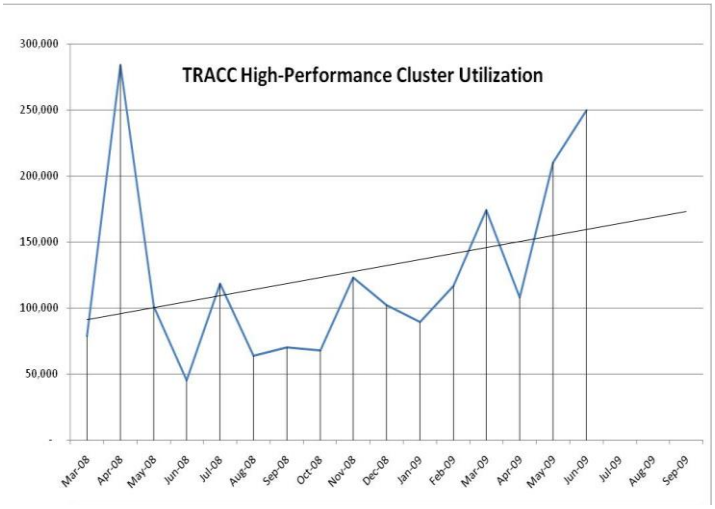
April 2009 to June 2009

The TRACC Collaboratory continued to provide an enriched meeting experience for many participants. Events that required sharing both video/audio and data among geographically distributed participants were prime applications for the technologies that were at the time housed at the TRACC Collaboratory at the DuPage airport flight center. Broadband connectivity provided the opportunity to utilize available technologies to collaborate with remote clients, colleagues and partners regionally and globally without having to physically travel to one specific site, thus making efficient use of time and travel.



The integration and deployment of multiple advanced visualization and communication technologies was unique to the TRACC Collaboratory. The capability allowed the TRACC Collaboratory to offer dialogues, remote collaboration, formal courses and professional events including distributed meetings and workshops.

The TRACC Collaboratory provided the equipment, experienced staff, and network access to provide outreach training using a variety of conferencing alternative technologies. The actual technologies selected for a particular course often depended on the visualization requirements of the particular course, network connectivity, security measures, and video equipment capabilities of the particular target site. Some classes lent themselves more to on-site training (i.e., require more sophisticated visualization of results or where site capabilities are restricted), some required higher levels of interaction between instructors and trainees (i.e., audio/video interactivity between the trainers site and remote sites), and other classes only required delivery of audio and PowerPoint presentations to sites (i.e., introductory classes).

There were 44 different meetings during the quarter, four training sessions, three seminars and one conference conducted during the quarter. Four of the events were held using the facility videoconference capabilities.

The facility technology infrastructure was upgraded to support expanded user support, training classes, meetings, and other outreach activities. These included:

- Upgrade to High Definition projectors (in the large conference room) providing higher resolution images of models and simulations.
- Upgrade to PolyCom HDX8004 and PolyCom HDX9004 systems to provide High Definition quality, dual stream video and data (H.239) for videoconference sessions.
- Completion of A/V Matrix system software changes to accommodate the new HD equipment.

Transportation systems simulation

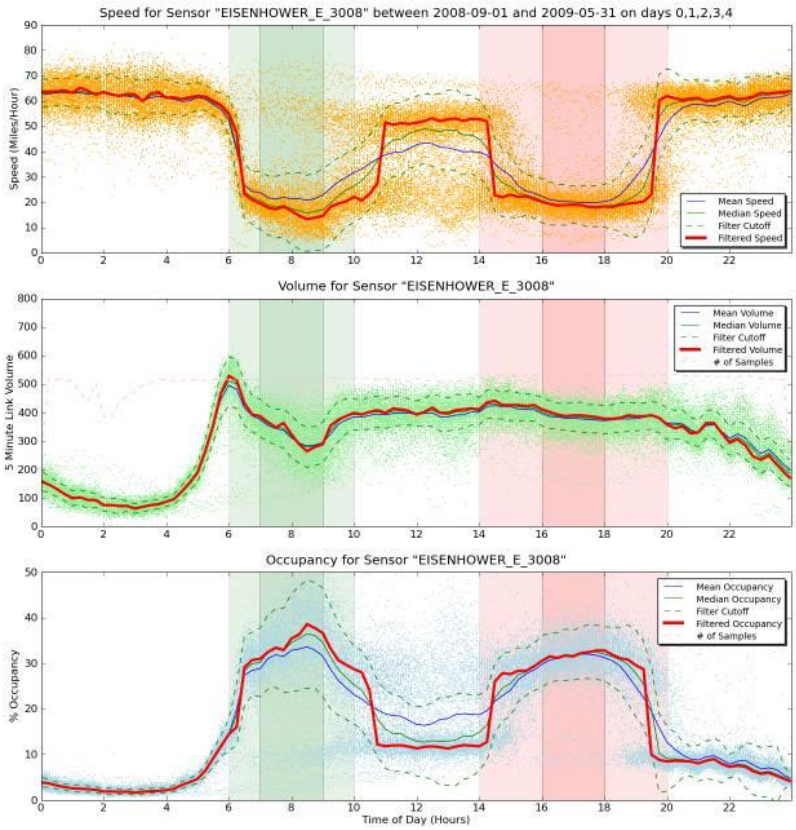
The work in this area had grown substantially by this time, and included a number of closely related and coordinated activities that together addressed all goals for this particular task. The individual activities varied widely, between network editing to improve the Chicago Metropolitan Area model to holding several TRANSIMS training courses as well as the development of new methodologies such as building evacuation modeling. The goal was to further develop both the state of the art of modeling as well as supporting existing and new users in applying the new technologies effectively and in a timely manner.

TRACC was also making excellent progress on the parallelization of TRANSIMS itself. A much improved methodology was implemented that resolved some of the limitations of previous approaches. The new methodology had numerous advantages over previous approaches, e.g. it had the potential for dynamic load balancing, decreased the amount of data being transferred between nodes, and provided a much more precise interface between partitions.

