ANL-12/TRACC-USDOT-Y6Q4

Argonne
NATIONAL LABORATORY

Energy Systems Division

Transportation Research and Analysis Computing Center (TRACC)

Year 6 Quarter 4 Progress Report (Final)

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Transportation Research and Analysis Computing Center (TRACC) Year 6 Quarter 4 Progress Report

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by
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submitted to
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Office of Research Development & Technology
Research and Innovative Technology Administration
U.S. Department of Transportation

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Introduction, Objectives, and Results

Argonne National Laboratory initiated a FY2006-FY2009 multi-year program with the US Department of Transportation (USDOT) on October 1, 2006, to establish the Transportation Research and Analysis Computing Center (TRACC). As part of the TRACC project, a national high performance computer user facility has been established, with full operations initiated in March 2008. The technical objectives of the TRACC project included the establishment of a high performance computing center for use by USDOT research teams, including those from Argonne and their university partners, and the use of advanced computing and visualization facilities for the performance of focused computer research and development programs in areas of interest for USDOT. The project was reauthorized for FY2010 and operated for 6 years.

The objectives have been met by establishing a high-performance computing facility, known as the Transportation Research and Analysis Computing Center (TRACC), and providing technical support for its use by USDOT staff and their university and industry contractors. In addition to facilities for advanced computing, visualization, and high-speed networking in the TRACC facility, advanced modeling and simulation applications research is being conducted by the TRACC facility scientific applications staff in coordination and collaboration with USDOT researchers.

This final project report for Year 6 of the project (Y6Q4) summarizes the principal activities associated with the operation of the computing center and in the performance of the computational research in the key application areas identified by USDOT as its highest priorities. As defined by the Year 6 Statement of Work (SOW) the activities and objectives for the sixth year of the project are: (1) traffic modeling and simulation and emergency transportation planning; (2) computational fluid dynamics for hydraulics and aerodynamics research; (3) multi-dimensional data visualization; and (4) computational structural mechanics applications.

The establishment of the high performance computing center based on a massively parallel computer system and the transportation research and demonstration projects associated with key focus areas included the use of computing facilities as well as the exchange of research results with the private sector and collaboration with universities to foster and encourage technology transfer.

The final report consists of highlights of the many activities at TRACC over the six years of operation. TRACC was first established at the DuPage Airport Flight Center with the plan to move to the new DuPage National Technology Park shortly after. This location would have been a catalyst for close collaboration with universities and the industry, but due to the economic downturn in 2008, the DuPage National technology Park was never fully developed. TRACC stayed at the DuPage Airport Flight Center until December 2010, establishing a unique supercomputing center for USDOT researchers from universities, government agencies, planning organizations, and consulting firms. TRACC funded university projects at Northern Illinois University and the University of Illinois in Urbana/Champaign to develop new technologies and support other users on the shared high performance platform.

TRACC used a multi-pronged approach to build a strong user community, by not only providing raw computing power, but also providing commercial software licenses, technical assistance, extensive training, one on one help, and outreach activities to identify potential users of the facility. TRACC started developing complex visualization software for transportation simulation software, parallelized software packages to make use of the HPC architecture at TRACC, and developed software interfaces such as TRANSIMS Studio to make the software more accessible to users.

Over the years, about 70 projects have made use of the TRACC HPC clusters, and operation will continue based on alternative funding. The 120 current users will be supported from several projects with USDOT under Interagency Agreements, and TRACC's operation has transitioned into direct work for USDOT agencies, such as FHWA and NHTSA. All this work has been enabled by the original TRACC grant, and allows USDOT, state DOT, and transportation researchers and engineers to perform research and analysis more cost effectively than before. The Turner-Fairbank Highway Research Center, for example, is now relying on TRACC to evaluate complex hydraulic problems using commercial CFD software, being able to reduce the need for costly experiments to satisfy requests guidance on new highway infrastructure designs from state DOTs. NHTSA is using TRACC's high performance computers for house-internal occupant safety calculations, such as the simulation of roll-over crashes and similar analysis. Most TRANSIMS transportation models in the US are making use of TRACC's clusters to run trip dynamics analysis of region-size multi-modal simulations.

Towards the end of the SAFETEA-LU grant period, TRACC acquired a new high performance cluster computer to support the future needs of all these USDOT projects. The operation of the machine for the coming years is funded by various sponsors from FHWA and NHTSA, and the TRACC facility has become an essential part of the USDOT research infrastructure, leveraging existing research projects with modern computational approaches that are cost-efficient and scale up to address real world challenges in maintaining and renewing the U.S. transportation infrastructure.

Organizations and Users with Access to the TRACC HPC Clusters

3-D Numerical Simulation of Direct-Injection, Mixture Formation and Combustion in a Hydrogen Engine			
	ES Division, Argonne		
		Scarcelli, Riccardo	***User***
	US DOE Engines and Emissions Control Technologies		
		Singh, Gurpreet	***Cognizant Engineer***
A Microstructure-Based Modeling Approach to Characterize Asphalt Materials			
	Michigan Department of Transportation		
		Staton, John	***Cognizant Engineer***
	Michigan Technological University		
		Barak, John	***Cognizant Engineer***
		Colbert, Baron	***User***
		Dai, Qingli	***User***
		Lu, Haizhu	***User***
		Ng, Kenny	***User***
		You, Zhanping	***Cognizant Engineer***
Analysis and Design of Roadside Safety Features for Safety Performance			
	Texas Transportation Institute		
		Abu-Odeh, Akram Y.	***User***
		Bligh, Roger P.	***Cognizant Engineer***
		Sheikh, N.M.	***User***
Analysis of THOR-NT Dummy for Vertical Impact Environments			
	NASA Langley		
		Annett, Martin S.	***Cognizant Engineer***
	Virginia Tech		
		Putnam, Jacob	***User***
		Untaroi, Costin	***User***
Application of Chaos Theory Analysis to Structural Health Monitoring of Cable-Stayed Bridges			
	FHWA NDE		
		Jalinoos, Frank	***Cognizant Engineer***
		Jin, Shuang	***User***

Application of TRANSIMS for Highway Work Zones			
	FHWA OoP		
		Yang, David	***Cognizant Engineer***
	Western Michigan University		
		Oh, Jun-Seok	***User***
Assessment Of Occupant Kinematics in Rollovers; Rollover Crash Analysis			
	NHTSA HID		
		Barsan-Anelli, Aida Cristina	***User***
		Ridella, Stephen	***Cognizant Engineer***
	TRACC, Argonne		
		Bojanowski, Cezary	***User***
Bridge Hydraulics - Analysis Support for Hydraulics Research in Transportation Applications			
	TFHRC		
		Kerenyi, Kornel	***Cognizant Engineer***
		Xie, Zhaoding	***User***
	TRACC, Argonne		
		Lottes, Steven A.	***Cognizant Engineer***
		Sofu, Tanju	***Cognizant Engineer***
	University of Nebraska-Lincoln		
		Bushra, Afzal	***User***
		Guo, Junke	***Cognizant Engineer***
		Shan, Haoyin	***User***
		Zhai, Yuan	***User***
Bridge Scour Modeling Using CFD			
	California Department of Transportation		
		Flora, Kevin Scott	***Cognizant Engineer***
CFD Analysis of Outlet Modifications to Improve Highway Pipe Efficiency at Peak Flows			
	Maine Department of Transportation		
		Hebson, Charles	***Cognizant Engineer***
		Mann, Alexander	***User***
		Pearce, Bryan	***User***
	TFHRC		
		Kerenyi, Kornel	***User***
CFD Modeling of FDOT's Sediment Erosion Rate Flume (SERF)			
	Florida Department of Transportation		
		Renna, Rick	***Cognizant Engineer***
	University of Florida		
		Crowley, Raphael	***User***
		Robeck, Corbin	***User***
	University of Nebraska-Omaha		
		Li, Chen	***User***
		Woldeyesus, Kokob Zeremariam	***User***

Chicago Business District Evacuation (IDOT)			
	NE Division, Argonne		
		Tentner, Adrian M.	***User***
	Northern Illinois University		
		E, Manli	***Developer***
		Liu, Lichuan	***Developer***
		Pasupuleti, Lok Aradhya	***User***
		Ronanki, Bharani	***Developer***
Chicago North Side Water Reclaimation Plant Studies			
	TRACC, Argonne		
		Lottes, Steven A.	***Cognizant Engineer***
	University of Illinois at Urbana-Champaign		
		Garcia, Marcelo	***Cognizant Engineer***
		Sinha, Sumit	***User***
		Tokyay, Talia Ekin	***User***
CMAP Activity-Based Model			
	CMAP		
		Heither, Craig	***User***
		Stratton, Matt	***User***
		Wies, Kermit	***User***
	FHWA OoP		
		Gardner, Brian	***Cognizant Engineer***
Computational Mechanics Research and Support for Aerodynamics and Hydraulics at TFHRC			
	Northern Illinois University		
		Lanka Venkata, Sudhir Kumar	***User***
	TRACC, Argonne		
		Lottes, Steven A.	***Cognizant Engineer***
Computer Aided Mix Design (CAMiD) Technical and Analysis Support for Advanced Computational Needs -- Bituminous Mixtures Laboratory at FHWA Turner-Fairbank Research Center			
	FHWA OoP		
		Gibson, Nelson	***User***
	TFHRC		
		Kutay, Muhammed Emin	***Cognizant Engineer***
CRIS Test Modeling			
	NHTSA		
		Kruszewski, Piotr Mateusz	***User***
Design-oriented Scoured Foundation Modeling for Bridge Performance Analysis			
	University of Missouri-Kansas City		
		Chen, ZhiQiang	***User***
Determining Wheel-Soil Interaction Loads using a Meshfree Finite Element Approach			
	NASA JPL		
		Contreras, Michael	***Cognizant Engineer***

Development and Evaluation of Climate Metrics for Aviation based on Climate-Chemistry Modeling Analyses			
	FAA		
		Jacob, Daniel	***Cognizant Engineer***
	University of Illinois at Urbana-Champaign		
		Lee, Huikyo	***User***
		Olsen, Seth	***User***
		Patten, Kenneth	***User***
		Wang, Dong	***User***
		Wuebbles, Donald	***User***
Development and Improvement of Roadside Safety Barriers			
	TFHRC		
		Arispe, Eduardo N.	***User***
		Eigen, Ana Maria	***User***
		Opiela, Kenneth	***Cognizant Engineer***
	TRACC, Argonne		
		Bojanowski, Cezary	***Cognizant Engineer***
Development of TRANSIMS Models to Evaluate Traffic Management Plans for Special Events and Construction Projects in the Chicago Business District			
	IIT		
		Lee, Sang Hyuk	***User***
		Lee, YongDoo	***User***
		Li, Zongzhi	***User***
		Rahman, Asadur	***User***
		Veliou, Eirini	***User***
	TRACC, Argonne		
		Ley, Hubert	***Cognizant Engineer***
Development of TRANSIMS Software for use in Parallelization of TRANSIMS			
	AECOM		
		Patnam, Krishna Chandra	***User***
		Roden, David	***Cognizant Engineer***
	Argonne		
		Toonen, Brian R.	***User***
		Yelchuru, Balaji	***User***
	USDOT		
		Gardner, Brian	***Cognizant Engineer***
Development of TRANSIMS Tools and Methodology for the Atlanta Metropolitan Area			
	Georgia Tech		
		Guin, Angshuman	***User***
		Leonard, John	***Cognizant Engineer***
		Shealey, Stephanie Lynne	***User***
	TRACC, Argonne		
		Ley, Hubert	***Cognizant Engineer***

