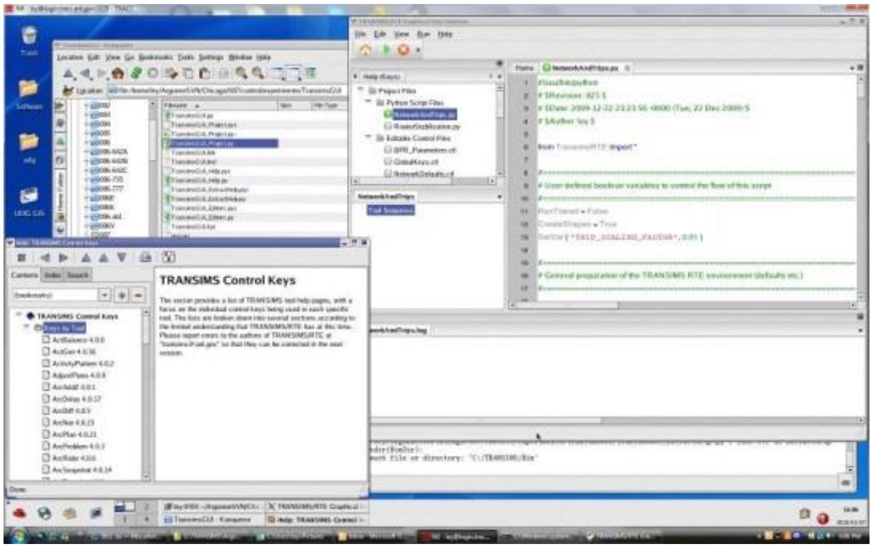
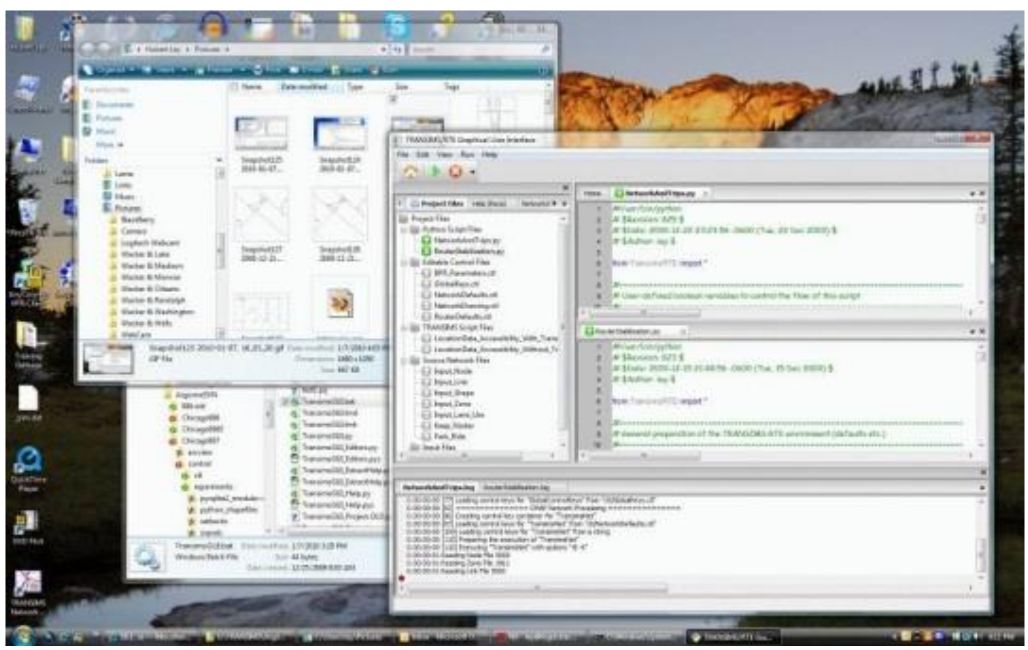
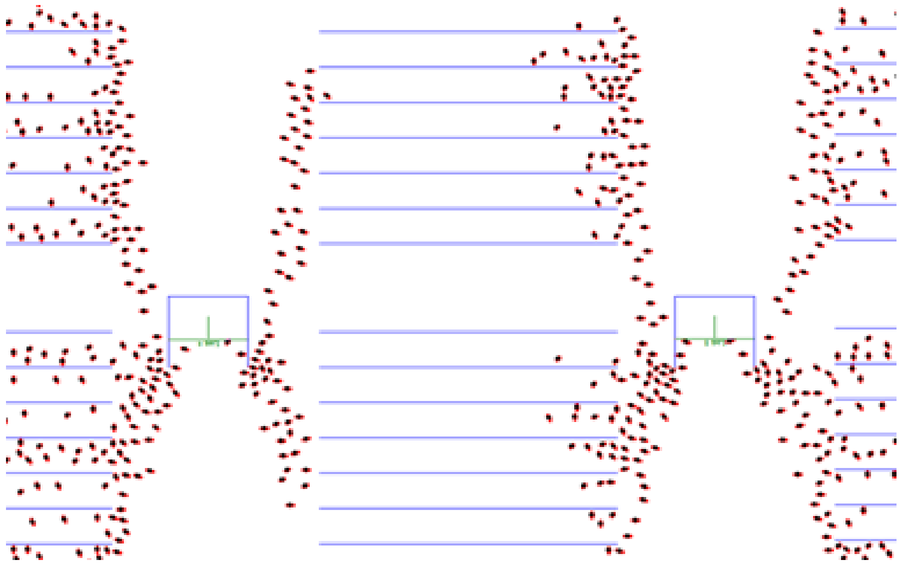
October 2009 to December 2009

Because of the conclusion of the evacuation project that was implemented for the Illinois Department of Transportation, renewed emphasis was placed on applying the lessons learned from that project to the development of much more general tools that simplify and enhance the use of TRANSIMS. One obvious need for the TRANSIMS community was a cross-platform execution environment that allows users to utilize the plethora of TRANSIMS tools without worrying about many complex details, such as the number of CPUs assigned to your job, or whether the case is running under Linux, on a Mac, or under Windows. A script developed for any case should run without modification on any of these platforms, and the user should be able to make use of powerful features such as parallelization in a transparent manner that hides the idiosyncrasies of operating systems and hardware to a high degree. For example, the newly programmed RTE environment allowed for running a case with a fixed number of partitions by virtualizing the number of processors so that tools can make efficient use of CPUs that are currently available. Also, sanity checks are performed on input and output files to make it easier for users to create models that are internally consistent. Other important features are the automatic determination of the need to actually run a tool (using a caching mechanism) and the ability to run in a special dry run mode that only checks the consistency of input and output files, a concept that allows checking for typical programming errors within a minute instead of hours.



The TRANSIMS/RTE run time environment library described above also serves as the foundation for a sophisticated graphical front end for TRANSIMS (TRANSIMS Studio). The user interface was designed similar to integrated development environments such as Visual Studio, with the ability to group files and other components into arbitrary groups, and opening them with the IDE in appropriate editors. The environment interacts with TRANSIMS/RTE to allow users to execute TRANSIMS cases right within the IDE, being able to follow the execution of individual tools as they are executed. All input and output files are directly accessible for inspection in the IDE. A prototype was developed to demonstrate the fundamental principles, including an extensive built-in help system that allows users to work productively. The system was also cross-platform compatible, and has been demonstrated to work under both Windows and Linux. That made the entire IDE remotely accessible to users of the TRANSIMS cluster.





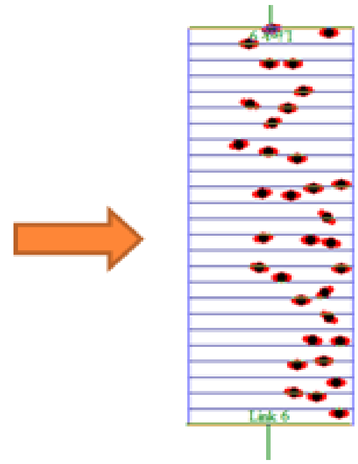
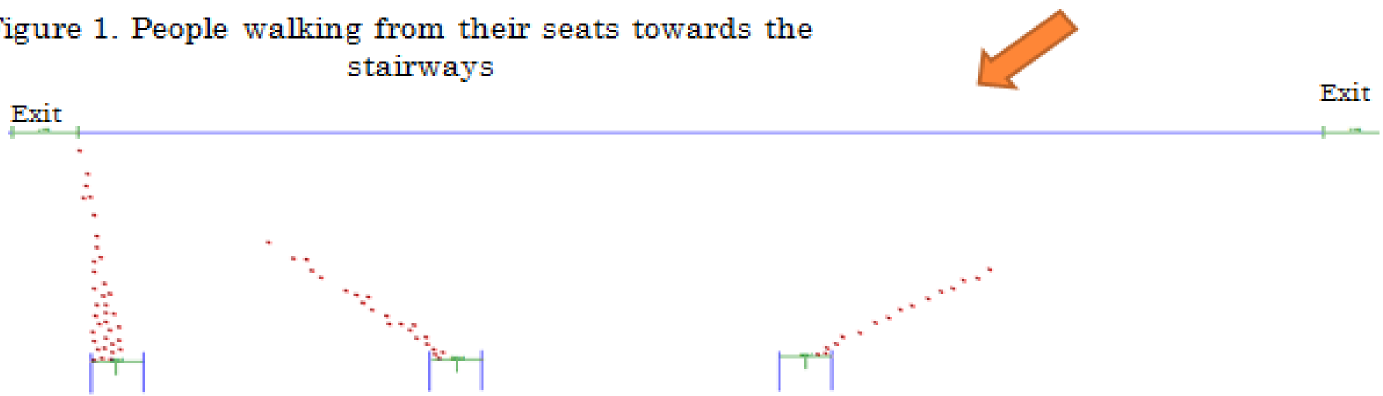
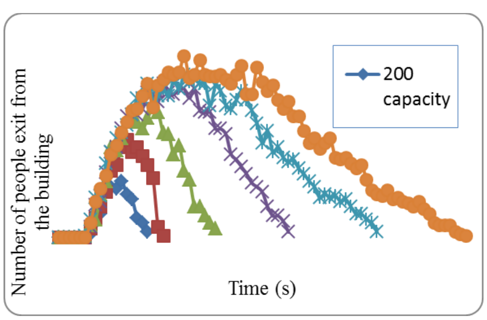


Figure 2. People walking down the stairs

Figure 1. People walking from their seats towards the stairways



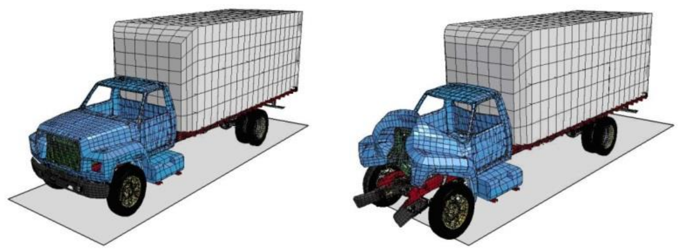
The team at Northern Illinois University also performed further studies of methodologies to appropriately model the pedestrian components of the evacuation model. A preliminary analysis was conducted using a dummy stadium configuration. The occupants are moving from their seats towards the stairways, and walk down the exits to the ground floor. They finally choose the nearest exit to evacuate the stadium. Using this dummy stadium the simulation for evacuation was run with various populations to establish a pattern or trend. The results show the evacuation of people from the stadium over time using various capacities.