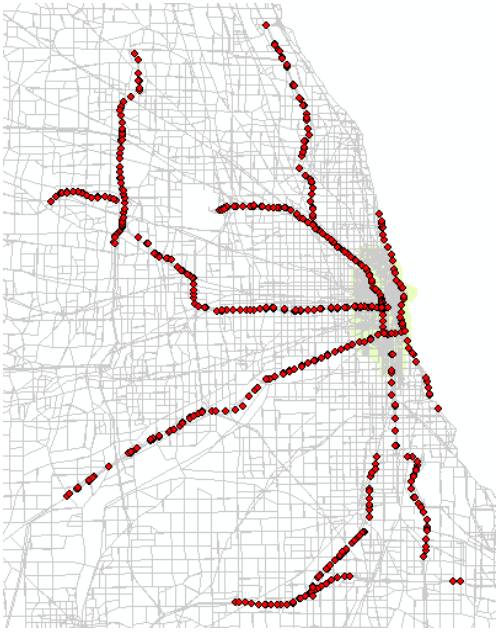
With regards to the improvement of the Chicago Metropolitan model, students from Northern Illinois University created a database of traffic signal locations that provided for a refined simulation of traffic signals in the city. This was another example on the use of high fidelity data that could be easily derived from Internet resources such as Google StreetView.

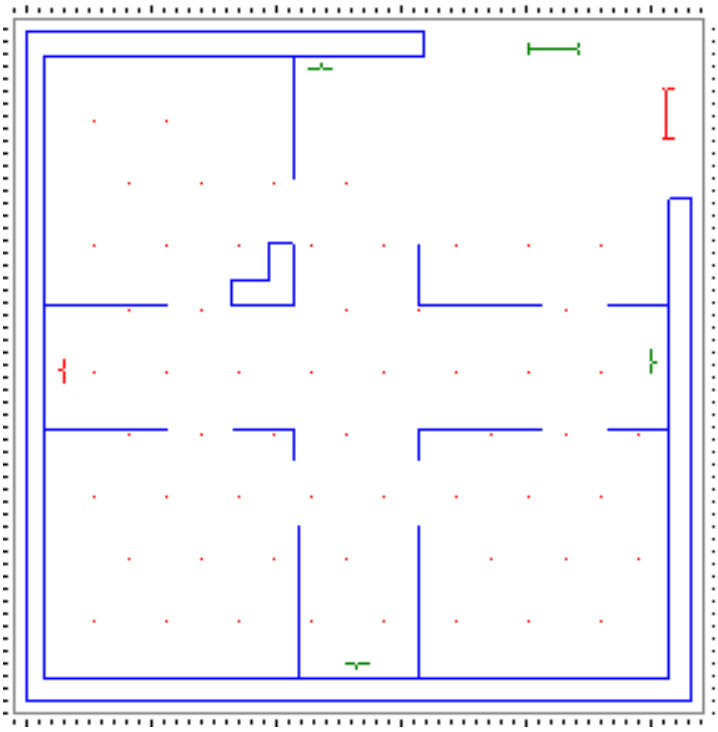
A major improvement of the model was based on the availability of Google Transit data from all regional transit authorities. Until then, TRANSIMS transit was of limited fidelity because detailed and precise scheduling information wasn't readily available. The Google Transit feeds, in combination with GPS traces of the buses, were used to build extensive and precise schedules that made the models more robust and realistic.

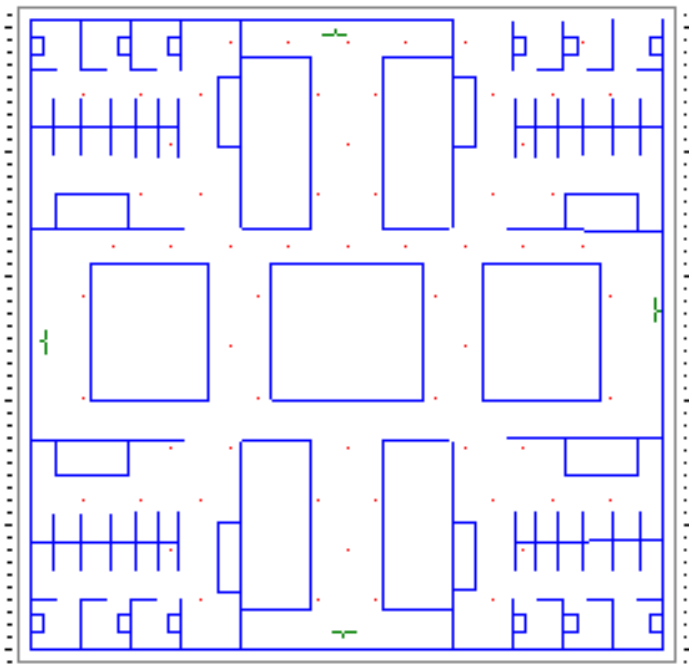
Starting earlier that year, TRACC started archiving 5 minute readings from approximately 800 sensors across the metropolitan Area, mostly on Interstate highways. The data allowed statistical analysis by time of day and was helpful for calibration, validation, and the development of more reasonable diurnal distributions for trip origins and destinations.



Northern Illinois University also did an interesting study of building evacuation models. The goal was to determine functions for the arrival of pedestrians on the walkway when evacuating from buildings. A more detailed understanding of these delays helped with building better evacuation models, especially once pedestrians were more





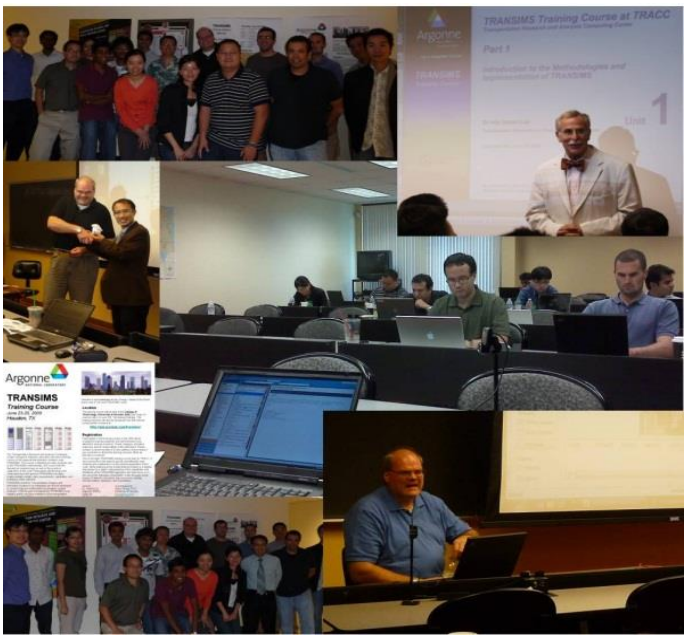


fully modeled, and when they park their associated vehicles in more realistic parking locations in the city.

