Advanced Crash Analysis Program (ACAP) to Improve Transportation Safety and Security – 2010 Status Report

Background
The Advanced Crash Analysis Program (ACAP) was initiated by the FHWA Office of Safety R&D of the Turner Fairbank Highway Research Center in December 2008. ACAP will continue FHWA efforts to promote the application of finite element models and crash simulations that have successfully been used to 1) design and analyze various types of roadside hardware (e.g., guardrails, sign supports, and concrete barriers); 2) assess vehicle-to-vehicle and vehicle-to-barrier impact compatibility; 3) investigate the causes of various types of crashes, including rollovers; 4) formulate improved guidelines for the selection and deployment of roadside safety or security hardware; and 5) develop concepts for new roadside treatments. These efforts are expected to result in new treatment options that can be used by DOTs to mitigate current or emerging safety or security problems; confirm or expand the findings of other analyses and testing; and/or improve hardware application effectiveness. ACAP will continue to exploit the significant advances in computer and software capabilities to enhance transportation safety and security.

ACAP will also serve as the platform for FHWA to support a broader spectrum of safety and security research, pioneer the use of new technologies, improve tools and methods, develop new devices, consider the implications of changing conditions, and promote state-of-the-art transfer of findings to public agencies, researchers, and industry. The sharing of models, data, and results that characterized past efforts will continue to support safety and security research and development efforts worldwide.

Objectives
The objectives of ACAP are to expand detailed knowledge about crashes, promote the application of emerging methods, enhance understanding of crash dynamics, and improve potential effectiveness of designs, materials, or applications for safety and security elements. Under ACAP, FHWA will continue to collaborate with the National Highway Traffic Safety Administration (NHTSA), the Department of State (DOS), and other organizations to continue advanced crash analyses and research.

Achieving these objectives will primarily involve the following efforts:

• Conduct advanced crash research to assist researchers and engineers in resolving safety and security issues in transportation.
• Advance techniques and tools for crash analyses, including finite element modeling, simulation, and vehicle design and dynamics analysis tools and demonstrate their application.
• Maintain a national repository (i.e., knowledge base) of crash videos, films, and documentation.
• Conduct crash and impact testing to provide data for modeling, material characterization, calibration, and validation.
• Disseminate the findings of the research and the applications of the advanced technologies to reap their benefits and accelerate their deployment for addressing safety and security issues.
• Support multifaceted outreach and educational opportunities, using state-of-the-art tools, to serve practitioners, decision makers, and students.
• Conduct detailed and clinical analysis of crash data and correlate it to analytical results to expand understanding of crash events.
• Investigate occupant risks in crashes and the effectiveness of mitigation measures.
• Evaluate improved designs and treatments to enhance transportation safety and security.

A key aspect in achieving these objectives is expected to be the continued sharing the resources, findings, data, models, and technologies with others to expedite efforts to address complex safety and...
security problems. This may involve prospecting in related fields, forming new partnerships to adapt advanced analysis tools, and consideration of novel applications to deal with the complexities of safety and security issues and means to mitigate them.

**Scope**

A task order-based contract has been initiated to support the various activities under ACAP. The George Washington University was selected as the contractor for this program after a rigorous, full, and open competition. The contract provides for research and development efforts to support the missions of the FHWA, NHTSA, DOS, and potentially other government agencies. Task Orders under ACAP may involve considerations of all types of vehicles, different roadway and roadside features, varying impact conditions (e.g., speed and angle of crash), and a range of occupant types and positioning.

Under this program the Federal Outdoor Impact Lab (FOIL) and the Vehicle Modeling Lab will be operated and maintained to allow full-scale and component level testing to provide essential dynamic response data. Testing and engineering efforts in these facilities will be undertaken in accordance with standard AASHTO, DOS, and ASTM protocols as appropriate. The Vehicle Modeling Lab (VML) will continue efforts to advance technologies to support reverse engineering and the creation of vehicle & hardware finite element models for the simulation of a broad spectrum of crashes.

**Task Areas**

The ACAP contract was structured to support multi-year research efforts in various subject areas, including:

- Roadside analysis and design
- Impact and material testing
- Development and validation of FE models
- Documentation of research efforts and findings
- Outreach and training
- Infrastructure barrier analysis and testing
- Occupant risk analysis
- Detailed data mining and analysis
- Maintaining and updating the library
- Analyzing feasibility and impacts of new materials
- Providing technical support

Efforts under one or more of these areas will occur as Task Orders are issued by FHWA defining specific objects, approaches, timetables, and products. Table 1 lists the Task Orders that have been initiated since the beginning of the contract. The accomplishments associated with each are noted in italics.