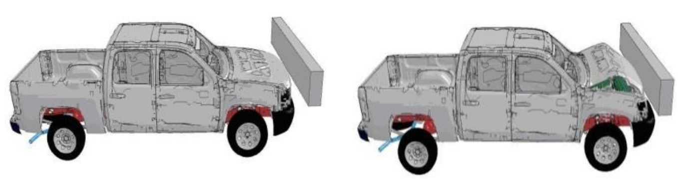
Another TRANSIMS training course was held on December 16 to 18, 2009. This was the ninth time that this course was presented. Feedback from former participants has shaped the content significantly and has made it more specific to the needs encountered by typical first time users. Most participants were from Northern Illinois University, the Illinois Institute of Technology, the Chicago Metropolitan Agency for Planning, and the Office for Emergency Management and Communication of Chicago.

Computational structural mechanics

The user group in the computational structural mechanics area was growing. During this quarter, help was continuously provided to the Florida Agricultural and Mechanical University-Florida State University (FAMU-FSU) College of Engineering users working on the crashworthiness of paratransit buses. In addition, help was provided to new users from Kineticorp. Kineticorp is a forensic firm working in both engineering and visualization disciplines for reconstruction of traffic accidents. Guidance was provided to initialize

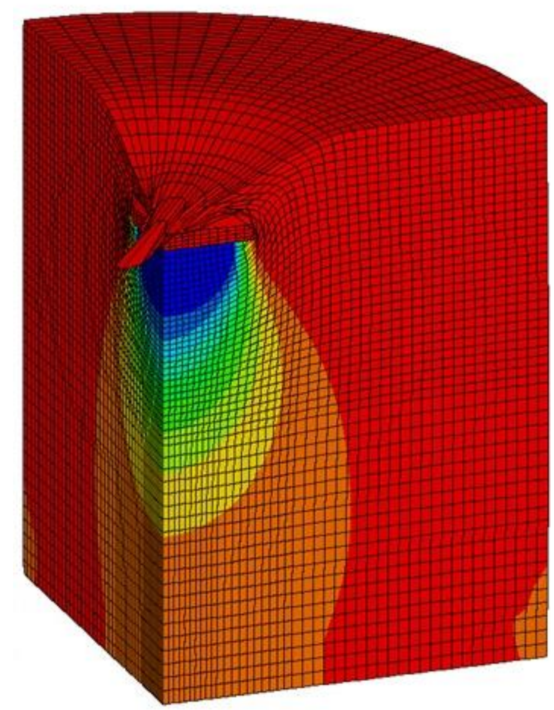


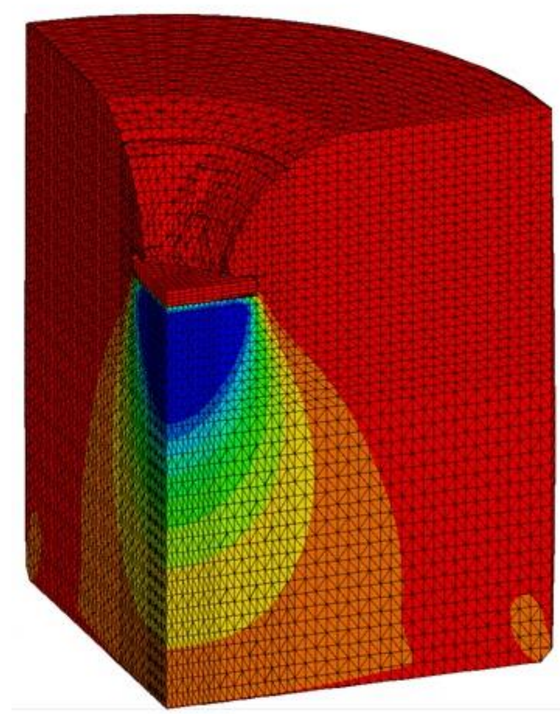
their work with MPP-DYNA on the cluster. Kineticorp was performing frontal impact simulations of vehicles using public domain FE vehicle models developed by National Crash Analysis Center (NCAC). The impact of a Ford Single Unit Truck into a rigid cylinder representing a tree and the low-speed frontal impact of a Silverado Pickup Truck into a barrier wall were investigated.

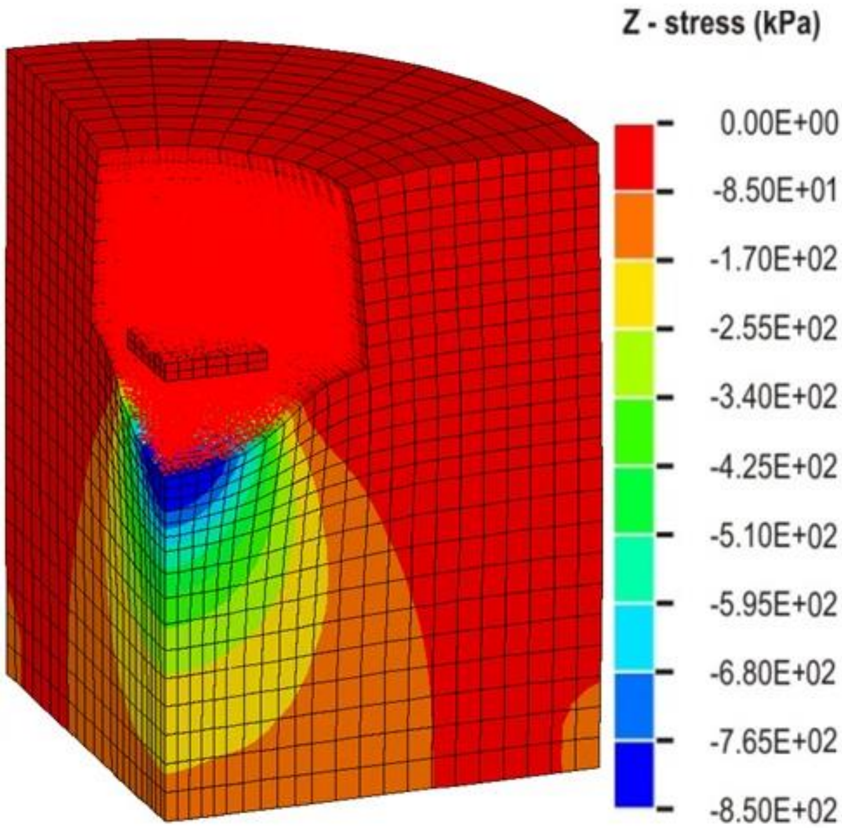


Collaborative research continued with Northern Illinois University in analyzing bridge stay-cables to parametric excitations. The study was performed previously on validating the LS-DYNA element formulations to represent cables in a finite element model of the bridge. In the current quarter research has shifted to modeling traffic loading on a simple bridge deck. The second track of analyzing different loads on cable stayed bridges focused on developing an efficient approach to compute wind loading on cable elements. Implementation of this approach in an LS-DYNA FORTRAN user subroutine was in progress.

Work continued for developing a multiphysics approach to evaluate the stability of bridges with piers in scour holes. The research expanded by adding the Smooth Particle Hydrodynamic approach for modeling the soil structure interaction between the pier and riverbed soil. Studies continued to evaluate three approaches: Lagrangian, Multi-Material Arbitrary Lagrangian Eulerian and Smooth Particle Hydrodynamics. A validation study was initiated using previous experimental results reported in the literature.





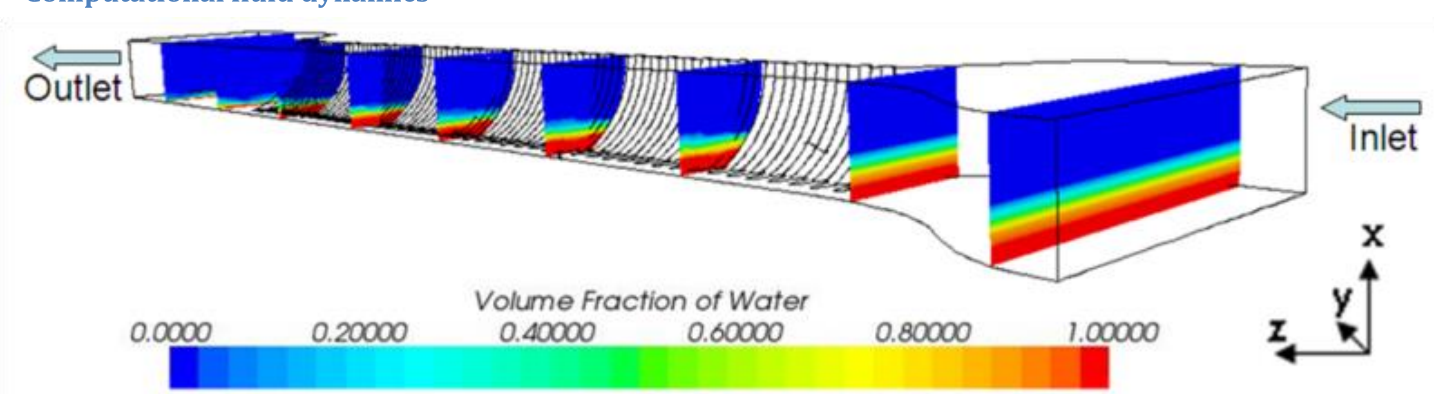


The University of Nebraska completed testing of the scour model in FLOW-3D on the TRACC cluster. They have an academic license for FLOW-3D use on the cluster that only allows U.N. staff and students to use it. In their initial evaluation of the FLOW-3D scour model, they found it to be useful for the limited range of cases where rapid events such as a dam break where the scour occurs in a period of minutes. Using FLOW-3D to compute scour that occurs in a flood over a period of days is currently not feasible because it would take a year or more to complete the computation. As with other CFD software applied to scour analysis, a method to bridge the flow and scour time scales is needed for prediction of scour that occurs during floods over a period of days or several weeks. Based on this evaluation, TRACC CFD staff decided not to seek to license FLOW-3D for general use.