The second half of 2009 was marked by several startups of new projects using TRANSIMS. SACOG, from Sacramento, started interfacing TRANSIMS with another application DaySim. The application, developed for Windows, is since running on the cluster under the WINE compatibility environment. This mix of Windows and Linux executables was a valuable capability for future projects that wanted to make use of software that was not designed to run under Linux generically.

A TRANSIMS training course was held in April 2009 at the University of Illinois in Urbana / Champaign for around 50 students and local planners as part of their course in Urban Planning. A second training course

was held in the more traditional three day format that highlights TRANSIMS in general during the first day, and then addressed all details of TRANSIMS for another two days. This training course sparked a lot of interest across the US, because it was announced with two months advanced notice, and was advertised locally and over the Internet, drawing a crowd of approximately 45 modelers and experts. This includes a number of students from the University of Houston with interest in this area. The new training course was updated on the TRANSIMS Microsimulator and TRANSIMS methodologies.



Another great opportunity to reach out to the community was given in May 2009 when operating a booth at the TRB Planning Applications conference.

The booth drew a lot of interest from modelers and from commercial application developers, and was visited by a large number of people. TRACC was also asked to participate in two peer review meetings of TRANSIMS projects funded by FHWA. This included a transportation forecasting study in Atlanta, as well as the efforts of modeling Hurricane Katrina at Louisiana State University.

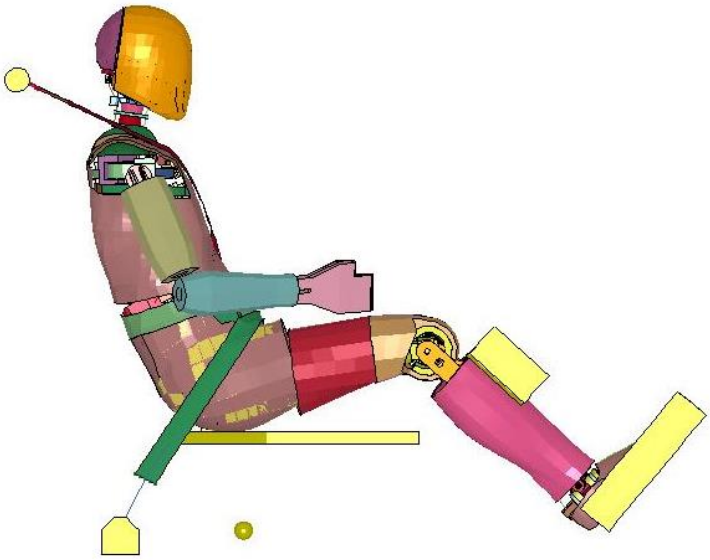
FHWA also started another round of proposals for the rollout of TRANSIMS, and TRACC users were supported in applying for funds from this program. The focus was on a few proposals that were of high interest for TRANSIMS users in general and for the Chicago Evacuation Study specifically.

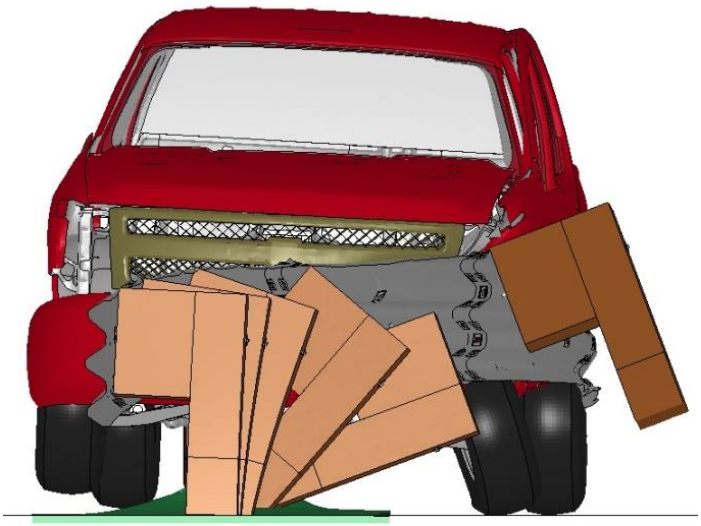
The Chicago evacuation project, separately funded by IDOT, ended in February 2009. Nevertheless, the work was being applied to develop advanced methodologies at this time, and to generalize some of the methodologies so that they can become applicable to other areas as well.

Computational structural mechanics

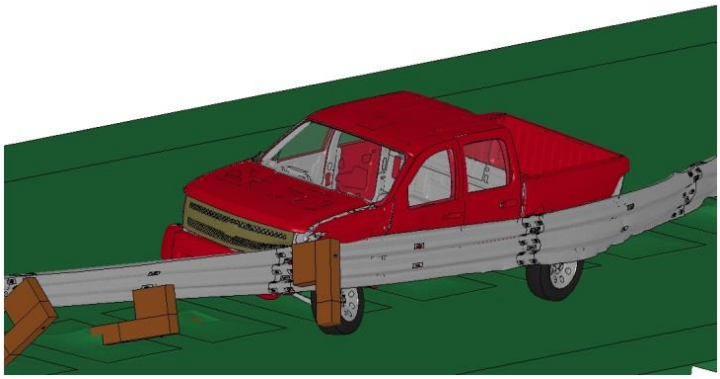
The use of TRACC cluster by the researchers from the computational mechanics area has grown in this quarter through the increased demand for LS-DYNA licenses from NHTSA, TTI, and new users from Florida State University. The researchers from NHTSA started their work on optimizing the occupant restraint system in a sled test simulation with the THOR FE dummy model. The successor of Hybrid III, THOR has a more humanlike spine and pelvis, and its face contains a number of sensors which allow analysis of facial impacts to accuracy currently unobtainable with other dummies. THOR's range of sensors is also greater in quantity and sensitivity than those of Hybrid III. NHTSA was TRACC's first collaborator using LSTC's LS-OPT software to perform optimization studies. The issues with running this software on the TRACC's cluster involved technical support from LSTC.

