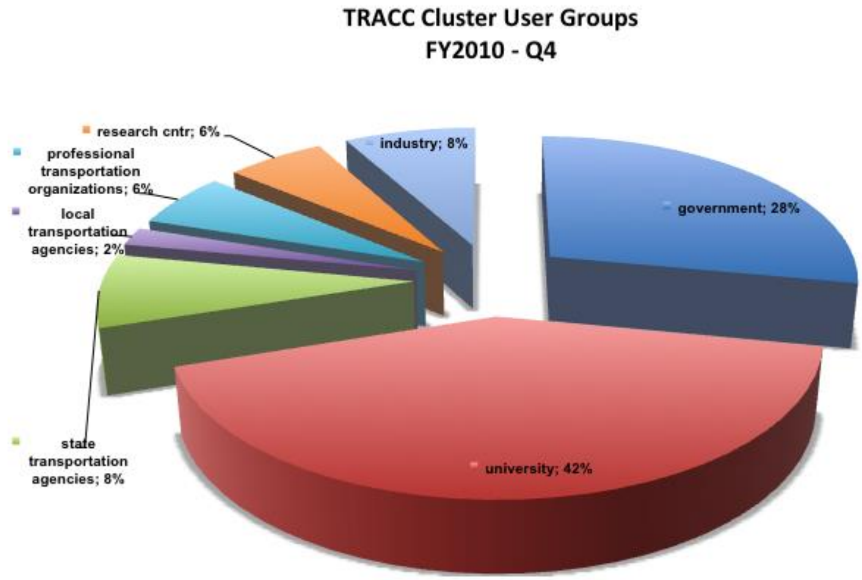
July 2010 to September 2010

In the summer of 2010, it became clear that it was necessary to move the TRACC facility, including the Collaboratory and the TRACC cluster, from the DuPage Airport location to the main Argonne National Laboratory site near Lemont, Illinois. An important part of the planning process was to identify the major Collaboratory facilities and capabilities to ensure that the same level of services or better could be provided from the Argonne location. Planning and design for conference rooms, videoconferencing rooms, and presentation rooms that would support remote participants was initiated.

High performance networking capability with direct fiber connectivity to the major networks that interconnect the major research laboratories and universities was one of TRACC's major tasks in the past. With a move to the Argonne site, TRACC facilities were now directly connected to the main Argonne site-wide network thus ensuring the same level of connectivity but better availability by not having to rely on third party vendors such as the vendor previously supplying the radio link that interconnected the DuPage Airport Flight Center (where the TRACC offices were located) to the Argonne network.

An important element of the TRACC Collaboratory was the hosting of meetings and workshops. In addition to the ability to host meetings in TRACC space of 50 or more people, it was desirable to accommodate occasional large meetings. Argonne has exceptional facilities to host such large meetings and foster collaboration. To complement the many collaborative meeting and workspaces, Argonne has also a Guest House, with 157 rooms, including 2-bedroom premiere suites with parlors, and 4-bedroom suites with parlors, for people who require overnight stays.

Due to its complexity, the integrity of the file system was of high importance during a move, and plans for backing up the data were a topic of many discussion. Other related activities included planning for the cluster's disassembly, shipment, and reinstallation, including all aspects of system administration. It also included gathering information relevant to heating, air conditioning, ventilation, and UPS to ensure that a potential new site had sufficient physical power to handle not only the immediate cluster requirements but also provided capacity for future growth.



Transportation systems simulation

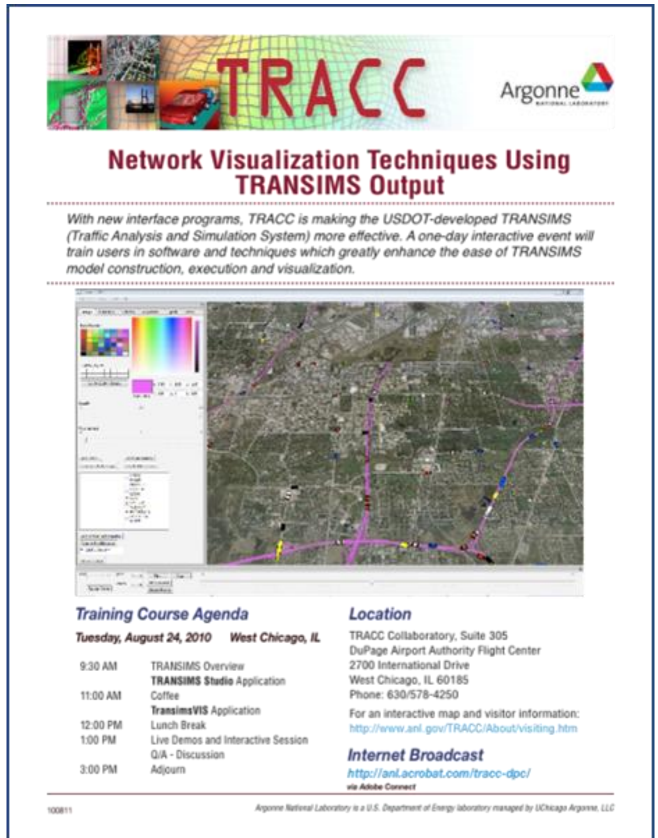
TRACC rolled out additional elements of its TRANSIMS Studio to AECOM, RSG, IIT, CMAP, and the City of Moreno Valley. Assistance was given to AECOM to get TRANSIMS Studio running on the TRACC cluster for their Jacksonville, FL model. Additional support was given to ensure that TransimsVIS was able to visualize all elements of interest within the Jacksonville model without error. RSG worked with TRACC in a step-by-step fashion to begin visualizing their models using TransimsVIS. IIT began working with the new TransimsEDT software in order to continue to edit and refine their model for downtown Chicago. The City of Moreno Valley began working through steps necessary to visualize their model with TransimsVIS. Finally, CMAP explored TransimsVIS, TransimsRTE, and TransimsGUI for use in their existing

Chicago regional models.