Development of TRANSIMS Visualization Software Metropolis			
	NCSA		
		Betts, Alex	***User***
		Cox, Donna	***User***
		Hall, Matthew	***User***
		Levy, Stuart	***User***
		Patterson, Robert	***User***
	TRACC, Argonne		
		Ley, Hubert	***Cognizant Engineer***
Electromagnetic Shock Absorber			
	Northern Illinois University		
		Fisher, Francisco Lucas	***User***
		Gupta, Abhijit	***Cognizant Engineer***
	TRACC, Argonne		
		Bojanowski, Cezary	***Cognizant Engineer***
		Kulak, Ronald F.	***Cognizant Engineer***
Evaluation of Thor Dummy FE Model in Crash Environments			
	NHTSA HID		
		Ridella, Stephen	***Cognizant Engineer***
	University of Virginia		
		Untaroiu, Costin	***User***
FHWA Signal Processing, Data Analysis and Computational Modeling for Highway Applications			
	TFHRC		
		Chintakunta, Satish Reddy	***User***
		Cobb, Lincoln	***Cognizant Engineer***
		Gagarin, N.	***User***
		Mekemson, James Robert	***User***
		Scott, Michael	***Cognizant Engineer***
	TRACC, Argonne		
		Bojanowski, Cezary	***Cognizant Engineer***
Geosynthetic-Reinforced Soil Integral Bridge System; Scour Countermeasure Design; Deformation Analysis of Bridge Supported on Shallow Foundations			
	FHWA OoP		
		Hartmann, Joey	***Cognizant Engineer***
		Nicks, Jennifer	***User***
Impact of Wide Base Tires on Pavements - A National Study			
	FHWA IR&D		
		Weaver, Eric	***Cognizant Engineer***
	University of Illinois at Urbana-Champaign		
		Al-Qadi, Imad L.	***User***
		Gamez, Angeli	***User***
		Hernandez, Jaime	***User***
		Ozer, Hasan	***User***

Improvements of LS-Dyna Models for Off-Road Traffic Accident Analysis			
	Kineticorp		
		Carter, Neal	***User***
		Rose, Nathan	***User***
		Zhu, Ling	***User***
Inner Nozzle Flow characterization of Biodiesel from Different Feedstocks			
	Argonne		
		Som, Sibendu	***User***
	TRACC, Argonne		
		Lottes, Steven A.	***Cognizant Engineer***
	US DOE EERE Vehicle Tech Prog		
		Stork, Kevin	***Cognizant Engineer***
In-situ Load Rating of Highway Bridges			
	University of Virginia		
		Chase, Robert Paul	***User***
		Chase, Steven Bradley	***Cognizant Engineer***
		Jin, Shuang	***User***
Investigation of Bridge Pier and Abutment Scour Using Large Eddy Simulation			
	University of Iowa		
		Constantinescu, Serban George	***Cognizant Engineer***
		Dunn, Mark	***User***
		Miyawaki, Shinjiro	***User***
		Tokyay, Talia Ekin	***User***
		Yuksel Ozan, Ayse	***User***
Investigation of Impact Factors for FDOT Bridges; and the Best Practices in Construction of Paratransit Buses			
	FAMU-FSU		
		Gepner, Bronislaw Dominik	***User***
		Kwasniewski, Leslaw	***User***
		Siervogel, Jeff	***User***
		Taft Ford, Eduardo E.	***User***
		Wekezer, Jerry	***User***
	Florida Department of Transportation		
		Westbrook, Robert	***Cognizant Engineer***
	TRACC, Argonne		
		Bojanowski, Cezary	***Cognizant Engineer***
Investigation of Occupant Injury Mechanism in Vehicle Small Overlap Impacts			
	NHTSA		
		Parent, Daniel	***Cognizant Engineer***
	University of Virginia		
		Crandall, Jeff	***User***
		Yue, Neng	***User***

Investigation of Occupant Response in Vehicle Crash			
	NHTSA		
		Parent, Daniel	***Cognizant Engineer***
	University of Virginia		
		Bollapragada, Varun	***User***
		Panzer, Matthew Brian	***User***
		Park, Gwansik	***User***
		Poulard, David	***User***
		Shin, Jae Ho	***User***
		Zhang, Qi	***User***
Investigation of River Flow and Transport Processes Using High Resolution Eddy Resolving CFD Simulations			
	South Florida Water Management District		
		Zeng, Jie	***User***
	TRACC, Argonne		
		Lottes, Steven A.	***Cognizant Engineer***
	University of Iowa		
		Chang, Kyoungsik	***User***
		Constantinescu, Serban George	***Cognizant Engineer***
		Kashyap, Shalini	***User***
		Steenhauer, Kate	***User***
		Suhodolova, Tatiana	***User***
Large Eddy Simulation of Interaction of Turbulent Flow with a Porous Media			
	TRACC, Argonne		
		Lottes, Steven A.	***Cognizant Engineer***
	University of Illinois at Urbana-Champaign		
		Samala, Rahul	***User***
		Vanka, Pratap	***User***
Large Scale Evacuation Planning with Microscopic Traffic Simulation			
	ORNL		
		Liu, Cheng	***User***
		Lu, Wei	***User***
Management			
	ES Division, Argonne		
		Drucker, Harvey	***Manager***
	TRACC, Argonne		
		Ley, Hubert	***Manager***
		Tate, Gail	***Manager***
		Weber, David	***Manager***

Modeling Hot Mix Asphalt Compaction - Technical Support for Pavement Design and Performance Modeling Team			
	Delft University of Technology		
		Jonsthovel, Tom Bernard	***User***
		Koneru, Saradhi	***User***
		Liu, X.	***User***
		Scarpas, Athanasios	***User***
	FHWA NDE		
		Kasbergen, Cornelis	***User***
		Weaver, Eric	***Cognizant Engineer***
	Texas A&M		
		Masad, Eyad	***User***
Modeling Soil-Structure Interaction in the Presence of Large Soil Deformations			
	TRACC, Argonne		
		Bojanowski, Cezary	***User***
		Kulak, Ronald F.	***User***
Moreno Valley TRANSIMS Transportation Modeling/ITS			
	FHWA OoP		
		Gardner, Brian	***Cognizant Engineer***
	Moreno Valley		
		Gross, Mark	***User***
		Keller, James	***User***
		Kerenyi, John	***Cognizant Engineer***
		Lloyd, Michael David	***User***
		Minard, Mark	***User***
		Van Simaeys Jr, Julien	***User***
MOVES (Motor Vehicle Emission Simulator), Modeling emissions from on road vehicles			
	EPA Office of Transportation and Air Qualilty		
		Aikman, William Russell	***Cognizant Engineer***
		Beardsley, Megan	
		Brzezinski, David	***User***
		Choi, Jongwoo David	***User***
		Church, Thomas Michael	***User***
		Faler, Wesley Gordon	***User***
		Glover, Ed	***User***
		Kahan, Ari	***User***
		Maciag, Ted	***User***
		Michaels, Harvey	***Cognizant Engineer***
		Shyu, Gwo Ching	***User***
	TRACC, Argonne		
		Ley, Hubert	***Cognizant Engineer***
MOVES Air Pollutant Emission Analysis for the GREET Model			
	Argonne		
		Burnham, Andrew	***User***

NCAC Finite Element Models Assessment			
	George Washington University		
		Marzougui, Dhafer	***User***
		Tahan, Fadi	***User***
	TFHRC		
		Opiela, Kenneth	***Cognizant Engineer***
NHTSA Human Injury Research Division			
	NHTSA		
		Parent, Daniel	***User***
	NHTSA HID		
		Takhounts, Erik	***Cognizant Engineer***
Nonlinear Analysis of Cable-Stayed Bridge Cables			
	Northern Illinois University		
		Balpande, Rohit Suresh	***User***
		Gupta, Abhijit	***Cognizant Engineer***
		Vannemreddi, S.	***User***
		Vannemreddy, B.	***User***
	TRACC, Argonne		
		Kulak, Ronald F.	***Cognizant Engineer***
Numerical Investigation of Single Point Incremental Forming			
	Northwestern University		
		Cao, Jian	***Cognizant Engineer***
		Huang, Ying	***User***
Open Channel Flow, Bridge Hydraulics, and Bridge Scour			
	Northern Illinois University		
		Biswas, Dipankar	***User***
		Edwards, Christopher M.	***User***
		Elapolu, Phani Ganesh	***User***
		Kostic, Milivoje	***Cognizant Engineer***
		Majumdar, Pradip	***Cognizant Engineer***
		Pati, Vishnu Vardhan Reddy	***User***
		Tulimilli, Bhaskar Rao	***User***
	TRACC, Argonne		
		Lottes, Steven A.	***Cognizant Engineer***
Picoscopic Modeling of Transportation Systems			
	UMASS Amherst		
		Collura, John	***Cognizant Engineer***
		Leiner, Gabriel	***User***
Ricardo CRADA			
	Argonne Tribology Section		
		Demas, Nicholaos G.	***User***
		Erck, Robert A.	***User***
		Fenske, George R.	***Cognizant Engineer***

RTSTEP: Regional Transportation Simulation Tool for Evacuation Planning			
	AECOM		
		Choi, Jongwoo David	***User***
		Gregerson, Christopher	***User***
		Patnam, Krishna Chandra	***User***
		Roden, David	***User***
		Santhanam, Srividya	***User***
		Singuluri, Sashank	***User***
	CDOT		
		Emmanuel, Abraham	***Advisor***
	City of Chicago - Office of Emergency Management		
		Halac, Yilmaz	***Sponsor***
	IIT		
		Arthur, Christina	***User***
		Liu, Yi	***User***
		Liu, Yifang	***User***
		Lu, Xi	***User***
		Qu, Fei	***User***
		Yi, Bo	***User***
		Zhong, Yaoqian	***User***
		Zhou, Bei	***User***
	Northern Illinois University		
		Moraga, Reinaldo J.	***User***
		Tanaka, Raul Augusto Alvarez	***User***
		Zhang, Quan	***User***
	TRACC, Argonne		
		Auld, Joshua	***Developer***
		Holifield, Justin	***User***
		Hope, Michael	***Developer***
		Kang, Sherry	***User***
		Park, Young Soo	***User***
		Qualls, Timothy	***User***
		Sokolov, Vadim O.	***Cognizant Engineer***
		Zhang, Kuilin	***Developer***
SACOG TRANSIMS Implementation			
	Resource Systems Group, Inc		
		Bowman, John L.	***User***
		Bradley, Mark Andrew	***User***
		Castiglione, Joseph	***User***
		Lawe, Stephen	***User***
		Mulandi, James	***User***
		Rentz, Erich	***User***
	USDOT		
		Gardner, Brian	***Cognizant Engineer***
		Grady, Brian Robert	***Cognizant Engineer***

SANDAG Activity-Based Model			
	SANDAG		
		Daniels, Clint	***Cognizant Engineer***
		Sun, Wu	***User***
SIMon Brain Model			
	NHTSA HID		
		Ridella, Stephen	***Cognizant Engineer***
		Takhounts, Erik	***User***
	USDOT		
		Hasija, Vikas	***User***
Simulation Analysis of an Integrated Model System for the Region of Southern California Association of Governments			
	SCAG		
		Cheng, Hao	***User***
		Cho, Joongkoo	***User***
		Cho, Sungbin	***User***
		Choi, Simon	***User***
		Hu, Hsi-Hwa	***User***
		Huang, Guoxiong	***User***
		Lee, Cheol-Ho	***User***
		Ryu, Sung Ho	***User***
		Sangkapichai, Mana	***User***
		Wen, Frank	***Cognizant Engineer***
		Yoon, Sung Su	***User***
		Zhang, Yongping	***User***
	UCSB		
		Chen, Yali	***User***
	University of Texas-Austin		
		Paleti, Rajesh	***User***
Simulation of Bridge Pier Failure from Flood Loading			
	TRACC, Argonne		
		Bojanowski, Cezary	***User***
		Kulak, Ronald F.	***User***
Snowdrift Mitigation			
	University of Iowa		
		Basnet, Keshav	***User***
		Constantinescu, Serban George	***Cognizant Engineer***
Software Testing			
	CD-adapco		
		Reynolds, Robert	***Vendor***
		Schnepper, Carol	***Vendor***
	NE Division, Argonne		
		Thomas, Justin W.	***User***
SToRM-Cluster; Computation River Hydraulics and Transfer			
	USGS		
		Simoes, Francisco J.M.	***Cognizant Engineer***