Support was provided to the users from TTI to get them up and running on the TRACC High Performance Cluster. The material developed for the LS-DYNA training course, which was held in November of 2008, was sent to Dr. Akram Abu-Odeh (TTI) to give him and his group a quick overview on how to use LS-DYNA on the cluster. Texas Department of Transportation (TxDOT) has expressed an interest in using





very high design speed for some future highway facilities to promote faster and more efficient roadway travel within the state. However, a roadside safety hardware device that performs successfully under the



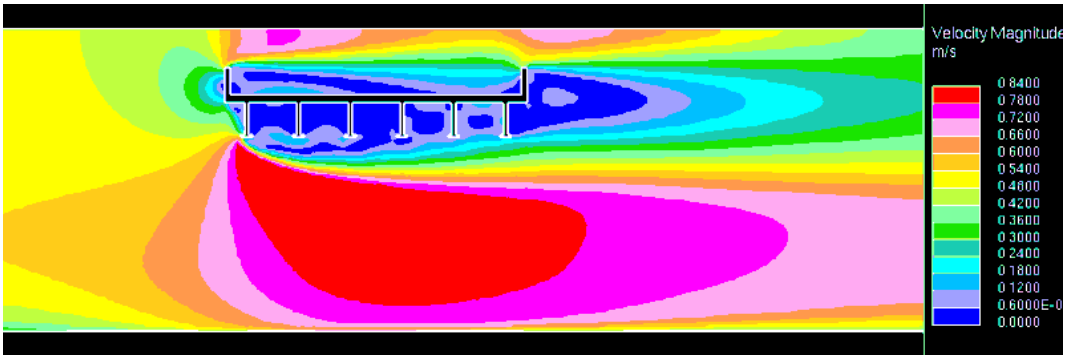
above mentioned guidelines was not necessarily going to perform under a higher impact speeds. TTI researchers were investigating the performance of certain roadway hardware under higher impact speed 137 km/hr (85 mph). Simulations were used to identify what type of devices were able to perform and what modifications were needed if it exhibited a rather marginal performance (strength and ability to redirect the vehicle).

As part of the commitment to interact with universities on ongoing research projects, TRACC computational structural mechanics staff was working with Prof. Gupta at Northern Illinois University (NIU) - an expert in mechanical vibrations, and his two students. Collaborative research with Northern Illinois University focused on analyzing bridge stay-cables parametric excitations due to multiple sources of external loadings. Work was initiated to include sources of wind loading on the stay cables by developing subroutines for LS-DYNA software to compute the drag and lift forces generated by the wind load.

Computational fluid dynamics

For the FHWA sponsors at the Turner-Fairbank Highway Research Center (TFHRC) hydraulics laboratory, research on scour at bridges, the washing away of riverbed material from around abutments or piers which hold up bridges is considered of high interest to the entire nation. There are about 500,000 bridges over waterways in the U.S. Statistics indicate that about 85,000 bridges in the U.S. are considered to be vulnerable to scour, and about 26,000 bridges from that group are classified as scour critical, meaning they can fail in a case of a severe flood event. More than 600 of all the bridge failures in the US in the last 30 years were caused by scour. As a result, the accurate prediction of scour depth, field monitoring, and prevention projects with emphasis on safety and economical aspects of the bridge maintenance are a high priority for the U.S. Department of Transportation, as reflected in the projects pursued at THFRC and at TRACC.

Work on a basic moving boundary formulation of scour with automated re-meshing and iterative CFD runs including an evaluation of the usefulness and limits of this approach was completed with STAR-CD CFD software. This approach to scour computation provides a good basic methodology that can be improved with better physics models. The difference between computational prediction and experiment for pressure flow saltation scour is up to 50%. However,



differences of the same order occur in a correlation of data by Dr. Guo to predict the scour depth. Improved accuracy requires improving the accuracy of the function for onset of particle motion, which might be a critical shear stress or some other combination of forces at the bed. The methodology also provides a basis for bridging the flow and scour time scales.

Work on development of training materials for a CFD training course was completed in the first weeks of April. The first offering of a CFD training course at TRACC was conducted on April 27-29, 2009. CD-adapco provided presentation material and user manuals to TRACC in electronic form as a basis for the course. Additional material on the use of the TRACC cluster was added and tutorials related to hydraulics analysis were developed. The course was given using Internet2 technology to create a virtual classroom with video and content sharing between three sites in the U.S. The TRACC Collaboratory was the host site for the CFD training course, and the two remote virtual classroom sites were the Turner-Fairbank Highway Research Center in McLean, Virginia and the University of Nebraska in Omaha, Nebraska. Large screens at each site showed views of the three classrooms and the technical course material. The Internet2 video, audio, and data links provided the technology for group discussions of course material with the remote sites. A highlight of the course was a set of hands-on tutorial problems in which participants at all three sites used CAD geometry and STAR-CCM+ CFD software to, for example, build a bridge geometry, set up the physics for bridge flooding conditions, and run the CFD software to compute flood forces on the bridge under the guidance of TRACC instructors. When students ran into problems in a tutorial, they were able to transmit their laptop screen content to the other sites allowing instructors at TRACC to help them resolve problems. Participants at all sites were able to see and hear how problems were resolved. Course participants without Internet2 access at the Illinois Institute of Technology, the University of Illinois at Champaign-Urbana, and the University of Iowa were able to watch and listen to the course using Adobe Connect in an internet browser. Feedback on the course via a set of questions was requested and received from the majority of participants. CD-adapco's training program policy was not to offer a training course in a local region of the country unless 15 to 20 people signed up to attend in person because they did not believe that videoconferencing and hands-on training would be successful. The CD-adapco representative for TRACC attended some of the sessions and concluded that the training with videoconferencing and trainees at remote sites was very effective.

Views of the CFD class at the TRACC location with one screen showing the other locations and the other screen showing technical content sharing between sites