Another TRANSIMS training course was delivered as a part of the Elgin O'Hare West Bypass Study project; the goal was to inform project sponsors about the new visualization techniques for TRANSIMS being developed as part of TRANSIMS Studio.

The training course rapidly gained popularity, however, and was attended by nearly a dozen live participants and nearly two dozen remote participants. The one-day course covered the following session topics:

- Overview of TRANSIMS
- Overview of TRANSIMS Studio
- Overview of TransimsEDT
- Overview of TransimsVIS
- Demonstration of TransimsVIS
- Demonstration of TransimsEDT
- Demonstration of Mini-Lambda four-tile display system for TransimsEDT



Another training course was held at Turner Fairbank Highway Research Laboratory Training Course in September 2010. The aim of this course was to expose USDOT transportation modelers and researchers to the fundamentals concepts of TRANSIMS as well as the new developments at TRACC under TRANSIMS Studio. The course was broken down into two days. The first day covered many of the core TRANSIMS concepts, with extra attention shown to the TRANSIMS Microsimulator as well as the TRANSIMS Router. The second day covered topics related to TRANSIMS Studio including live demonstrations of: TransimsGUI, TransimsVIS, and TransimsEDT.

Computational Fluid Dynamics

Outreach at the 2010 National Hydraulic Engineering Conference

TRACC had a booth at the 2010 National Hydraulic Engineering Conference in Park City, Utah, August 31 to September 3, that highlighted the recent doubling of the TRACC cluster capacity to 1024 cores and advances made in scour modeling capabilities. Two technical sessions at the conference featured CFD hydraulic analysis work done on the cluster in collaboration with TFHRC, the University of Nebraska, Northern Illinois University, and TRACC.

New Project: Computational Mechanics Research and Support for Aerodynamics and Hydraulics at TRHRC

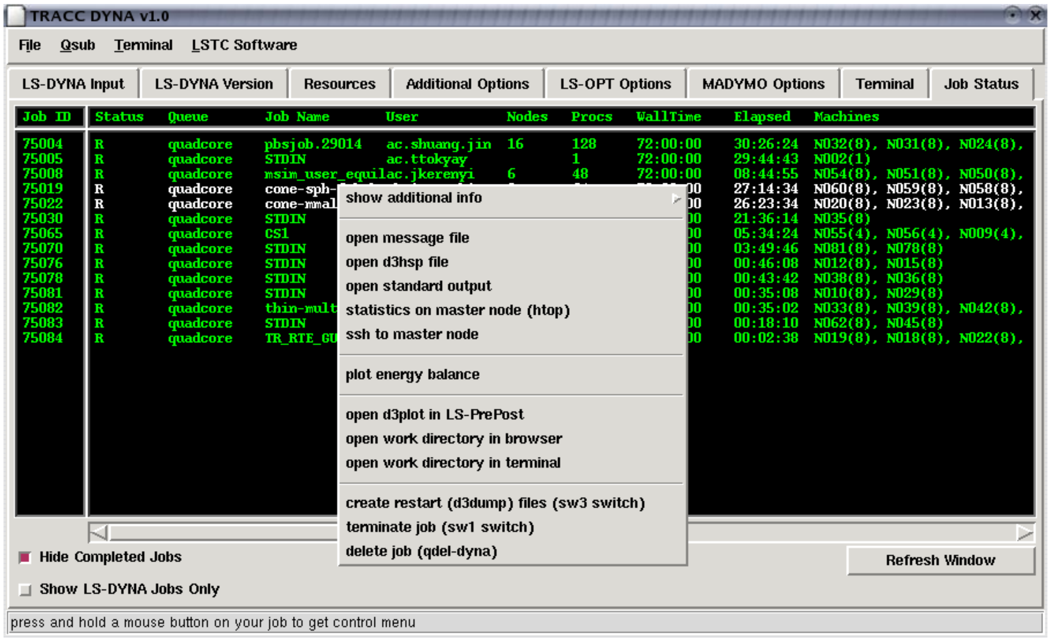
Computational Fluids Dynamics and Computational Structural Mechanics staff at TRACC developed a collaborative research proposal to perform computational mechanics research and development in areas of interest to the Aerodynamics Laboratory and the Hydraulics Laboratory at TFHRC and to provide computational mechanics analysis and support to enhance the experimental work at these laboratories. The proposal was developed in consultation with the senior managing staff at the TFHRC laboratories and implemented with a new U.S. Department of Transportation/Federal Highway Administration interagency agreement with the U.S. Department of Energy. The project began on October 1, 2010 and is now in its third year.

The primary purpose of the project was to provide CFD and computational multiphysics mechanics (CMM) support to TFHRC to solve problems in hydraulics and aerodynamics areas of current importance to the mission of the FHWA, and to provide expert consultation, collaboration, high performance cluster computer computational resources, technical support, and training in the areas of CFD, CSM, and CMM. CMM incorporates coupling of CFD and CSM analysis in problems and applications where interaction of the fluid dynamics and structural mechanics is important.