Based on the type of support that was provided to cluster users during this quarter and acquiring an in-depth knowledge of their needs and shortcomings, a report with recommendations for future training in the computational structural mechanics area was completed. Two training courses were scheduled for the next quarter: Introduction to LS-OPT and Modeling and Simulation using LS-DYNA. The material for the first one was prepared entirely during this quarter by the TRACC CSM staff.

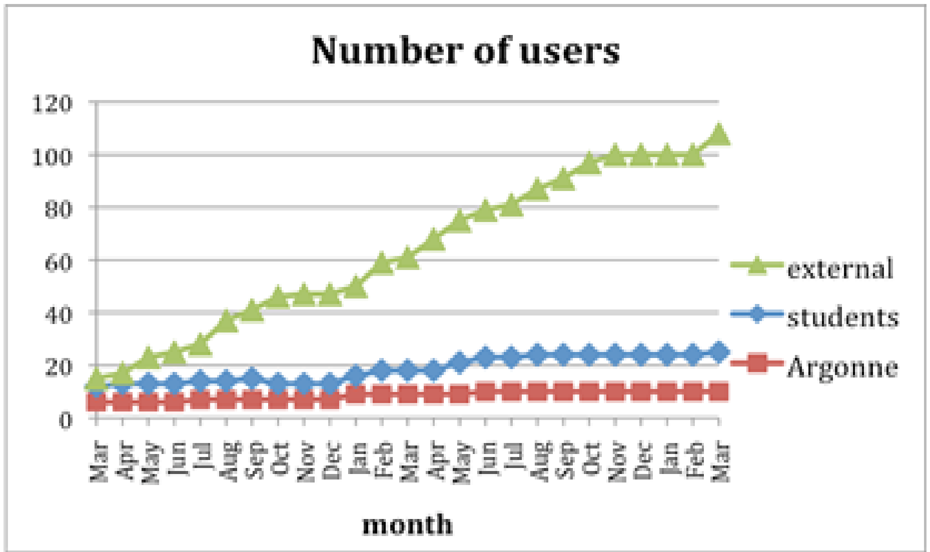
Computational fluid dynamics

The effort on the culvert model continued with initial testing on a mesh containing about 2.5 million cells. Much of the culvert geometry model was actually occupied by air, and it was noted in the simulations that the free surface interface between water and air was not well resolved in the computational mesh. In a sufficiently fine mesh near the free surface the transition between a water volume fraction of 1, or all water, to 0, or all air, should be rapid, but it was not. A decision to create a much finer mesh near the free surface was made.



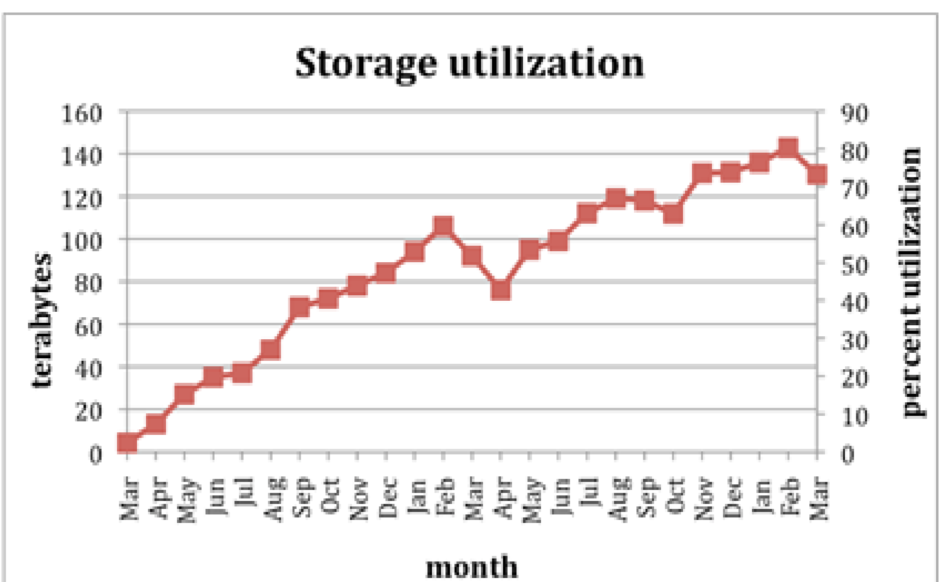
January 2010 to March 2010

In January 2010, TRACC completed the upgrade of the CPUs in the cluster's compute nodes from dual-core AMD Opteron 2216s to quad-core AMD Opteron 2278s, doubling the number of cores from 512 to 1024. The upgrade was performed incrementally in order to allow users to continue to use the cluster during the upgrade, which altogether took about 80 man-hours to complete over December and January.



As mentioned in the previous quarterly report, the second part of our upgrade plan was to increase each compute node's RAM from 4GB to 8GB, so that the nodes would have 1GB of memory per core. In February TRACC ordered and received the RAM, and immediately began installing it. This upgrade was also performed incrementally, so that TRACC would not have to take more than 10 nodes at a time offline. As the nodes were upgraded, the memory was stress-tested for 24 hours using High Performance LINPACK (HPL), a standard HPC benchmarking application. The testing revealed approximately 6% of the RAM to be defective. Determining which RAM chips were defective required that several nodes be offline for several days.

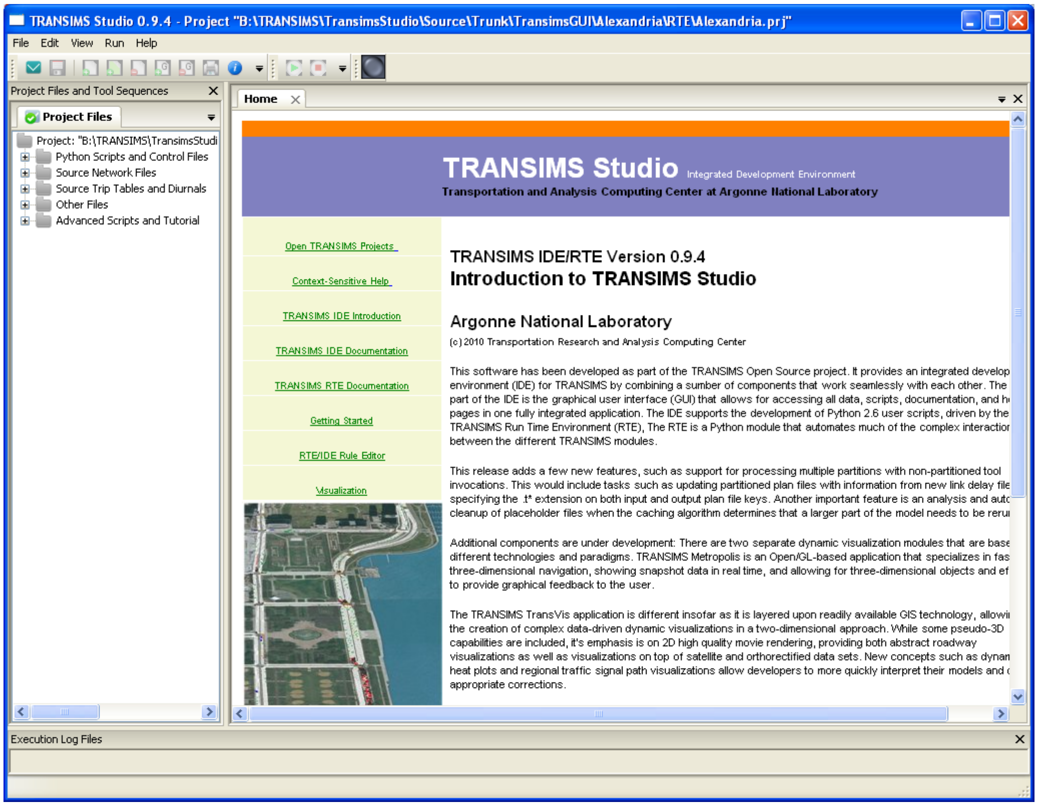
The number of users of the cluster increased over this quarter to 108, 10 of whom are Argonne employees, 15 students working directly with Argonne, and 83 external government and academic users. Cluster utilization continued to rise after the CPU upgrades, and for March reached 74% of the current cluster capacity, or 147% of the cluster capacity before the upgrades.



Transportation systems simulation

The TRANSIMS Studio Graphical User Interface (GUI) was released to the community and runs on all major computing platforms and allows for easily creating and managing complex TRANSIMS projects. The TRANSIMS community had been asking for such a tool for a long time, and several inadequate attempts had been made in previous years. The availability of a rapid prototyping tool such as Python, as well as the experience gained both with TRANSIMS as well as the users of TRANSIMS, TRACC was well-positioned to address this need. On the cluster, the user interface is integrated with the job submission and control system to allow flexible use of available resources. The GUI works in direct interaction with the previously described RTE, and forms a complete Integrated Development Environment for TRANSIMS users.