July 2009 to September 2009

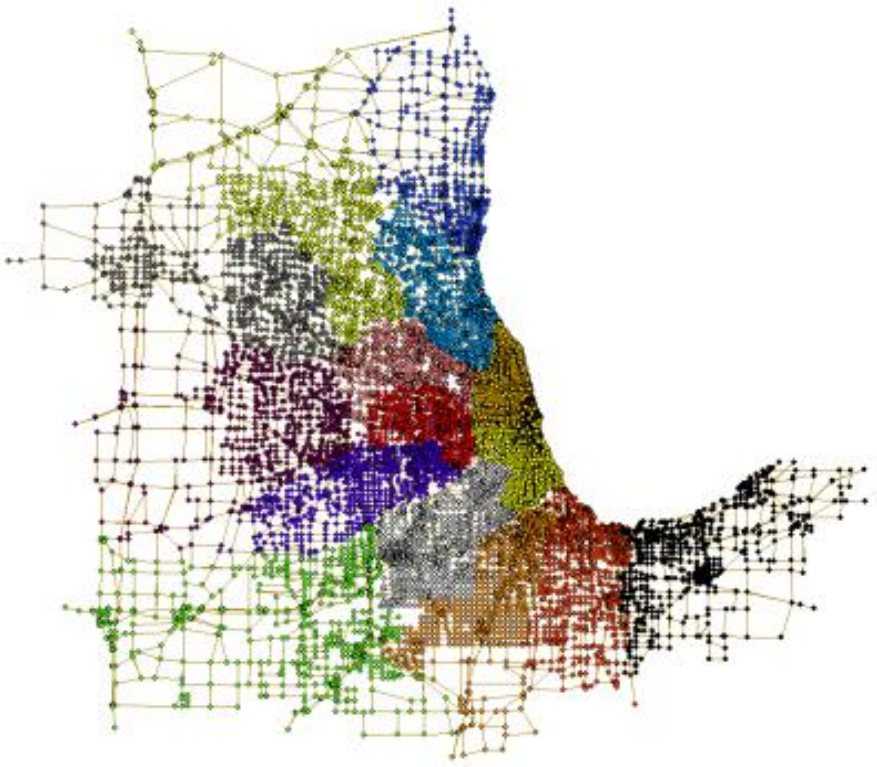
The number of users of the TRACC cluster increased to 91 from 29. Cluster utilization also increased during the quarter, peaking at approximately 85% in July. This substantial utilization also increased the mean wait time for users. Since utilization is expected to increase in the long term, TRACC initiated an activity to test and replace the cluster's dual-core AMD Opteron 2216 CPUs with quad-core Opteron 2378 CPUs and increase each compute node's RAM from 4 GB to 8GB. Standard benchmarks for two of the key applications codes at TRACC, LS-DYNA and STAR-CD, were run and performance approximately doubled as expected.

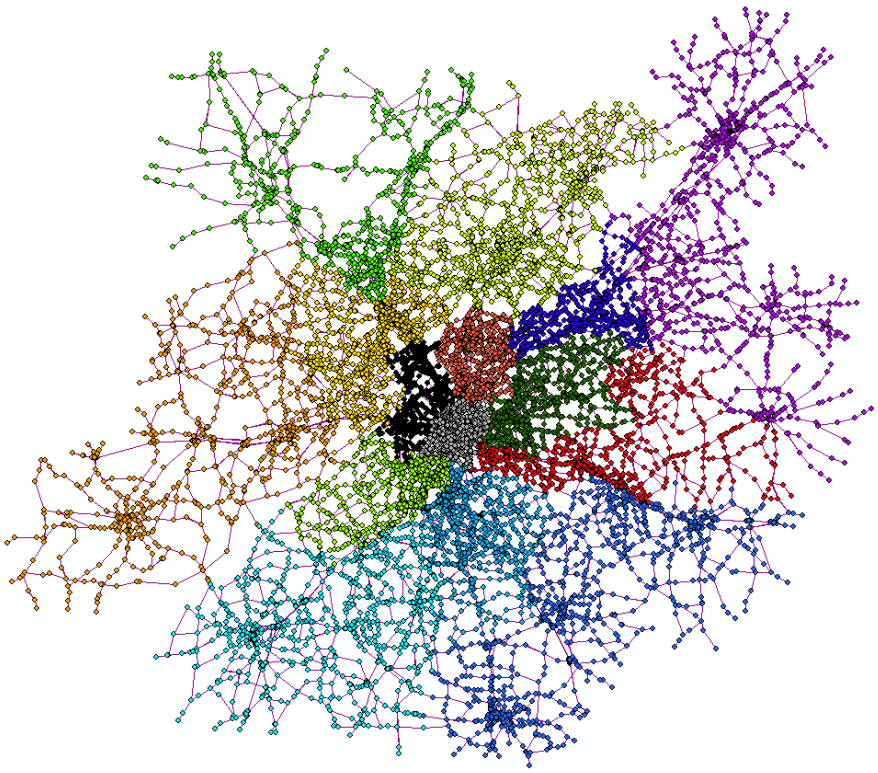
Network connectivity from TRACC to the main Argonne National Laboratory was also reviewed for possible upgrading during the quarter. The network link from the TRACC facility at the DuPage Airport flight Center to the TRACC cluster at the DuPage National Technology Park was provided by a 1 Gbps radio link, with a 20 Mbps backup radio link. To provide better availability, higher speed backup and support for Jumbo packets, for better throughput for visualization applications, an upgrade was being undertaken through the use of new radios and larger dishes.

Transportation systems simulation

The parallel TRANSIMS Microsimulator improved in several key areas. The necessary transfer protocols were added to properly parallelize transit trips. A traveler monitoring system was implemented to allow the Master node to keep track of which travelers are active. Several memory-saving changes were made which enabled the full regional Chicago model to be run and many performance optimizations resulted in much faster run times. TRACC cooperated with AECOM to run their Atlanta regional model on the parallel Microsimulator and obtain performance results. Finally, the NCSA-developed visualization package Metropolis for TRANSIMS was used to analyze differences in the results from parallel and non-parallel versions and as a result, the parallel results have come much closer to the non-parallel results.

The efforts to improve the transit network for the Chicago Metropolitan Area fell into four primary categories. The "L" system network (this is the elevated light rail system in Chicago) was completely updated based on electronic track details provided by the Illinois Department of Transportation. Paths for all CTA buses and "L" system trains were imported and adjusted to be compatible with the existing TRANSIMS model. The new routes and schedules for the METRA system (the Chicago Regional Commuter Rail System) were implemented into the TRANSIMS transit model based on the Google Transit Feed, the internal mechanism by which the data is transferred continuously from transit authorities to the Google site. The availability of detailed scheduling information for each individual bus and train was of high value for TRANSIMS, creating very accurate transit models.





The Atlanta TRANSIMS Model

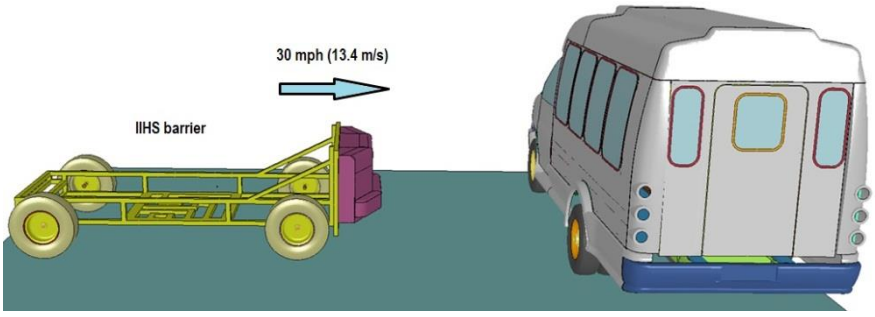
Building evacuation models were also further improved. Models were added for a typical shopping complex as well as typical residential buildings. Extensions to the modeling approach allowed for the differentiation of special populations, such as staff and elderly people. Based on these models, new methods to determine evacuation curves for these cases were developed. These results were then verified and validated through a comparison between Simulex (a code suitable for the detailed simulation of building evacuations) output and a Monte Carlo simulation using this new evacuation curve. Also, two new areas of investigation were embarked upon during this quarter in the area of building evacuation. First, research was done into methodologies usable for the simulation of stadium evacuation. Second, investigations into the applicability of another software package called AnyLogic were performed.