The broad topic areas for the project were defined as computational mechanics analysis of (1) forces of water flow on bridges and other waterway structures during flood events, (2) erosion of riverbeds due to scour at bridges and other waterway structures that could lead to failure, (3) flow through culverts and the effects on fish passage, (4) aerodynamic forces on signs, traffic lights and other road side structures, and (5) aerodynamic forces on and the stability of bridge cables. Topics were not limited to those listed topic areas and additional topics were added in the first two years to meet the needs and priorities of the FHWA Aerodynamics and Hydraulics Laboratories. This project was initiated to move to a funding source beyond the TRACC research and facility funding provided by RITA, and it came about because of the high value work product in terms of CFD, CSM, and related training and support produced by TRACC in the application of high performance computing to problems of interest to FHWA at the TFHRC Hydraulics and Aerodynamics laboratories.

Computational structural mechanics

During this quarter, the GUI, qsub-dyna-gui, was significantly improved, and all the designed features were coded into the application. The final stage of the development primarily included implementation of the tools for diagnosis of the jobs: (1) viewing statistics files from LS-DYNA calculations, (2) tracking standard output messages from the solver, (3) viewing energy balances of the simulation, and (4) viewing activity of the master compute nodes of a specific job. The figure below shows the job diagnosis and tools menu that is invoked in GUI by clicking on a specific job listed in the Job Status window. The most useful feature added is the automatic plotting of the energy balance components, time step size and energy ratio graphs for a given simulation process. These quantities are the most important measures of numerical stability and correctness of the simulations of the physical problem. Adding this feature to the GUI allows users—in a very short time—to determine



the quality of the results from a numerical point of view.

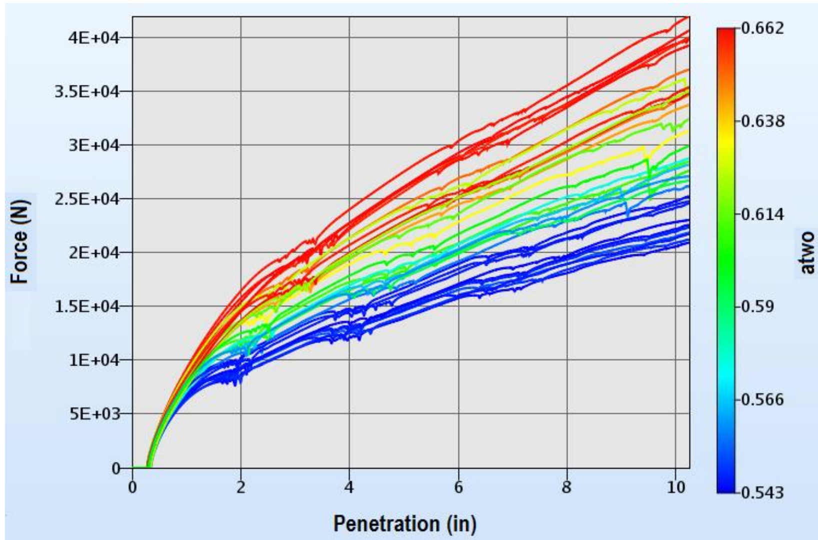
FAMU-FSU was still the most active collaborator in the CSM research area. The initial FE models of the buses that were used by FAMU-FSU were developed by current TRACC staff member Dr. Cezary Bojanowski when he was still a student at FSU. Extensive consultation was provided to FAMU-FSU College of Engineering on their current research related to enhancement of safety in paratransit buses. At that time two different safety standards for roof integrity were investigated: the US standard FMVSS 220 and the European UN-ECE Regulation 66 (ECE-R66) with its variation applicable to paratransit buses -- the Florida DOT Standard. FMVSS 220 establishes performance requirements for school bus rollover protection, but is also frequently used as a required safety standard for the other types of buses used in the US. The concept of FMVSS 220 is to statically apply the force equal to 1.5 times of the weight of an unloaded vehicle (UVW). If the vertical displacement does not exceed 5.125 in, during a force application process, and all of the emergency exits are capable of opening during the maximum force application, and after the load was removed, then the vehicle is considered to have passed the test.

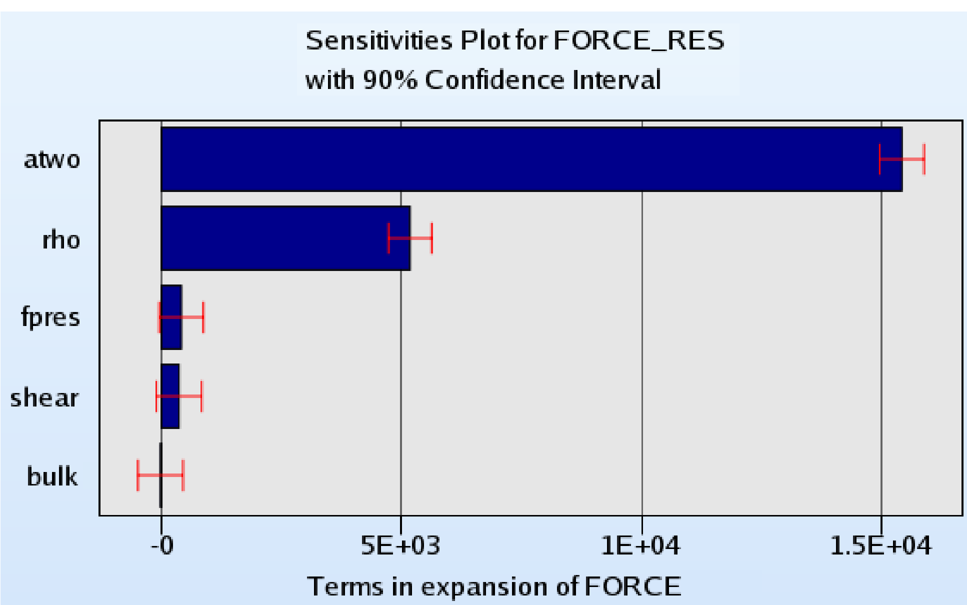
ECE-R66 defines a full scale dynamic rollover procedure as a basic approval experiment. Expanded version of the ECE-R66 is presented in Florida Department of Transportation (FDOT) Standard, which was developed as a Crash and Safety Assessment Program for Paratransit Buses. The FDOT standard defines additional requirements for validation of computational models and introduces Deformation Index as a measure of overall deformation experienced by the bus. In ECE-R66 the tested bus, with blocked suspension, is placed onto the tilting table, and slowly tilted to its unstable equilibrium position. Next, under its own weight, the bus falls into the 31.5 in deep, dry and smooth, concrete ditch. The pass-fail criteria in Regulation 66 are based on the concept of the residual space (RS). The residual space is defined as a space required to be kept intact in order to provide a survival zone for passengers and a driver. No part or element of the vehicle can intrude into the RS during and after the impact.