**Future Research Challenges**

It is envisioned that ACAP will support efforts to address various future research challenges, including:

- tire-surface interaction and failure modeling,
- enhancing the knowledge about occupant risks in crashes,
- fracture models and their applications in crash simulation,
- development and validation of new FE models by reverse engineering,
- analytical studies of motorcycle safety,
- investigations of the effects of using lightweight materials on vehicle safety,
- linkage of vehicle & body models to understand the forces acting on occupants in crashes,
- application of analytic models to address the full gamut of rollover conditions,
- development of improved software tools and application protocols in simulation,
- analyses of vehicle dynamics in road departures,
- analyses of rollover crashes & potential remedies,
- investigation, through crash dummy and human body models, of the risks to vehicle occupants,
- development of new models or applications (e.g., material fracture or tire-to-surface models) to increase the predictive power of advanced tools,
- support of agencies in the investigation of catastrophic crashes,
- enhancement of the capabilities of safety professionals in the applications of advanced methods,
- maintaining and upgrading the repository of crash test data,
- analysis and testing of devices aimed at enhancing safety and infrastructure security,
- optimization of safety and security hardware designs,
- development of state-of-the-art training materials to enhance the capabilities of safety and security professionals,
- investigation of the safety implications of the next generation of vehicles, and
- development of techniques & tools for monitoring health and performance of deployed hardware.
These efforts will enhance the understanding the causes of roadside crashes, evaluate the effectiveness various roadside safety treatments, and provide the basis for future crashworthiness requirements. ACAP will also continue to support the crash simulation community by creating finite element vehicle models and material models, and making them available for public use.

Products of these efforts will include reports, technical summaries, presentations, finite element models, software tools, data sets, and technical assistance. The specific products from any task order effort will be a function of the level of analysis, objectives, audience, and scope defined at the outset.