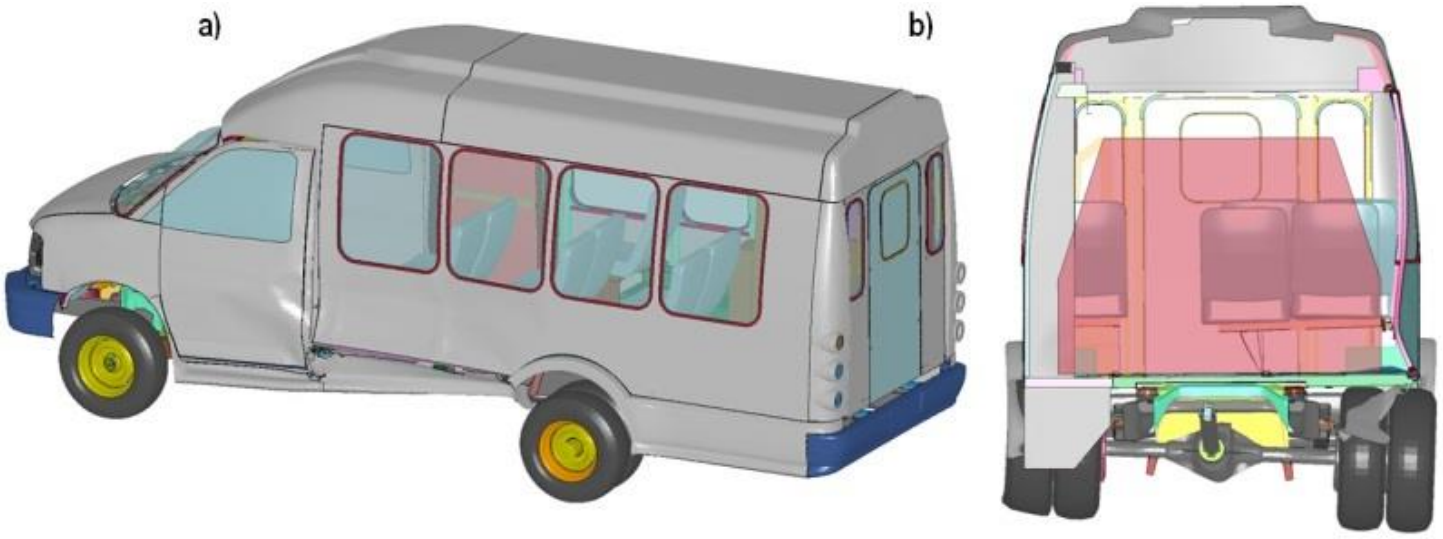
In the area of TRANSIMS evacuations, an extensive study was done to determine appropriate values for Microsimulator parameters which would best be able to describe a high congestion event. TRANSIMS employs the concept of "lost cars" to alleviate unrealistic congestion, which is often brought about due to unavoidable shortcomings in the agent-based framework before a fully equilibrated state is achieved. While effective numerically, the mechanism lacks precision when an operations-quality result is desired. Therefore, investigation proceeded to determine which values of these parameters were optimal to minimize these "lost cars" and thus increase the fidelity of the simulations.

Work done on the Gary-Chicago-Milwaukee sensor data fell into two major categories. First, the data was re-grouped by sensor rather than by day, with each sensor occupying a different database. This allowed a data filtering process to extract outliers among the sensor readings. Also, efforts were undertaken to match the geographically coded locations noted by the sensor data with corresponding ones in the TRANSIMS network.

Computational structural mechanics

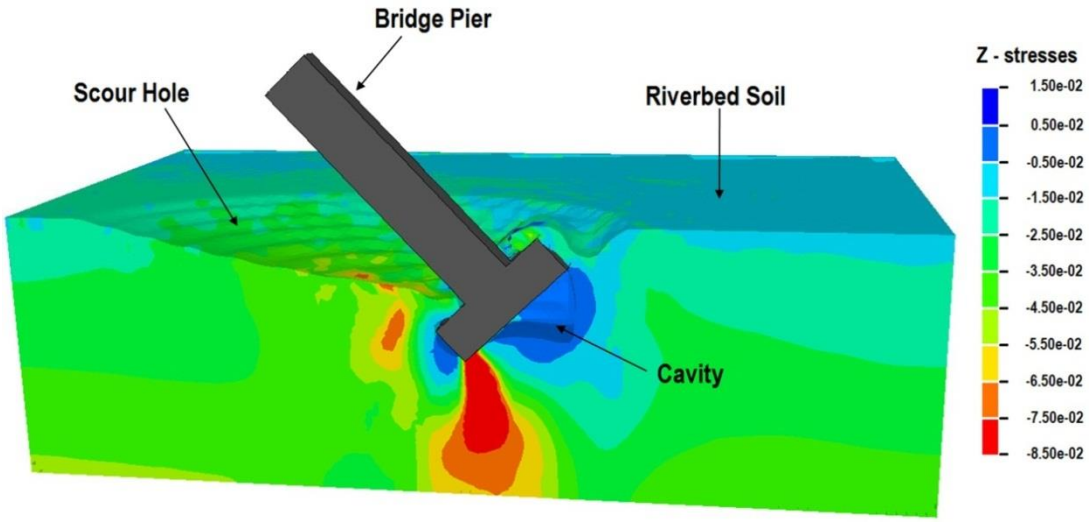
Extensive help was provided to the new users from Florida Agricultural and Mechanical University-Florida State University College of Engineering (FAMU-FSU). Research conducted at FAMU-FSU College of Engineering pertained to comprehensive crashworthiness and safety evaluation of paratransit buses. The design process of passenger compartment structure in paratransit buses is not regulated by any crashworthiness standards. FAMU-FSU College of Engineering and Florida DOT worked jointly for over a decade on development of a safety and testing standard for the paratransit buses purchased by the state of Florida. Bus rollover test (per European Union Regulation 66) and side impact tests are the sub-





ject of their standard enforced in the summer of 2007. The standard stipulates that either experimental or computational approach be used for testing the structures of the buses. FAMU-FSU College of Engineering used LS-DYNA software as a primary code for the computational evaluation of the buses.