The software had been downloaded close to 250 times, and several TRANSIMS users made TRANSIMS Studio their choice of development environment, both under Windows and Linux on the TRACC cluster. A



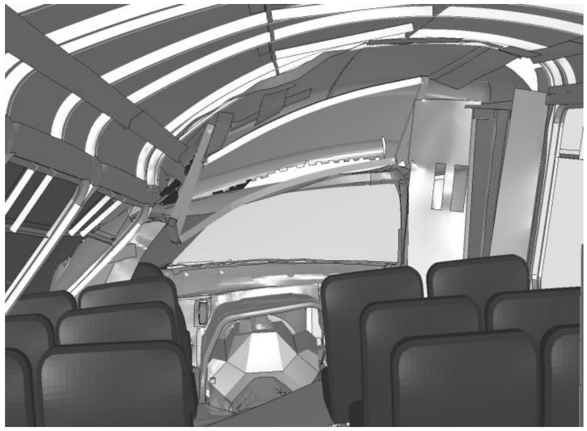
recent workshop showed large interest in this new software, and many more users were expected to actively use this application. It has also become an excellent training tool and was adopted by a team from the Illinois Institute of Technology to learn about TRANSIMS for their own separately funded TRANSIMS Chicago Project.

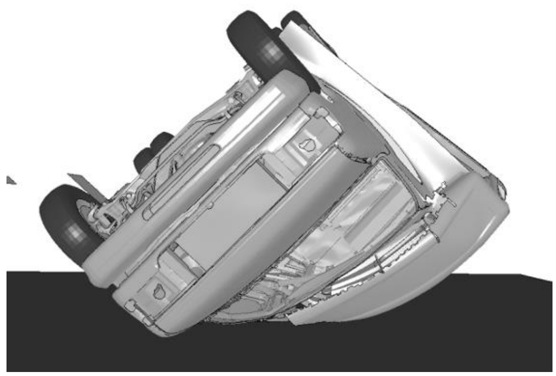
TRACC held a workshop on TRANSIMS applications and development on April 7 to 9, 2010. This was a unique meeting for the TRANSIMS community with high interest from a large mix of participants from FHWA, research centers, universities, and consulting companies. It was also the first meeting where many of the key TRANSIMS users had a chance to meet in person and to exchange ideas and learn about each other's projects.

Participation over the Internet was quite active as well, due to many travel restrictions for potential participants from public agencies (e.g. many local agencies do not allow out of state travel). Several people participated from overseas, including a professor of the University of Wollongong in Australia. The number of participants at TRACC was around 30, with many more over the Internet. At the peak, 29 remote connections were listening in. Remote users were connected for a total of 158 hours in 190 separate sessions. Due to the fact that providing names upon connecting was optional (and that a single connection had likely more than one researcher participate), we estimate from the information provided by remote participants that we had about 60 individual people listening in at various times. Altogether, the TRANSIMS workshop was considered a great success by the participants, and helped with regards to a number of long recognized problems, such as a push towards more consistent documentation and the need for an improved forum and support web site.

Computational structural mechanics

FAMU-FSU College of Engineering was working on the project titled: “Best Practice Guidelines for Construction of Paratransit Buses”. The project was a continuation of two previous research projects conducted for the Transit Office of the Florida Department of Transportation. Experiences gained from those studies helped FDOT in development of the Crashworthiness and Safety Assessment Standard for Paratransit Buses, which became effective in August 2007. In this quarter FDOT conducted a full scale rollover test at the Florida Department of Transportation’s (FDOT) facility located in Tallahassee, Florida. The test was conducted on a Champion Challenger bus with a 158 inch long chassis. The purpose of this test was to acquire data to be used in the validation of a previously developed finite element model by current TRACC employee Dr. Cezary Bojanowski. Selected

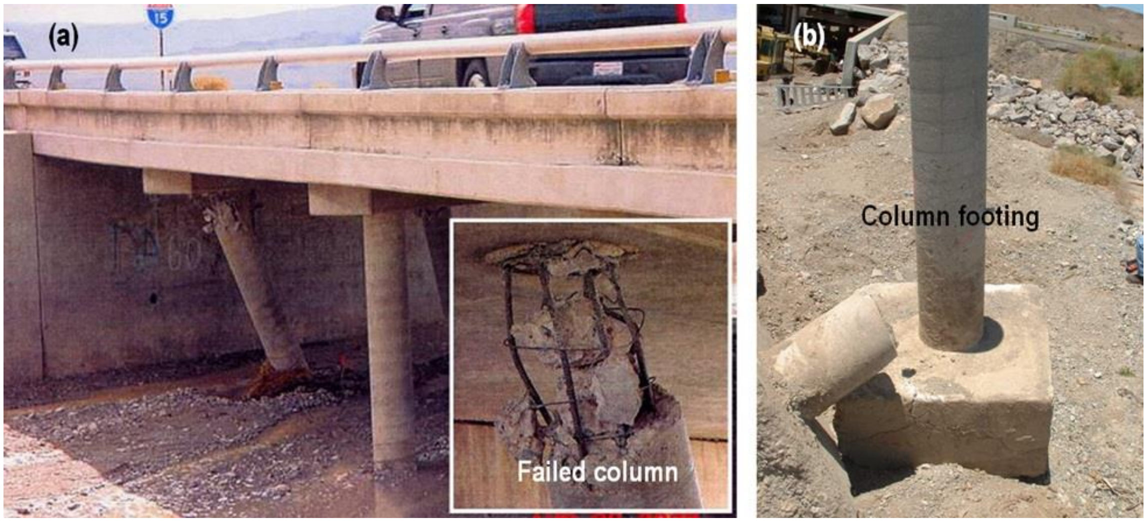


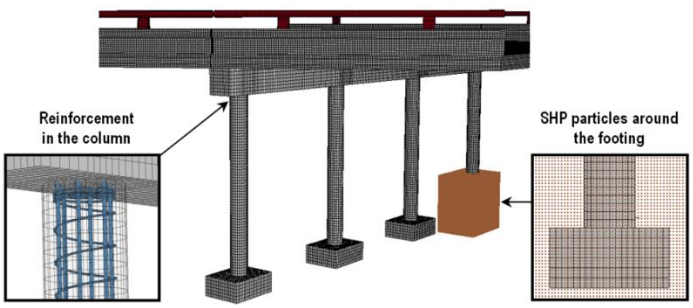


pictures from the test and the equivalent simulation are shown below. The experiment together with conducted simulations has proven credibility of the FE models and applied modeling techniques. TRACC staff performed an additional study on multi-objective optimization of the bus structure subject to rollover and side impact test simulations. Linear ANOVA and Sobol’s Indices were used to identify and rank the most relevant elements of the structure for the objective functions considered.

The number of TRACC cluster users in the area of computational structural mechanics was increasing. New users from Worchester Polytechnic Institute and Clemson University were assigned TRACC Cluster accounts. Worchester Polytechnic Institute planned to use the TRACC cluster to study the propagation of ground vibrations resulting from pile driving at construction sites. These vibrations can damage surrounding structures, and this is a serious concern. This work was performed for the Louisiana Department of Transportation. Clemson University was planning on studying the rate of deterioration of bridges and pavements as affected by trucks for South Carolina Department of Transportation. Part of the work proposed by Clemson coincided with current work in TRACC’s Computational Structural group, which at that time was the traffic loading on cable stayed bridges.

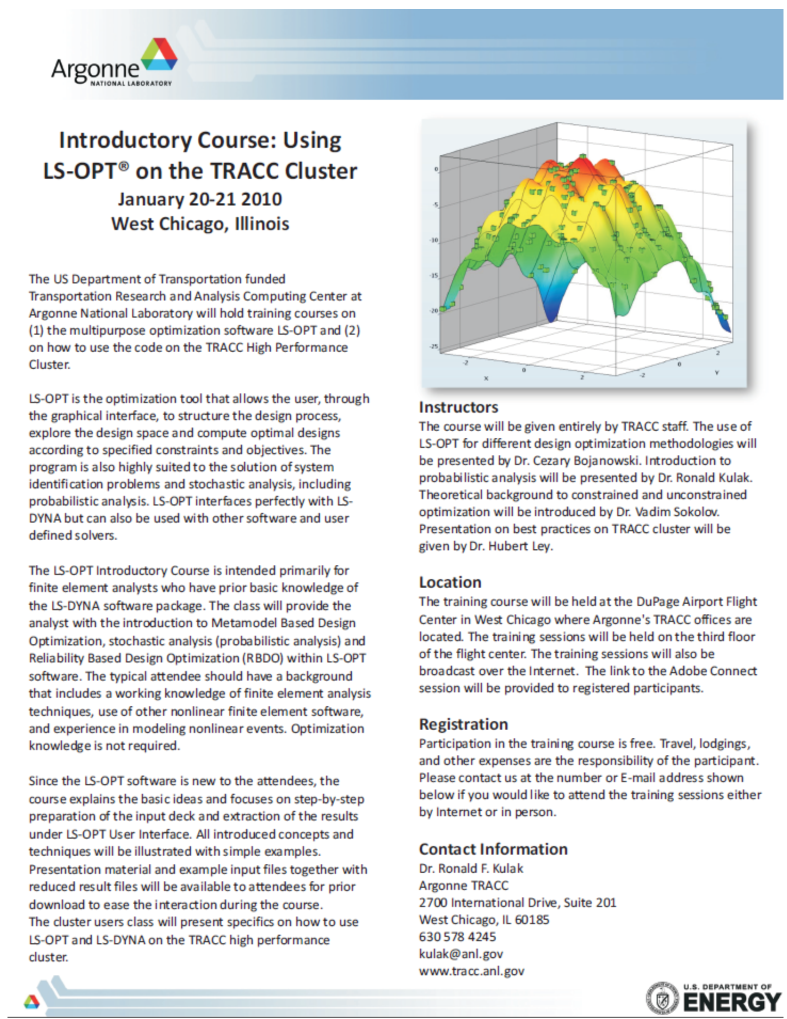
TRACC CSM staff continued the work on developing a multiphysics approach to evaluate the stability of bridges with piers in scour holes. Once the most suitable method of soil-structure interaction modeling was chosen, the next step in the research was to apply it to reconstruct a real life problem of bridge stability. Sufficient amount of data was gathered to build a finite element model





of Oat Ditch Bridge located in California and model its failure during the flood of 2003. The Oat Ditch Bridge on I-15 is a 5-span continuous reinforced concrete slab on 4 reinforced concrete bent columns. Each column was first supported by an individual rectangular footing pad. Although analyzed for scour in 2000 and found to be not scour critical, three columns at bent five of the bridge failed during the flood on 08/19-20/2003. As reported by California DOT, during the flood the bending moment created by hydraulic forces caused the concrete failure at the abutment of columns in the pier bent. The analysis of the failure followed in the upcoming quarter.