Multiple LS-DYNA simulations of both tests were performed recently on the TRACC cluster. The investigated bus failed the simulated rollover test according to the ECE-R66 and the FDOT Standard. The residual space has been compromised by the side wall entering the RS during the test. The deformation exceeded by over 60% the critical limit.

The same FE model has been used to simulate the conditions of FMVSS 220 for quasi-static load resistance of the roof structure. The investigated bus passed the FMVSS 220 quasi-static load resistance test of the roof structure. The roof withstood the load of 1.5 UVW without exceeding the limit value of the deformation. The maximum displacement of the force application plate was 4.76 in (with 5 in being the limit). Although the validated FE model of a paratransit bus passed the test procedure FMVSS 220, it significantly failed the dynamic rollover test as specified in ECE-R66. This leads to the conclusion that the tests are not equivalent and different approval decisions can be issued based on different methods of testing. For the paratransit buses more conservative – dynamic rollover testing according to UN ECE R66 should be used.

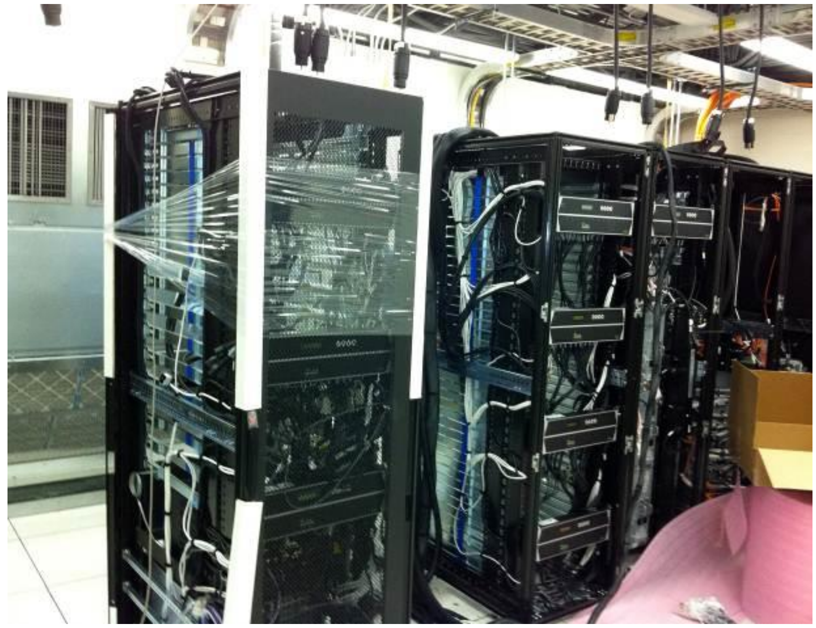
In order to implement the work done by Northern Illinois University students to a real bridge, TRACC CSM staff developed a FE model of the Bill Emerson Memorial Bridge. During this quarter, vehicle-bridge interaction was studied in more detail and simulations of traffic loading on the bridge have been performed. The interaction between the simplified model of the vehicle and the bridge structure was performed with LS-DYNA using RAIL algorithms. A track represents the path built of beam elements that is followed in the simulation by a generalized vehicle. The road roughness was defined in the interaction as well. The roughness can either be taken from the field measurements or generated using mathematical expressions based on empirical approach. For that purpose, the road surface was considered to be a random deviation from a perfect flat road surface. The RAIL algorithm in LS-DYNA allows solving this problem by modeling only simplified vehicles. For this study, a truck was modeled as a 3D mass-spring-damper system. The vehicle had mass and size properties representing the standardized AASHTO HS 20-44 truck. Results of two cases of traffic loading were considered: with one truck and with twenty trucks (ten in each direction). The maximum deflection in the case with one truck was about 0.04 m. The maximum deflection with twenty trucks was about 0.43 m. For the analyzed cases, the traffic loading did not introduce parametric excitations in the stay cables, most likely because the cable system uses multiple levels of cross-ties between the cables.





The Computational Structural Mechanics staff continued evaluation of the most efficient numerical multi-physics approach for modeling bridge stability for bridges with supporting piers embedded in scour holes. Using LS-OPT, a sensitivity study was performed on the Lagrangian model. It can be confirmed by this study that the most robust and reliable approach turned out to be a hybrid approach that used the SPH formulation in the soil region with high material distortion and the Lagrangian formulation away from the highly distorted soil. This approach was insensitive to loading rates and mesh density. Sensitivity studies on parameters used in soil material models showed that a yield surface parameter was the most influential on the response of the soil. It must be determined experimentally with great accuracy. The second most important factor was soil density.