**Contact**
For more information contact:
FHWA Office of Safety R&D
Turner Fairbank Highway Research Center
Dr. Kenneth S. Opiela, PE
202-493-3371
kenneth opiela@dot.gov
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<thead>
<tr>
<th>Task Order</th>
<th>Title</th>
<th>Objectives/Accomplishments</th>
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| 1          | Project Organization and Kick-Off                                      | Objective: To provide a systematic transition to the new contract and set the basis for management of subsequent Task Order efforts as well as to continue maintenance of the FOIL, the NCAC Library, and the finite element models archive. 
Accomplishments: Established contract management system, continued FOIL O&M activities, and provided technical simulation support and problem analyses. |
| 2          | Provide Analysis and Evaluation Support for Roadside Safety Team       | Objective: To undertake short-term detailed analyses related to roadside safety issues to develop or improve hardware, enhance deployment, understand the causes of crashes, and/or assist in training agency personnel. These efforts are expected to expand the demonstrated applications of advanced tools and may establish a basis for further analyses. 
Accomplishments: Completed directives to 1) evaluate performance of raised block-outs for W-beam guardrails, 2) conduct simulation analyses of crash tests of Silverado into common barriers, 3) evaluated the enhanced tractor-trailer model, 4) analyzed slope testing protocols, 5) analyzing barriers on curved roadways, and 6) support TRB and TCRS presentations. Current efforts are focused on 1) developing improved tire models, 2) analyzing the influence of slope rounding, 3) analysis of vehicle compatibility issues, 4) study safety performance of barriers on curved roads, and 5) analyzing barrier terminal anchorage. |
| 3          | Operation and Maintenance of the FOIL                                 | Objective: To provide staff to support the basic efforts to operate and maintain the FOIL facility and the various equipment needed for different testing functions and conduct limited testing in support of research efforts. 
Accomplishments: Since the beginning of the contract more than 100 tests (including 30 full-scale) have been conducted and documented. In addition new high speed digital cameras, a new test control computer, various safety devices and tools, and a new storage building have been acquired. Efforts to secure lab accreditation will be completed in 2011. |
| 4          | Conduct Efforts to Document and Disseminate Research and Support Outreach Efforts | Objective: To assist the research staff in efforts to 1) generate reports, tech summaries, web materials, and other research products, 2) establish standards for documenting the products under ACAP, 3) support various outreach efforts, and 4) implement a process to track the production of research materials and maintain an on-going catalog of them. 
Accomplishments: The NCAC Website has had 46 new documents added related to work from both the previous and current contracts since the contract began. Many additional documents are being prepared for posting. NCAC staff has organized and conducted various meetings, workshops, and conferences and has participated in various forums to disseminate the findings of the research and keep abreast of advances by others. |
| 5          | Update and Maintain of Vehicle and Hardware Models and Associated Documentation | Objective: To maintain and upgrade the various vehicle and hardware models (e.g., finite element, rigid body), provide support to users, and manage website. 
Accomplishments: The 2007 Chevy Silverado and Toyota RAV4 vehicle models have been added to the array and numerous updates to hardware models have been made and posted. |
| 6          | Analyze Terrain Effects on the Trajectories of Vehicles that Leave the Road | Objective: To 1) generate the data necessary to verify or update relationships for terrain effects on vehicle trajectories for the current vehicle fleet, and 2) assess the implications on crashworthiness requirements and/or highway design guidelines to promote enhanced safety. 
Accomplishments: Vehicle Dynamics Analyses has been used extensively to understand trajectory effects over a very broad range of road departure conditions. Plans are in place to conduct trajectory tests at the FOIL in early 2011 to provide data to validate the vehicle dynamics analysis results. |
|   | Investigate Causes of Rollover Events for Various Crash Types Using Analytic Methods | Objective: To 1) undertake detailed analyses of rollover crashes to better understand underlying causes, 2) evaluate the potential effectiveness of new treatments or countermeasures, and 3) investigate whether current design practices can be improved to reduce the contributions to rollovers. It is expected that analytical and simulation methods will be used to assess these effects for various vehicles and impact conditions. The research should focus on rollovers for passenger cars and sport utility vehicles.  
Accomplishments: Literature was reviewed, recent empirical data analyzed, new sources of data explored, and a plan generated for Phase 2 efforts to analyze rollover crashes associated with road features. The draft report is being revised and is expected to be available in early 2011. |
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|   | Develop Updated Bogie Test Vehicle for the FOIL | Objective: To model, construct, test, calibrate, and document a reusable bogie vehicle to enhance testing capabilities at the FOIL. 
Accomplishments: A bogie vehicle has been fabricated from a Silverado pick-up frame. The stability of this platform has been assessed with tests at the FOIL. Efforts to model this bogie are underway to complete the design and begin use in testing. |
|   | Analyses and Testing of the Improved Infrastructure Security Barriers (DOS) | Objective: To undertake the testing and analyses efforts needed to improve or enhance the infrastructure barrier systems noted above to higher certification levels and to assess barrier performance for combinations or arrays of barriers. 
Accomplishments: FOIL testing of a tubular steel fence and a fixed bollard were successfully completed and documented. |
|   | Analysis of Improvements to Infrastructure Barriers to Enhance Performance (DOS) | Objective: To undertake the simulation analyses efforts needed to improve or enhance existing infrastructure barrier systems to achieve higher certification levels, simplify the designs to facilitate construction, and assess barrier performance in combinations or arrays. 
Accomplishments: Crash simulation analyses were completed for the tubular steel fence, improvements to bollard and knee wall barriers, and various combinations of barriers that were previously tested. |
|   | Develop and Validate an FE Model for a Small Car (with NHTSA) | Objective: To develop a detailed vehicle finite element model of an 1100kg small car through reverse engineering and then validate the model in accordance with accepted practices to support future crashworthiness analyses related to vehicle and highway safety research. 
Accomplishments: A 2010 Toyota Yaris was procured, subjected to a series of non-destructive tests to capture data for model validation, subjected to reverse engineering, and scanned & meshed to create a finite element model. Teardown and scanning is complete and model development is on schedule. After the primary validation of the FE model is complete the model will be released (Spring 2011). More extensive validations will follow. |
|   | Maintain the Crash Tests Library and Continue Digital Conversion (with NHTSA) | Objective: To support basic management of the crash test library with primary emphasis on supporting the FHWA and NHTSA research efforts, cataloging new items, and continuing efforts to convert existing library materials to digital formats. 
Accomplishments: Various materials have been cataloged added to library. The process of converting films and reports to digital formats continues. |
|   | Provide On-Going Analysis and Evaluation Support for FE Modeling and Simulation (DOS) | Objective: To provide on-going engineering and analytic support, to include finite element analysis to support research and testing activities, related to the evaluation of anti-ram truck barrier systems and assemblies on an as needed basis. 
Accomplishments: Simulations of various modifications to anti-ram barriers or changes to impact conditions were completed and documented. Undertook assessment of the nature of the world truck fleet to determine candidates for a next generation test vehicle modeling effort. |
|   | Assess Effectiveness of Child Safety Devices in Rear Seat Placement (NHTSA) | Objective: To use simulation analyses to analyze the risks to child occupants of varying ages in different types of crashes using available restraint devices. The findings will support rulemaking efforts. 
Accomplishments: A draft report summarizing the modeling of three additional child safety seats and the analysis of occupant risks in rear seat placement has been completed. Based upon the results additional simulations of varying crash... |
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<th>Analyses of New Materials on Vehicle Crash Integrity (NHTSA)</th>
<th>Objective: To provide technical support for NHTSA research on potential safety benefits of Plastic and Composite Intensive Vehicles (PCIVs) using current FE models modified to reflect the replacement of components with structural plastics and composites. Accomplishments: The selection of structural components to be replaced by plastic or composite materials has been completed. Samples of plastic and composite materials have been manufactured for characterization testing. Efforts to replace parts in the vehicle model and conduct simulations of NCAP tests will begin in Spring of 2011.</th>
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<td>Occupant Risk Implications of New Vehicle Designs Using Structural Modeling</td>
<td>Objective: To investigate measures that will further improve the self and partner protection of occupants of new vehicle designs through structural and restraint system optimization across real world crash scenarios focusing on light-weighting strategies and power train changes. To assess the implications for angle crashes with roadway features. Accomplishments: Task Order initiated in September 2010 and organizational efforts have been completed.</td>
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<td>On-Going Analyses &amp; Testing of Improved Infrastructure Barriers</td>
<td>Objective: To undertake simulation analyses and testing to improve the design, applicability, constructability, and deployment of previously developed infrastructure barriers for the Department of State. Accomplishments: Task Order initiated December 2010.</td>
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