During this reporting period, two computational structural mechanics training courses were given. The first course entitled “Introductory Course: Using LS-OPT® on the TRACC Cluster” was given entirely by TRACC staff on January 20-21. Participation included 13 onsite participants and 20 internet participants for a total of 33. The video recordings were posted on the TRACC website along with the course advertisement. The second course, entitled Modeling and Simulation, was offered on February 11-12. Two international experts, Dr. Len Schwer and Mr. Paul Du Bois, were invited to present the course. There were 8 onsite participants and 29 internet participants (via Adobe Connect) for a total of 37. Because of contractual agreement with the presenters, the video recordings are available only to the following: TRACC staff, class participants and TRACC collaborators. Both training courses were attended by university professors and their students, federal and state DOTs, and commercial companies.



Argonne NATIONAL LABORATORY

Introductory Course: Using LS-OPT® on the TRACC Cluster
January 20-21 2010
West Chicago, Illinois

The US Department of Transportation funded Transportation Research and Analysis Computing Center at Argonne National Laboratory will hold training courses on (1) the multipurpose optimization software LS-OPT and (2) on how to use the code on the TRACC High Performance Cluster.

LS-OPT is the optimization tool that allows the user, through the graphical interface, to structure the design process, explore the design space and compute optimal designs according to specified constraints and objectives. The program is also highly suited to the solution of system identification problems and stochastic analysis, including probabilistic analysis. LS-OPT interfaces perfectly with LS-DYNA but can also be used with other software and user defined solvers.

The LS-OPT 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 Metamodel Based Design Optimization, stochastic analysis (probabilistic analysis) and Reliability Based Design Optimization (RBDO) within LS-OPT software. The typical attendee should have a background that includes a working knowledge of finite element analysis techniques, use of other nonlinear finite element software, and experience in modeling nonlinear events. Optimization knowledge is not required.

Since the LS-OPT software is new to the attendees, the course explains the basic ideas and focuses on step-by-step preparation of the input deck and extraction of the results under LS-OPT User Interface. All introduced concepts and techniques will be illustrated with simple examples. Presentation material and example input files together with reduced result files will be available to attendees for prior download to ease the interaction during the course.
The cluster users class will present specifics on how to use LS-OPT and LS-DYNA on the TRACC high performance cluster.

Instructors
The course will be given entirely by TRACC staff. The use of LS-OPT for different design optimization methodologies will be presented by Dr. Cezary Bojanowski. Introduction to probabilistic analysis will be presented by Dr. Ronald Kulak. Theoretical background to constrained and unconstrained optimization will be introduced by Dr. Vadim Sokolov. Presentation on best practices on TRACC cluster will be given by Dr. Hubert Ley.

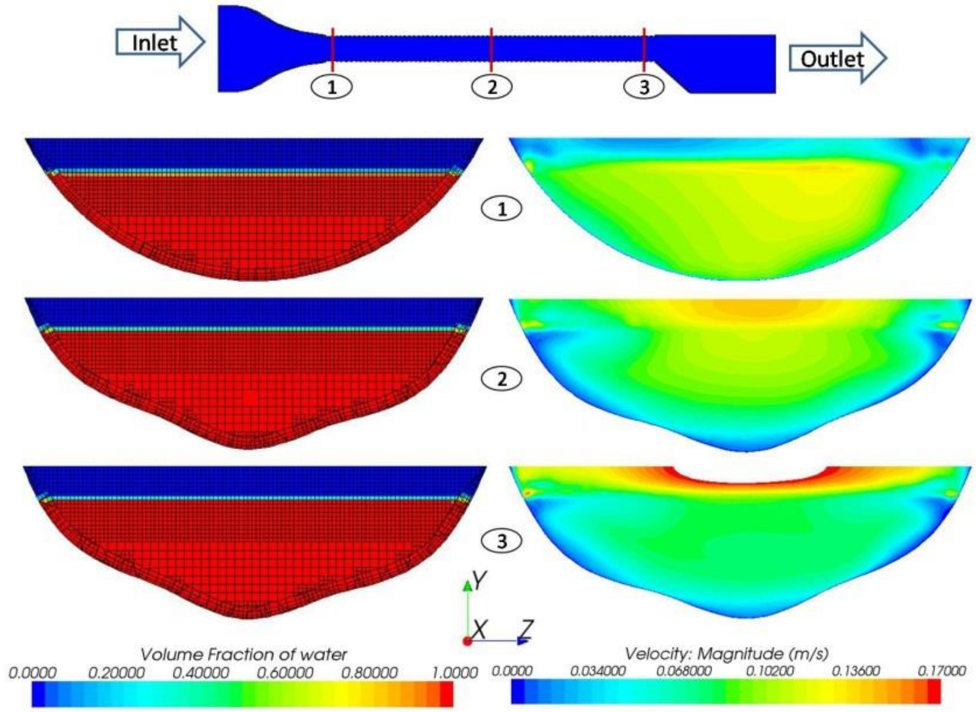
Location
The training course will be held at the DuPage Airport Flight Center in West Chicago where Argonne's TRACC offices are located. The training sessions will be held on the third floor of the flight center. The training sessions will also be broadcast over the Internet. The link to the Adobe Connect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

Registration
Participation in the training course is free. Travel, lodgings, 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
Dr. Ronald F. Kulak
Argonne TRACC
2700 International Drive, Suite 201
West Chicago, IL 60185
630 578 4245
kulak@anl.gov
www.tracc.anl.gov

U.S. DEPARTMENT OF ENERGY

Computational Fluid Dynamics



Scour model development was continued on both a flooded bridge deck under conditions of pressure flow scour and scour at a cylindrical bridge pier. A primary problem in scour model development was to deal with bed displacements that then require propagation of the bed displacements through the mesh. While moving mesh capabilities existed in most commercial CFD software including CD-adapco's STAR-CD and STAR-CCM+, these capabilities were first for problems that involved uniform mesh motion, such as the motion of the piston in the analysis of in cylinder combustions. Arbitrary motion of a mesh arising from large boundary displacement that depends on the solution of the flow field and forces exerted on the boundary were under development with the goal to handle FSI problems. The available options in both STAR-CD and STAR-CCM+ for boundary displacement and mesh motion were under investigation. One of the feasibility studies using STAR-CD allowed for rapid exploration by limiting the problem to two dimensions using the flooded bridge deck problem and focusing on a two dimensional slice down the center of the channel. Progress was made with this approach, however, it depended on detailed knowledge of the STAR-CD mesh point numbering for the particular geometry, which was very simple, and on user coding to morph the mesh. While the methodology worked fairly well, it would require a great deal of development effort to adapt it to other geometries and no easy route to adapt it for arbitrary three dimensional geometries.

A new culvert geometry model was built because the Turner-Fairbank hydraulics laboratory converted its culvert experimental flume from a quarter culvert to a smaller diameter half culvert that would fit in the flume. This change removed the physically unrealistic Plexiglas wall that ran down the centerline of the previous experimental culvert. The new model was meshed out with a much finer grid in the zone containing the free surface to verify that the position of the free surface could be well resolved with a finer mesh. The culvert barrel had spiral corrugations and was joined at its ends to short sections of circular corrugated culvert that could be easily joined to the converging channel at the inlet and the diverging channel at the outlet. An initial comparison with the experimentally determined water depth along the length of the culvert barrel yielded a good match with the computational model results.

CFD Training Course for Hydraulic and Aerodynamic Analysis Held March 15 to 17

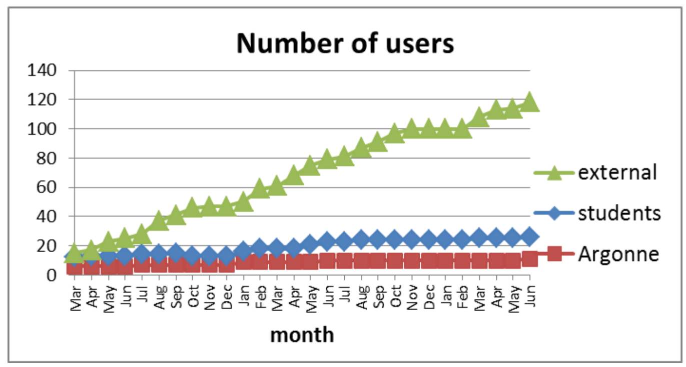
Work on development of training materials and new tutorials for a CFD training course based on STAR-CD was completed in March, and the first offering of this course was conducted on March 15-17, 2010. Experience with the previous STAR-CCM+ CFD training course and feedback from trainees indicated that the tutorials were considered to be one of the most valuable parts of the course. Therefore an effort was made to develop new tutorials relevant for civil engineers and students doing transportation research and analysis. The new tutorials included analysis of a simple free surface flow problem, hydraulic CFD analysis of forces on a flooded bridge deck, aerodynamic CFD analysis of high wind load distribution on road side signs, and a methodology for analysis of pressure flow scour under flooded bridge decks. CD-adapco provided their STAR-CD basic training material and a trial licenses for trainee laptop computers to allow participants at TRACC and

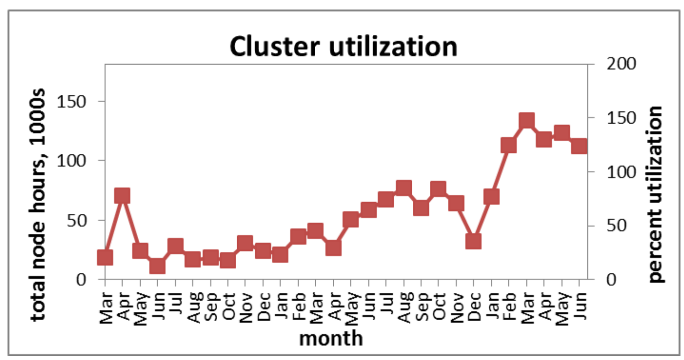
remote participants to get hands-on experience with the software by working on the tutorials as a learning vehicle during the class. Additional material on the use of the TRACC cluster was added.