Structural Performance of Flexible Pavements			
	Louisana TRC		
		Chen, Xingwei	***Cognizant Engineer***
		Zhang, Zhao	***User***
Structural Testing Laboratory Computational Mechanics Research; Finite Element Modeling of Highway Structures			
	TFHRC		
		Adams, Michael	***User***
		Beshah, Fassil	***Cognizant Engineer***
		Chen, Linfeng	***User***
		Graybeal, Ben	***User***
		Greene, Gary	***User***
		Ocel, Justin	***User***
	TRACC, Argonne		
		Bojanowski, Cezary	***Cognizant Engineer***
Study of Erosion Mechanisms at Piers of Rectangular Shape using Eddy Resolving Techniques and use of the Databases for Improvement of RANS Scour Models			
	TFHRC		
		Kerenyi, Kornel	***Cognizant Engineer***
	University of Iowa		
		Cheng, Zhengyang	***User***
		Constantinescu, Serban George	***Cognizant Engineer***
		Koken, Mete	***User***
		Yuksel Ozan, Ayse	***User***
Study of the Rate of Deterioration of Bridges and Pavements as Affected by Trucks			
	Clemson University		
		Amirkhanian, Serji	***Cognizant Engineer***
		Chowdhary, Ronnie	***User***
		Dunning, Anne	***User***
		Pang, Wei Chiang	***User***
		Putman, Brad	***User***
		Swanka, Merrill	***Cognizant Engineer***
	TRACC, Argonne		
		Bojanowski, Cezary	***Cognizant Engineer***

Systems Administation			
	CIS, Argonne		
		Dust, James	***SysAdmin***
		Hall, Corey	***SysAdmin***
		Hilden, Michael	***SysAdmin***
		Schmitz, Corby B.	***SysAdmin***
		Winkler, Linda	***SysAdmin***
	MCS Division, Argonne		
		Valdes, John P.	***SysAdmin***
	TRACC, Argonne		
		Amiot, Lawrence W.	***SysAdmin***
		Bernard, Jon	***SysAdmin***
		Kolpacki, Penny	***SysAdmin***
		Mihalo, William E.	***SysAdmin***
		Nowakowski, Waldemar	***SysAdmin***
		Reitzer, Joe	***SysAdmin***
		Schmitt, Robert	***SysAdmin***
Temecula Traffic Circulation Analysis of Alternate Networks			
	City of Temecula		
		Pina, Art	***User***
	Moreno Valley		
		Kerenyi, John	***Cognizant Engineer***
	WILLDAN		
		Smith, Ruth	***User***
Time Domain Fatigue Simulation of Metals			
	Northern Illinois University		
		Balpande, Rohit Suresh	***User***
		Gupta, Abhijit	***Cognizant Engineer***
Traffic Simulation of St. Louis Transportation Network for Earthquake Impact Assessment			
	Newmark Civil Engineering Laboratory		
		Elnashai, Amr S.	***Cognizant Engineer***
		Spencer, William F.	***Cognizant Engineer***
	University of Illinois at Urbana-Champaign		
		Chang, Liang	***User***
Transient Structural Dynamics of Bridges Subjected to Traffic, Seismic and Blast Loadings			
	TRACC, Argonne		
		Bojanowski, Cezary	***User***
		Kulak, Ronald F.	***User***
TRANSIMS Configuration Control, Testing, Automation, and Software Release			
	AECOM		
		Roden, David	***User***
	Northern Illinois University		
		Malar, K	***Developer***
	USDOT		
		Ducca, Fred	***Cognizant Engineer***
		Gardner, Brian	***Cognizant Engineer***

TRANSIMS Evacuation Traffic Models of New Orleans and Houston			
	Louisiana State University		
		Dixit, Vinayak	***User***
		Montz, Thomas	***User***
		Wolshon, Brian	***Cognizant Engineer***
		Zhang, Zongjie	***User***
TRANSIMS Technology and Tools development technical assistance for the development Buffalo USA/Canadian Region cross-border model.			
	USDOT		
		Chase, Robert Paul	***User***
		Mekuria, Maaza	***Cognizant Engineer***
		Smith, Scott	***Cognizant Engineer***
TRANSIMS Traffic Simulation Software Development/Parallelization			
	Northern Illinois University		
		Kanaga-Nayagam, Kanesa	***User***
	TRACC, Argonne		
		Hope, Michael	***User***
		Ley, Hubert	***Cognizant Engineer***
Unspecified			
	Argonne		
		Faber, Merlyn	
		Nguyen, Vu	
		Pinkerton, Scott	
	Arizona State University		
		Pendyala, Ram	***User***
		Plotz, Joseph	***User***
		Volosin, Sarah Elia	***User***
	Chrysler		
		Zhu, Yuhua	
	MCS Division, Argonne		
		Kim, Jong G.	
	Medical College of Wisconsin		
		Hallman, Jason	***User***
	Michigan Technological University		
		Stanton, Brett	
	Northern Illinois University		
		Kuppa, Lakshmi Pratyusha	***User***
	South Carolina Department of Transportation		
		Zwanka, Merrill	
	TRACC, Argonne		
		Balcerzak, Marcin	***User***
	University of Iowa		
		Jahra, Fatima	***User***
	USDOT		
		Rudd, Rodney W	

Update LA DOTD Policy on Pile Driving Vibration Management			
	Louisana TRC		
		Gautreau, Garvin	***User***
	TRACC, Argonne		
		Lottes, Steven A.	***Cognizant Engineer***
	Worcester Polytechnic Institute		
		Tao, Mingjiang	***User***
		Zhang, Mo	***User***
Using TRANSIMS to Quantify the Impacts of Planned Transportation Projects on Congestion and Air Quality			
	Georgia Regional Transportation Authority		
		Davis, Curt	***User***
		Goodwin, Robert	***User***
		Pihl, Eric	***User***
		Rousseau, Guy	***User***
		Zuehlke, Kai	***User***
	TRACC, Argonne		
		Ley, Hubert	***Cognizant Engineer***
Vehicle Stability under High Winds			
	Northern Illinois University		
		Patil, Rohan Satish	***User***
Wind Loads on Highway Sign and Traffic Signal Structures			
	University of Iowa		
		Constantinescu, Serban George	***Cognizant Engineer***
		Miyawaki, Shinjiro	***User***
		Tokyay, Talia Ekin	***User***

Advanced Degrees Awarded to Graduate School Students for Computational Fluid Dynamics Work Done on TRACC High Performance Computer Clusters on Problems of Importance to the FHWA Turner-Fairbank Highway Research Center and U.S. DOT

1. Bishwadipa Das Adhikary, "Flow and Pressure Scour Analysis of an Open Channel Flow Having an Inundated Bridge Deck under Various Flooding Conditions," M.S. Thesis, Northern Illinois University, July 2008
2. Dipankar Biswas, "Development of an Iterative Scouring Procedure for Implementation in CFD Code for Open Channel Flow under Different Bridge Flooding Conditions," M.S. Thesis, Northern Illinois University, June 2009
3. Afzal Bushra, "Computational Fluid Dynamic Analysis of Hydrodynamic Forces on Inundated Bridge Decks and the Effect of Scaling," Ph.D. Thesis, University of Nebraska, November 2009
4. Bhaskar Rao Tulimilli, "Development of a Three-dimensional Scouring Methodology and its Implementation in Commercial CFD Code for Open Channel Flow Over a flooded Bridge Deck," M.S. Thesis, Northern Illinois University, June 2010
5. Phani Ganesh, Development of Three-Dimensional Iterative Methodology Using a Commercial CFD Code For Flow Scouring Around Bridge Piers, M.S. Thesis, Northern Illinois University, October 2010
6. Vishnu Vardhan Reddy Pati, "CFD Modeling and Analysis of Flow through Culverts," M.S. Thesis, Northern Illinois University, October 2010
7. Zhaoding Xie, "Theoretical and Numerical Research on Sediment Transport in Pressurised Flow Conditions," Ph.D. Thesis, University of Nebraska, July 2011
8. Chris Edwards, "3-D Mesh Morphing Iterative Methodology for Flow Scouring Around Bridge Piers Implemented in a Commercial CFD Code," M.S. Thesis, Northern Illinois University, August 2011
9. Yuan Zhai, "Time-Dependent Scour Depth under Bridge-Submerged Flow," M.S. Thesis, University of Nebraska, May 2010
10. Yuan Zhai, "CFD Modeling of Fish Passage in Large Culvert and Assistance for Culvert Design with Fish Passage," Ph.D. Thesis, University of Nebraska, July 2013

Dr. Steven Lottes, Argonne TRACC, served on the thesis committees for Bishwadipa Das Adhikary, Dipankar Biswas, Bhaskar Rao Tulimilli, Phani Ganesh, Chris Edwards, and Vishnu Vardhan Reddy Pati.

From the acknowledgements of Afzal Bushra's thesis:

"I am thankful to Dr. Kornel Kerenyi, Research Manager of the FHWA Hydraulics R&D Program for providing the access to the hydraulics lab at TFHRC and support for this research. I would also like to thank Dr. Tanju Sofu from Argonne National Laboratory for his expertise in CFD and for his valuable feedbacks and guidance. I am grateful to Dr. Steven Lottes and Dr. David Weber for organizing the useful CFD workshops, and providing the vital access to the supercomputing facility at Argonne National Laboratory. This thesis would not have been possible without the support of Turner Fairbank Highway Research Centre and Argonne National Laboratory."

Advanced Degrees Awarded to Graduate School Students for Computational Structural Mechanics Work Done on TRACC High Performance Computer Clusters on Problems of Importance to the U.S. DOT

1. Rohan Patil, “Stability of Single-Unit Truck under Wind Loading”, M.S. Thesis, Northern Illinois University, December 2011, directed by Abijith Gupta
2. Francesco Lucas Fisher, “Design of a Semi-Active Controllable Electromagnetic Shock Absorber”, M.S. Thesis, Northern Illinois University, December 2011, directed by Abijith Gupta
3. Eduardo E. Taft Ford, “Dynamic Interaction Between Heavy Vehicles and Highway Bridges”, M.S. Thesis, Florida State University, October 2010, directed by Jerry Wekezer
4. Bharathi Vannemreddy, “Aerodynamic Vibrations of Stay Cables of a Cable Stayed Bridge”, M.S. Thesis, Northern Illinois University, August 2010, directed by Abijith Gupta
5. Srihari Vannemreddi, “Numerical Modeling of Stay Cables and Stay Cable Bridges” , M.S. Thesis, Northern Illinois University, August 2010, directed by Abijith Gupta
6. Sharnie Earle, “Evaluation of Dynamic Load Allowance Factors for Reinforced Concrete Highway Bridges”, M.S. Thesis, Florida State University, April 2010, directed by Jerry Wekezer

Dr. Ronald F. Kulak served on the thesis committees for Rohan Patil, Francesco Lucas Fisher, Bharathi Vannemreddy, and Srihari Vannemreddi

Dr. Cezary Bojanowski served on the thesis committees for Rohan Patil, Francesco Lucas Fisher, and Srihari Vannemreddi. He also advised to Eduardo E. Taft Ford and Sharnie Earle on their thesis.

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The DuPage Airport Flight Center was chosen as a suitable location to facilitate technology transfer to USDOT and collaborators in academia and the industry

October 2006 to December 2006

Argonne National Laboratory initiated a program with the US Department of Transportation (USDOT) in late 2006 to establish the Transportation Research and Analysis Computing Center (TRACC). As part of the TRACC project, a national supercomputing user facility was established to provide high performance computing and advanced modeling services to the U.S. transportation community, with full operations starting in 2007.

The technical objectives of the TRACC project included the establishment of this high performance computing center for use by USDOT research teams, including those from Argonne and their university partners, and the use of advanced computing and visualization facilities for the conduct of focused computer research and development programs in areas specified by USDOT.