TRACC researchers started the work on developing a multiphysics approach to evaluate the stability of bridges with piers in scour holes. The research initially focused on validating the Multi-Material Arbitrary Lagrangian approach implemented in LS-DYNA code for modeling the soil structure interaction between the pier and riverbed soil. Riverbed scour can undermine the soil around bridge support piers to the point that the piers become unstable and the bridge collapses. A computational fluid dynamics approach was used by the CFD group at TRACC to analyze riverbed scour to determine the depth and shape of the scour pit around bridge piers and abutments. Once these profiles are determined, the critical question is: Will the bridge structure remain stable? To answer this question, a structural stability analysis must be performed for the shape-evolving scour hole to find the depth and shape at which structural failure occurs. For simple geometries, favorable comparisons were obtained between known analytical results and numerical simulations.

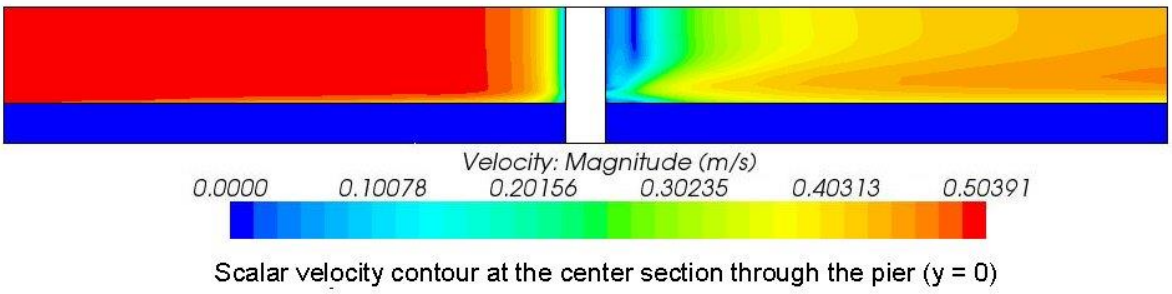


The National Highway Traffic Safety Administration (NHTSA) planned to expand the use of the TRACC cluster. NHTSA's Human Injury Research Division (HIRD) was doing a lot of work related to real world crash reconstruction. For reconstruction purposes, HIRD used two different software modules: MADYMO and modeFrontier. MADYMO software allows for simulating kinematics of the human body while modeFrontier is a tool that helps in probabilistic analysis and optimization of designs. In response to this need, TRACC has ordered a 100 token license for MADYMO/modeFrontier and installed it on the TRACC cluster.

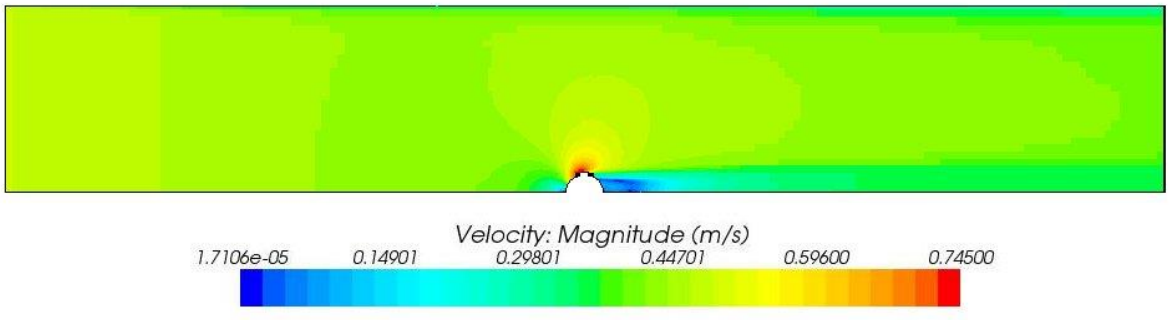
Computational fluid dynamics

Scour around cylindrical piers

To evaluate scour risk at a real bridge, local scour at piers and abutments must be adequately predicted in addition to general scour due to a flood or pressure flow scour due to flooded bridge decks. A new effort was begun to develop and test a clear water scour methodology using the commercial CFD software STAR-CCM+ for analysis of local scour at cylindrical bridge piers. Industry efforts to develop fluid structure interaction (FSI) capabilities led to the development of capabilities to displace wall boundaries as a function of forces on the boundary. In the typical FSI problem an object in the flow will deform primarily due to normal (pressure) force on the object. When scour is occurring, the river bed deforms because bed sediments are eroded under the action of shear force. Whether it is shear force or pressure force responsible for the boundary deformation does not matter, and therefore, the FSI capabilities being developed could be applied to the scour problem. As boundary deformation occurs the computational cells next to the boundary stretch or compress, degrading their quality and leading to computational error in solving for the flow and pressure fields. To avoid this problem, computational mesh deformation near deforming boundaries is distributed throughout the entire mesh in a way that maintains high mesh quality. This procedure was relatively new and was called "mesh morphing." It offered the potential to leverage rapidly developing FSI capabilities to compute scour. For the initial effort, a geometry was set up with an assumed symmetric half of a flood flow past a cylindrical pier cut through the centerline in the flow direction to save on computational resources. The 3D velocity field was computed in the first part of the study.



