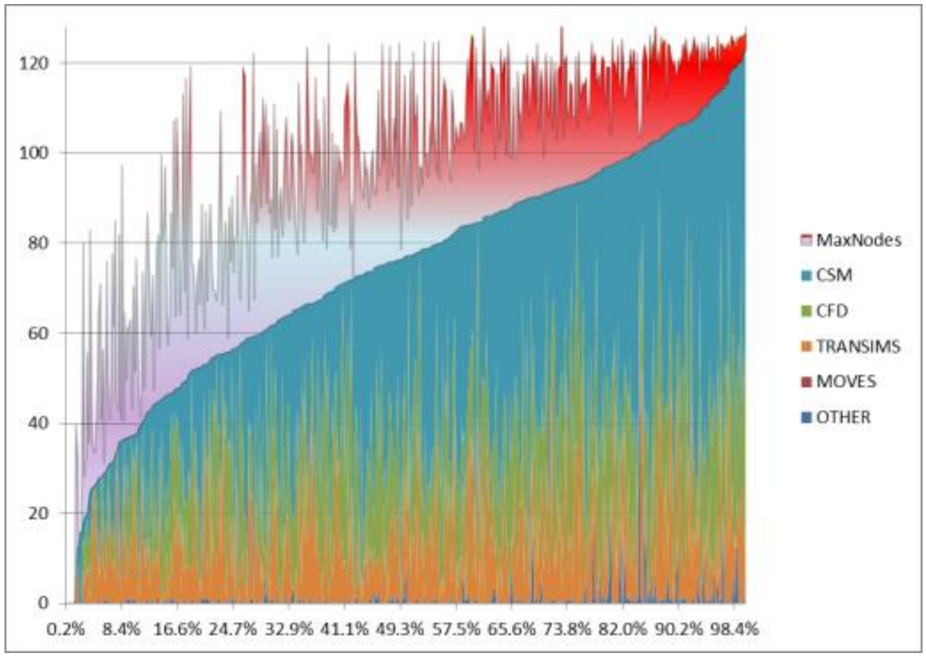
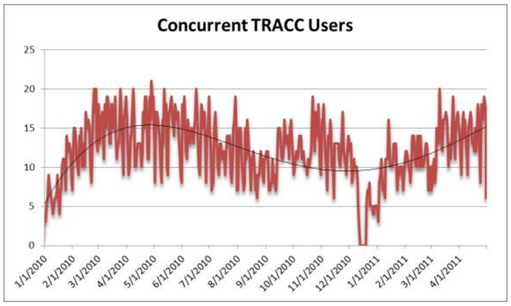
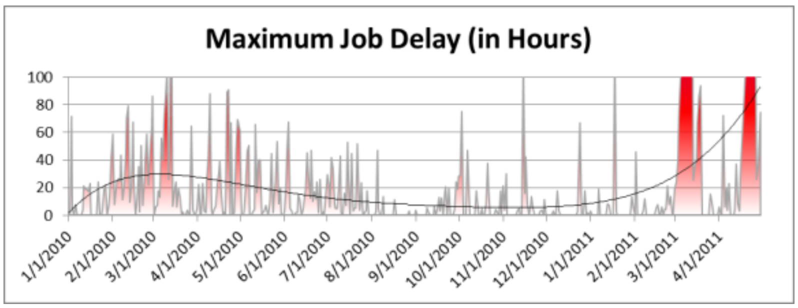
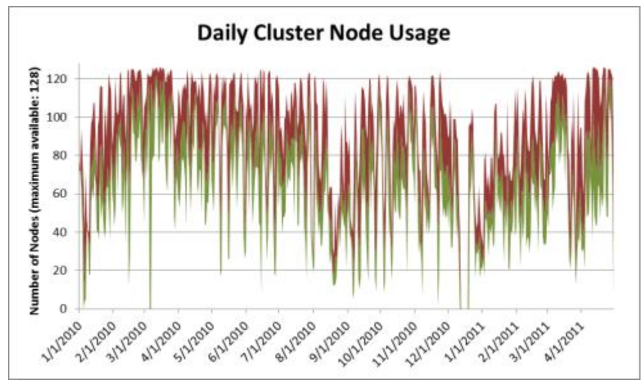
January 2011 to March 2011

The cluster started to be heavily used, with about 125 users. While the load dropped during the holiday season *and summer break, the average* utilization was about 65%. Given the









fact that the TRACC cluster is a limited resource that was being used for relatively large jobs as well as for interactive work, a long term load average beyond 70% significantly reduces the user experience and was detrimental to effective project performance. For example, peak waiting times for larger jobs were at times over 100 hours, a resource shortage that needed to be addressed soon to increase user satisfaction and project performance. Another important factor was the availability of the cluster, which was only turned off twice in the past 2 years. The first time was for a very short time period, while the second time was about 8 days due to the move of the machine from the off-site location at the DuPage Airport Flight Center to the Argonne Site.

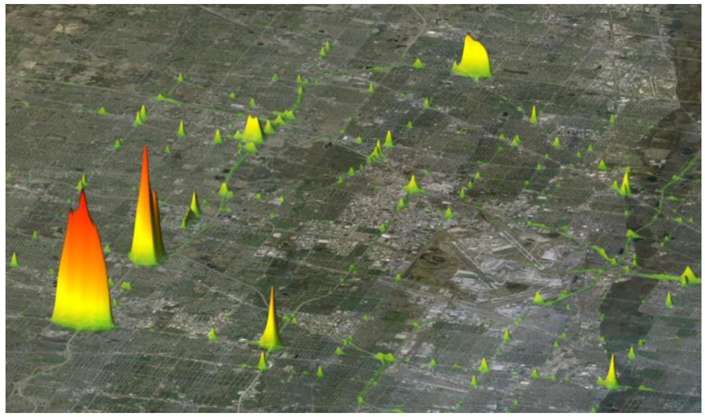
The cluster was actively being used by an average of 12 users, with typical variations from 5 to 20. The usage patterns became more obvious when looking at the overall usage by node. The overall load on the cluster, as well as the wait times experienced by users, caused TRACC to start evaluating the cost of adding or replacing capacity in the current system to increase the usefulness of the existing machine.

Transportation systems simulation

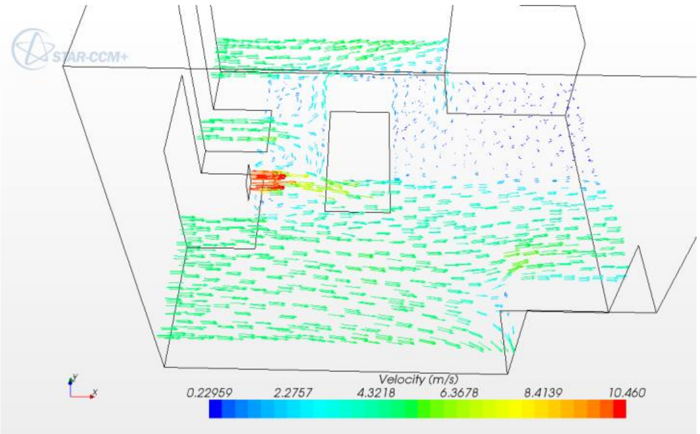
The Regional Transportation Simulation Tool for Evacuation Planning Training course format in January 2011 was different from the usual TRANSIMS training courses. The aim of the course was to bring together modelers working on transportation aspects of evacuation events and to expose existing TRANSIMS functionality and to discuss potential design changes to improve usability of TRANSIMS for this kind of studies. A part of the course was conducted in the form of a workshop, when participants were able to make suggestion for the future developments and comment on existing functionality. The first day covered the basics of TRANSIMS version 4. The supply and demand models as well as assignment procedures and micro-simulation were discussed. The second day was mostly in the form of a workshop and was dedicated to discussions about features to be implemented in the new version 5. The second day of the training course helped the developers to identify necessary design changes and implementation details based on the user's feedback. Most of the discussion was around the changes in the methodology and implementation related to evacuation simulations.

Large-scale evacuations from major cities during no-notice events – such as chemical or radiological attacks, hazardous material spills, or earthquakes – have an obvious impact on large regions rather than on just the directly affected area. The scope of impact includes the accommodation of emergency evacuation traffic throughout a very large area; the planning of resources to respond appropriately to the needs of the affected population; the placement of medical supplies and decontamination equipment; and the assessment and determination of primary escape routes, as well as routes for incoming emergency responders. Compared to events with advance notice, such as evacuations based on hurricanes approaching an affected area, the response to no-notice events relies exclusively on pre-planning and general regional emergency preparedness. Another unique issue is the lack of a full and immediate understanding of the underlying threats to the population, making it even more essential to gain extensive knowledge of the available resources, the chain of command, and established procedures. Given the size of the area affected, an advanced understanding of the regional transportation systems is essential to help with the planning for such events.

The objective of the work on RTSTEP was the development of a multi-modal regional transportation model that would allow for the analysis of different evacuation scenarios and emergency response strategies to build a wealth of knowledge that could then be used to develop appropriate regional emergency response plans. TRACC started this project for the City of Chicago in December 2010, and significant progress had been made by the spring of 2011. The team at TRACC was fully assembled. Three new staff members were hired at TRACC, in junior engineering and postdoctoral positions. All of them were experts in transportation system modeling.



An important part of this work involved the redesign of the visualization software. The new approach, based on OpenGL and other advanced programming concepts, led to a fully interactive three-dimensional navigation environment, allowing users to go forward and backward in space and time and observe the data from any observation point in space. Algorithms were developed to visualize congestion patterns macroscopically to attract the attention of the user and make use of the human visual system.



TRACC's TRANSIMS microsimulation capability allowed for the estimation of radiological exposures as an aggregate on an individual personal level. This addressed securing the availability of a suitable plume dispersion model, and subsequent integration with the TRANSIMS model developed for RTSTEP. In addition to the utilization of existing capabilities, an alternative path for the development of a dispersion modeling capability was explored. In March 2011, an initial CFD model of urban air flow was built by leveraging in-house computational fluid dynamics capabilities at TRACC.

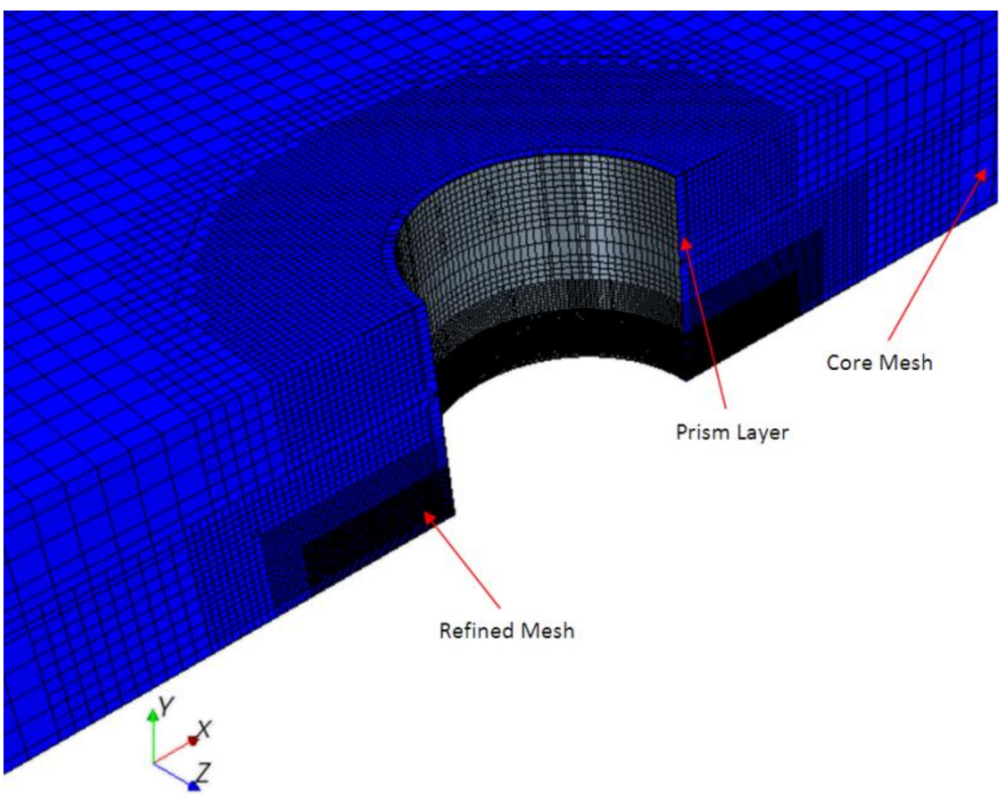
Computational Fluid Dynamics

Pier Scour Modeling

Incorporation of new physics models into the pier scour model with mesh morphing was begun. The first of these enhancements was to account for the effect of bed slope on the critical shear stress that determines the onset of erosion. Particles are set into motion at a lower shear stress on a downslope and a higher shear stress on an upslope. This model was a necessary addition to the scour physics, but did not resolve the overly steep slope of the computed scour hole in front of and to the side of the pier.

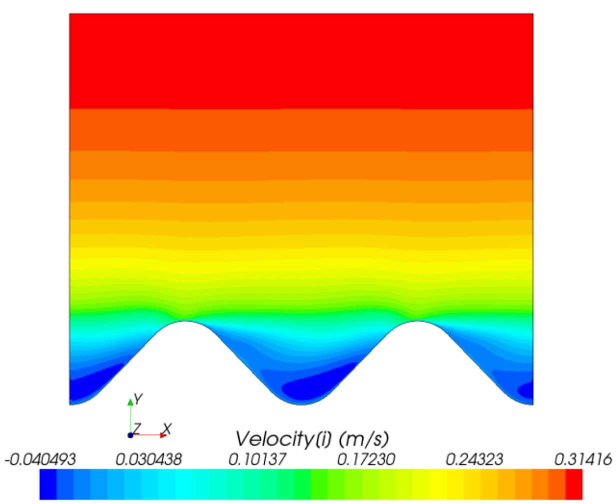
Culvert Modeling

The focus of the culvert modeling effort turned to evaluation of flow through culverts under low flow conditions to allow for fish passage. Fish passage through culverts is an important component of road and stream crossing design. As water runoff volume increases, the flow often actively degrades waterways at culverts and may interrupt natural fish migration. Culverts are fixed structures that do not change with changing streams and may instead become barriers to fish movement. The most common physical characteristics that create barriers to fish passage include excessive water velocity, insufficient water depth, large outlet drop heights, turbulence within the culvert, and accumulation of sediment and debris. Major hydraulic criteria influencing fish passage are: flow rates during fish migration periods, fish species, roughness, and the length and slope of the culvert.