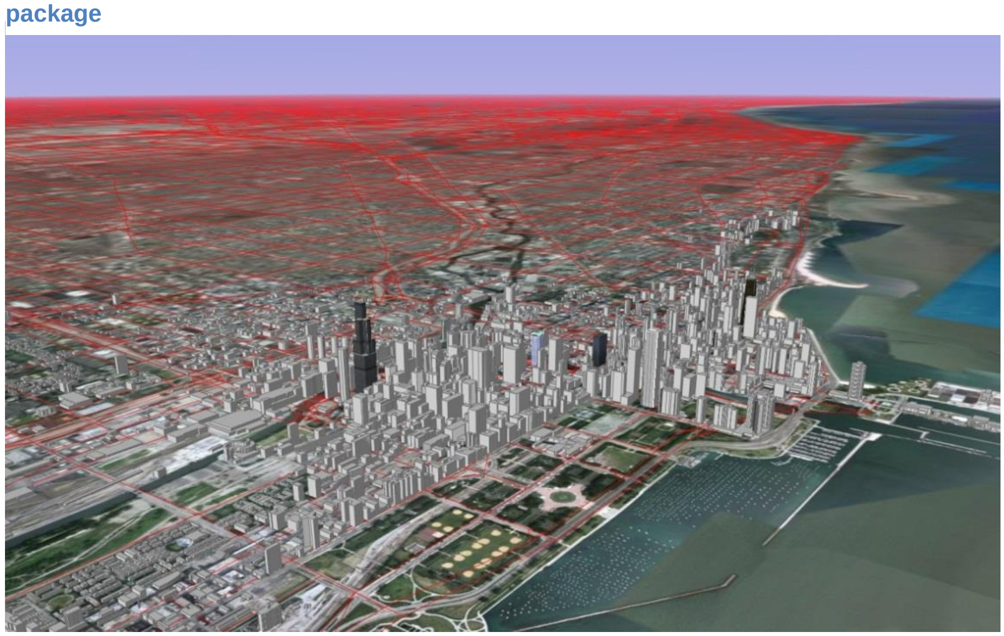
The initial set of activities identified by USDOT included: (1) traffic modeling and simulation and emergency transportation planning; (2) mesh-free methods for analysis of optimum design of safety structures; and (3) multi-dimensional data visualization. Other focus areas were added later.

Transportation research and demonstration projects at TRACC focused on the exchange of research results with the private sector and collaboration with universities to foster and encourage technology. Argonne's university partners included the University of Illinois and Northern Illinois University.

At the beginning of the project, the plan included building a facility at the DuPage National Technology Park near the DuPage Airport in Illinois. Occupancy was expected as early as February 2008. These plans were later abandoned in favor of building TRACC out at an existing facility (the DuPage Airport Flight Center).

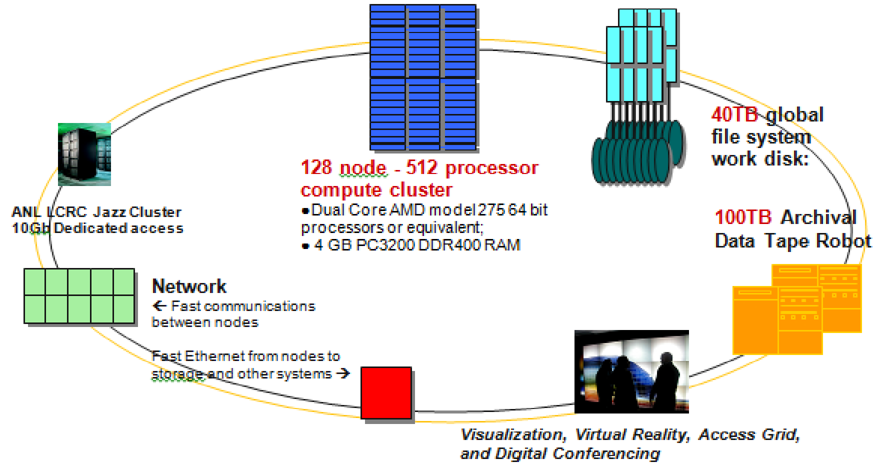
Concurrently, a large additional project for the Illinois Department of Transportation was established to extend and improve the Chicago Metropolitan Area TRANSIMS model. Funding agencies for this work were the Illinois Department of Transportation, Illinois Terrorism Task Force, the Illinois Emergency Management Agency, and the Federal Highway Admin-

Development of a regional transportation simulation model for the City of Chicago was started. The network consisted of 40,000 road segements and 22,000 intersections, and utilized the USDOT-developed TRANSIMS simulation software package



istration (FHWA). The focus of the project was on using TRANSIMS to analyze emergency evacuation options for the City of Chicago.

At this point in time, discussions started with the FHWA Turner-Fairbank Highway Research Center to explore computational fluid dynamics support.



Error! No text of specified style in document.**The original concept of a high performance cluster to be acquired for TRACC, and its integration into existing resources at Argonne and the new TRACC facility at the DuPage airport**

January 2007 to March 2007

Recognizing the computational demands of the TRANSIMS software for large metropolitan applications, a plan for the development of a parallel version of the latest version of TRANSIMS was developed in discussions among colleagues at FHWA and their consultants, Argonne, and colleagues from Northern Illinois University, who later conducted the corresponding parallelization task. The statement of work written for NIU focused on the development of routing and microsimulation techniques for TRANSIMS, and work was initialed later in 2007.

Argonne and FHWA colleagues also discussed and proposed that the initial focus of the visualization task be directed toward enhancing the visualization capabilities of the TRANSIMS traffic simulation code. This recommendation was approved by Ms. Lydia Mercado, the USDOT program manager. The key investigators were chosen for this project at the National Center for Supercomputing Applications at the University of Illinois in Urbana Champaign.

A critical component of the TRACC program was the acquisition and deployment of a massively parallel computing system that would be suitable for transportation applications used by the USDOT research community. The detailed technical specifications, statement of work, acceptance plan, proposed bidders list and evaluation criteria were transmitted to the Argonne Procurement Department on March 23, 2007.

Initial efforts also focused at this time on facilitating the use of the TRACC facility for Computational Fluid Dynamics (CFD) applications by the FHWA's Turner-Fairbank Highway Research Center. Turner-Fairbank identified at that time the commercial CFD software FLUENT as their analysis tool of choice, and most initial effort had been focused on the acquisition of a FLUENT license for use on the existing Argonne JAZZ computing platform and, eventually, the TRACC computing cluster that was anticipated to become available during the summer of 2007.

The sketch below shows the proposed development of the DuPage National technology Park, including proposed locations for a TRACC facility. The development of the park stalled in 2007, and the TRACC facility remained at the DuPage Airport Flight Center until its move back to the Argonne site in December 2010.

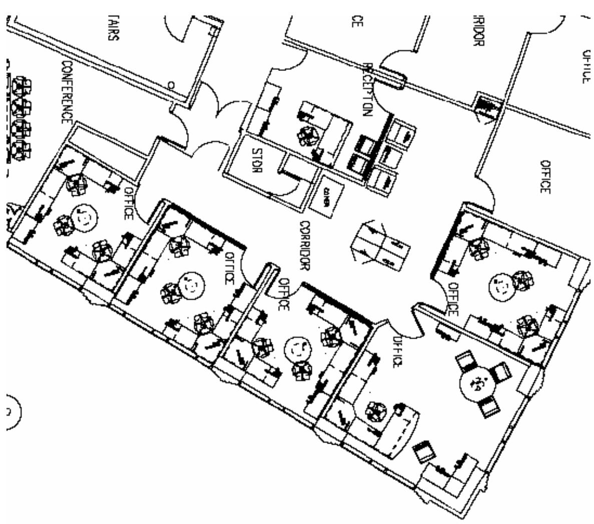
Argonne personnel would also provide training to Turner Fairbank users on accessing and use of the computational platforms, and would provide supplemental support in the application of FLUENT, as well as independent simulations using FLUENT or other software to help ensure the successful application of CFD analysis tools to applications of interest. Initial application areas included the evaluation of lift and drag forces acting on flooded bridge

The DuPage National Technical Park's Communcations Center was chosen to house the TRACC HPC cluster until a more permanent facility could be found

decks and the analysis of riverbed scour under bridges in flooding conditions.

It also became evident that Computational Structural Mechanics (CSM) capabilities would be needed for the assessment of many safety issues that were of major concern to USDOT. These included (but were not limited to) the following areas: crashworthiness with focus on automotive and truck impact into roadside hardware (guardrails, portable concrete barriers, bridge supports, etc.); collision safety for new high-speed passenger rail corridors, which includes crashworthiness and occupant survivability; dynamic analysis of highway bridge superstructures; and aircraft impact into water or soft soil.

Based on discussions with experts at TFHRC, a potential new application for TRACC focused on modeling and simulation of structural responses of bridge decks to aerodynamic loading, which in turn led to aerodynamic-structure coupling requiring the simultaneous use of computational structural mechanics and computational fluid dynamics simulation codes. The proposed 512 CPU parallel machine would greatly reduce simulation times for existing models, providing results in less time and allowing significantly more simulations to be performed.



April 2007 to June 2007

Acquisition of the parallel computing system progressed significantly at that time. The formal Argonne procurement process was initiated in March, and the request for proposal (RFP) was formally issued in early April 2007. Responses from a number of vendors were received in early June, 2007. The key component was a massively parallel computer, with 512 computing cores in a 128-node configuration, and an expected peak performance of several teraflops.

Technical and software licensing discussions with providers of key engineering software, including LS-DYNA, FLUENT and STAR-CD, were also initiated at the time. Key application software in transportation planning and analysis, including the TRANSIMS microsimulation traffic analysis, computational fluid dynamics, and computational structural mechanics, were part of a thorough testing and acceptance plan and would be available to external users when the TRACC system became formally available to the user community a few months later.

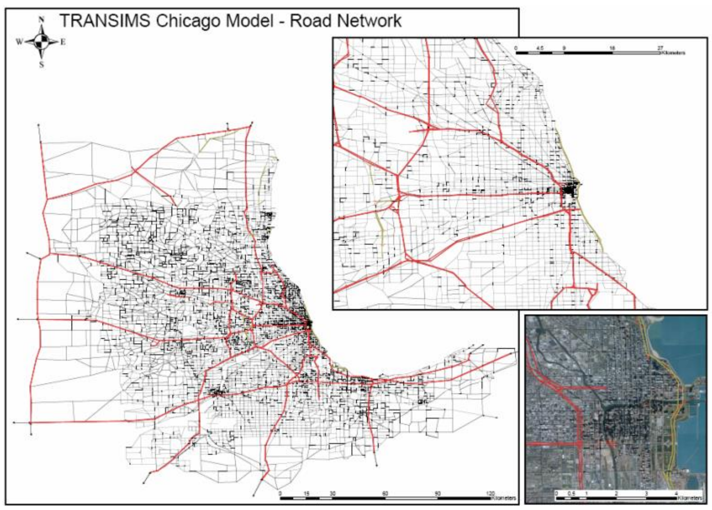
TRACC Offices at the DuPage Airport Flight Center

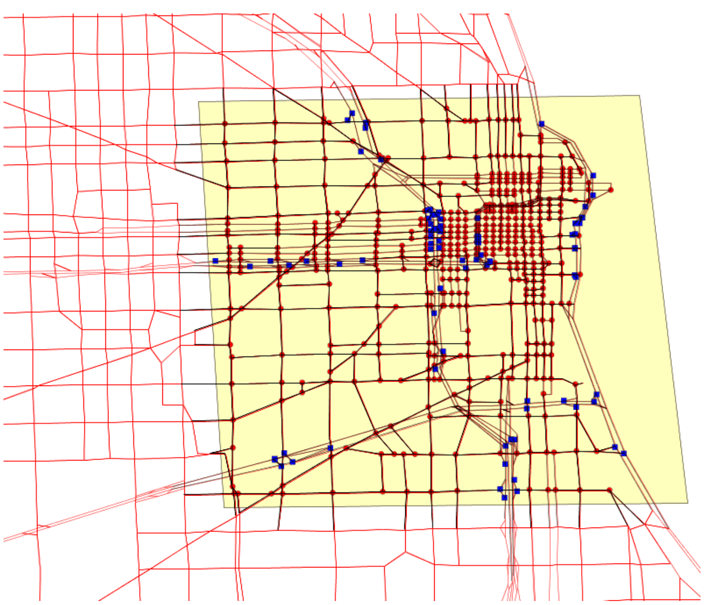
On June 1, the TRACC team also occupied its interim offices in the DuPage Airport Flight Center, which were planned to be the home of TRACC until more permanent facilities would be available in the DuPage National Technology Park. Due to the lack of development at the park, TRACC finally moved back to the Argonne site in December of 2010 to collaborate more closely with other research groups at the laboratory.