Scalar velocity contour at the center section through the pier (y = 0)



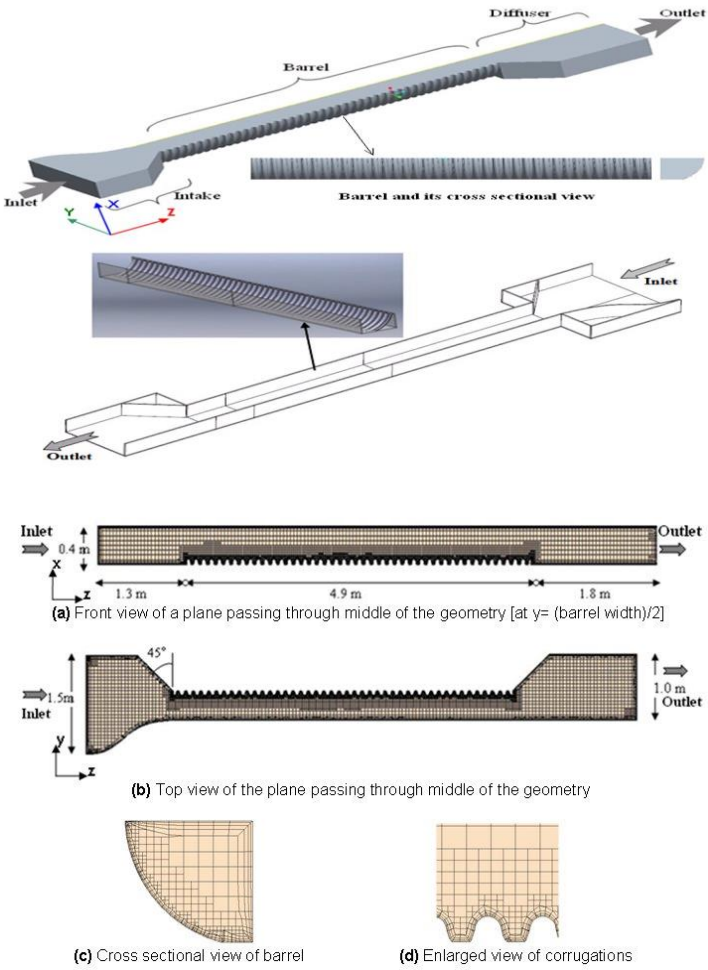
Scalar velocity contour at the interface (z = 1 mm)

Flow through culverts for fish passage

Another major modeling effort was begun to verify that 3D free surface flow could be computed through the detailed geometry of a culvert that was not running full. A culvert is a conduit used to enclose a flowing body of water. They are often corrugated for strength. They may be used to allow water to pass underneath a road, railway, or embankment. They may carry flood waters, drainage flows, and natural streams below earth fill and rock fill structures. From a hydraulic aspect, a dominant feature of a culvert is whether it runs full or not. Culverts come in many shapes and sizes, including round, elliptical, flat-bottomed, pear-shaped, and box. They vary from the small drainage culverts found on highways and driveways to large diameter structures on significant waterways or supporting large water control works. The Federal Highway Administration (FHWA) was conducting experiments on culverts to provide designers with better information to allow for fish passage in the design. Several key parameters considered were: design approach, culvert slope, culvert geometry, stream width, and passage performance. CFD analysis of FHWA culvert experiments was begun to help experimental-

ists in experimental design and in understanding of experimental results.

The culvert model considered in this study was based on an initial set of culvert experiments in a flume at TFHRC. A quarter portion of the circular cross section of the culvert having spiral corrugations on it was used. A CAD model was created based on



the dimensional details provided by TFHRC and the simulations were performed for different conditions to compare with the experimental data provided by TFHRC. Pro-ENGINEER was used for creating the CAD model of an 8 m long culvert and was imported into STAR-CCM+ in IGES (*Initial Graphics Exchange Specification*) file format. The CAD model consisted of three parts: the *intake* (also called the inlet), the *barrel* (or corrugated portion) and the *diffuser* (also called outlet). Simulations were performed for a culvert with water depth of 116 mm and discharge of 3.7 *L/sec*) with spiral corrugations.

Workshop on Computational Hydraulics for Transportation

A workshop on Computational Hydraulics for Transportation was held at TRACC on September 23 and September 24, 2009. The goals of the workshop were to: (1) bring together researchers who are using high performance computing in the area of scour to share ideas and status in the development of state-of-the-art of 3D scour models, (2) invite major commercial CFD software vendors to attend, present their current scour modeling capabilities, and encourage them to add to or enhance the scour modeling capabilities of their software, (3) discuss the role of 2D hydraulics software and models and ways to interface 2D and 3D software, and (4) discuss other topics of interest to attendees.

Thirty four researchers from across the U.S. registered for the workshop. Twenty three people, not counting TRACC research staff attended at the TRACC site in West Chicago, Illinois. Five people registered for participation via videoconferencing facilities at the Turner-Fairbank Highway Research Center and the University of Nebraska at Lincoln. Six people registered for participation via Adobe Connect. Two 15 ft. by 18 ft. video projection walls divide the TRACC Collaboratory into a general event area and a training area with tables. The training area was used for speakers and major participants to provide a place where they could use their laptops and take notes. Each table was equipped with a small microphone so that remote participants would be able to hear the group discussions that took place.

The training area can accommodate about twenty people. It was fully occupied. The general event area can accommodate more than thirty people, and it was used for students who participated at the TRACC site, and also served as a place to have small group discussions.

Presentations from the academic researchers focused on physics based modeling and analysis of scour and the question of how detailed the physics needed to be to accurately predict scour. Because scour processes at bridges are inherently transient over a long time scale and vortex structures in the flow that play a large role in scour are transient phenomena over small time scales, the two approaches to scour modeling presented and discussed in detail were solving unsteady Reynolds averaged Navier-Stokes (RANS) equations and large eddy simulation (LES) techniques, which solve the transient Navier-Stokes equations directly for large eddies while using some form of closure model that does not require resolving eddies at small length scales. LES techniques push the limits of computing capacity of current supercomputers. To obtain reasonably accurate results with LES, length scales must be resolved over several orders of magnitude, which normally require the use of tens to hundreds of millions of points in the computational grid for relatively small problems (not river flow past an entire real bridge). RANS techniques, however, can be applied to full scale bridges using currently available high performance computing clusters. Several researchers had been using LES simulations to study the physics of large vortex structures in the flow past bridge piers and abutments to better understand how the detailed physics of a turbulent flow field are related to scour. One goal of the research was and continues to be to use new knowledge about the physics of scour gained from LES simulations to add empirical physics based enhancements to unsteady RANS scour models to obtain advanced three dimensional scour analysis capabilities that are feasible on current high performance computing (HPC) clusters. The participants agreed that as long as the scour predictions are conservative, i.e. do not under predict scour, an unsteady RANS approach to scour analysis with CFD software could be highly useful to field engineers in bridge design, scour countermeasure design, and the assessment of scour risk for existing bridges.

The group was also aware that the computational resources of HPC clusters that can be applied to large problems is growing very rapidly as computer hardware evolves and becomes more massively parallel at the chip and sub-chip level. Given the rate of advancement of computing hardware, the group also agreed that the development of multiphase LES techniques for the analysis of scour was a worthwhile pursuit because by the time these techniques become mature and validated, the HPC clusters needed to apply them would likely be available at reasonable cost.