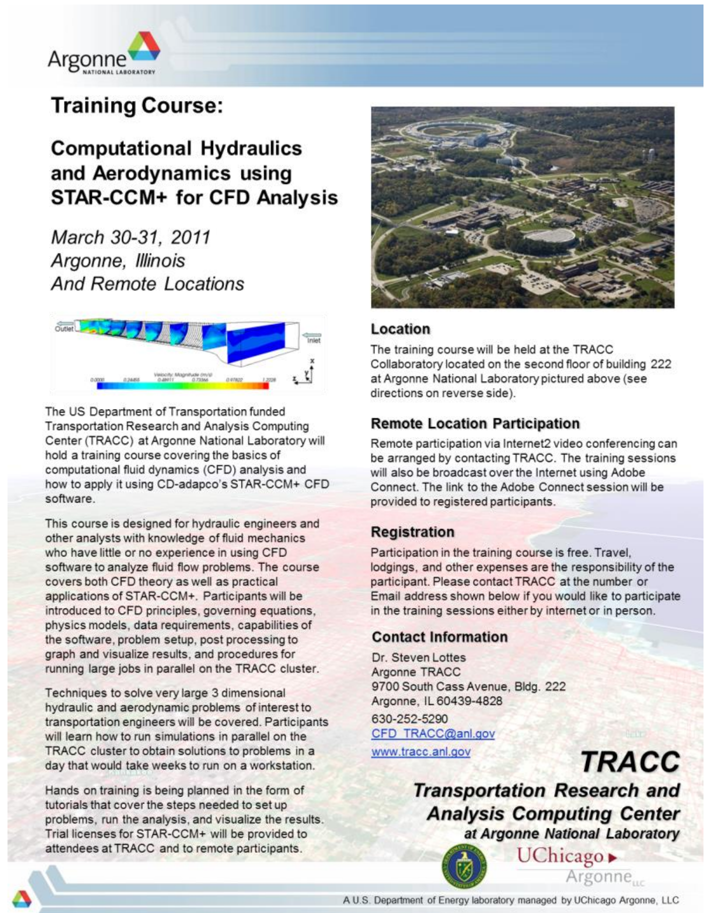
The objective of the new culvert analysis project was to develop approaches to CFD modeling of culvert flows and to use the models to perform analysis to assess flow regions for fish passage under a variety of flow conditions. The flow conditions to be tested with CFD analysis were defined in the tables of a work plan from Turner Fairbank

Highway Research Center (TFHRC). The CFD models were verified by comparing with data from experiments conducted at the TFHRC. A primary goal of CFD analysis of culverts for fish passage was to determine the local cross section velocities and flow distributions in corrugated culverts under varying flow conditions. A typical culvert simulation that included the entire length of the culvert would consume several days or more of wall clock time on the TRACC cluster. A more computationally efficient means to determine the cross section velocity distribution in a large set of culverts under different conditions was sought. Fully developed flow conditions were determined to be adequate for the intended more refined culvert design guidelines, and a very computationally efficient method to compute the flow under these conditions appeared to be to use a very short segment of the culvert barrel with cyclic boundary conditions. With cyclic boundary conditions under the fully developed flow condition, the outlet flow is fed back in as the inlet condition with a pressure jump to compensate for the pressure loss through the domain. The conditions were designed for straight pipe flow analysis and testing showed that simulations matched theoretical results for straight pipes. Culvert barrels are however often corrugated, and it was not known if the cyclic boundary conditions could be successfully applied to a culvert segment cut through troughs. This was of particular concern because the inlet to outlet interface would cut through a recirculation zone in the troughs. Tests showed that the cyclic boundary conditions did work well in this geometry.



CFD Training Course

A new STAR-CCM+ training course was planned and scheduled to be held as soon as the new training facility for TRACC's on site location was ready with video conferencing facilities and two screens for content and viewing from virtual class rooms at remote sites. The training course, "Computational Hydraulics and Aerodynamics using STAR-CCM+ for CFD Analysis" was held on March 30-31, 2011.



Argonne NATIONAL LABORATORY

Training Course:

Computational Hydraulics and Aerodynamics using STAR-CCM+ for CFD Analysis

March 30-31, 2011
Argonne, Illinois
And Remote Locations

The US Department of Transportation funded Transportation Research and Analysis Computing Center (TRACC) at Argonne National Laboratory will hold a training course covering the basics of computational fluid dynamics (CFD) analysis and how to apply it using CD-adapco's STAR-CCM+ CFD software.

This course is designed for hydraulic engineers and other analysts with knowledge of fluid mechanics who have little or no experience in using CFD software to analyze fluid flow problems. The course covers both CFD theory as well as practical applications of STAR-CCM+. Participants will be introduced to CFD principles, governing equations, physics models, data requirements, capabilities of the software, problem setup, post processing to graph and visualize results, and procedures for running large jobs in parallel on the TRACC cluster.

Techniques to solve very large 3 dimensional hydraulic and aerodynamic problems of interest to transportation engineers will be covered. Participants will learn how to run simulations in parallel on the TRACC cluster to obtain solutions to problems in a day that would take weeks to run on a workstation.

Hands on training is being planned in the form of tutorials that cover the steps needed to set up problems, run the analysis, and visualize the results. Trial licenses for STAR-CCM+ will be provided to attendees at TRACC and to remote participants.

Location

The training course will be held at the TRACC Collaboratory located on the second floor of building 222 at Argonne National Laboratory pictured above (see directions on reverse side).

Remote Location Participation

Remote participation via Internet2 video conferencing can be arranged by contacting TRACC. The training sessions will also be broadcast over the Internet using Adobe Connect. 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 TRACC at the number or Email address shown below if you would like to participate in the training sessions either by internet or in person.

Contact Information

Dr. Steven Lottes
Argonne TRACC
9700 South Cass Avenue, Bldg. 222
Argonne, IL 60439-4828
630-252-5290
CFD_TRACC@anl.gov
www.tracc.anl.gov

TRACC
Transportation Research and Analysis Computing Center at Argonne National Laboratory

UChicago Argonne LLC

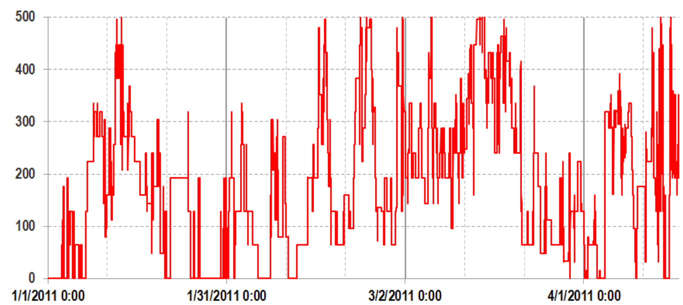
A U.S. Department of Energy laboratory managed by UChicago Argonne, LLC

The course included lectures covering an introduction to CFD theory, best practices in setting up and solving CFD problems, and a heavy emphasis on hands-on learning through the use of tutorials. CD-adapco supported the training effort by providing temporary licenses to the trainees for installation of the software on their laptop computers to do the tutorials during the course and experiment with variations of the tutorials or other small problems for about a week after the course. The course was based on CD-adapco training lectures and one CD-adapco tutorial, but was designed for the relatively new user community of hydraulic and wind engineers. Four tutorials covering methods needed for solving problems in hydraulics and wind engineering were developed. The tutorials covered setting up problems with

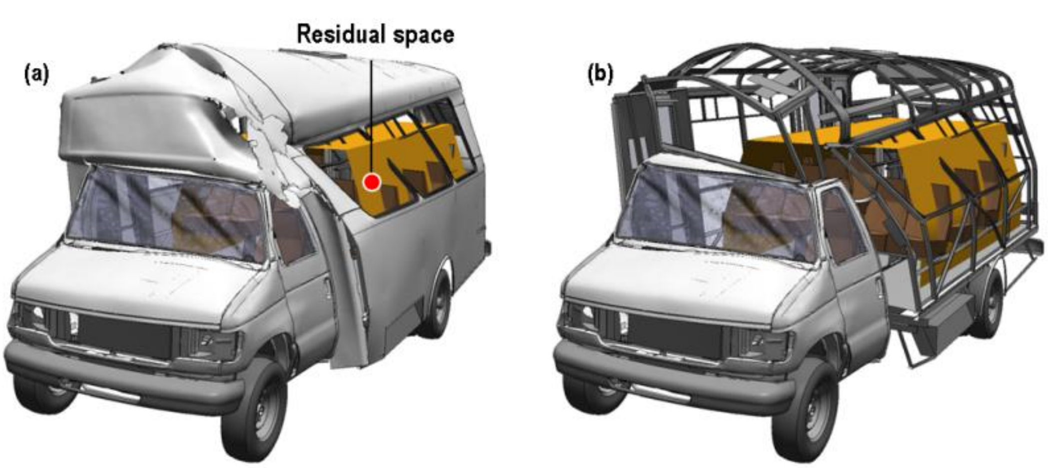
a free surface as in open channel hydraulics flows, analysis of the flow of 80 mph wind past a pair of road signs in close proximity, a method for modeling fully developed flow through culverts using cyclic boundary conditions, computing the forces on a flooded bridge deck, and a method for transient boundary displacement with mesh morphing to maintain mesh quality needed to model riverbed erosion during floods. Each of the half day sessions included work on a tutorial.

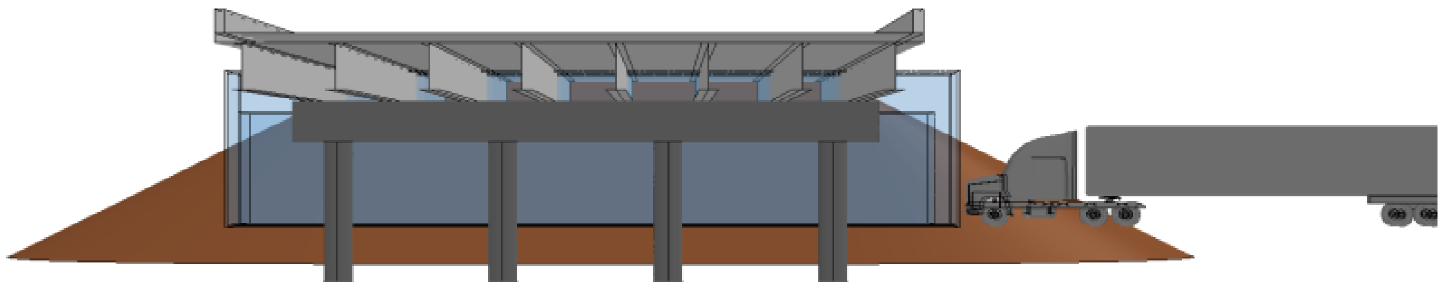
Computational structural mechanics

TRACC's Computational Structural staff continued its support to the external users. LS-DYNA usage on the cluster varied but frequently all the 500 licenses were in use. The average usage over the last three months was equivalent to 190 cores with continuous load. The heaviest users of the LS-DYNA package in the recent quarter were Florida State University, NHTSA and TRACC with Northern Illinois University (NIU). The new NIU students started to heavily utilize TRACC resources for analyzing vehicle stability under high wind loads and design and analysis of electromagnetic shock absorbers for vehicle stability under high wind conditions.



The research conducted by FAMU-FSU College of Engineering was focused on comparison of the results of two crashworthiness testing standards: Federal Motor Vehicle Safety Standard FMVSS 220 standard "School bus rollover protection" and UN ECE Regulation 66 – "Strength of the superstructure of large passenger vehicles". Several states in the US adopted the quasi-static symmetric roof loading procedure according to the standard FMVSS 220 for testing the integrity of the paratransit buses. However, as many researchers point out, the dynamic rollover test according to UN-ECE Regulation 66 (ECE-R66), which was approved by more than forty countries in the world, (excluding the US), may provide more realistic assessment of the bus strength. The results of the current study show that the final assessment of the bus crashworthiness from both procedures can be divergent. Although the tested





bus passes the quasi-static FMVSS 220 test, the same bus fails the dynamic rollover procedure of the ECE-R66 test. FAMU-FSU researchers used TRACC cluster and LS-DYNA simulations to identify the weakest spots of the bus structures potentially causing this divergence. TRACC staff expanded their research by performing a sensitivity study for both the simulated tests.

The Turner Fairbank Highway Research Center (TFHRC) was interested in studying the transport of salt spray generated by vehicle tires from the pavement up to the exposed steel support beams of steel bridges as the tires roll over wet pavement. The research was aimed to update the Technical Advisory, which was already over 20 years old, with results based on current state-of–the-art computational analysis and experimental data acquired at critical locations. Based on blueprints of the Bridge No. 4172 in West Virginia, an initial multiphysics model was developed to represent a large semi-trailer truck traveling under the bridge. The LS-DYNA/MPP model used the Multi-Material Arbitrary Lagrangian-Eulerian (MM-ALE) formulation. Although LS-DYNA MM-ALE algorithm is widely used in simulations of explosions in air, it has quickly turned out that the salt spray transport simulations would be more computation intensive. The time duration of wake formation behind the truck and its passage underneath the bridge is measured in seconds (around 10 seconds). Such long time required a large domain to be modeled, fully utilizing memory capacity on the TRACC cluster compute nodes.