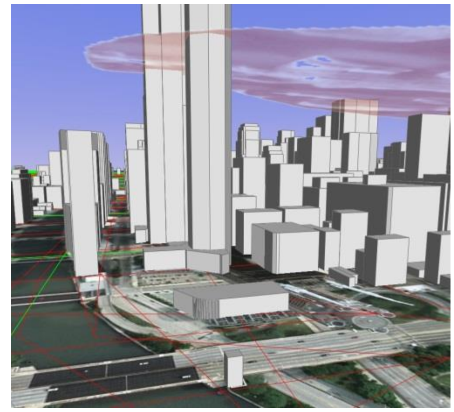
Co-location with the TRECC facility (the existing NCSA facility on the third floor of the flight center) improved collaboration capabilities, and provided significant cost savings on telecommunications, networking, and operational costs to the overall project. These facilities and resources were in close proximity to the other university partner, Northern Illinois University, and allowed for more effective collaboration with NIU faculty and students in the applications areas defined by the work plan.

Transportation Systems Modeling

At the time, huge progress was made on the transportation simulation model for the Chicago Metropolitan Region. The network, received from CMAP, was fully converted to the format needed by TRANSIMS, and many details were added to improve the fidelity of the road representation. The network was highly detailed in the business district and rather sparse in the outlying areas (towards Milwaukee in the north and Michigan in the East). The network size was suitable to run full scale simulations to explore the limitations of the existing computing systems in preparation for extensive testing of the soon to be delivered TRACC HPC cluster.







In addition to the road network, complex model details including conversion of the various trip tables had to be performed, and methods were being developed to make use of TRANSIMS features considered important for its use as an emergency evacuation planning tool.

At the time, data was obtained for the inclusion of transit modeling in the TRANSIMS model. This included routes and trip tables obtained from CMAP. The inclusion of mass transit capabilities in the model was an important step for using the software for emergency evacuation models.

Another important added capability was a system for shared software development, so that developers at Argonne as well as other collaborators could reliably use the same code base for their development. Based on Argonne's previous experience with shared software development,, the SVN system was implemented and still forms the basis for the shared development of TRANSIMS and other related tools.

Argonne also implemented a contract with Northern Illinois University to work on the parallelization of some of the TRANSIMS components. While the original emphasis of TRANSIMS was on a parallel implementation of dynamic traffic modeling algorithms, the most recent version 4 had been written with single processor logic in mind, much surpassing the performance and usability of previous TRANSIMS versions, but lacking in the extensibility required for full scale regional models.

Around this time, the large independent project for the Illinois Department of Transportation went into effect as well. This work complemented the model development at Argonne, and added resources through the inclusion of collaborators from Northern Illinois University. A group of 9 students from NIU was scheduled to start working at CMAP's offices in the Sears tower to edit the network and improve the fidelity of the model. An additional cadre of 4 master's students and one PhD student started work at TRACC to implement software and develop methodologies to perform this work for IDOT.

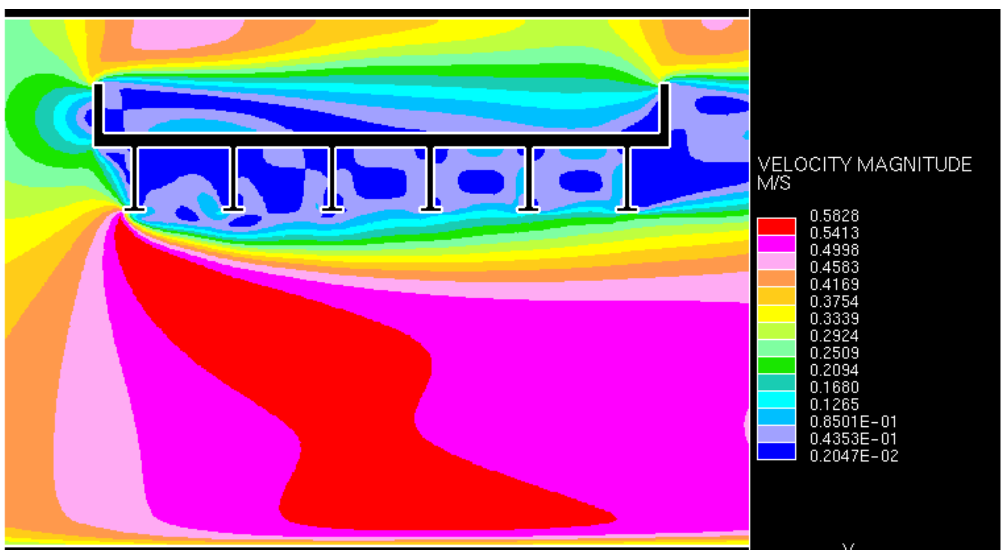
Two of these students graduated with advanced degrees, Ph.D. and M.S., and are still working at TRACC to this day (as staff members), and have been invaluable with their contributions to the area of transportation simulation research. Their task was, at the time, to devise methods to implement road closures and traffic redirections in the model, to be used by emergency responders during large scale evacuations.

Advanced Visualization

One of the obvious needs identified in traffic modeling was the development of an effective strategy to visualize the results and thus communicate complex results in a clear, vivid, and optimized manner to a variety of target audiences. A computer simulation of over 25 million daily trips in the Chicago Metropolitan Area led to an enormous amount of data, including the exact locations of all travelers at all times, delays at all road segments and intersections, traffic signal queues, and much more. Due to the fact that the above-mentioned details are largely the result of simulating the travel behavior of a synthetic population, these microscopic results were possibly of limited value without further processing. The raw results were important to validate certain aspects of the simulation and to increase confidence in the results obtained, but it proved to be more important to derive a number of macroscopic results that described the traffic flow in more general terms, e.g. travel times on road segments, congestion hot spots, and the overall effect of the scenarios being modeled compared to normal day base cases. The concepts formed the basis for the visualization project initiated with NCSA at that time.

Computational Fluid Dynamics

The analysis support for hydraulics research with an emphasis on bridge flooding and scouring was one of the identified collaboration opportunities supporting FHWA programs. Argonne researchers worked with Turner-Fairbank Highway Research Center (TFHRC) personnel to study Computational Fluid Dynamics (CFD) techniques for simulating open channel flow. Reduced scale experiments conducted at the TFHRC hydraulics lab provided data to establish a validated CFD-based advanced simulation methodology to address the research needs of the transportation community in a spectrum of focus areas ranging from coastal to inland to environmental hydraulics.



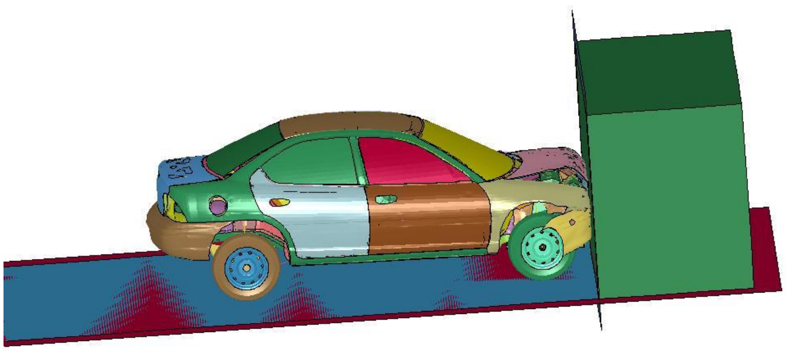
Initial results for the flow field for a flooded inundated bridge with six girders. The bridge surface is surrounded by concrete walls.

The CFD simulations were anticipated to address a range of hydraulics research including, but not limited to: the assessment of lift and drag forces on bridge decks under various flood conditions, optimization of bridge deck shapes to minimize pressure flow scour, analysis of sediment transport and its influence on scouring, evaluation of active or passive scour countermeasures to mitigate the damage, and addressing environmental issues such as fish passage through culverts. In this effort, the applicability of commercial CFD codes for prediction of these phenomena were to be investigated, and the agreement between the software predictions and experimental data from

TFHRC flumes would be determined for various modeling options. The scalability of these simulations to large numbers of processors, particularly for the simulation of full-scale bridge deck interactions, would be evaluated and guidelines would be developed for the decomposition of problems of this type.

On May 22, 2007 a team from the University of Nebraska visited Argonne for a training session on using Argonne's parallel computing resources for their simulations. During their visit, they were provided with the needed software components and procedures to run parallel cases with FLUENT. After acquiring a new FLUENT license for two seats and 20 processors, the components of the FLUENT software suite were installed on Argonne's 350-node Linux cluster JAZZ, and an interactive parallel FLUENT run submission script was tailored and provided for the University of Nebraska researchers' exclusive use.

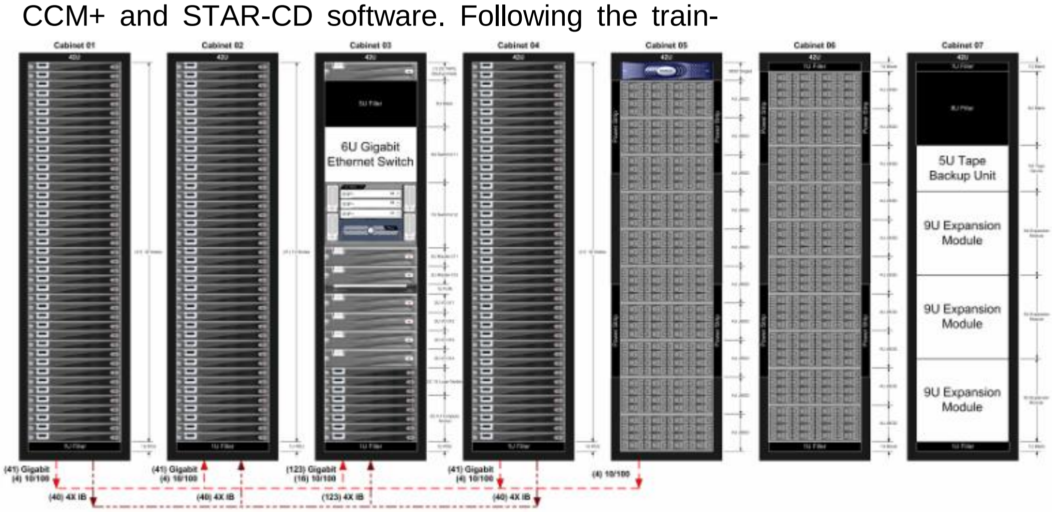
The first TRANSIMS Training Course at TRACC, held for TRACC staff and members of the team from Northern Illinois University and NCSA at the University of Illinois In Urbana Champaign



In parallel, a new team from the University of Northern Illinois attended a week-long CFD foundation training session from June 4 to 8 in Michigan, receiving training on basic CFD concepts and the STAR-CCM+ and STAR-CD software. Following the training, the STAR-CD and related software have been installed on NIU computers, and two technical exchange meetings were held in DeKalb, Illinois to discuss the scope and initial direction of the project.

July 2007 to September 2007

The computer acquisition process was completed and the parallel computer system, consisting of 128 compute nodes with 4 cores each, was selected from a company called LiNuX NetworX. The procurement process was concluded and the purchase requisition was issued shortly after the end of the quarter, on Oct. 5, 2007. The vendor planned on providing the system to Argonne within 60 days, at which time, a 30 day evaluation period would take place, testing general system performance and, where possible, examining performance of the system on application codes in the key areas of interest to USDOT and TRACC on traffic simulation, computational fluid dynamics and computational structural mechanics.