One technical problem faced by the instructors in preparing for the course was resolving issues related to installing trial licenses for the software on participant laptop computers to enable them to participate in doing the tutorials. This difficulty was primarily a consequence of the complexity of the license server software. It was overcome by providing direct help via video conferencing to a primary contact at each of the remote locations, if needed, in the software installation procedures about a week before the course and then having the primary contact help others at the remote location install the software.

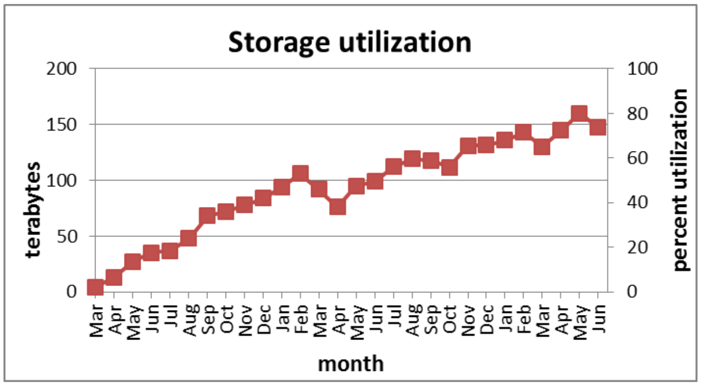
A major advantage of using the videoconferencing for CFD training appears to be that a training class can be composed of several small groups of participants at different locations, when participants in the small groups cannot afford to travel to a central location for a course and when instructors cannot afford to travel to a distant location to provide training for a group of less than about ten participants. Thus the videoconferencing option allowed knowledge of how to use CFD tools to be disseminated via training in virtual classes much more rapidly than when it was restricted to real classes in a single location with ten or more people.

April 2010 to June 2010





The number of users of the cluster in June 2010 increased to 118, 11 of whom are Argonne employees, 15 students working directly with Argonne, and 92 external government and academic users. The TRACC project achieved significantly expanded overall user education, training and support. TRACC staff experienced in the key applications and software and the availability of state-of-the-art visualizations and communications facilities provided by TRACC partners at the University of Illinois were essential components of our success in these outreach activities.



Throughout the TRACC project, applications software products have been obtained and implemented on the TRACC high performance computing system in order to meet the needs and requirements of USDOT researchers and the broader TRACC user community. In May 2010, TRACC added MADYMO, a CSM code that could be coupled with LS-DYNA.

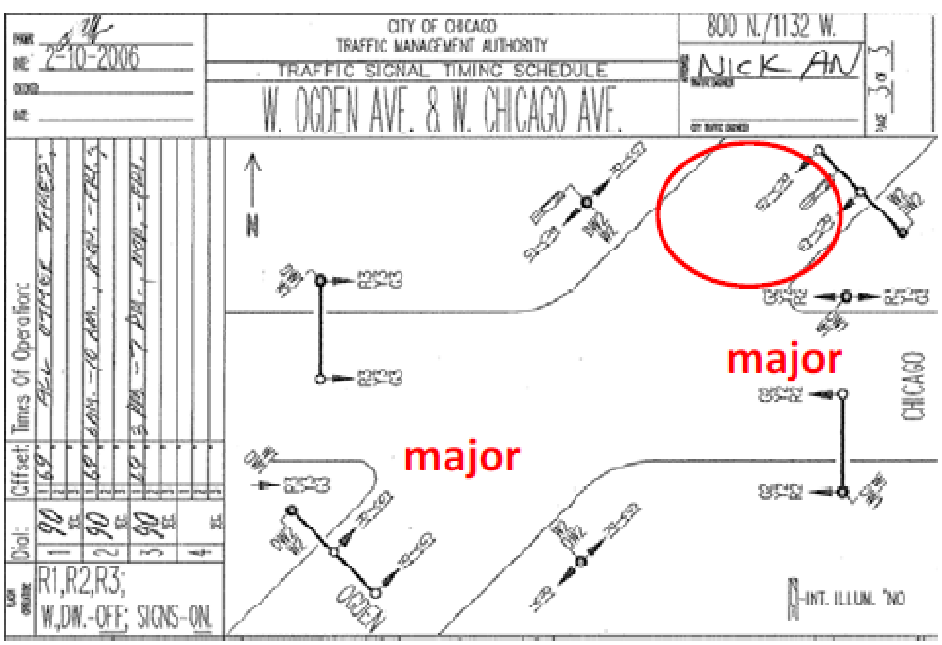
Transportation systems simulation

The team from the Illinois Institute of Technology working together with the Chicago Department of Transportation and the Chicago Metropolitan Agency for Planning on a TRANSIMS model for the City of Chicago was hosted by TRACC since early 2010. The co-location of the TRACC and IIT teams ensured an effective transfer of knowledge and ensured that the improvements of the Chicago model flow back to the work performed at TRACC. The IIT team was funded separately by FHWA, and made great progress in modifying and improving the Chicago model.

The TRANSIMS Studio application, recently developed by TRACC for the TRANSIMS user community, was increasingly rolled out to testers and early adopters. Feedback from users was provided to the developers and was used to identify bugs and improve the usability of the software. The latest version of the software included for the first time the TransimsVIS visualization application.

Some of the key features that were added include a mechanism to save hard drive space by removing unneeded files automatically without disturbing the equilibration mechanism. This algorithm was enhanced by an automatic recovery feature that triggers re-execution of a script in case there was a need for a previously removed file. On a typical TRANSIMS model, this methodology may save 90% of the disk space requirements that would otherwise be needed.

Based on a previous effort by RSG (Resource System Group Inc.) of collecting the documentation of about 40% of the more than 1000 individual keys used across TRANSIMS, the automatic help system feature was rewritten to build quick reference documents for the TRANSIMS Studio built-in help system automatically. The methodology made it easier to maintain an updated and consistent rule base and documentation system for TRANSIMS Studio.



A new release of TRANSIMS itself was prepared in late June 2010, and work on the new version 5.0 started. TRACC staff was involved in the design and conceptualization as part of the open source development team. The new software laid the foundation of much of the upcoming Chicago Evacuation project and other US TRANSIMS projects.

The tenth TRANSIMS training course was held in Baton Rouge for Louisiana

TRANSIMS
Training Course at LSU
Agenda

Wednesday, May 26, 2010

9:00 am	Introductions, Project Overview, Discussion of Agenda
9:15 am	Background of TRANSIMS at TRACC and ***LSU's Experience with Katrina Model*** - *Section 0*
10:15 am	**Coffee Break**
10:30 am	General Overview of TRANSIMS and its Components - *Section 1*
12:00 pm	**Lunch Break**
1:15 pm	The TRANSIMS Road and Transit Networks - *Section 2*
2:45 pm	**Coffee Break**
3:00 pm	The TRANSIMS Router - *Section 5*
4:30 pm	Discussions
5:00 pm	**Adjourn**

Thursday, May 27, 2010

9:00 am	The TRANSIMS Microsimulator - *Section 6*
10:30 am	**Coffee Break**
10:45 am	TRANSIMS Trip Table Conversion - *Section 10*
12:00 pm	**Lunch Break**
1:15 am	TRANSIMS Control Files and Syntax - *Section 9*
2:00 pm	TRANSIMS Configuration and Framework - *Section 8*
3:00 pm	**Coffee Break**
3:15 pm	The TRANSIMS Open Source Project – Available Resources - *Section 13*
3:45 pm	Visualization Tools and Techniques - *Section 17*
4:30 pm	Discussions
5:00 pm	**Adjourn**

Friday, May 28, 2010

9:00 am	TRANSIMS Feedback and Equilibration - *Section 7*
10:30 am	**Coffee Break**
10:45 am	TRANSIMS GIS Tools - *Section 11*
11:15 am	TRANSIMS Subarea Simulation - *Section 12*
12:00 pm	**Lunch Break**
1:15 pm	Introduction to the TRANSIMS SVN Source Code Archive and Code Structure - *Section 15*
2:15 pm	Partitioning and Parallel Processing - *Section 14*
3:00 pm	**Coffee Break**
3:15 pm	TRANSIMS on the TRACC Cluster - *Section 16*
4:30 pm	Discussions
5:00 pm	**Adjourn**

Location

The LTRC Transportation Training and Education Center (TTEC) is located at 4099 Gourrier Avenue at the southern end of LSU's campus.
For information on Baton Rouge accommodations, please visit: http://www.visitbatonrouge.com

Internet Broadcast

http://anl.acrobat.com/transims/

Detailed instructions can be found on the TRANSIMS forum site in the "Front Desk" section.

State University and attracted participants from LSU as well as Houston. The teams were tasked with the development of evacuation models for New Orleans and Houston, and were funded by FHWA and the Department of Homeland Security.

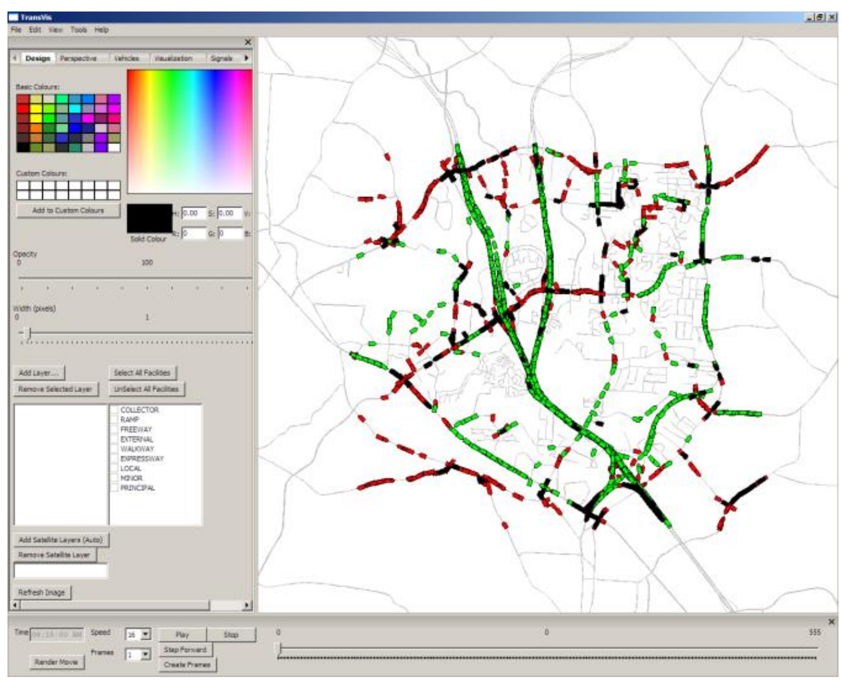
AECOM was collaborating with TRACC on several projects at the time. The major collaboration areas included TRANSIMS software development and maintenance, TRANSIMS training sessions and utilization of TRACC for TRANSIMS project applications. AECOM was leading the development of TRANSIMS Version 5.0 while also maintaining the TRANSIMS Version 4.0 software. TRACC provided feedback and support in this effort which was geared towards better overall user-experience through improved software functionality and performance. The collaboration helped keeping individual TRANSIMS-related development efforts at AECOM and TRACC synchronized and complimentary.