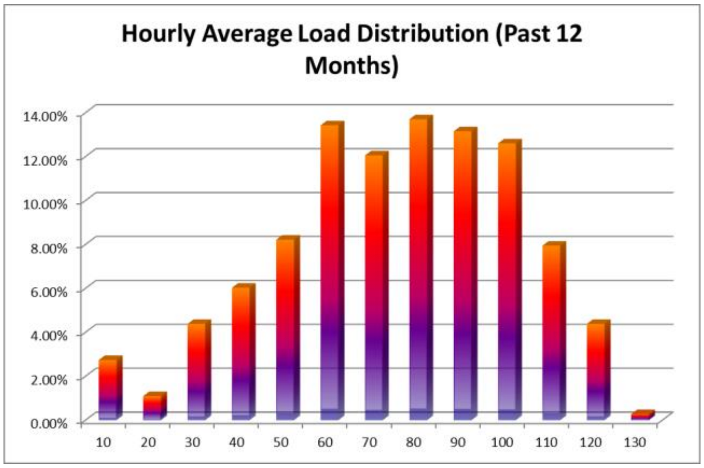
In this quarter, three papers submitted to the Transportation Research Board (TRB) Annual Meeting Committee, Washington, D.C., 2011 were presented at the conference. The new work performed by CSM staff in the current quarter was accepted for presentation and publication at international conferences:

- Kulak R.F., Bojanowski C., Modeling of Cone Penetration Test Using SPH and MM-ALE Approaches, 8th European LS-DYNA User's Conference, Strasbourg, France, May 23-24, 2011.
- Bojanowski C., Gepner B., Kwasniewski L., Rawl C., Wekezer J., Roof Crush Resistance and Rollover Strength of a Paratransit Bus, 8th European LS-DYNA User's Conference, Strasbourg, France, May 23-24, 2011.
- Wojciechowski J., Balcerzak M., Bojanowski C., Kwasniewski L, Gizejowski M., Example Validation of Numerical Modeling of Blast Loading, Protect 2011 Performance, Protection & Strengthening of Structures under Extreme Loading – Third International Workshop, Palazzo dei Congressi, Lugano, Italy, August 30 – September 01, 2011.

April 2011 to June 2011

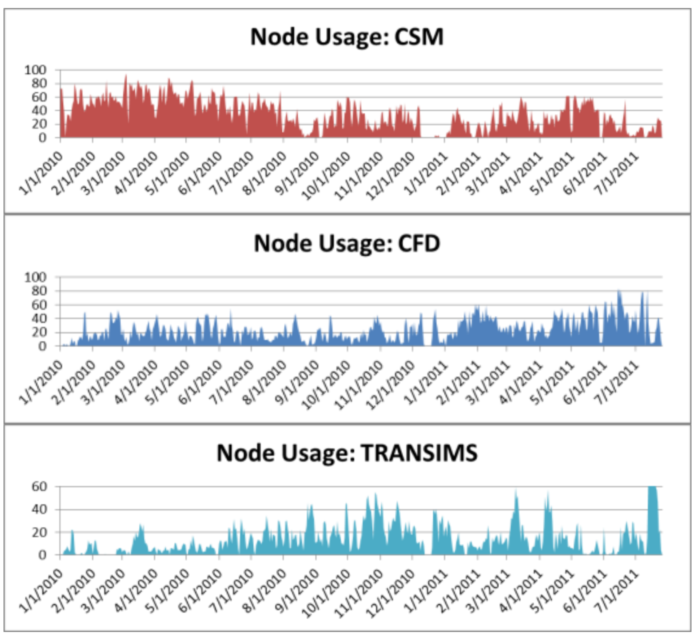
For the 3rd quarter of FY2011, the cluster was particularly heavily used, with an average utilization of about 67% for April, 66% for May, and 63% for June 2011. More significantly, the average of daily maximum usage was 91%, 82%, and 87% respectively. These numbers are important because they reflect the likelihood of jobs starting within a reasonable time upon submission, a criterion that is important for effective code development and non-production runs.

Given the fact that the TRACC cluster is a limited resource that was being used for relatively large jobs as well as for interactive work, a long term load average beyond 70% significantly reduced the user expe-



rience and was detrimental to effective project performance.

The number of users that were actively submitting jobs on the TRACC cluster during the time period from January 2010 to July 2011 was about 80, a significant number considering the fact that most users are part of a team where only some of the team members have direct access to TRACC's machines.



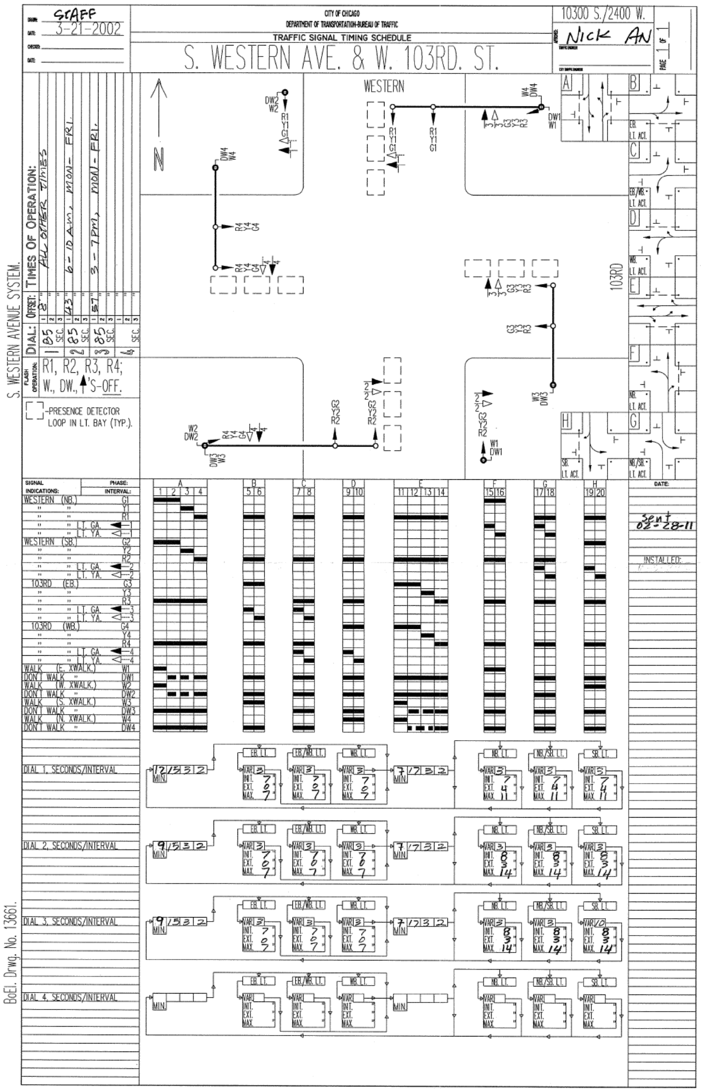
The total number of individuals having active accounts at the time was about 130. This included project supervisors and individuals that did not actively run jobs. They may have used the cluster interactively, uploaded and downloaded data files, or used other TRACC resources such as source file archives and collaboration tools. Except for the week-long shutdown period when the cluster was moved from the DuPage airport flight center to Argonne's building 240, there were at least 6 concurrent users active on any given day, including weekends. This demonstrated that a shared resource like the TRACC cluster was a very valuable resource to researchers and students.

Transportation systems simulation

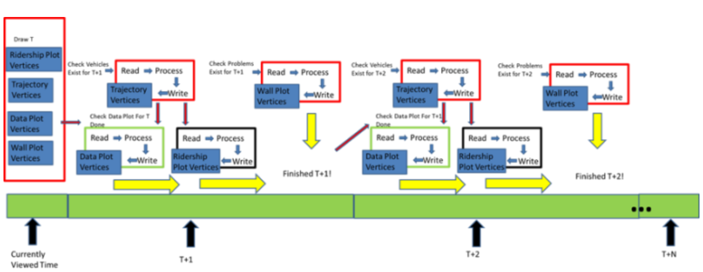
The RTSTEP project, a $2M project involving about 25 collaborators at Northern Illinois University, the Illinois Institute of Technology, the Chicago Metropolitan Agency for Planning, the City of Chicago, and AECOM, a large consulting and engineering company, was in full operation by the summer of 2011. TRACC managed the project and hired three additional staff members. Seven full time staff members at TRACC were working on this project, and the work was closely related to work performed earlier for USDOT. The project finished in November 2011, with many training sessions and demonstrations held until May 2012 to roll out the capabilities to emergency responders.

The team worked on refining the design and preparing inputs of the candidate evacuation routes set. The team found some errors and is in the process of refining those problems. After some refinements, a final candidate evacuation routes set was defined by the IIT students who continued working on the inputs of the set of candidate evacuation routes, which was tedious work. In addition, the updated normal day network induced further modifications of the inputs.

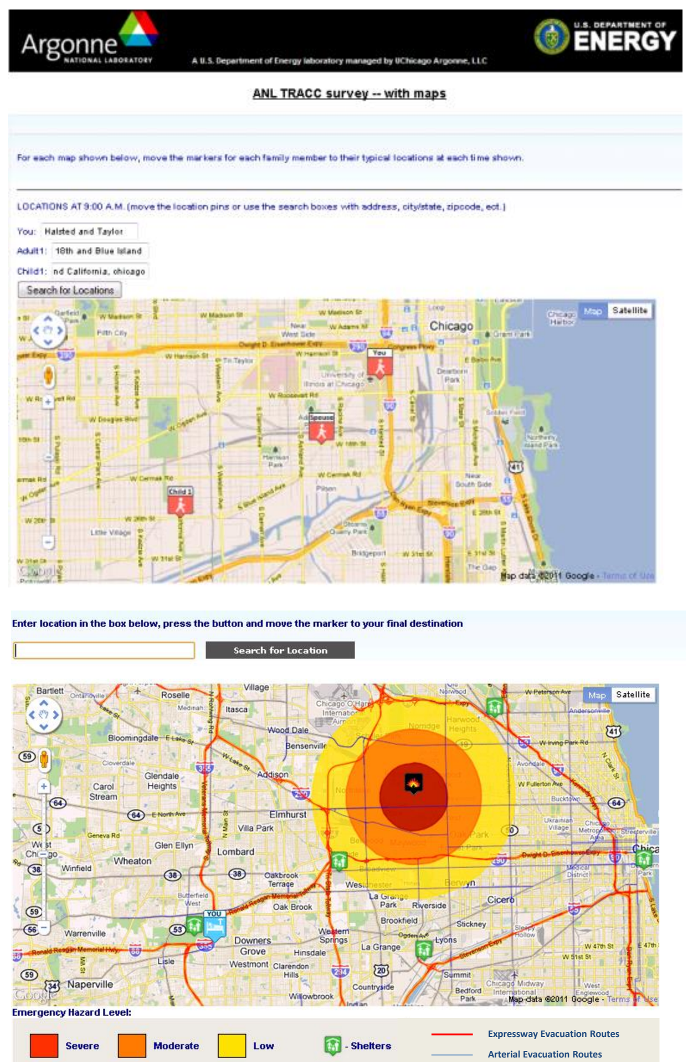
A team of IIT students also worked on detailed traffic signal models for hundreds of intersections in the City of Chicago. They interpreted engineering drawings for phasing and timing of traffic signal systems and translated the information into appropriate model data sets.



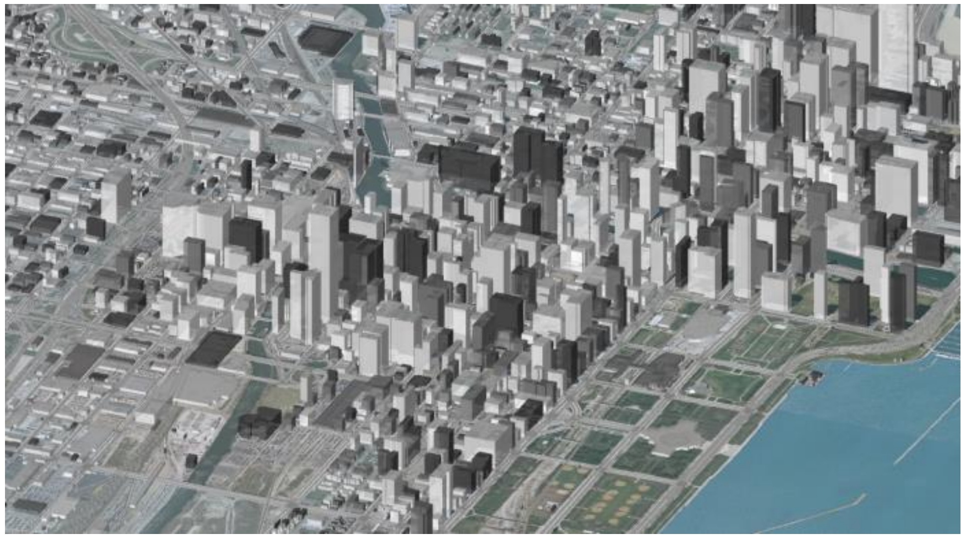
The projects involved many different pieces of software that had to be developed, integrated, and tested thoroughly. AECOM took the lead on TRANSIMS tools, Argonne developed the visualization and execution frameworks, and the universities supported this work with specialized capabilities and data pre- and post-processing.



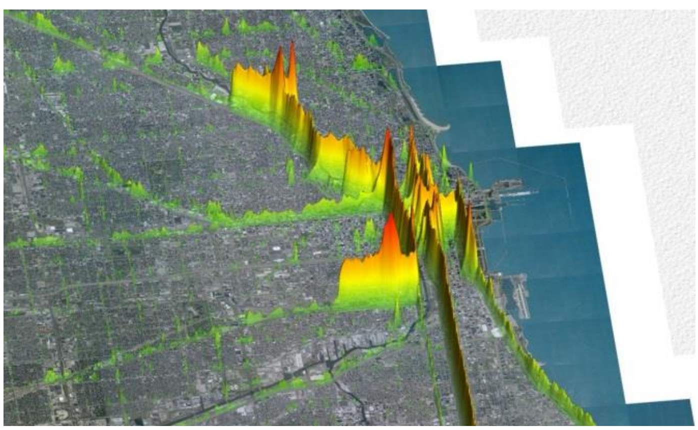
Also, a planned evacuation decision survey was implemented. The survey was designed as a stated choice survey which was to be completed by a random stratified sample of individuals in the Chicago region. The survey collected basic demographic information on the respondents, as well as the locations of all household members and distributions of vehicles for three time periods during a typical day. Then one base scenario and three randomly generated scenarios of emergency evacuation were presented to the individuals, where the location, severity, timing, and event size of the emergency were varied. The survey was implemented using the KeySurvey web-application, but required significant customization using JavaScripts to handle the location inputs, scenario descriptions and evacuation responses needed from the survey.



