sophisticated models are developed.

Focus on Casualties in Requirements Development and Evaluation

As indicated earlier, DOT&E has already signaled an increased emphasis on casualty evaluation and reduction in a letter to the Joint Aircraft Survivability Program (JASP) stating that "assessment of aircraft crew and passenger casualties to the point of safe return or egress is an important element of the Congressionally mandated Live Fire Test and Evaluation, including evaluation of personnel casualties due to combat-related in-flight escape and crash events. This necessitates acquisition decision makers, system designers and requirements writers to make quantifiable casualty predictions to evaluate applicable technologies and procedures that reduce crew and passenger casualty risk after initial aircraft hits." The resulting methodology could be particularly useful in establishing and evaluating related Force Protection requirements and Key Performance Parameters (KPPs), as well as in design trade studies.

Until now, JASP survivability technology development programs have focused on susceptibility and vulnerability of the aircraft, and have not considered egress, ditching, and crashworthiness as elements of aircraft survivability. Consequently, an increase in resources will likely be required in order to support this expanded scope and reduce air combat casualties.

Recommendations

The general recommendation from the workshop is for DoD to support the aircraft survivability and safety communities in gathering, sharing, and distributing data on combat-related aircraft crew and passenger casualties; extend current aircraft survivability evaluations to include explicit estimates of occupant combat casualties; require that post-test damage assessments take into account any inferences that can be drawn regarding personnel casualties; and encourage the use of casualty-based metrics as a basis for the development of aircraft Force Protection requirements.

Five specific recommendations emerged from the workshop. DoD should—

1. Encourage design engineers and evaluators to consider crashworthiness, egress, and other casualty reducing features during acquisition of new systems, and improve occupant survivability from combat-related crashes.
2. Develop a process to acquire and integrate combat-related casualty data with mishap casualty data, and enable release of these data to the aircraft design communities to improve crew and passenger survivability. Questions to be answered include—
   - Were casualties induced by direct fire, combustibles' reactions or crashes?
   - What system failures caused each crash?
   - Do combat threat-induced crashes produce more post-crash fatalities/injuries than non-combat causes for crashes?
   - What safety features (seats, egress, fire suppression) need to be improved, especially considering threat effects?
   - What aircraft features contributed to the casualties (loss of cabin space, pilot impact with control stick, inability of seats to attenuate vertical Gs) and what aircraft features prevented casualties (crashworthy seats, crashworthy landing gear)?
3. Develop evaluation metrics, techniques and models to determine crew and passenger casualty levels for aircraft; pursue the establishment of casualty-

related aircraft Force Protection requirements using these metrics; and evaluate legacy aircraft performance using these metrics to reduce casualties. Specific actions should include—

- Include crew casualty evaluation in the system Test and Evaluation Master Plan (TEMP), incorporating safe landing and egress considerations.
- In Live Fire test plans, include explicit requirements and test issues for assessment of crew and passenger survivability (including effects on safe landing or egress) as part of the post-test damage assessment.
- Once a verifiable casualty-related methodology is developed, pursue the development of Force Protection KPPs that relate directly to crew and passenger casualties
- Develop computer models that determine fixed and rotary wing crash conditions given damage, considering that there may different approaches between these aircraft.
- Models should—
  - Support the requirements definition process
  - Support the design and trade study processes
  - Maintain relevance to the acquisition decision process.

4. Establish routine opportunities for exchange and/or joint development of technology, design tools and evaluation methodologies within the aircraft combat survivability and the aircraft non-combat operational safety communities. Areas of emphasis should include—
   - Simulated combat damage and secondary effects (smoke, impediments, *etc.*) in aircraft egress safety evaluations.
   - Coordination with other organizations that might have an interest in this area, such as FAA, NASA, and the auto industry.
     - Survey available crash test facilities, manikins, technologies, *etc.*
     - Survey injury categories from peacetime mishaps and DoD ground vehicles in formulating casualty metrics.
5. Support the expanded role of the Joint Aircraft Survivability Program as the Tri-Service coordinator for above recommendations. ■