October 2010 to December 2010



The major change in TRACC's operation in December 2010 was the move of the facilities (as well as the high performance computing system) to the Argonne National Laboratory site, located near Lemont, IL. TRACC's location at the DuPage Airport Flight Center had always been a temporary solution, and had been initially envisioned as being a driving factor in establishing the DuPage National Technology Park close to this location in West Chicago. With the economic downturn of previous years, as well as decreased interest by partner universities in investing in the research park, the decision of operating TRACC at a remote facility were re-examined,

and senior Argonne management decided to provide a suitable location for TRACC onsite. TRACC's offices were now located in building 222 close to Argonne's main entrance, and the high performance computing cluster system was relocated to an ideal computer room in Building 240, co-located with some of the fastest computers in the world. This placement ensured state of the art support, and full integration into one of the most secure but widely accessible network environments in the United States.

The move to Argonne was decided upon at very short notice, but didn't interfere significantly with TRACC's regular operation. TRACC facilities were unavailable for a few days, with the HPC system being back in full operation within a week. The move was scheduled around training courses and other utilization of the TRACC facilities, and similar capabilities were reestablished at building 222. The visualization equipment on loan under a bailment agreement with UIUC was returned to UIUC. A continuation of the bailment agreement with the university would not have been cost effective due to the aging of the equipment that had been in use at the DuPage Airport facility for over 8 years. TRACC decided to create needed visualization and training capabilities based on more cost-effective equipment, and started operating a suitable training facility for up to 32 participants.

A number of new users and projects started up as well. Most notably, the EPA signed up a larger group of users and even visited the TRACC facility for a few days to work side by side with TRACC system administrators to design an appropriate mechanism to run MOVES on the TRACC HPC cluster.

TRACC also hosted the 2010 Yearly Meeting of ITS Midwest. The meeting was held at conferencing facilities at Argonne's main site, and a reception was held at TRACC's DuPage Airport facility right before closing it down.

Despite the move, the TRACC facility still hosted two training sessions during the quarter. This included a training class in the computational structural mechanics area and a workshop on the Highway Capacity manual. Other meetings were held in cooperation with the Chicago Metropolitan Agency for Planning as part of their outreach programs.

Transportation systems simulation

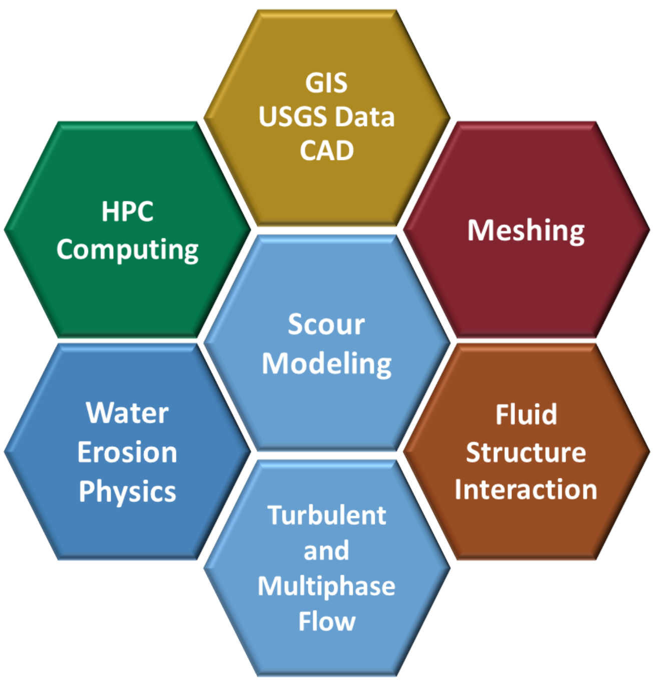
A major event in the area of transportation systems simulation and evacuation planning was the commencement of the RTSTEP project with the City of Chicago. The project had been proposed to the City two years earlier, and the development of a contract that the City of Chicago, the University of Chicago, Argonne, and the US Department of Energy could agree upon took until December 2010. The project started under serious time constraints in December 2010, and was targeted to be fully finalized by August 31, 2011. An eventual time extension allowed TRACC to work on this project until November 2011.

Under the contract, TRACC was the lead agency with subcontracts for AECOM (a large consulting company with essential expertise in the application of TRANSIMS), CMAP (the Chicago Metropolitan Agency for Planning), IIT (the Illinois Institute of Technology), and NIU (Northern Illinois University). TRACC personnel were coordinating the project closely with Chicago's Office of Emergency Management and Communications (OEMC) and the Chicago Department of Transportation (CDOT). In addition, Argonne's experts were on the transportation subcommittees of the ITTF (Illinois Terrorism Task Force) and the RCPT (Regional Catastrophic Preparedness Team) to interact with emergency responders.