The first portion of the survey that required a significant amount of design work was the average day location input for family members. In this portion of the survey, the respondent was asked about the locations of members of the household at three different time periods (9AM, 2PM and 7PM), which were then used to randomly generate scenarios. It was important to have only relevant options shown to the respondent. Therefore the location input was implemented as a selection of Google Maps, which allowed the user to drag a marker to the requested locations, and an address finder if the individual was not as skilled at map usage. The address finder allowed any location information the individuals had (i.e. City/state, zip code, address, cross streets, etc.) to be entered, and used the Google Geocoder API to transform this input to a latitude-longitude pair and places a marker at the location on the map. This also provided quality control as the Geocoder produced warnings if the location information was invalid.



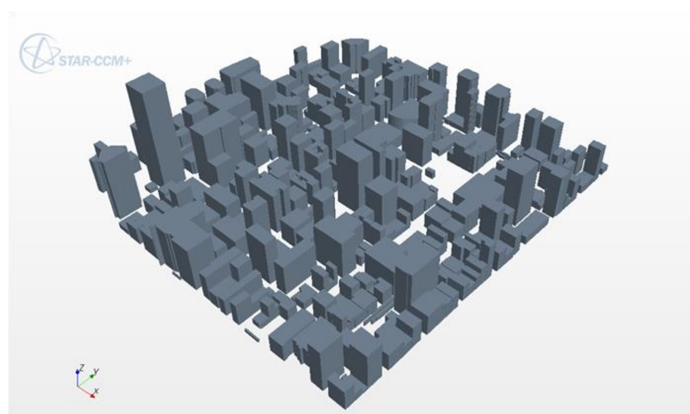
Development continued on both the TransimsVIS and TransimsEDT applications. The TransimsVIS development was done as part of the RTSTEP project.



Development of TransimsEDT included the addition of transit-related features to the core network editing capabilities. Transit editing has traditionally been a large challenge for TRANSIMS users as any network changes made will tend to disrupt the transit network built on top of it. This is due to the fact that the transit routing was not able to correct small gaps in the routes.

The new visualizer was based on OpenGL and had been significantly improved. The original concept as a data analysis tool for the post-processing of TRANSIMS results had been extended, and the visualizer was now able to run as part of the Microsimulator itself, as well as create modifications of the models through an editing system that allowed for a more efficient model building and optimization process.

Developing a CFD model of urban air flow and dispersion is a computationally intensive task mainly due to the large scale of the simulation volume. To address such computational challenges, CFD models were first developed for a small urban area model. This helped develop and verify various modeling methods and capabilities.

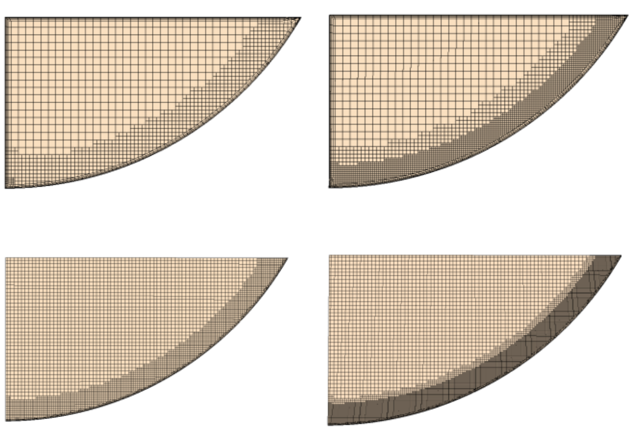


In a real radioactive dispersion event, the plume was expected to be composed of not only multi-component gases but also of multiple phase particles. Therefore a multi-phase flow model was added to the plume model. This was accomplished in Star-CCM+ by redefining the model with an addition of a Lagrangian multiphase component. For the purpose of demonstrating the modeling capability, solid particles of Aluminum were added. These particles were injected into the pollutant.

Particles were assumed to rebound with perfect restitution. With the addition of the particle component and the previous multi-component model, the simulation model was solved in unsteady state mode.

Computational Fluid Dynamics

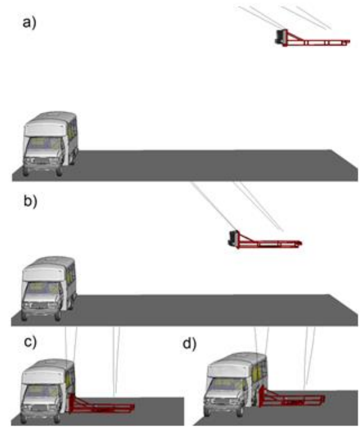
Work on two additional physics models needed in the pier scour model was begun during the quarter. In the previous formulations the scour process eroded the bed directly downward in alignment with the gravity vector. This approach is fine when starting from a flat bed when the slope of the scour hole remains small. However, once the slope starts to become steep and approaches the angle of repose, then the scour should occur normal to the angle of the sediment boundary. For cohesive soils this model enhancement captures the effect of a river scouring nearly horizontally into a nearly vertical riverbank. Work on adding a sand slide model for non-cohesive sediments was also begun. The simplest sand slide model is one in which bed material on slopes greater than the angle of repose simply collapses and is carried away by the flow.



In the culvert flow analysis for fish passage, a study of computational mesh refinement sufficient to resolve recirculation zones in the troughs and the velocity distribution in the main part of the barrel was undertaken. The investigation involved refining the mesh by different amounts in different zones in the culvert until one was found that gave near mesh independent results yet still allowed for efficient computation.

Computational structural mechanics

Out of the TRACC CSM users most active were again researchers from FAMU-FSU College of Engineering. FAMU-FSU, together with Florida DOT, was expanding their bus testing facility. New devices for tube impact testing and bus side impact testing were developed. The devices were designed mostly based on previous FE simulations of these tests. Based on design drawings obtained from FDOT Structures Laboratory a preliminary FE model of cable pendulum mounting was developed. The impact head consists of a FE model of the Insurance Institute for Highway Safety (IIHS) side impact barrier downloaded from the LSTC website and modified for this specific use. A study of the proposed side impact experiment was performed in which the impact head is released to gather kinetic energy and then impacts the bus.

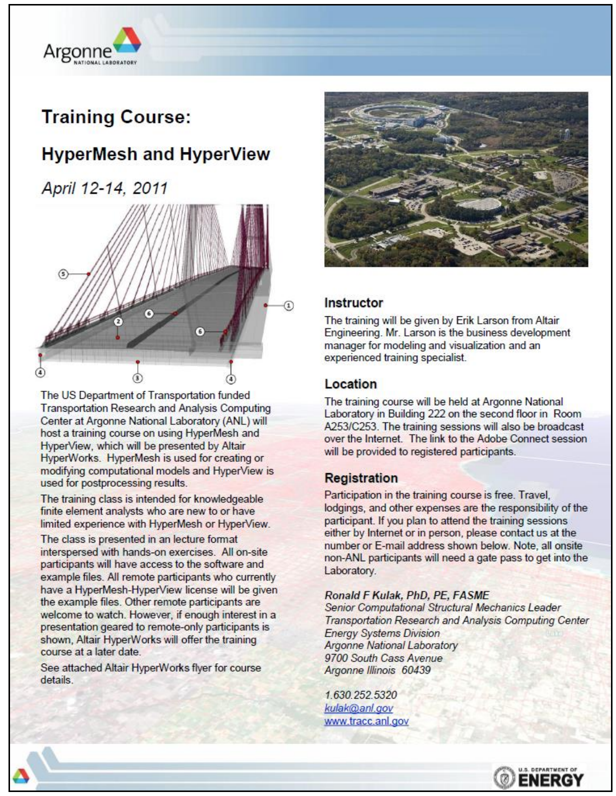


Work on developing credible models for making reliable predictions of the response of bridges and their components to blast loading has continued. Previously, LS-DYNA capabilities were utilized to simulate the transient response of stay cables in a long span cable stayed bridge (Bill Emerson

Memorial Bridge) subjected to blast loading over a portion of the deck structure. The model took into account the pretension in the stay cables. The model was validated by comparing the calculated natural frequencies with those extracted by the Missouri Department of Transportation from data recorded during the 2005 earthquake of magnitude 4.1 on the Richter scale (Assessment of the Bill Emerson Memorial Bridge, Report No. OR08-003, September 2007). Detailed modeling of the deck and the blast with Multi-Material Arbitrary Lagrangian Eulerian approach was further needed to verify the results and confirm that the localized damage to the deck will not cause the bridge to collapse. A detailed model with over 1,500,000 elements was built for this study. The simulations confirmed findings from the simplified modeling.

In this quarter the CSM group gave a Training Course: HyperMesh and HyperView. The training was held April 12-14, 2011 at TRACC in Lemont, IL with interactive participation on-site as well as remotely via the Internet. The training class was intended for knowledgeable finite element analysts who are new to or have limited experience with HyperMesh or HyperView. The class was presented in a lecture format interspersed with hands-on exercises. The training hosted 8 on-site and 13 remote participants.

Two papers describing TRACC's research in computational structural mechanics were presented at the 8th European LS-DYNA User's Conference, Strasbourg, France, May 23-24, 2011:


Argonne NATIONAL LABORATORY

Training Course:

HyperMesh and HyperView

April 12-14, 2011

The US Department of Transportation funded Transportation Research and Analysis Computing Center at Argonne National Laboratory (ANL) will host a training course on using HyperMesh and HyperView, which will be presented by Altair HyperWorks. HyperMesh is used for creating or modifying computational models and HyperView is used for postprocessing results.

The training class is intended for knowledgeable finite element analysts who are new to or have limited experience with HyperMesh or HyperView.

The class is presented in an lecture format interspersed with hands-on exercises. All on-site participants will have access to the software and example files. All remote participants who currently have a HyperMesh-HyperView license will be given the example files. Other remote participants are welcome to watch. However, if enough interest in a presentation geared to remote-only participants is shown, Altair HyperWorks will offer the training course at a later date.

See attached Altair HyperWorks flyer for course details.

Instructor

The training will be given by Erik Larson from Altair Engineering. Mr. Larson is the business development manager for modeling and visualization and an experienced training specialist.

Location

The training course will be held at Argonne National Laboratory in Building 222 on the second floor in Room A253/C253. 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. If you plan to attend the training sessions either by Internet or in person, please contact us at the number or E-mail address shown below. Note, all onsite non-ANL participants will need a gate pass to get into the Laboratory.

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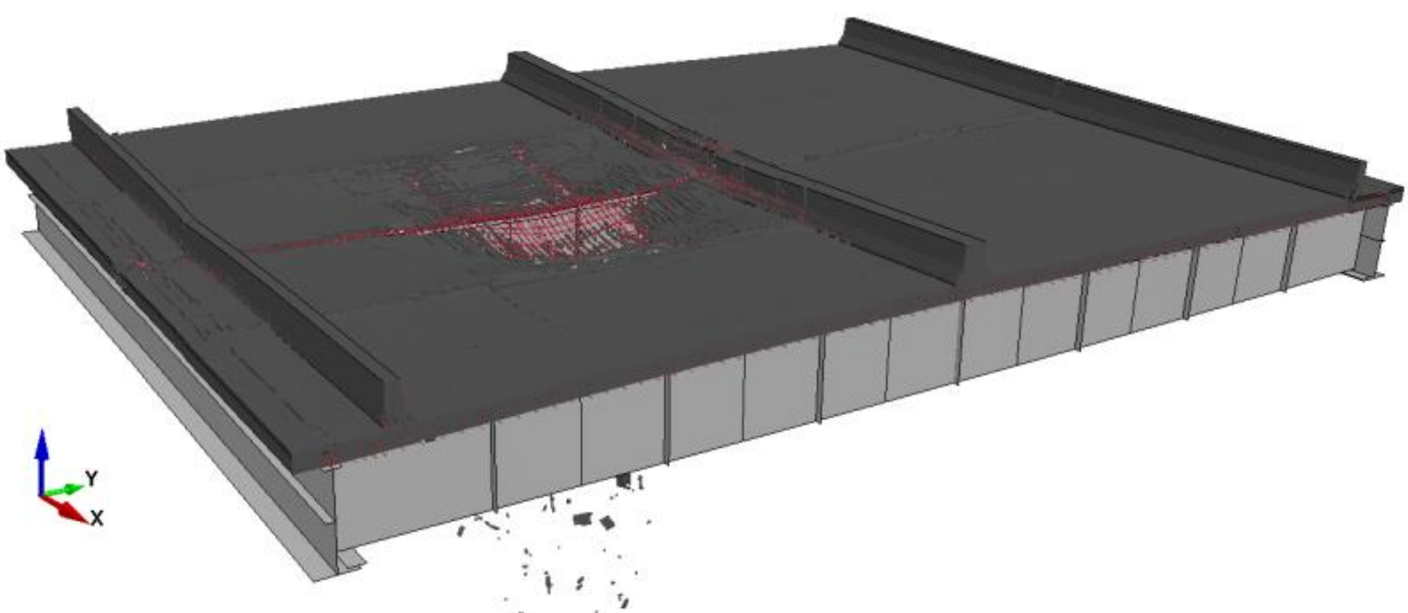
U.S. DEPARTMENT OF ENERGY

- Kulak R.F., Bojanowski C., Modeling of Cone Penetration Test Using SPH and MM-ALE Approaches, 8th European LS-DYNA User's Conference, Strasbourg, France, May 23-24, 2011.
- Bojanowski C., Gepner B., Kwasniewski L., Rawl C., Wekezer J., Roof Crush Resistance and Rollover Strength of a Paratransit Bus, 8th European LS-DYNA User's Conference,



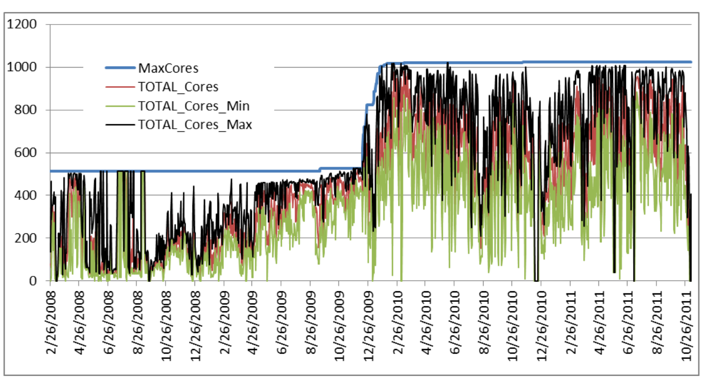
Strasbourg, France, May 23-24, 2011.