AECOM also shared its TRANSIMS experience through online TRANSIMS training courses conducted by TRACC on a regular basis. Such courses were a convenient way of introducing TRANSIMS to AECOM's clients and workforce.

Advanced visualization

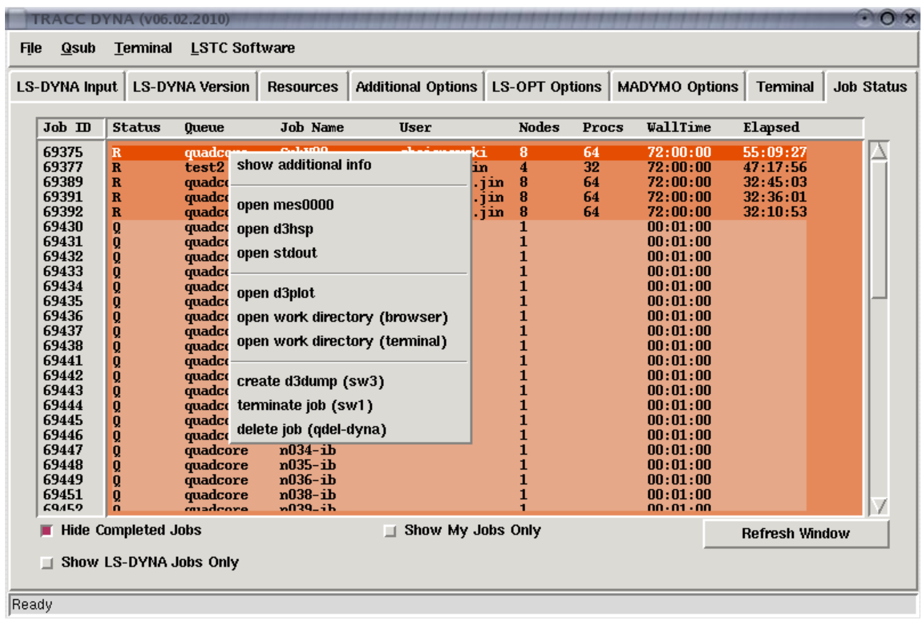
A major addition to the capabilities of TransimsVIS was the creation of high definition animations using a new waypoints feature. Users were able to bookmark positions in time and space, which could be returned to at a later time. This feature was extended to save a series of waypoints at fixed intervals and follow a path between each of them as the simulation plays or records frames. This enabled the creation of a movie which can present multiple traffic situations.

Computational structural mechanics



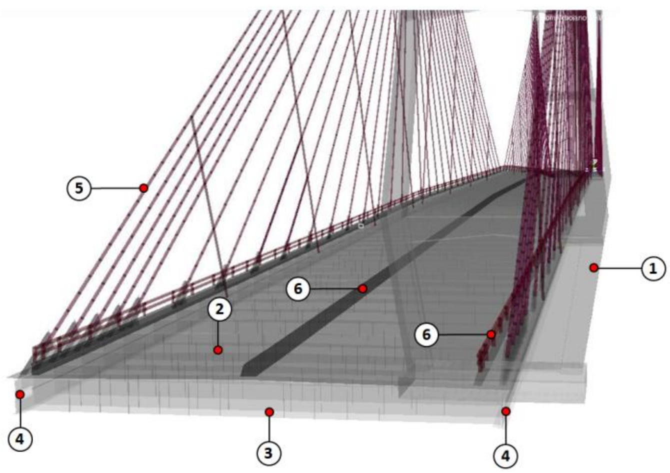
At the request of NHTSA, TRACC was expanding its computational mechanics code offerings to include MADYMO/modeFrontier. NHTSA was interested in greatly expanding its accident reconstruction efforts, and in order to do this, NHTSA needed to use MADYMO/modeFrontier on TRACC's cluster. In the current quarter MADYMO was already operational and modeFrontier was being configured. Also, the Hypermesh software was acquired to pre- and post-process LS-DYNA files and to generate sophisticated meshes for modern FE models.

TRACC gives its cluster users a lot of flexibility when it comes to requesting software version and computational resources for submitted jobs. To fully utilize that flexibility, users need to get familiar with on-line documentation of all the installed releases of different software and modules on the cluster. As on other LINUX based HPC systems the submission and controlling of LS-DYNA jobs at TRACC was done through the text commands. Especially for new users, memorizing and understanding all the commands and submission process lead to confusion and multiple errors. To reduce the number of problems and facilitate quick start for new users on the cluster, TRACC staff developed an application allowing for submitting LS-DYNA® jobs in a graphical mode called qsub-dyna-gui (GUI). The GUI allows for creating job submission scripts, running and checking the status of the jobs. It also allows for tracking the available resources on the cluster. The use of GUI is simple and self-explanatory for current users of LSTC software. The user needs to go through several tabs from the left to the right side and specify input parameters in series of entry fields, checkboxes and dropdown lists. The basic error checking of the input is performed internally in the application. Once all the necessary fields are filled correctly, the application creates a job script and submits the job to the cluster. Subsequently the job can be monitored and results can be easily accessed from the GUI. Problems analyzed by the CSM users frequently involved coupling between several independent codes. Structural optimization tasks can involve coupling between LS-DYNA® and LS-OPT®, and occupant safety analysis in crash problems can involve coupling between LS-DYNA® and MADYMO®. Submitting such jobs is even more complicated through the text based commands. Since all that software was already available on the cluster the GUI also was coded to facilitate submitting coupling jobs. The GUI reduces needed familiarity with the cluster commands to almost zero level. The GUI manual pages, posted on the TRACC Wikipedia, were noticed by several external supercomputing facilities and were ported to their systems. The GUI was requested among others by Army Research Lab, Johnson Space Center - NASA, University of Virginia, University of Nebraska.



TRACC staff directed thesis research by two Northern Illinois University students and worked with them on two projects: cable-stay bridge vibrations due to traffic loading and aerodynamic loading on stay cables. As part of this effort the user defined loading *loadud* subroutine was being developed for LS-DYNA code to apply wind loading to cables. A series of relatively simple problems have been designed to assure its validity and the validity of the formulation developed for computing the nodal load vector for a cable finite element subjected to wind loading.

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. This is a cable-stayed bridge connecting Missouri's Route 34 and Route 74 with Illinois Route 146 across the Mississippi River. The choice of the bridge was made primarily upon the availability of the geometry, material properties, and experimental data for the natural frequencies of the bridge structure. A validation study was performed on the model through comparison of calculated and experimentally obtained first seven natural modes of vibration and associated with them frequencies. The model was judged as valid and was made available to NIU for implementation of their work.

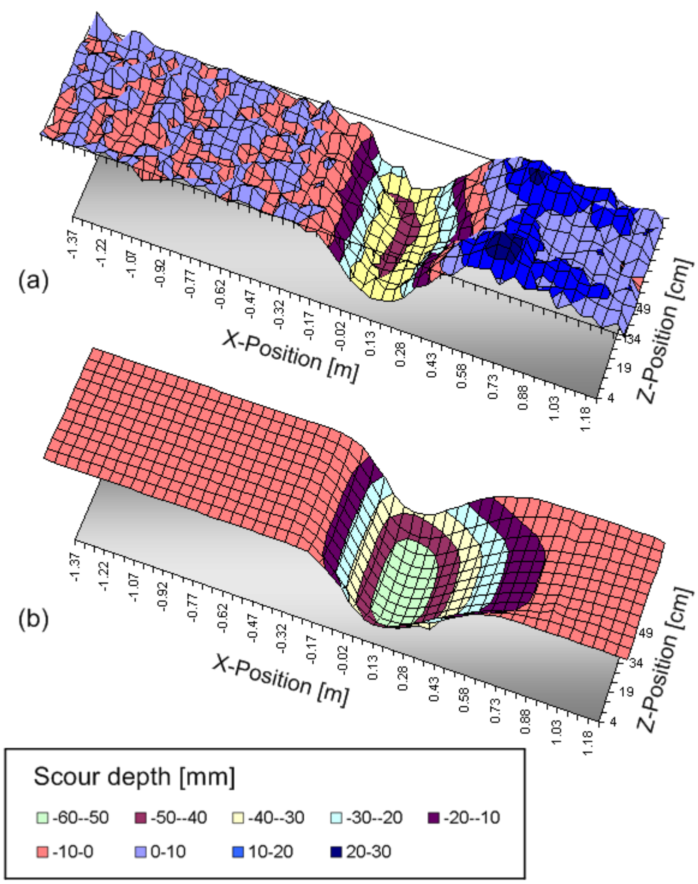


The research and development performed by the Computational Structural Mechanics staff has resulted in the current reporting period in two papers that were accepted by the 11th International LS-DYNA Users Conference in Dearborn, MI:

- *Comparison of Lagrangian, SPH and MM-ALE Approaches for Modeling Large Deformations in Soil* by Cezary Bojanowski and Ronald F. Kulak.
- *Safety Assessment and Multi-objective Optimization of a Paratransit Bus Structure*, Cezary Bojanowski and Ronald F. Kulak.