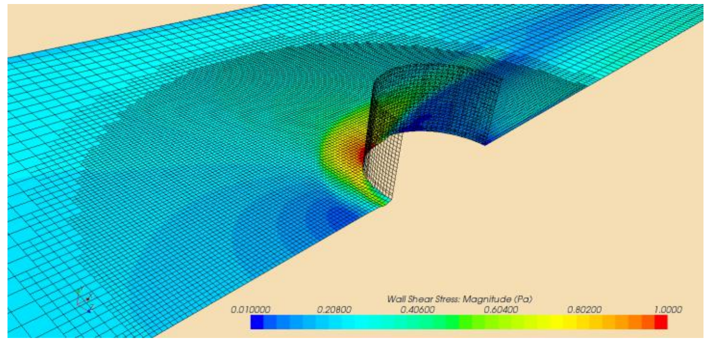
Computational Fluid Dynamics

Scour Analysis

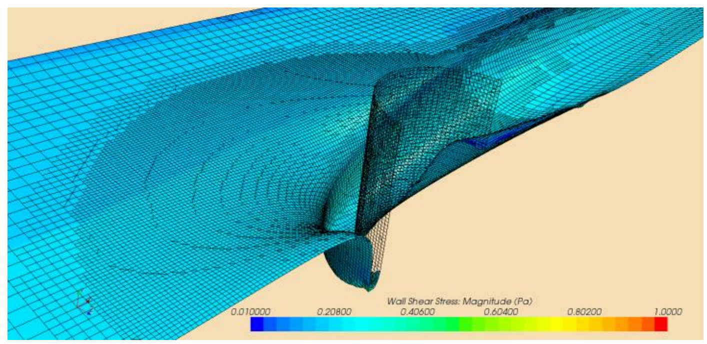
Analysis of three-dimensional scour processes at real bridges was recognized to be a complex multidisciplinary problem that included several research topics beyond just the CFD that included turbulent and multiphase flow with water erosion physics: it's successful development also relied on the new area of fluid structure interaction, meshing that required complex mesh morphing, high performance computing, and eventually GIS or USGS topographic data on flood plains, channel bottoms, and structures and vegetation along rivers and streams.



With all of these interdependent software modeling, computation, and data needs, the value of using well benchmarked commercial software that is independently benchmarked by a large community of users was also accepted to be an important factor in moving toward more comprehensive 3D scour models that could be applied to real bridge foundations. A significant success in getting all of this software to work together on TRACC's high performance cluster was the completion of a master's degree on cylindrical pier analysis with mesh morphing and remeshing when the bed displacement became large.



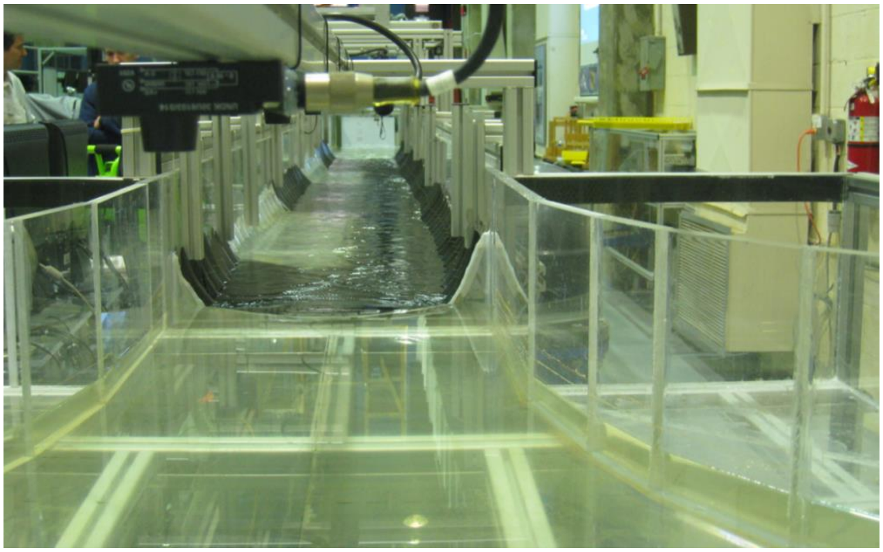
Sand bed shear stress distribution near the start of the scour process around a cylindrical pier. The critical shear stress for initiating motion of sand on the bed is approximately 0.18 Pa.



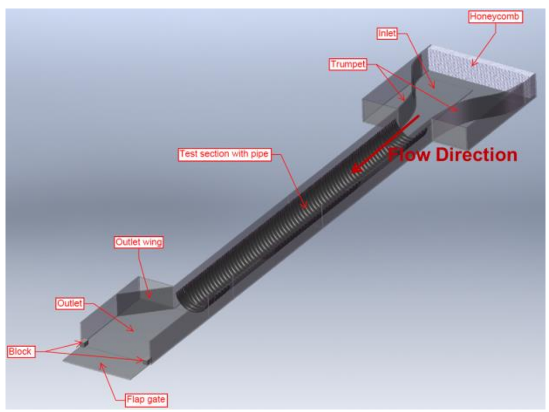
A symmetric half of scour around a single pier was computed, and although the scour hole was clearly too steep for conditions of non-cohesive sand sediment, the complex procedure to compute the evolution of the scour hole through a large series of automated computer runs with remeshing over a time period of several days was in place. This capability would provide a basis to add refined physics models to achieve a more realistic scour hole.

Culvert Analysis

The focus of culvert modeling turned to modeling and computation of flow energy losses, primarily turbulent energy dissipation in a culvert. In the laboratory at TFHRC, the culvert flume was converted to a tilting flume to determine a tilt angle needed to keep the water level constant as water flowed through the culvert. Under these conditions gravitational potential energy added to the flow kinetic energy as it flowed downhill exactly made up for the flow energy losses



due to turbulent energy dissipation created by walls and the ribbed barrel. The CFD model was modified to iteratively seek that same tilt angle by adjusting the angle of the gravity vector acting on the flow field. Post processing computation of the energy lost to turbulent dissipation was also successfully performed. The capability to directly compute flow energy losses through a culvert demonstrated the potential of using CFD to determine quantities that are very expensive to determine with laboratory experiments.