The machine also provided

a much larger than anticipated hard drive system, which turned out to be a very important feature for the work eventually performed at TRACC. It also included a 300 tape robot library, and other components such as login servers, IO servers, admin servers, Infiniband and Ethernet switches, and much more.

Computational fluid dynamics

Development efforts were focused on the analysis of lift and drag forces on inundated bridge decks under flooded conditions, work that started earlier in the year. The CFD models for the TFHRC flume tests were developed to validate them for prototypical open channel flow conditions. A key objective of this effort was to evaluate the capabilities of state-of-the-art computational fluid dynamics codes for the prediction of experimental results for lift and drag forces on experimental tests on inundated bridges being conducted at Turner Fairbank Highway Research Center. Argonne staff worked with colleagues from the University of Nebraska and Northern Illinois University (NIU) on the examination of CFD results and the development of "best practices" for the application of CFD to these open channel flows.

Colleagues from the University of Nebraska and at TFHRC were using the commercial software FLUENT on the massively parallel computing system at the Argonne Mathematics and Computer Science Division, JAZZ, where the CFD software had been previously installed.

In addition, Argonne and NIU colleagues were using the commercial software STAR-CD on Argonne and NIU computing facilities. Early results focused on the examination and determination of best practices for these kinds of problems, with emphasis on mesh spacing, time step selection and turbulence modeling.

Computational structural mechanics

Computational Structural Mechanics (CSM) was used for the assessment and resolution of many safety issues that were of major concern to USDOT. TRACC started exploring capabilities needed to support USDOT efforts in this area. Applications at TRACC would include potentially the following areas: crashworthiness with focus on automotive and truck impact into roadside hardware (guardrails, portable concrete barriers, bridge supports, etc.); collision safety for new high-speed passenger rail corridors, which includes crashworthiness and occupant survivability; dynamic analysis of highway bridge superstructures; and airframe impact into water or soft soil. A potential new application for TRACC centered on modeling and simulation of the structural response of bridge decks to aerodynamic loading.

The CSM software needed for the simulations described above required the use of advanced computational algorithms: mesh-based finite element algorithms and mesh-free algorithms. The finite element method was ideal for a large number of the problems of interest to DOT. However, for the more recent structural problems that DOT researchers were addressing — which exhibit significantly large deformations — mesh-free methods had to be employed to get realistic results. The following were some examples that required mesh-free methods: the simulation of guardrail post-soil interaction during impact, the simulation of car occupants during side impact accidents and the simulation of aircraft impacts into water and soft-soil.

October 2007 to December 2007

The DNTP Communications Building was equipped to house the TRACC Phoenix HPC cluster and was already a fully equipped and operational communications and networking facility, remotely alarmed, and monitored as a restricted access facility.

This facility and existing infrastructure provided substantial installation and operating cost savings for TRACC. The key facility resources/capabilities included:

- A heating system designed for heat loss of 6.8 KVA;
- Approximately 20 to 30 Tons Liebert fan coil (air cooled) units with temperature and humidity controls;
- FM-200 Clean Agent Fire Suppression System;
- Uninterruptible Power System providing a minimum of 150 kVA and a minimum or 120 kW output for 30 minutes;

- Two turbocharged and after cooled, 10cyl, diesel engine emergency generators rated at 800 amps (fuel tank provides 26.3 hours at full load); each generator providing 600kW, 480/277 volts, 800A service.

During this quarter the agreement between the DuPage Airport Authority and Argonne was formally executed and the contracts for electrical and cooling modifications to support the Center were established.

The TRACC HPC cluster Phoenix at the vendors facility during remote testing and evaluation

From December 5-7, the system administrator for the TRACC cluster participated in milestone acceptance testing of the cluster at LiNuX NetworX's offices in Utah. The testing consisted of basic functionality testing to ensure that all the requirements specified in the contract award were materially satisfied, followed by 48 hours of stability testing to burn-in the cluster hardware and to ensure that the system functioned reliably under heavy load. No significant problems were discovered during this onsite testing.

Onsite testing was followed by remote application testing and benchmarking from December 10 to 17. This testing involved running standard test cases for LS-DYNA, STAR-CD, and TRANSIMS, as well as TRACC's own test cases. These software packages were representative applications for USDOT capabilities needed in the areas of computational structural mechanics, computational fluid dynamics, and traffic simulation. The overall performance of the cluster during the application testing was extremely good.

Visualization technologies were also a key component of the TRACC implementation. As noted earlier, the availability of visualization facilities and their use in the application area identified as multi-dimensional data visualization was tied to the use of the facilities of the Technology, Research, and Education Commercialization Center (TRECC), a facility of the University of Illinois' National Center for Supercomputing Applications housed on the third floor of the DuPage airport flight center. TRACC signed a memorandum of understanding with TRECC, and a cooperative use agreement was finalized to give TRACC access to the facility as needed.

Bridge Hydraulics Simulations

The analysis support for hydraulics research with an emphasis on bridge flooding and scouring has been one of the identified areas of study to support Federal Highway Administration programs. Argonne researchers and its subcontractor, Northern Illinois University (NIU), worked in collaboration with the researchers at the Turner-Fairbank Highway Research Center (TFHRC) and its subcontractors at the University of Nebraska (UNE) to study Computational Fluid Dynamics (CFD) techniques for simulating open channel flow around inundated bridges. In this effort, reduced scale experiments conducted at the TFHRC hydraulics laboratory established the foundations of a CFD-based simulation methodology to address the research needs of the transportation community. The overall objective of this effort was to establish validated computational practices to address the research needs of the transportation community in bridge hydraulics via simulations.

The CFD simulations addressed a range of hydraulics research including the assessment of lift and drag forces on bridge decks when flooded, optimization of bridge deck shapes to minimize pressure scour, and addressing environmental issues such as fish passage through culverts. In this effort, the applicability of the commercial CFD software for prediction of these phenomena was investigated, and good agreement between the computed predictions and experimental data from TFHRC flumes was established for various modeling options. The Argonne and NIU teams were using STAR-CD, while TFHRC and UNE teams were using FLUENT in their simulation efforts.

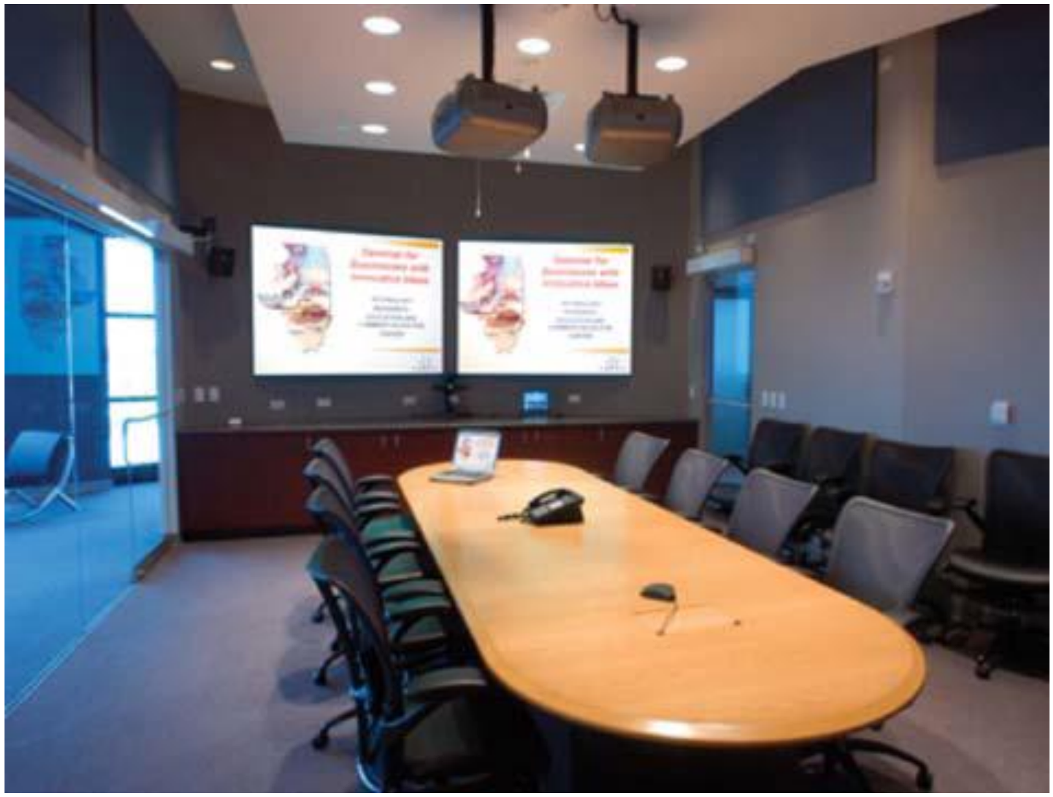
Computational structural mechanics

Initially, the major focus was on evaluating the performance of the new Phoenix cluster using representative problems from bridge dynamics and crash simulation. The first cluster performance evaluation was done using an input file prepared by Turner-Fairbank Highway Research Center and was a numerical model (finite element) for the Bill Emerson Memorial Bridge (BEMB), which is a cable-stayed bridge, located over the Mississippi between Cape Girardeau, Missouri and East Cape Girardeau, Illinois.

The three-dimensional finite element model for one of the two major structural subsystems of the BEMB consists of over 500,000 finite elements to represent the bridge structural components including the stay cables.

For 16 cores, the TRACC cluster required 8.61 days and the Thinkmate (a 16 core cluster at TFHRC) required a little over 14 days, which indicated that for the same number of cores the TRACC cluster was significantly faster, especially for large scale problems.

January 2008 to March 2008



Prior to installation of the cluster the Argonne Mathematics and Computer Science Division (MCS) and Computing and Information Systems Division (CIS) scheduled activities to ensure the TRACC cluster was integrated into the Argonne computing infrastructure upon installation and power up. As a result of this prior planning and up-front work, account provisioning, authentication, and access to the overall network was achieved on January 19, three days after initial power-up of the system at the Communications Building of the DuPage National Technology Park.

Argonne acceptance testing and benchmark validation was performed through the end February 2008. This testing involved running the manufacturer's software tests, software tests for LS-DYNA, STAR-CD, and TRANSIMS and TRACC's own test cases that were initially conducted in 2007 at the LiNuX NetworX manufacturing site in Utah.

Visualization and Communications Facilities

The University of Illinois TRECC's conference and meeting facilities provided point-to-point and group-to-group videoconferencing, with multicasting capabilities for collaboration. The TRECC and TRACC technical staff provided onsite reviews and training for the IDOT Evacuation Project External Review Board, including representatives from the Illinois Emergency Management Agency (IEMA), the Illinois Department of Transportation (IDOT), and the Illinois Terrorism Task Force. Additionally the visualization and support resources provided by TRECC were used in conjunction with a training course on TRANSIMS in March, 2008 for participants from Cambridge Systems and Northern Illinois University.

Transportation Systems Simulation

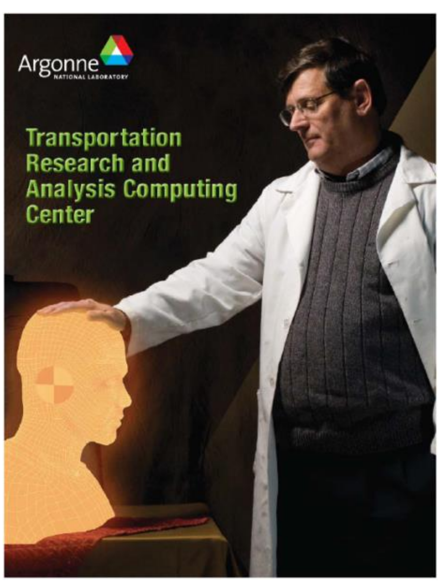
In close collaboration with the Chicago Metropolitan Agency for Planning, a new version of the road and transit network was implemented into the existing TRANSIMS model for the Chicago Metropolitan Area. This road network had been improved over previous versions by the nine Northern Illinois University students deployed at CMAP. The improvements covered about 50% of the metropolitan area, and focused mostly on the Chicago Business District. This was of special significance because the Chicago Business District is the high resolution area being used in the evacuation work, and improved fidelity of the network leads to better results in the evacuation studies.