July 2011 to September 2011

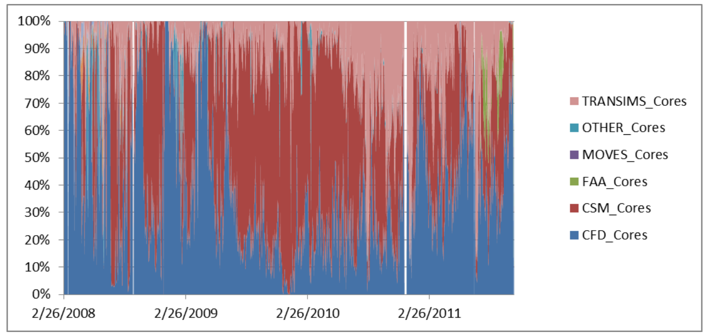
TRACC expertise with videoconferencing and remote collaboration has led to a leading role at Argonne for the deployment of such technologies throughout the laboratory, in particular to reduce travel and cut down both on costs and greenhouse gas emissions. This activity also significantly reduced the cost to TRACC for maintaining and even expanding this capability.

The Facility was heavily used to support the multiple monthly meetings of collaborators in the RTSTEP project as well as all the university projects that TRACC is involved in. TRACC also helped with the establishment of advanced communications technology for the new Emergency Management Operations Center at Argonne that was opened in late summer 2011.

New options for acquiring a sufficient computing resource for future use by TRACC users were developed. The load on the current system is very high, while the infrastructure is aging rapidly. New specifications call for an architecture with many cores per node to better support multi-threaded shared memory applications, a trend in supercomputing that needs to be supported in the future. Acquiring a new system will also help with upgrading the existing system to a more modern operating system, something that cannot be easily accomplished when the machine is in heavy use.



Data on the HPC cluster's hard drive system is now backed up on a near-daily basis. A typical full backup requires approximately 10 days, and is performed from time to time. In between, daily differential backups are performed to ensure that data recovery is possible in case of the very unlikely failure of the highly redundant disk system.



Transportation systems simulation

Much of the early road network work was performed by the team from the Illinois Institute of Technology under direction of Prof. Zongzhi Li. Prof. Li was working with a team of 6 students on both the RTSTEP project as well as an independently funded project for FHWA that IIT was working on in collaboration with the City of Chicago Department of Transportation, the Chicago Metropolitan Agency for Planning, and other collaborators. Before their involvement with TRACC as a subcontractor under the RTSTEP project, the IIT team focused on improving and validating the Chicago Business District model. Staff at TRACC defined individual work assignments that were implemented by students from IIT to address high priority network editing. The team at IIT also worked on the adjustment procedures for Origins and Destinations in the original demand model, as well as calibration of the traffic assignment process for normal days. This work formed a necessary foundation for RTSTEP due to the fact that the normal day is in fact the starting point for deviations caused by evacuation trips.

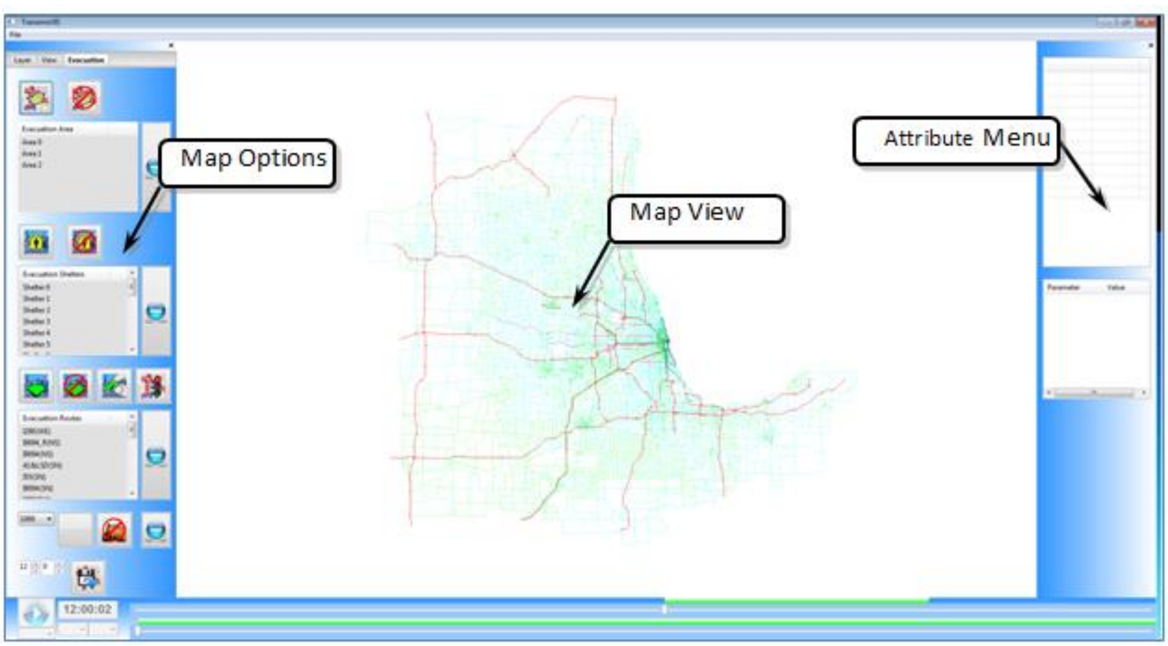
AECOM was heavily involved with this task as well. A work planning meeting was held in January 2011 on defining individual responsibilities, and AECOM was working on the conversion of the underlying data sets to the new TRANSIMS 5 format. TRANSIMS 5, which was still under development at the time, was also modified to better perform as part of the RTSTEP application. Throughout the project, AECOM was developing the underlying software library that drives the individual tools that TRANSIMS consists of.

By March 2012, TRACC, AECOM and IIT finished much of the work on the network supply model, correcting insufficiencies and introducing a number of network enhancements. A large number of modifications were made to the network. Large sections of I-294, I-90, I-290, I-355, I-88, I-57, I-55, I-65 and I-80 have been realigned to match the ortho-imagery. Missing ramps and loops were added to replace simplified straight links from the original CMAP network. A new tool allowed reading in the Open Street Map (OSM) network data and to generate a routable TRANSIMS network from this open source project. The TRANSIMS network was modified based on the OSM data. Specifically, the nodes which correspond to arterial road intersections were aligned to match those of the OSM data. Also, the Chicago Business District (CBD) area signal timing and phasing data originally prepared by IIT for the version 4 model of TRANSIMS was converted into the new version 5 format.

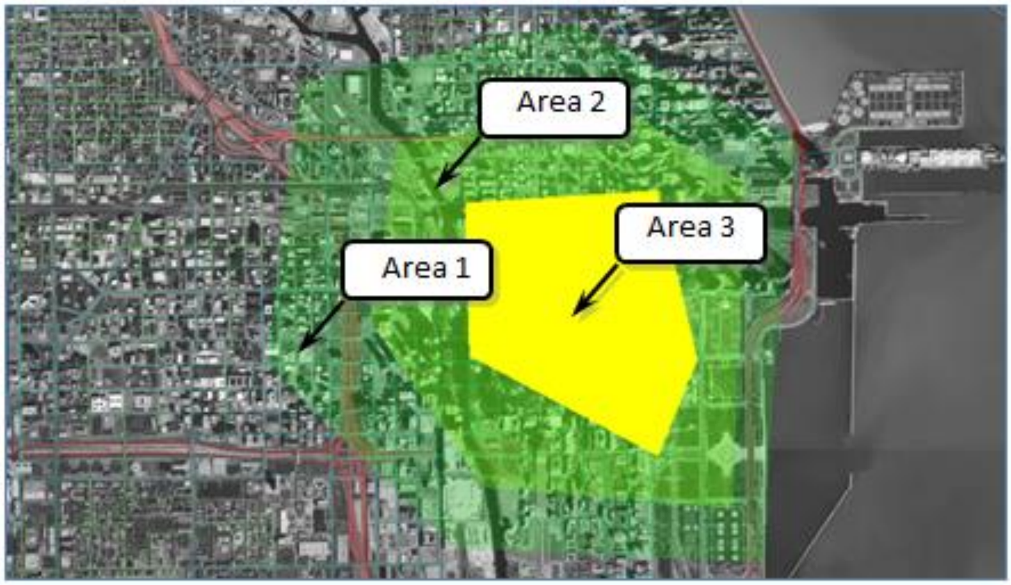
To obtain an accurate traffic assignment result, it is important to mimic the real life transportation network details as detailed as possible. Significant effort was spent on refining the locations of activity locations (the abstract equivalent of homes and work locations, or rather the start and end locations of all trips that are simulated in a given model) and intersection controls (such as traffic signals and stop signs). Activity locations (the trip loading and unloading points) are spatial locations that represent dwelling units, employment locations, social and recreational facilities, and shopping centers. These locations either produce or attract trips. Activity locations were synthesized based on the area type (business district, rural area, etc.) and facility type (highways, major and minor arterials, local streets, ramps, etc.). In some situations, the activity locations were not generated properly using the default settings in TRANSIMS. For example, there were no activity locations generated on Lower Wacker Drive, while there are quite a few loading docks and parking spots located on that street. Some of those changes were automated and some required manual tweaks. Also the traffic assignment process had to be calibrated.

Traffic assignment is the process of calculating a path for each of the travelers on the network based on the current understanding of congestion patterns. For the validation of the model assignment result, field link counts were used. The TRANSIMS Router, along with several other TRANSIMS utilities, was used to perform the assignment. To mimic real live traffic volumes, several of the TRANSIMS Router attributes were adjusted. For example, facility bias factors and distance values were adjusted. Those parameters are specific to a given geographical region. Facility bias helps modeling a situation in which a traveler does not necessarily choose the fastest route but rather prefers to take a highway, even if it takes longer.

The RTSTEP team also worked on increasingly accurate models of traffic signals. In a transportation model, it is very important to replicate real life traffic signal timing and phasing because the transportation network is a highly sensitive dynamical system. This means that a small change in the intersection control timing and phasing may lead to large changes of traffic patterns in a relatively large area. There are approximately 430 of those intersections in the model



area covering the Chicago metropolitan region. TRACC along with AECOM developed an Excel tool which streamlined the process of converting the data into the TRANSIMS format. The tool also performs quality control and helps to minimize human error.



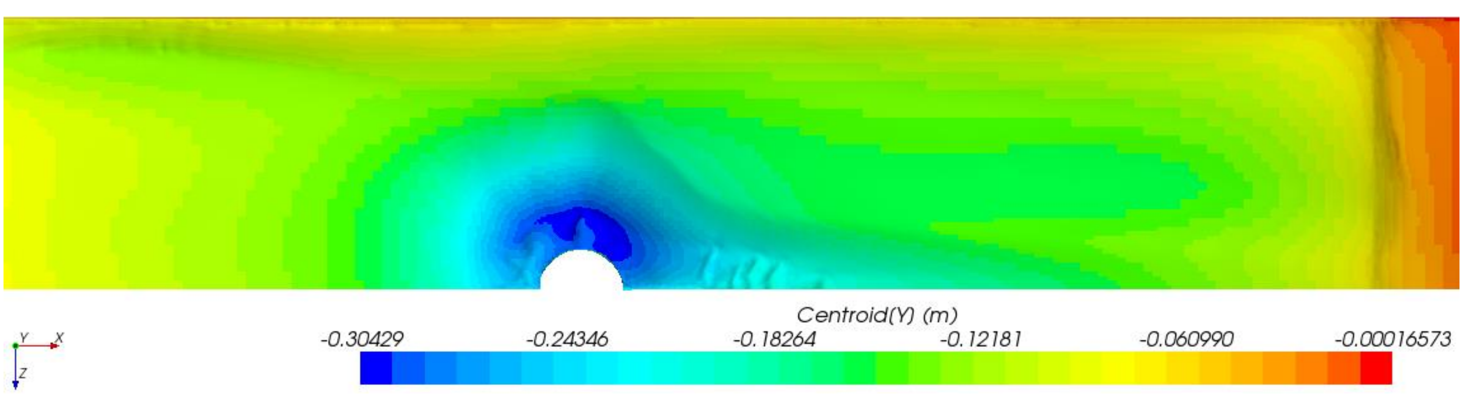
Finally, toll data was refined in the normal day model for the metropolitan region. In the previous revision, the tolls were the same for trucks and passenger cars, while they are different in real life. Previously, there was no distinction between express (for I-PASS users) and cash lanes. The accurate representation of toll stations on the network allows predicting path choices as well as to estimate the traffic density and speed on the toll links more accurately.

Advanced Visualization

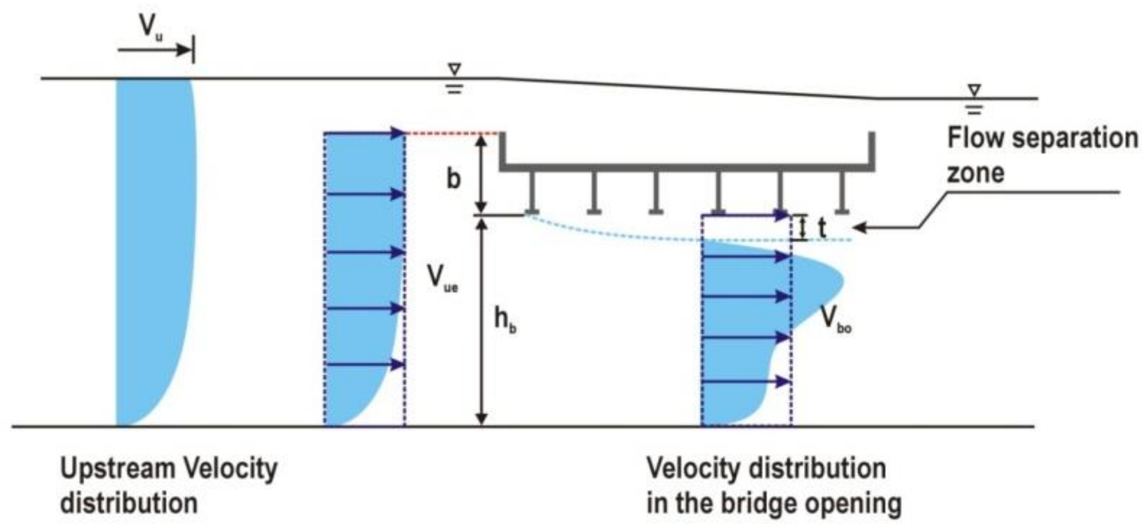
Most on the work on the visualizer for TRANSIMS and RTSTEP was finished at this time. The software became a fully interactive tool that allowed users to configure evacuation scenarios, start the TRANSIMS runs to execute the actual simulation, and then start the visualization component that allows for navigation in three-dimensional space and time to summarize results, analyze model details, find bottle-necks in traffic patterns, and zoom in at any level of detail into any area of interest.