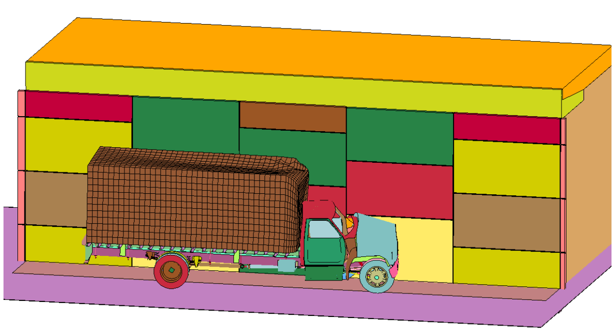


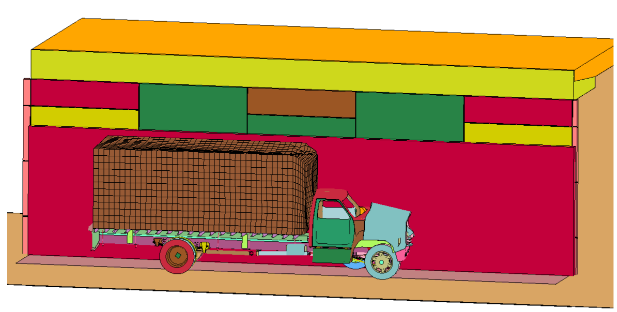
Computational structural mechanics

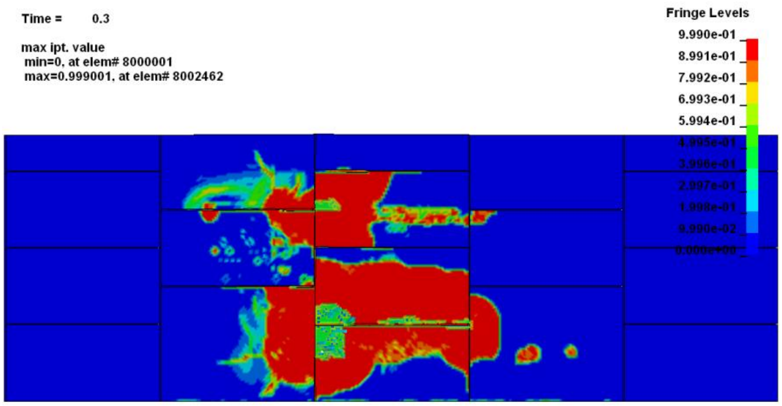
The TRACC cluster, Computational Structural Mechanics staff, and cluster administrator continued to provide computational and support resources to an expanding user base of DOT researchers using computational structural mechanics tools to address design and safety issues. Two new Computational Structural Mechanics collaborators were added; both were students at Northern Illinois University who continued the research work of the two students who graduated and did their thesis work in CSM.

TTI researchers were investigating the performance of a crash wall design to determine its effectiveness in reducing the damage to wall panels during a vehicular impact. The simulations were based on Test Level 4 impact conditions of the new AASHTO *Manual for Assessing Safety Hardware (MASH)*. This involved a 10000-kg single unit truck (SUT) impacting at 90 km/h (56 mi/h) and 15 degrees. The figure below shows SUT impact on the MSE wall panels and for SUT impact on the crash wall. Damage to the MSE wall panels resulting from direct vehicle impact was extensive and would require very costly repairs. Damage was significantly reduced by the inclusion of the crash wall. Based on these simulations, a 0.2 m (8 in.) thick crash wall was considered adequate to reduce damage to the MSE wall below levels that would require repair.

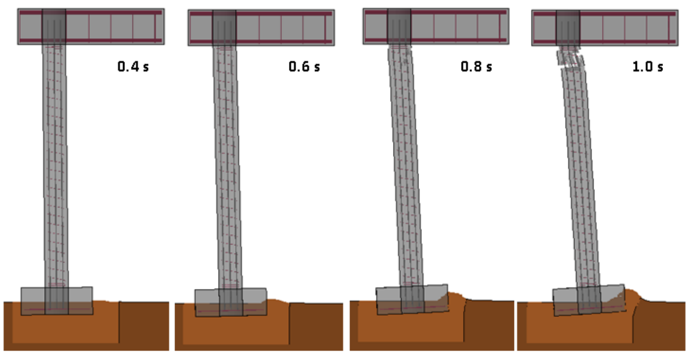
TRACC staff continued work evaluating the most efficient numerical multi-physics approach for modeling bridge stability for bridges with supporting piers embedded in scour holes. A second set of published data for soil penetration tests was located and favorable comparisons between experimental test results and simulation results were achieved using both the Smooth Particle Hydrodynamics and multi-material Arbitrary Lagrangian-Eulerian approaches. With the acquired knowledge about simulating large deformations in soils simulations were performed to analyze the failure of the Oat Ditch Bridge in California. This bridge was classified as not-scour-critical, but failed during a flash flood. Numerical simulations using LS-







DYNA/MPP on the cluster produced the observed failure mode.



New work was initiated to develop credible models for making reliable predictions of the response of bridges and their components to blast loading. The task has an experimental component to it through TRACC's planned participation in a proposed NATO project. A multi-year research plan has been developed, to provide a capability to assess critical transportation structures—initially bridges—to blast load effects. In the first quarter of this project, TRACC focused mainly on studying the literature and exploring LS-DYNA capabilities in regard to modeling blast loading effects. Also benchmark tests for further LS-DYNA simulations were chosen.