The improvements were largely focused on road characteristics, such as the number of lanes, connectivity, speed limits, capacities, and similar parameters. To improve visualization and presentation of results, some improvements were made to the location of each of the network nodes to coincide better with aerial photography. However, the road network was still a straight line diagram and somewhat abstract, especially at elevated facilities such as Wacker Drive. Additional cleanup procedures were tried to determine the level of difficulty that is to be expected, and it was found to be quite feasible to improve the network by adding shape points to the individual links.

However the identification of the links was complicated by the fact that street names were not part of the existing data set and had been only recently added as an extra feature for the loop area.

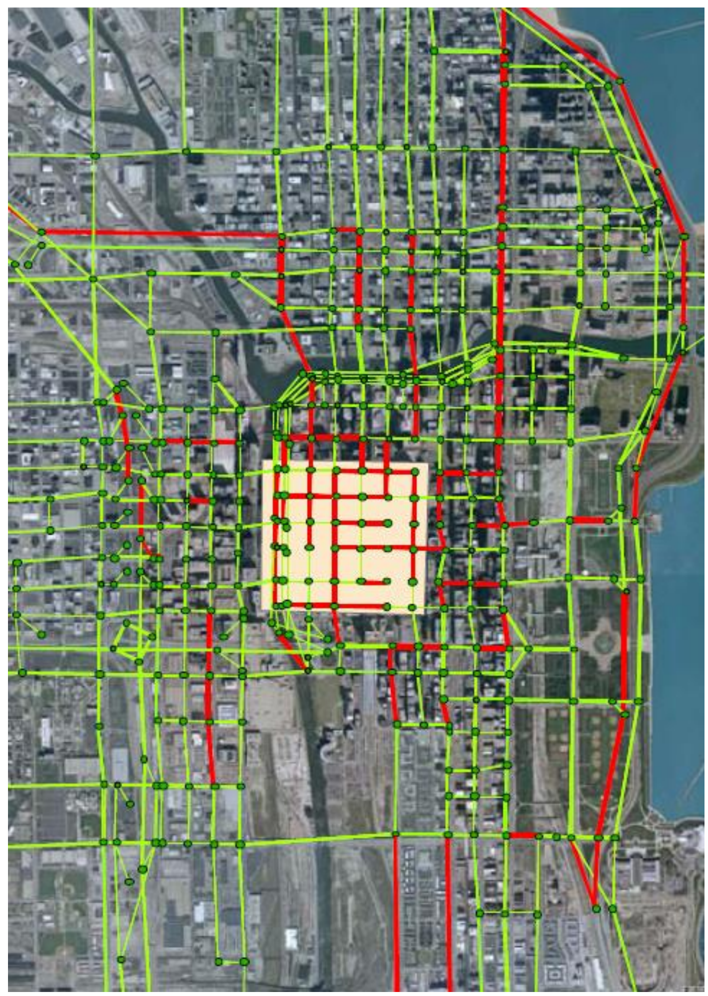
Improvements to the model also included widening of the area and an increase in the fidelity in some areas. The new model included Rockford and some other new areas on the boundaries of the network. The new network encompassed about 1950 traffic analysis zones.

A total of over 27 million daily trips must be routed through the entire road network, with the routing considering the exact time of travel using a time-aware routing approach. This process takes around 12 hours to compute on a single CPU, and had been performed this way on desktop machines until the new cluster became available. The cluster has sped up this calculation dramatically. Routes are inherently independent from each other in any given iteration. A schema called partitioning allowed for running the router tool on many machines at the same time, each working on a different subset of trips. The team was able to run the entire population of trips in about 20 minutes when using just 32 out of 512 CPUs on the cluster, instead of the 12 hour computation time experienced on Desktop PCs. This enormous gain in speed allowed for fine-grained optimizations by running the iterations numerous times. As a rule of thumb, about 50 complete iterations could be performed in a 12 hour time period using the typical 32 CPUs on the cluster, a set of calculations that previously required 25 days to complete could be easily run over night by running routing in parallel.

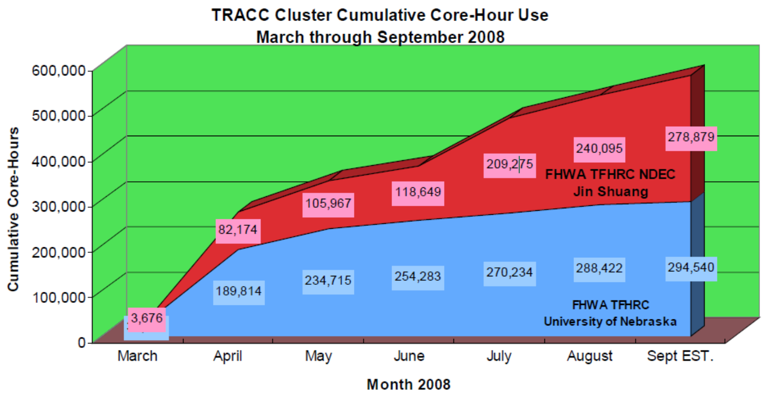


Training Courses

Another 3-day training course on TRANSIMS was held during March 2008. The training course materials were updated, and some of the lectures were given by previously trained students from Northern Illinois University. Participants were from Northern Illinois University and Cambridge Systems. This activity created additional interest in TRANSIMS training, and another training course was already be-

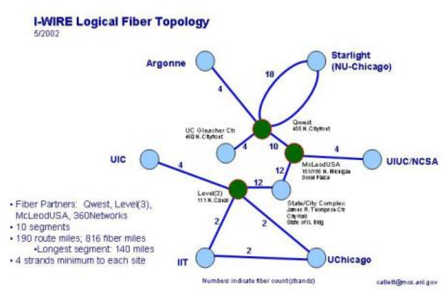


Expanding TRANSIMS capabilities when running the software on the TRACC cluster enabled researchesrs to build complex models with lane and turn restrictions to simulate evacuation traffic flow.



ing prepared for April 21 to 23 of the same year. This training course included participants from NCSA, Citi Labs, Calmar Telematics, and others, and was also held at the TRECC facility. In total, TRACC held about 15 to 20 training courses and technical support missions to support TRANSIMS users around the country. Many of the training sessions were recorded and are being used by the transportation research community.

April 2008 to June 2008



In the spring of 2008, TRACC's HPC cluster Phoenix entered into full operations. Initially, fourteen projects involving twenty-nine investigators requested computing resources on the TRACC cluster. Procedures for processing allocation requests had to be established and put into effect to manage those users appropriately. Procedures for handling requests from non US citizens using the recently established Cyber Gate Pass system at Argonne were also established and tested. This was a very important accomplishment, because bringing outside users onto a USDOE operated computer system was not a well-established, streamlined process at the time.

The TRECC visualization and communications facilities were used in the education and outreach programs associated with additional training sessions for the USDOT traffic simulation code TRANSIMS, including on-site conference facilities, simultaneous web based broadcast of the training seminars, and video recording of the training sessions, which are also available on TRACC's web site for future use.

July 2008 to September 2008

The number of users of the TRACC cluster increased quickly in 2008. The total number of projects with accounts on the TRACC cluster by the end of September was 20, and the number of approved users was 50 (31 external, 19 Argonne).

The two largest users were the FHWA Turner Fairbank Highway Research Center (TFHRC) / University of Nebraska Bridge Hydraulics project using Computational Fluid Dynamics and the FHWA TFHRC Non-Destructive Evaluation Computational Structural Mechanics project. To assist the users in the interpretation of the large amounts of data being produced by the simulations, software was implemented on the cluster to allow users to easily run any visual application directly on the cluster.

The new cluster operated well. There have been only seven days of unscheduled down time since the cluster became operational in March, 2008. A major part of the down time, 5 days, was the result of a computer security incident in September where an attacker obtained a user's password to gain access to the cluster and obtain administrative privileges on one of the login nodes. Upon review, no damage was done to the cluster or its users. As a result, highly effective steps were taken to prevent future attacks, including greatly improved authentication procedures and installing tools to continuously monitor the integrity of the cluster. For the duration of the operation of the clusters at TRACC to date, there is no indication of a similar security compromise.

TRACC Transportation Research and Training Center

As outlined earlier, concurrent with the move of the TRACC project to the DuPage Airport Authority (DAA) Flight Center, TRACC partnered with the University of Illinois' Technology, Research, Education, and Commercialization Center (TRECC), also located at the Flight Center. This partnership included use of: the Center's broadband connection (10Gb/s) to access the Argonne networks, the Voice Over Internet Protocol (VOIP) telephone system, meeting spaces, and the visualization and communications infrastructure located within the Center.

During the summer of 2008, the University of Illinois announced plans to close TRECC, effective August 31, 2008, due to expiration of the federal funding for the project. Since TRACC was utilizing the advanced visualization and communications equipment and facilities in the Center, a plan to replace the services was required. The plan developed addressed four major areas:

- Visualization and communication equipment
- Multiuse meeting rooms
- Broadband network service, and
- Telephone service.

Negotiations were initiated between TRACC and the University of Illinois to create an arrangement that would allow TRACC to continue utilization of the Center resources.

The University of Illinois and Argonne finally reached an agreement whereby the advanced visualization and communications equipment and facilities of TRECC would be made available to the USDOT TRACC project at no cost to USDOT as part of the cost share for the TRACC program. This agreement was for a period of two years (1 October 2008 – 30 September 2010).

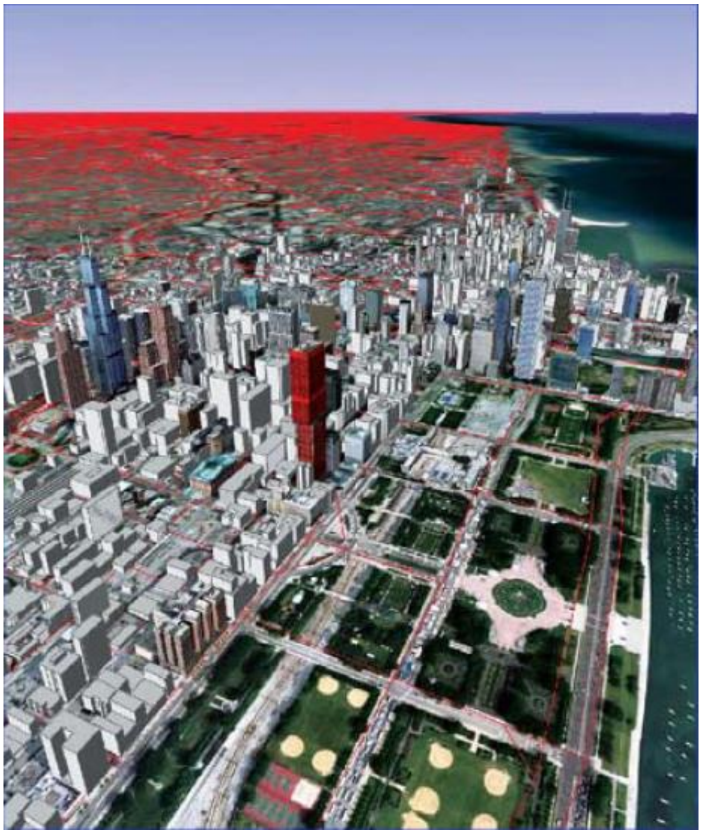
TRACC also initiated negotiations with the DuPage Airport Authority for acquisition of space in which the Center was located (the third floor of the Flight Center). The TRACC lease was amended to include the current space on second floor and the space on third floor. Additional funds from local and regional sources for annual operating costs for the facility were also being identified to be included as part of the project cost share.