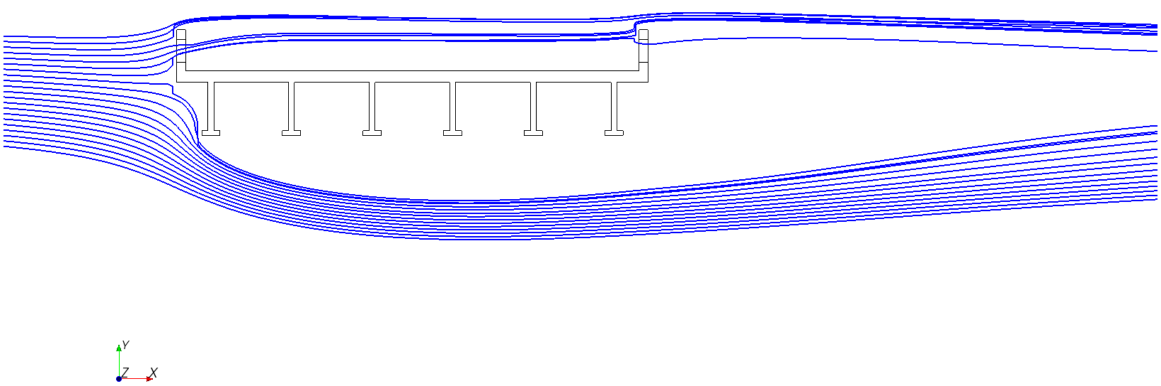
Computational Fluid Dynamics

Work on three physics model enhancements to the pier scour model was completed, and a Master's Degree was awarded to a Northern Illinois University student for this work. The three model enhancements were (1) a variable critical shear stress model that accounts for the reduction in force needed to set particles in motion on a downhill slope and vice versa; (2) scour bed displacement that is normal to the bed replacing a model than displaced the bed vertically downward; (3) implementation of a sand slide model that initiates a sudden collapse and erosion of bed sediment material on slopes that exceed the angle of repose of the sediment. The physics model having the largest impact on the formation of the scour hole around the pier was the sand slide model. With it, the computed scour hole shape came close to the bowl shaped scour hole observed in the experiments on which the model was based. This was a major breakthrough in scour modeling using commercial CFD software. It supplemented the existing capabilities of the software, including arbitrary boundary displacement as a function of forces on the boundary and mesh morphing, with a set of user defined field functions that define the bed displacement



rate as a function of bed shear stress, the variable critical shear stress function, the normal to bed slope scour angle, the sand slide model, and a number of others, totaling 18 field functions. The set of user



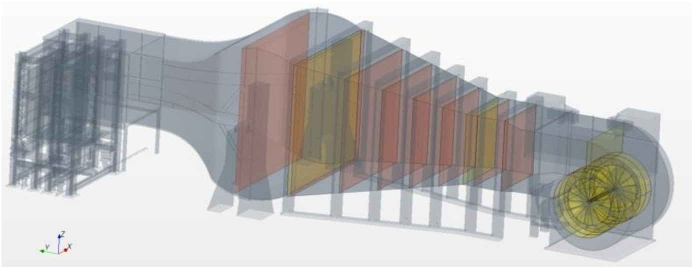


defined field functions for the model was published in a quarterly report, the software needed to pause the computation, do periodic remeshing, and restart it in an automated series of incremental series of CFD computations to compute the scour process are available from TRACC upon request.

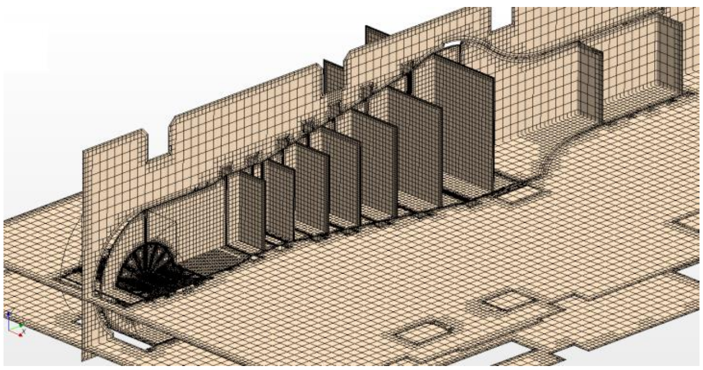
The completion of this work was a major success in the scour modeling effort at TRACC. It provides a methodology to compute three dimensional scour at the cylindrical pier bridge foundation structure. The primary methods of the model are not limited to cylindrical piers and therefore can be extended to piers of different geometry, sets of piers, bridge abutments, etc. In the future, the model still needs to be expanded to include sediment transport and the settling back of sediment onto the riverbed. However, without sediment transport, the model is conservative and therefore conservative for engineering application related to the evaluation of bridge failure risk due to scour.

Another important effort related to scour risk evaluation was begun. A new correlation for the evaluation of pressure flow scour depth at flooded bridge decks was being developed by TFHRC for the ten year HEC 18 update. The new correlation was to be more physics based and developed using a combination of non-dimensional analysis and CFD analysis. The physics concept was that flow diverted under a flooded bridge deck would erode bed material until the opening under the deck was large enough to pass the flood flow with the bed shear stress under the deck equal to or less than the critical shear stress for the onset of scour. Because flood flow diverted under the deck is, in general, not able to make a sharp turn at the leading edge of the deck, a separation zone forms under the deck that does not contribute to the area available to pass flood flow through. The thickness of this separation zone in combination with the depth of the scour hole are both strongly related to the scour depth needed for scour to stop. Work to use CFD analysis to study the conditions and relative importance of parameters to the thickness of the separation zone under a flooded bridge deck was begun.

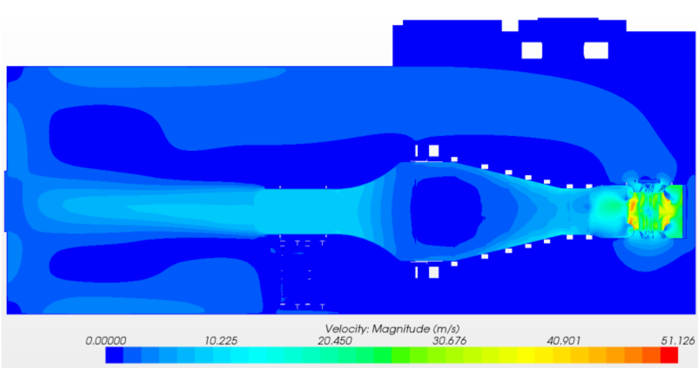
An analysis of the wind tunnel laboratory at TFHRC was begun to aid in planning and possibly modifying room equipment locations in preparation for a new series of experiments. CAD data files defining the wind tunnel were provided by TFHRC.



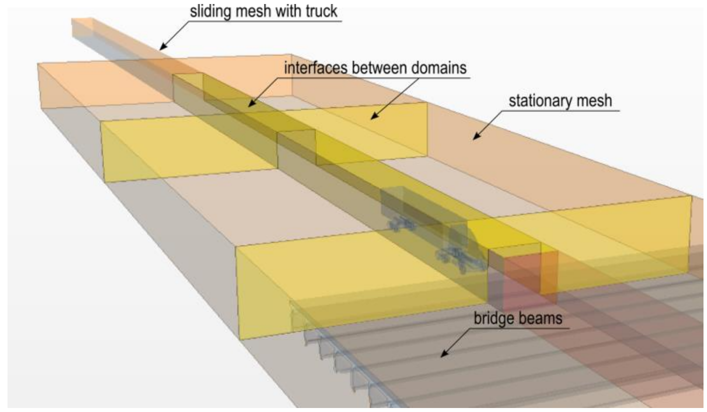
An initial computational mesh was developed for the wind tunnel in place with the laboratory room geometry, but without the details of all of the furniture and additional equipment in the laboratory. Test bridge sections are hung from a stand downstream of the wind tunnel exit, and therefore it is important that the high velocity air flow in the immediate downstream of the exit be as uniform as possible.



Initial simulations were run to verify that the basic model was working.

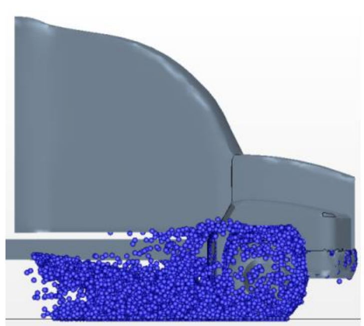


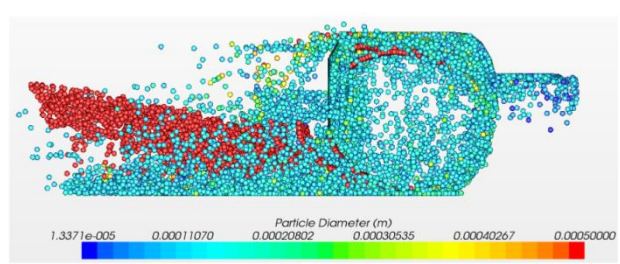
A CFD approach to the modeling of truck generated salt spray was initiated. The work was part of a project to identify better guidelines for the use of weathering steel in bridges in regions of the country where roadways are salted during snow and ice storms. The technique of using a sliding mesh was employed to introduce movement of the vehicle. Domains with the truck and the bridge were separately built and meshed. The sliding mesh model capability is one of the more sophisticated models involving subdomains that have interfaces that are moving with respect to each other. The initial effort was to include the complex geometry of a large truck and the sliding mesh, and to verify that it would generate a physically realistic wake flow when moved under a bridge.

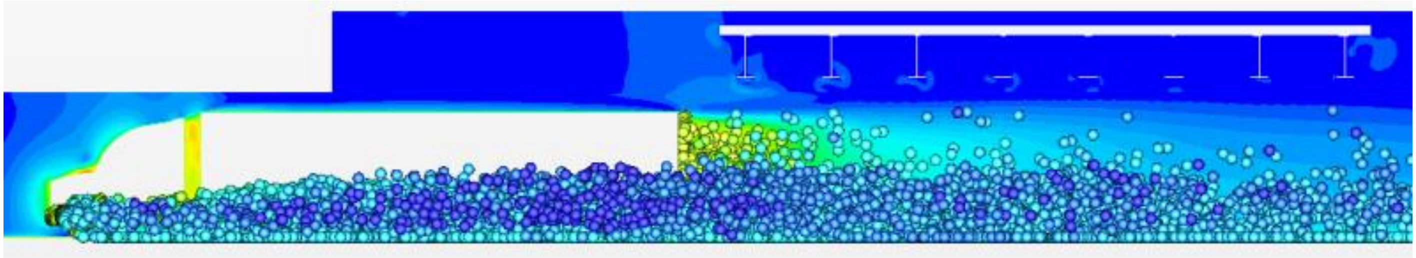


An initial investigation of injecting droplets from tire surfaces and using Lagrangian droplet transport models to track the paths of droplets coming off the truck were also performed. Part of this work was in identifying from the literature and CFD analysis the size ranges of droplets that would be important in studying mechanisms and conditions that are conducive to droplet sprays from truck tires reaching bridge beams where they could accelerate corrosion on weathering steel to unacceptable levels.

The results of these investigations indicated that large droplets over about 200 microns tend to either settle quickly back onto the road or they are broken up into smaller droplets in wheel wells of the truck undercarriage to a size range with a mean of around 100 microns. These smaller droplets can stay aloft for minutes to many hours and form a mist in the truck wake that extends to about half the height of the truck trailer.



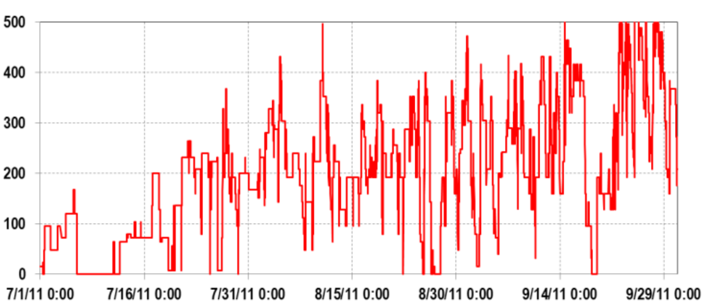




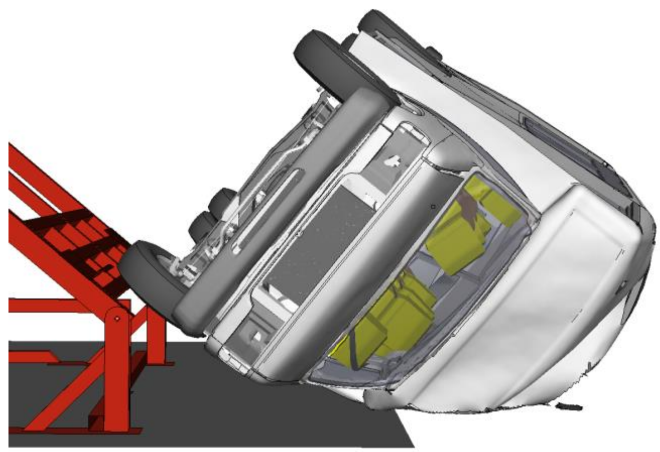
Because the flow in the truck wake did not carry a significant number of droplets up to bridge beam height in initial testing, other factors that could influence droplet transport to the bridge bean height were planned for investigation in the following quarters.