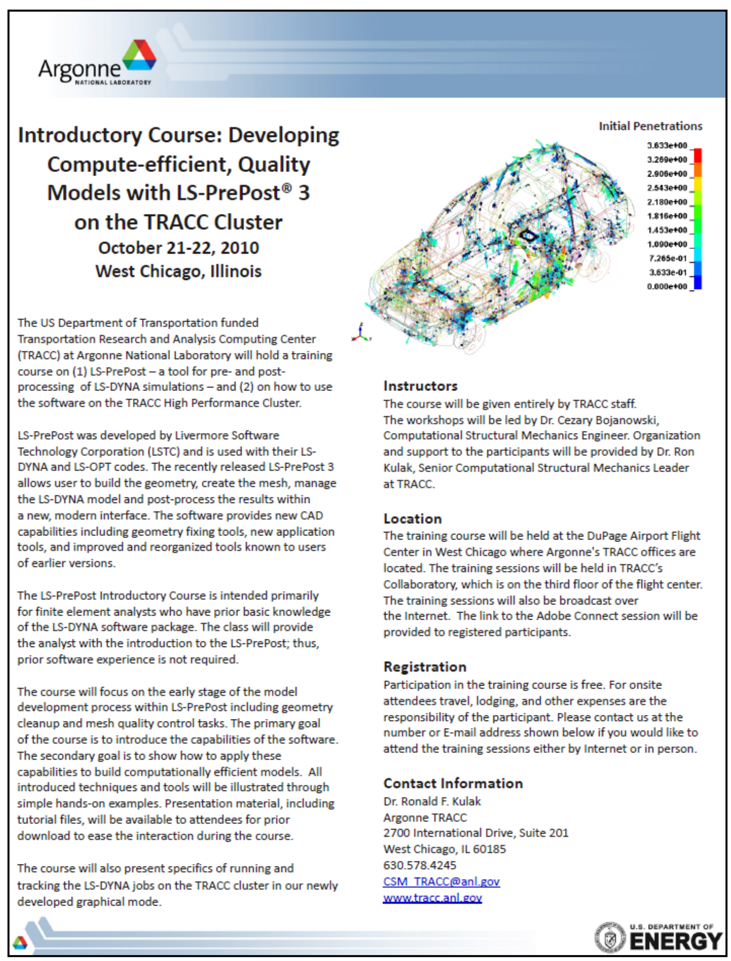
In this quarter, the CSM group gave an Introductory Course*: Developing Compute-efficient, Quality Models with LS-PrePost® 3 on the TRACC Cluster*. The training was held October 21-22, 2010 at TRACC in West Chicago with interactive participation on-site as well as remotely via the Internet. The training hosted 9 on-site and 35 remote participants.

Three papers submitted to the Transportation Research Board (TRB) Annual Meeting Committee, Washington, D.C., 2011 were accepted for presentation. The research conducted entirely by TRACC CSM staff was described in two papers:

- Bojanowski C., Kulak R.F., Seismic and Traffic Load Modeling on Cable Stayed Bridge, Transportation Research Board Annual Meeting, Washington, D.C., January 23-27, 2011
- Kulak R.F., Bojanowski C., Modeling of Soil-Structure Interaction in Presence of Large Deformations in Soil, Transportation Research Board Annual Meeting, Washington, D.C., January 23-27, 2011.

Collaborative research between TRACC and FAMU-FSU College of Engineering was described in a third paper:

- Gepner B. Rawl C., Kwasniewski L. Bojanowski C., Wekezer J., Comparison of ECE-R66 and FMVSS 220 Tests for a Selected Paratransit Bus, Transportation Research Board Annual Meeting, Washington, D.C., January 23-27, 2011.



Argonne NATIONAL LABORATORY

Introductory Course: Developing Compute-efficient, Quality Models with LS-PrePost® 3 on the TRACC Cluster

October 21-22, 2010
West Chicago, Illinois

Initial Penetrations

The US Department of Transportation funded Transportation Research and Analysis Computing Center (TRACC) at Argonne National Laboratory will hold a training course on (1) LS-PrePost – a tool for pre- and post-processing of LS-DYNA simulations – and (2) on how to use the software on the TRACC High Performance Cluster.

LS-PrePost was developed by Livermore Software Technology Corporation (LSTC) and is used with their LS-DYNA and LS-OPT codes. The recently released LS-PrePost 3 allows user to build the geometry, create the mesh, manage the LS-DYNA model and post-process the results within a new, modern interface. The software provides new CAD capabilities including geometry fixing tools, new application tools, and improved and reorganized tools known to users of earlier versions.

The LS-PrePost Introductory Course is intended primarily for finite element analysts who have prior basic knowledge of the LS-DYNA software package. The class will provide the analyst with the introduction to the LS-PrePost; thus, prior software experience is not required.

The course will focus on the early stage of the model development process within LS-PrePost including geometry cleanup and mesh quality control tasks. The primary goal of the course is to introduce the capabilities of the software. The secondary goal is to show how to apply these capabilities to build computationally efficient models. All introduced techniques and tools will be illustrated through simple hands-on examples. Presentation material, including tutorial files, will be available to attendees for prior download to ease the interaction during the course.

The course will also present specifics of running and tracking the LS-DYNA jobs on the TRACC cluster in our newly developed graphical mode.

Instructors
The course will be given entirely by TRACC staff.
The workshops will be led by Dr. Cezary Bojanowski, Computational Structural Mechanics Engineer. Organization and support to the participants will be provided by Dr. Ron Kulak, Senior Computational Structural Mechanics Leader at TRACC.

Location
The training course will be held at the DuPage Airport Flight Center in West Chicago where Argonne's TRACC offices are located. The training sessions will be held in TRACC's Collaboratory, which is on the third floor of the flight center. The training sessions will also be broadcast over the Internet. The link to the Adobe Connect session will be provided to registered participants.

Registration
Participation in the training course is free. For onsite attendees travel, lodging, and other expenses are the responsibility of the participant. Please contact us at the number or E-mail address shown below if you would like to attend the training sessions either by Internet or in person.

Contact Information
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U.S. DEPARTMENT OF ENERGY