Computational Fluid Dynamics

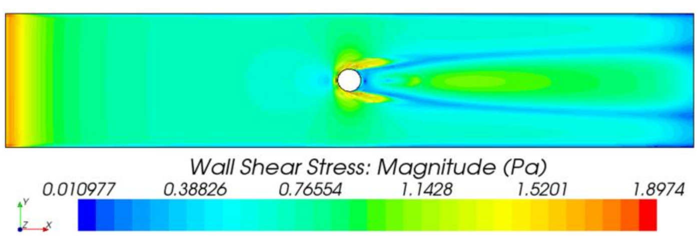
In the third quarter work on the computational procedures for two approaches to managing bed displacements as a function of bed shear stress and moving the entire mesh as a consequence to preserve mesh quality continued. The first effort uses STAR-CD to displace the soured bed. The displaced surface geometry is then exported and the flow domain is remeshed using the STAR-CCM+ automeshing capability. This new volume mesh is then imported into STAR-CD and the flow field is solved again with the new more eroded bed geometry. The sequence is repeated until shear stress on the bed is at or below that required for further scour. This procedure was one that could handle complex 3D geometries, however, it involved a number of user programmed steps, and using the features for handling the geometry changes that occur during scour from 2 separate CFD software packages and transferring geometry files between them at each flow computation iteration in the evolution of scour. While this approach was yielding good results and was one that would work for the full 3D problem at the time, it was an intermediate approach awaiting a CFD software package that had all geometry handling capabilities needed for a scour computation. Even though it was known that the procedure was an intermediate one that would be superseded by better automated methods in the near future, it was a significant success



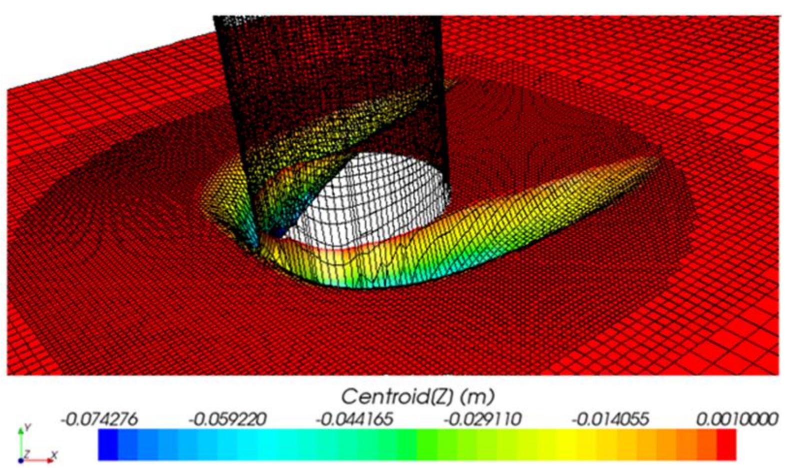
because it was a first demonstration that 3D scour effects observed in laboratory experiments could be computed with commercial CFD software.

The second approach to handling scour geometry changes during scour computation was to use the new mesh morphing capabilities of STAR-CCM+ applied to pier scour. The mesh morphing capability in STAR-CCM+ allowed the bed to be displaced and the mesh to be adjusted for optimum quality (the morphing) as part of the ongoing simulation without stopping the computation to displace the bed with pre-processing geometry handling capabilities at each step in the scour process. The morphing capability was developed for application to fluid structure interaction (FSI) problems with small total displacements. When the scour depth began to become large, the computation did need to be stopped and the flow domain remeshed. This process required an external control program to manage the starting, stopping, surface mesh export, remeshing, and restart of STAR-CCM+, however, all of this could be accomplished with one commercial CFD package.

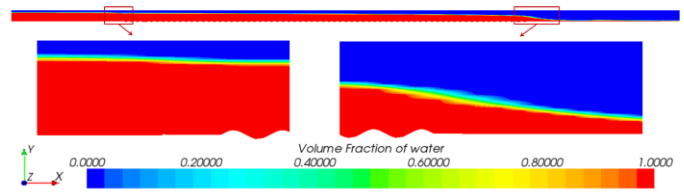
Initial tests on the 3D scour around a cylindrical pier

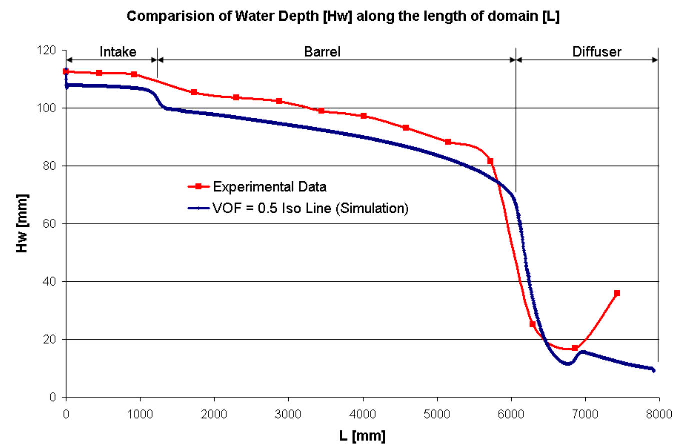


indicated that the procedure worked well, and scour hole depth was close to that predicted experimentally. However, the scour hole shape was much steeper than that observed in experiment. Additional physics models would be required to do better.

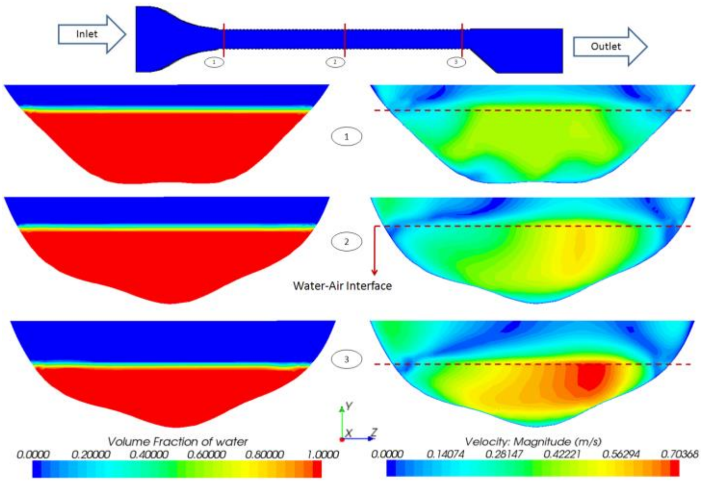


In culvert modeling, two experiments were modeled. One had the flap gate at the exit completely down and the other used a flap gate angle of about eleven degrees. The position of the flap gate at the exit in combination with the pump rate controls the flow rate through the culvert. With the flap gate down, there was a rapid acceleration of water in the diffuser at the end of the barrel with a transition to supercritical flow and a rapid drop in the water depth. These features were captured well by the model.

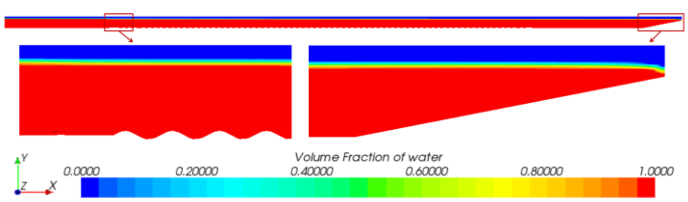




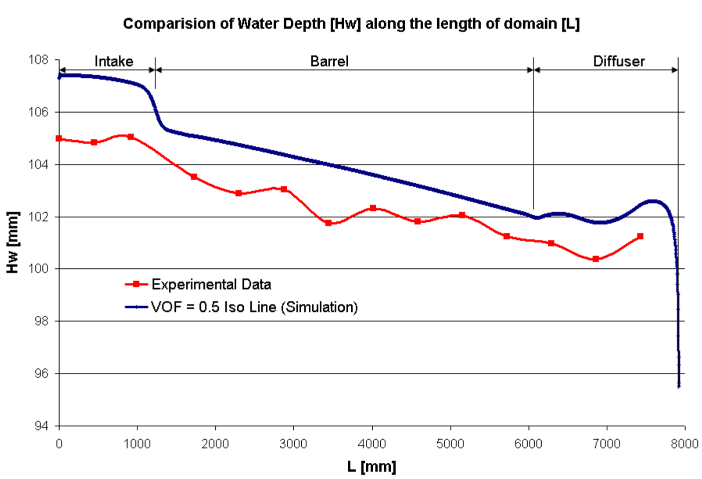
The model also showed that the asymmetric diffuser section at the outlet produced an asymmetric velocity profile in culvert barrel that extended more than halfway upstream to the barrel inlet. This impact of the outlet diffuser geometry was not obvious to flume designers, and requires costly particle image velocimetry (PIV) experiments to verify. The CFD analysis demonstrated that it can be very useful during initial flume design. It can be done at relatively low expense before a candidate flume section design is built and tested, saving a large amount of both funds and time in the flume design and construction process.



In the second case analyzed with the flap gate at 11 degrees, the water level in the flume diffuser did not drop off, which also match the experimental behavior.



Flow over the flap gate is like that of a waterfall and does transition to supercritical. This transition can be captured in the model, but was too difficult and costly to try to capture in the experiments, and showed that CFD analysis can fill in information about the flow state in portions of a flume where it is hard to make measurements.



A University of Iowa team used the TRACC cluster to do large eddy simulation (LES) and detached eddy simulation (DES). They provided TRACC with a summary report on their research showing how they benefited from access to the supercomputing resources available at TRACC. The LES and DES techniques are very compute intensive and are not possible without facilities like TRACC. LES and DES analysis provide the most detailed time varying characterization currently possible using all but the world largest supercomputers. The computations resolve a range of eddy structures in the flow and their fluctuations that relate directly to scour mechanisms and the extent and pattern of scour on a riverbed that is caused by a structure, such as a pier or abutment. A single simulation for a single bridge abutment consumed about six percent of the TRACC cluster resources and required about a month to complete. This computing resource requirement limits the number of cases of this type of analysis to between ten and twenty per year. The results, however, vividly revealed the differences between turbulence models that use averaging over all length scales, and LES and DES turbulence models that do not average over the large scales and preserve eddy structures over those scales. Eddies whose effect on mean bed shear did not yield a mean shear sufficient to cause scour over large portions of the river bed in the vicinity of a bridge abutment, were shown to have sufficient strength in the fluctuating shear stress to cause scour over a much larger area of the river bed than that predicted by the traditional turbulence models.