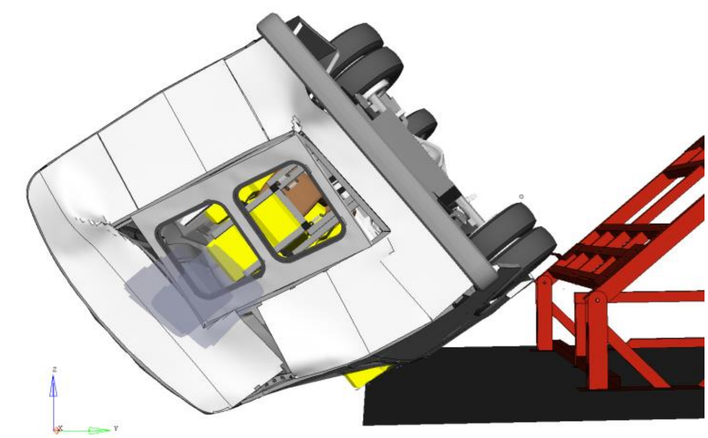
Computational structural mechanics

The use of LS-DYNA software decreased at the beginning of July but it grew toward the end of the month and stayed high till the end of the quarter. Average constant use of LS-DYNA was 213 licenses with max use going frequently above 400 at a time. Most of this use was produced by TRACC collaborators from NIU, FAMU-FSU College of Engineering, NHTSA and TRACC staff.



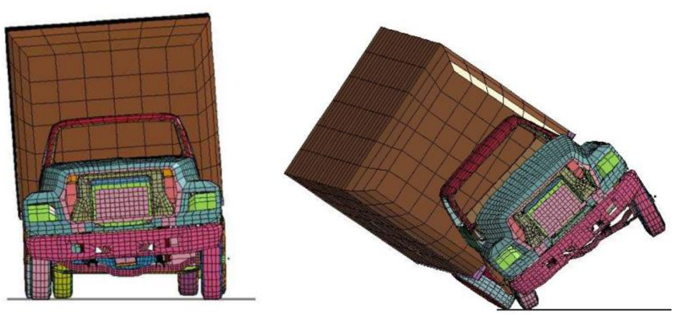
In the recent quarter FAMU-FSU researchers were working on finalizing their year-long project and preparing the final reports. A significant number of simulations were performed in order to validate their FE models before they are delivered to the sponsors at Florida DOT. Previously conducted full rollover experimental tests gave a lot of insight into the bus behavior during the impact. Two major discrepancies noticed during the experiment were friction coefficient of the concrete slab and fracture behavior of the windshield in the FE simulation of the 800mm rollover test. Using LS-OPT parameter fitting capability engineers from FAMU-FSU found new material properties that provided better correlation with the experimental results.





Ground vehicles, such as automobiles, trucks and trains, are often subjected to crosswinds that can lead to vehicle instability and, in the worst case, vehicle rollover. The new NIU students were analyzing vehicle stability under high wind loads and design and analysis of electromagnetic shock absorbers for vehicle stability under high wind conditions. A publicly available FE model of single unit truck Ford F800 was used in the study. A series of parameters were selected to have potential influence on the stability of this type of vehicles in high winds: vehicle velocity, wind velocity, vehicle cargo weight and road conditions (friction coefficient on the road due to different atmospheric conditions). A matrix of runs was built and the simulations were performed on the TRACC cluster. It was found that the highest influence on the vehicle stability had the pressure exerted on the vehicle due to the wind, followed by the friction coefficient on the contact surface between the tires and the road, cargo weight and the vehicle velocity.

Using Matlab-Simulink a simple Electro-Magnetic Shock Absorber (EMSA) system was designed as a second part of this project. Properties of the Ford F800 truck suspension were used as an input to the Simulink to analyze the system of quarter car model. The results indicate an improvement for reduction of the suspended mass acceleration, while maintaining road holding ability and satisfying other requirements such as deflection limit of the suspension.



October 2011 to December 2011

As of October 1, 2011, TRACC started work on a new major research and support project for the Office of Planning of the Federal Highway Administration. The project is sponsored by the Office of Planning, and is titled “TRANSIMS Research and Deployment Support”. The project provides for four specific tasks, supporting the development and deployment of TRANSIMS on the TRACC cluster for current users of the technology, as well as for the development of completely new modeling paradigms and software solutions to model complex transportation issues, such as 3CI, ITS, and similar.

TRACC’s staff was uniquely qualified to work on this new project. Previous development and support activities under TRACC funding were continued using this new funding source, and new analytical capabilities had been developed previously as part of the RTSTEP project to position the TRACC transportation modeling team strategically to build highly efficient and flexible modeling tools for the future.

Transportation models are insularly developed and are not built to interoperate easily with each other. When transportation planners approach a problem, they may need to utilize a suite of tools in order to answer the necessary questions across all model scopes. However, due to this lack of federation among tools, it is either expensive to do so or perhaps even infeasible. This was the primary motivation for the project to address the creation and formalization of an interoperability protocol between this and other models.

Transportation models do not properly support the core decision making process when they are applied by end-users. They tend to elucidate one possible system outcome with one set of performance measures. However, that is often insufficient to address the range of outcomes which would be necessary to evaluate and validate a real world project, such as new infrastructure construction. This was the impetus for conceptual developments in this project to keep the specific problem well in mind and to ensure the focus would be on providing planners with the appropriate performance measures or allowing the planner to dictate the performance measure.

Transportation models are very often applied in the confines of a specific transportation planning project; as such it is vital for these tools to keep the transportation planning process scope strongly in mind. Transportation planning projects are aimed at solving a specific problem in a given amount of project time. The average modeler is not always familiar with scripting and often does not have sufficient time or data to build a model with an extremely high level of detail if it is not relevant to the problem at hand. This was the impetus for development in this project to keep the model development and execution process simple as well as to require only the minimum data which is sufficient to answer the question at hand.

Computational Fluid Dynamics

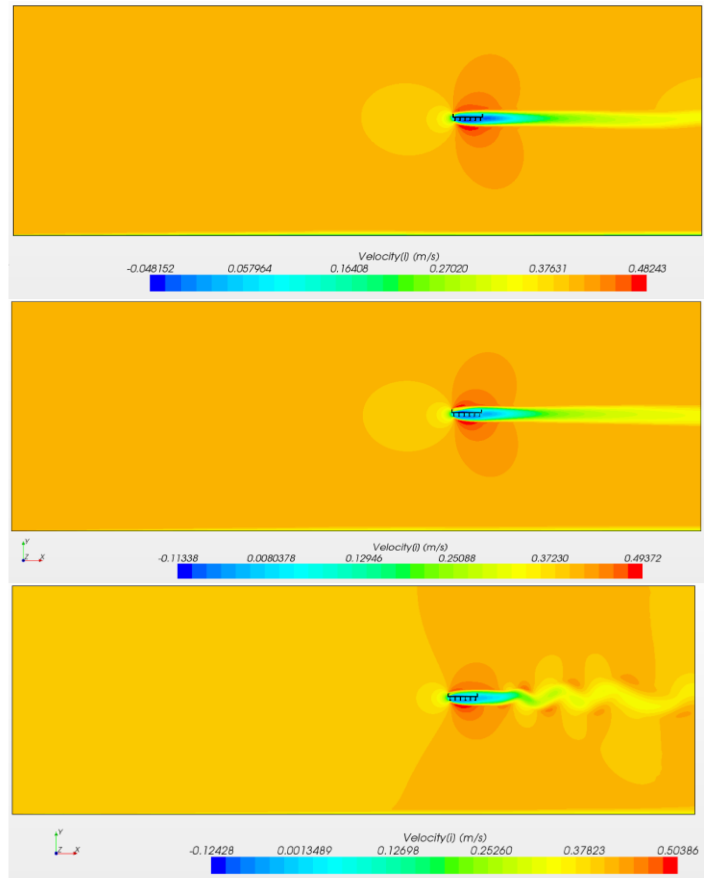
Scour Modeling

The primary Computational Fluid Dynamics (CFD) activities during the quarter concentrated on the development of models and methods needed to continue the ongoing work in scour modeling, culvert modeling, CFD analysis of the Turner-Fairbank wind tunnel, CFD modeling and analysis of salt spray from large trucks passing under bridges using weathering steel, and modeling and analysis of concept testing for an in-situ scour device to measure scour related properties of sediment bed material.

The primary goal in the scour modeling effort was to use the CFD modeling to continue to guide and complete the development of a new pressure flow scour evaluation for the Hydraulic Engineering Circular No. 18, "Evaluating Scour At Bridges, Fifth Edition, due to be issued during the spring of 2012. A combination of non-dimensional analysis and CFD modeling was used to formulate the terms in a new correlation to evaluate scour depth resulting from flood waters reaching the height of a bridge deck and also overtopping the deck and roadway. The CFD computations were used to help determine parameter ranges that would fit existing experimental data, to determine the trends as conditions and bridge deck geometry parameters were changed, and to guide the formulation of the terms in the correlation to insure that the terms would have the same trends with changing parameters as were determined with the CFD analysis.

All the experiments from previous pressure flow scour studies used to determine the parameters in correlations for scour depth were conducted on the lab scale model which is about two orders of magnitude smaller than the typical real bridges. A comparative study was performed using CFD to determine influence of the scale of the model on the results, i.e. on the separation bubble thickness underneath the inundated deck. For that purpose a model with a large domain around the bridge deck was built to simulate the deck acting as a bluff body in an infinite ocean. That way the influence of the boundaries and free water surface were eliminated. Three sizes of the domain and the deck were considered:

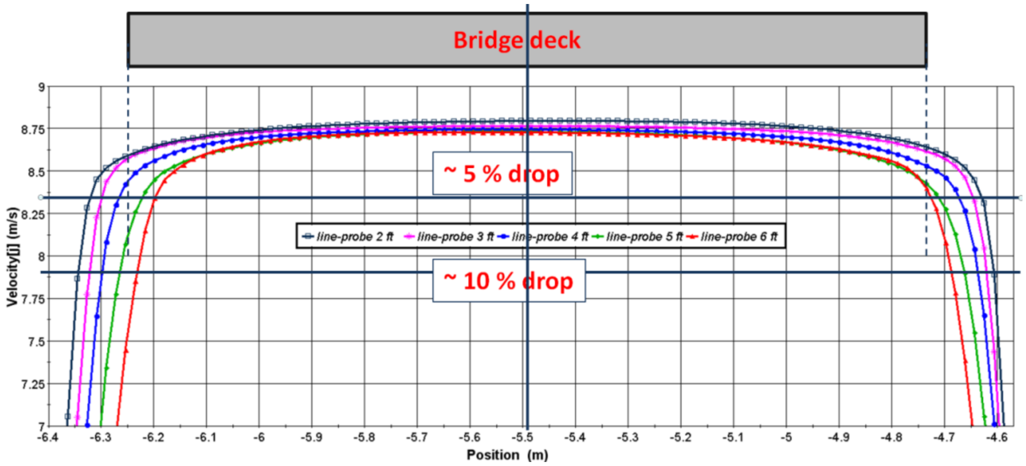
- A lab scale model (deck height of 0.058 m and domain of 2 m x 6 m)
- 10 times the lab scale model (deck height of 0.58 m and domain of 20 m x 60 m), and
- 100 times lab scale model (deck height of 5.8 m and domain of 200 m x 600 m)



Velocity profile in the three models (top) lab scale (middle) 10 times the lab scale (bottom) 100 times the lab scale

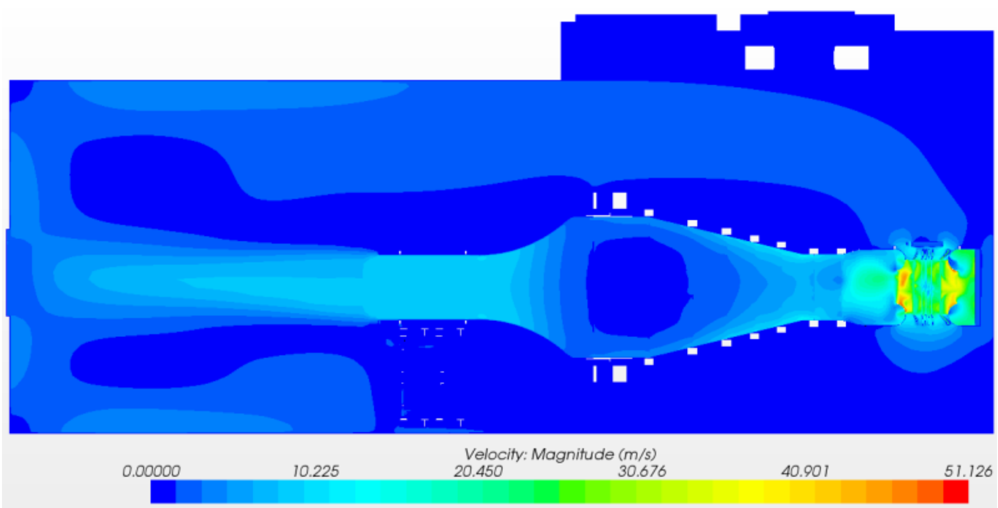
The full scale 100x model had an unsteady wake using an unsteady k-epsilon turbulence model. Using a turbulent Reynolds number defined with the eddy viscosity, μ_t, in the wake region, that Reynolds number was around 35 for the 10x scale up and increased to near 500 for the 100x, full scale case. Under those conditions the mean flow in the RANS simulation became unstable and had to be computed with using an unsteady RANS model. This unsteady behavior did not affect the separation zone thickness under the bridge deck, however. The ratio of separation zone thickness to deck height remained nearly constant from the laboratory scale to full scale.

The thickness of the separation zone in these models was 0.0320 m in the lab scale model, 0.357 m in the 10 times bigger model and 3.34 m in the biggest model. The study showed that the separation zone thickness scaled linearly with the scale of the model and that consequently the lab scale results could be used to determine pressure scour conditions underneath the bridge with sufficient engineering accuracy.



Modeling of the Wind Tunnel Laboratory at TFHRC

The model of the wind tunnel laboratory was completed with inclusion of the major pieces of furniture in the room. The primary test section for wind effects on scale bridge deck models and other model structures is located in the immediate downstream of the outlet of

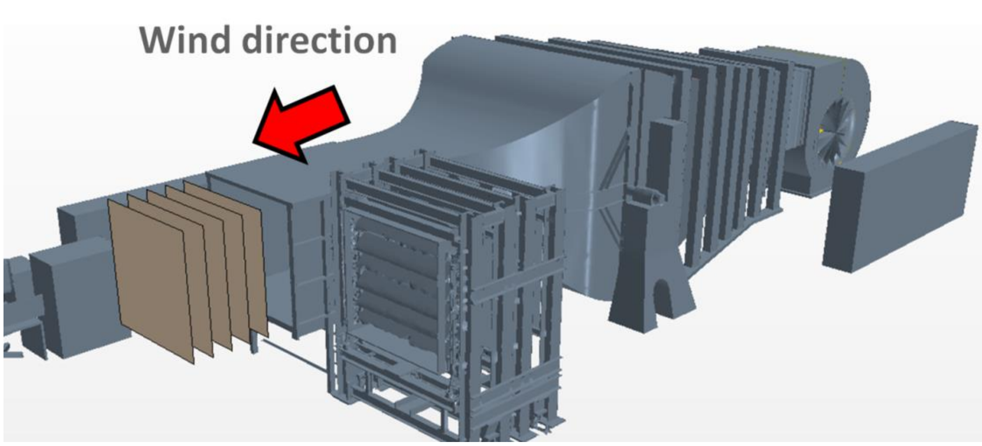


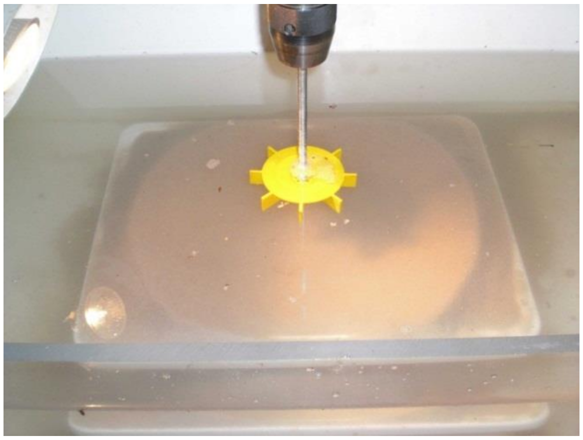
the wind tunnel in the room. Uniformity of the jet of air in this test zone is therefore of concern.

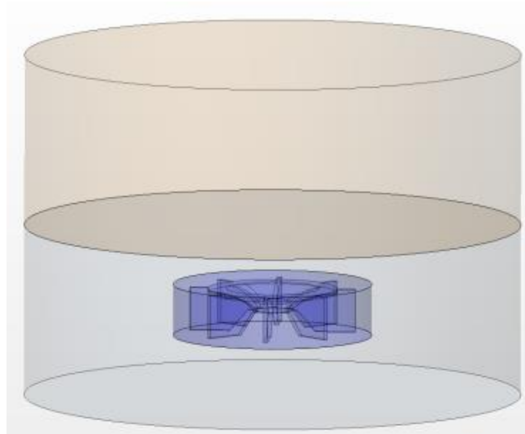
Primarily due to the asymmetric placement of the wind tunnel in the room, return air flow in the completed simulations was shown to be slightly asymmetric, and the air jet leaving the tunnel turned slightly to the side of the room with more open space.

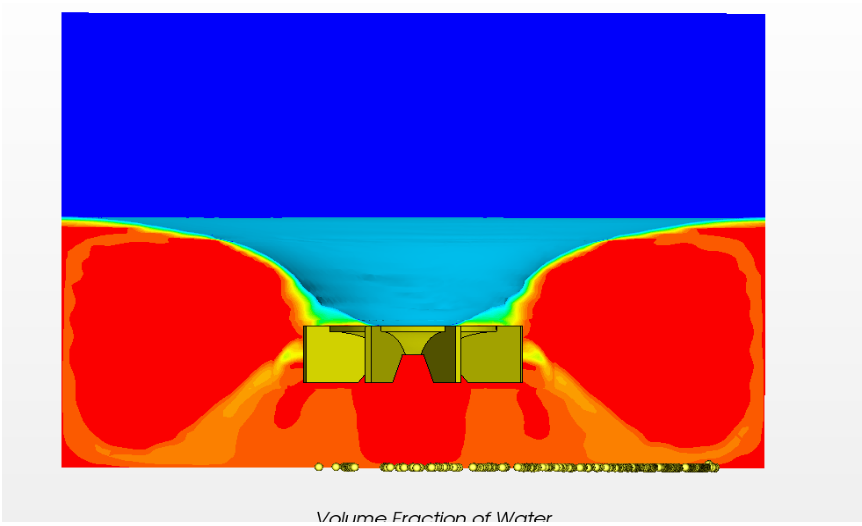
The analysis showed that a wide model bridge deck placed in the test section would be exposed to different wind velocities by a few percent at the ends of the model deck. Based on these results, scientific staff at Turner-Fairbank decided to measure air flow at a set of points in the test section and around the room to verify the model results and to determine if test model structure placement needed to be altered or other remedial steps need to be taken to achieve sufficient symmetry in the wind flow over the model deck.

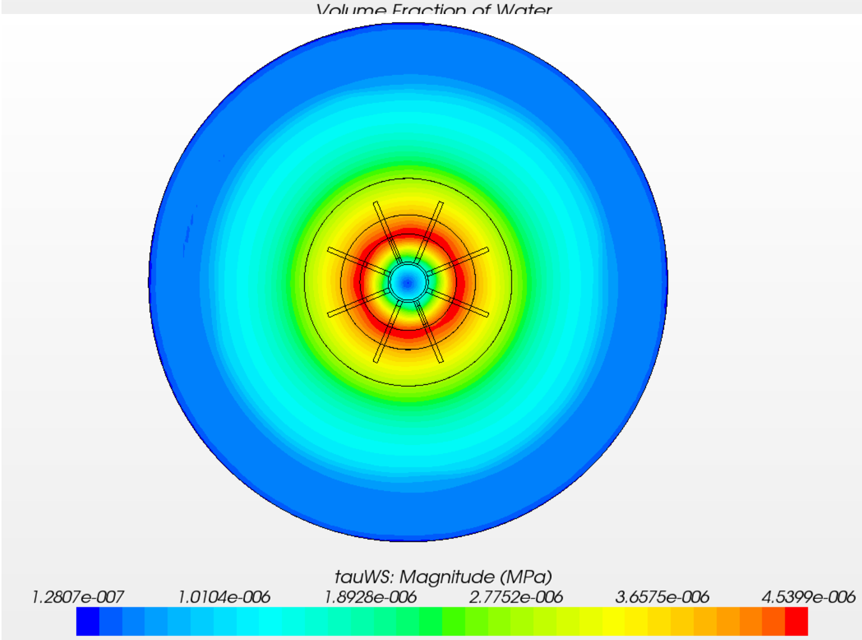
The Turner-Fairbank laboratory began working on a device that could be placed on a riverbed and used to generate a variable amount of shear stress to determine the shear required to erode sediment without disturbing the sample by removing it from the riverbed. CFD modeling was used to investigate several design options for this device and eliminate from consideration design concepts that would not function well. An initial concept that was investigated was the use of a propeller to generate a vortex with high shear on the bed. The idea was tested in the laboratory by mounting a pro-









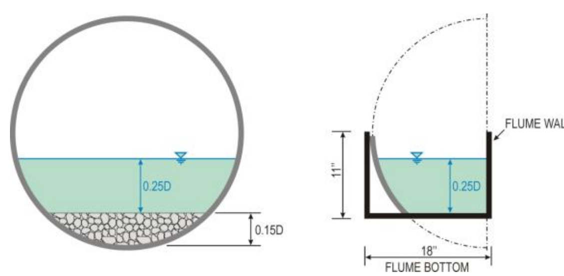


peller on a drill and testing it in a tray of sand where it appeared to function reasonably well.

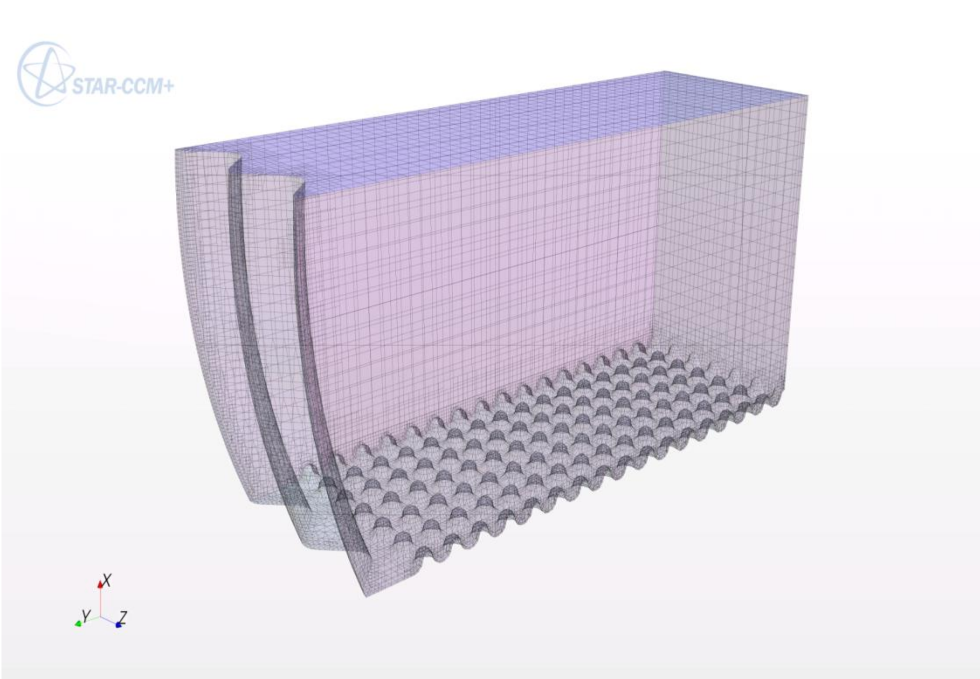
Modeling of this concept showed that the propeller would generate high shear in a ring pattern with a peak in the shear stress at some radial distance from the center of the propeller. In a shallow pan, nearly all of the sand in the middle was thrown to the sides in experiments. However, in a deeper sediment bed, like that of a real riverbed, a mound would be left in the center that would block downward movement of the device to determine erosion rates of different sediment layers. The device went through a number of design iterations with alternate design concepts guided by CFD until a concept was found that worked well.

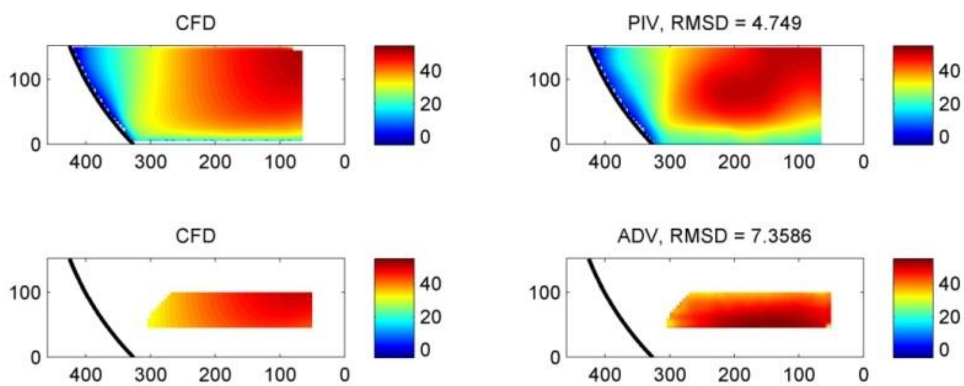
Modeling of culvert flow for fish passage

Efforts to model different configurations of culverts to better determine conditions that allow fish passage continued with culverts that had a layer of large gravel on the bottom. This layer creates modeling challenges because the roughness of large gravel was too large to model as a rough wall using the traditional wall functions to compute shear stress at the gravel boundary.



Two approaches to model the gravel were tested. One treated the gravel as a porous media; the other meshed out representative roughness elements that were approximately the size of the gravel. Several problems were encountered in trying to use the porous media model with flow parallel to the porous media interface to model the effects of large gravel on the flow above the bed. The model with meshed out roughness elements that were repeated in a uniform pattern over the bed matched with experiment





sufficiently well to be used for engineering purposes in improving design for fish passage. CFD cross section velocity predictions were within the range of experimental uncertainty of particle image velocimetry (PIV) and acoustic Doppler velocimetry (ADV) measurements.

Computational structural mechanics

In preparation for increasing collaborator demands for computing resources, TRACC was considering acquiring another high performance cluster computer. The purchase decision for the cluster hardware configuration depended on many metrics: performance, cost, delivery, compatibility, etc. Since several vendors were considered, it was important to perform a suite of benchmark problems to compare performance metrics among the potential cluster hardware configurations. In the benchmarks the following configurations were used: (1) Supermicro Node with 2 x 16 Core AMD Interlagos, 32 cores clocked at 2.1 GHz, (2) DELL Node 4 x 6 Core Intel E5-2667 – 24 cores clocked at 2.9 GHz, (3) TRACC cluster (2 nodes) – 16 cores clocked at 2.4 GHz.

The AMD 16 Core Interlagos CPU was an 8 core processor that can processes two threads simultaneously. Because of this, the operating system actually reports 32 cores and is therefore marketed as a 32 core CPU. However, each chip contained 8 floating point cores. The two Interlagos CPUs in the Supermicro server contained 16 floating point cores.

Throughout this benchmark, TRACC cluster administrators focused on comparing 16 Interlagos cores to 16 Intel's Xeon E5-2667 (Sandy Bridge) cores, and two TRACC cluster nodes. LS-DYNA version R6.0 was used for this study. The Intel platform appeared to be the most efficient for the tested case of three car crash LS-DYNA simulation. However, it was one of the most expensive solutions available.