Plans were also developed to extend the network connectivity already in place at the DuPage national technology Park to the Flight Center (due to the expiration of TRECC and the lack of high speed connectivity at the flight center). In September 2008, a 1 Gbps broadband radio link (with backup 20 Mbps radios) was installed between the DNTP and Flight Center sites. This allowed TRACC to take advantage of full integration into an established Argonne network security infrastructure, such as its firewall, VLAN partitioning, automated vulnerability scanning, and Crypto Card server and provide excellent network bandwidth between the Flight Center and DNTP sites as well as access to the national and international research and education networks for the Flight Center facilities.

Information and Exhibits

TRACC staff attended the August, 2008 National Hydraulic Engineering Conference in Portland Maine with a new booth display and a set of information folders. TRACC staff composed comprehensive information to be distributed to cluster users and others at conferences and meetings. The information folders included one page information sheets for each of the three TRACC divisions (Computational Structural Mechanics, Computational Fluid Dynamics, and TRANSIMS Traffic Modeling) as well as a document describing the TRACC computational capabilities. Also included in the information folders were the TRACC brochure from the Argonne Now publication, a TRACC allocation of services request form, and a comprehensive list of contacts at TRACC.

On October 22nd, TRACC staff attended the 57th Illinois Traffic Engineering & Safety Conference in Urbana, Illinois. TRACC TRANSIMS staff promoted the TRACC Center as



well as the Evacuation Planning and Visualization capabilities of TRANSIMS traffic simulation software available on the TRACC cluster.

Training Courses on TRANSIMS

Based on the success of the April 2008 training class held at TRACC, another class was held in Atlanta for Georgia Tech, the Atlanta MPO, and other interested organizations. The scope of the training course was extended to include synthetic populations and activity-based modeling, and a new section on TRANSIMS source code and programming was added. About 15 to 20 participants came from local organizations, while an additional 10 to 20 participants joined the training sessions over the internet.

Another training and support mission was undertaken to support the Jon A. Volpe National Transportation Systems Center (Volpe) and the Buffalo Metropolitan Planning Organization (MPO) in its effort to model cross-border traffic simulations using TRANSIMS in the Buffalo area. This mission was based on a request by FHWA, in an effort to improve collaboration and to spread knowledge of modeling capabilities among current projects using TRANSIMS.

A set of training DVDs was prepared from the April training sessions at TRACC. The DVDs were sent out to interested users, and all materials are available in the form of an on-line course posted on the TRANSIMS Wiki site.

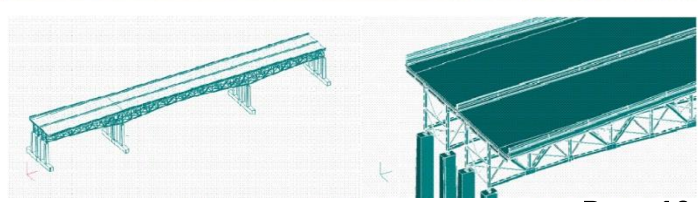
Beyond outright training activities, TRACC held a number of briefings on the technology for a variety of organizations, such as the Chicago Police and Fire Departments, the Regional Catastrophic Planning Team, the Illinois Terrorism Task Force, and the Illinois Department of Transportation. TRACC also participated actively in an FHWA evacuation workshop held in Chicago in September, 2008, as well as a FEMA training exercise on earthquake preparedness in Indianapolis.

Advanced Visualization

Another new development was a visualization tool that allows for the easy and effective creation of vehicle animations from TRANSIMS snapshot files. This software addressed the urgent need for developers to see congestion patterns both at a microscopic as well as a macroscopic level.

This capability was especially of value because it used only readily available tools that operate both on Linux and Windows machines. Thus, this capability was easily reproduced by other TRANMSIMS researchers to visualize their results effectively. Previous visualization solutions, such as the Bal4 Visualizer used by FHWA in Washington, were too costly (>$10k) and required significantly more expertise and data preparation.

The visualization software also had potential for future real-time visualization applications. The rendering of high quality images, even at extreme resolutions, was further parallelized, and integrated into a



high-resolution visualization system. Experiments were even undertaken with the Lambda system at TRACC, a visualization platform with a resolution of 8000 by 4800 pixels, proving the scalability of this approach.

October 2008 to December 2008

During the first two years of the project, the TRACC facilities located at the DuPage airport flight center were served by a 10Gbps network provided by the University of Illinois Technology Research and Education Commercialization Center (TRECC). The contract for the 10Gbps service ended at the end of September 2008. Beginning in the first quarter of year three, the TRACC facilities in the DuPage Airport Flight Center were connected with the DNTP Communications Center and the TRACC cluster via a 1Gbps radio link and backup 20Mbps radio link. TRACC had now a 1 Gb/s connectivity between the Flight Center and the cluster location, and 10Gb/s connectivity between the DNTP Communications Center and the main Argonne National Laboratory site in Lemont, Illinois. The radio link and the connectivity of all of the TRACC equipment and the visualization/network equipment loaned to the TRACC project by the University of Illinois was successfully migrated to the radio link in October and November 2008. The TRACC networks were fully integrated into the Argonne cyber security system using appropriate VLAN and firewall technology.

Computational fluid dynamics

Activities in the area of Computational Fluid Dynamics (CFD) for Hydraulic and Aerodynamic Research focused largely on technical support for CFD simulation, CFD analysis related to the FHWA bridge hydraulic programs and CFD outreach and user support. Particular emphasis was placed on the development and validation of CFD based analysis techniques for sediment transport and scour. This work was a collaboration among researchers at Argonne, the Turner Fairbank Highway Research Center (TFHRC), the University of Nebraska and Northern Illinois University. Considerable progress had been made in the utilization and evaluation of CFD methods and associated scour models to predict accurately scour development observed in the experimental configurations being used at TFHRC. Several standard and advanced CFD methods were examined, including examination of the effects of turbulence models, the use of multi-component and multi-phase flow formulations, moving meshes at the riverbed, the effects of bridge depth, et cetera in the development of bed shear stresses, which are important in the prediction of scour. Results illustrated the ability of CFD methods to predict important fluid dynamics results including velocity profiles and local shear stresses, particularly for submerged bridges well above the river bed.

Computational structural mechanics

In the area of Computational Structural Mechanics Applications (CSM), efforts concentrated on multi-physics bridge analysis and CSM outreach and training, including the first course on the LS-DYNA® CSM analysis code held at TRACC. An important new application using the TRACC cluster and CSM software has been initiated by the National Highway Traffic Safety Administration (NHTSA). NHTSA started to perform parameter studies related to Traumatic Brain Injury.

The first CSM training course focused on the LS-DYNA code and was held at TRACC on November 17 - 19, 2008. The class had both on-site and remote attendees, taking advantage of the TRACC Collaboratory training facility and using Adobe Connect remote meeting software.

Multi-physics analysis of bridge components was initiated as well in a collaboration between TRACC partners at Argonne and Northern Illinois University. The focus of this activity is on undesirable cable vibrations from motion of cable anchorages, the result of either traffic on the bridge, wind loading on the bridge deck and/or tower(s), or a combination of the two.

Transportation Systems Simulation

At the request of USDOT, another TRANSIMS training course was held at TRACC in November 2008. The training materials were updated based on newly developed features and documentation for a number of TRANSIMS tools. The chapters that were largely revised are related to the population synthesis and activity generator. Another new lecture was added to teach specifically about the use of TRANSIMS on the TRACC cluster, with a focus on how to access the remote machine, and how to effectively interact with TRANSIMS and the large amounts of data being created during TRANSIMS runs.

There are some fundamental differences between the TRANSIMS community and users of other applications available at TRACC. TRANSIMS, as a fairly new open source software at the time, was not widely known yet and was still heavily under development. Therefore, the typical user was faced with having to learn fundamental concepts of TRANSIMS in general, but also how to run the raw software efficiently on a multi-machine environment such as TRACC. It was clear that most TRANSIMS projects would benefit from running on the TRACC cluster, but the initial development was still typically performed on Windows machines, despite the drop in performance. The complexity of learning about Linux, remote access and files transfer, as well as the new software and modeling strategy was quite a challenge for most users.

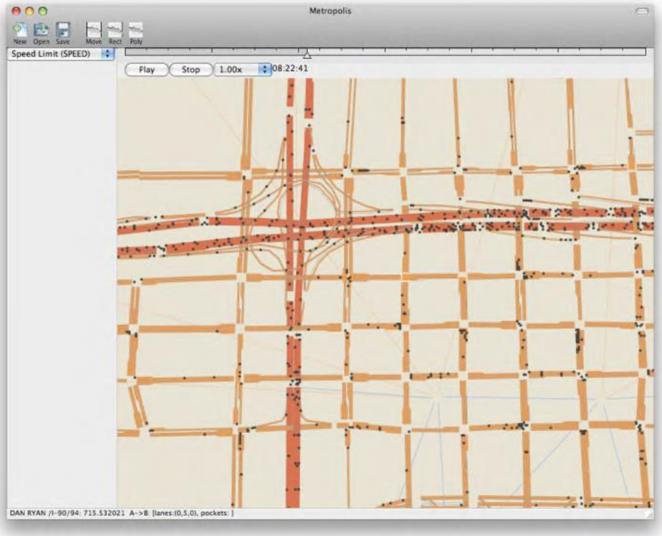
TRACC supported users in all these areas through training and one to one communication. Specific training materials that were highly specific to the TRACC cluster were being developed, and simplified the transition from Windows to Linux significantly. The goal was to support users independently of the operating system platform chosen, but to encourage them to make the transition to the TRACC cluster early enough in a project so that they could run complex models and sensitivity studies on the TRACC systems effectively.

In addition to the TRB exhibit, TRACC also participated in a number of evacuation-related events in the region. USDOT held a training exercise for the evacuation of Chicago in October 2008, and TRACC gave a presentation on their evacuation study. Discussions were held with emergency responders to identify the needs for transportation modeling in the emergency responder's community, and to build awareness for TRACC capabilities in the community. FEMA also held a training exercise in Indianapolis in November 2008. TRACC was invited to participate to apply their experience to the special circumstances of earthquake response, and address the question of how transportation issues could be solved using existing or future capabilities at TRACC.

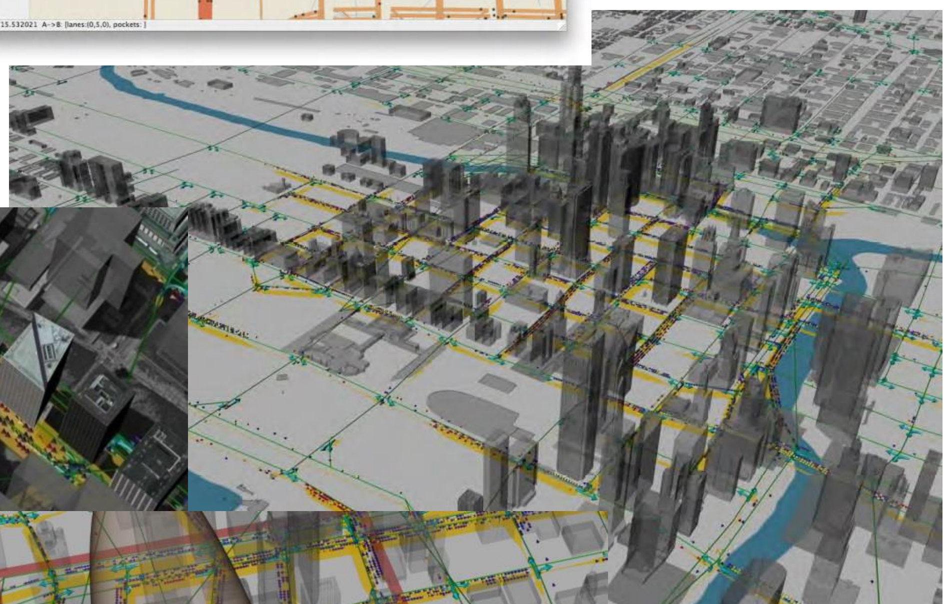
Advanced Visualization

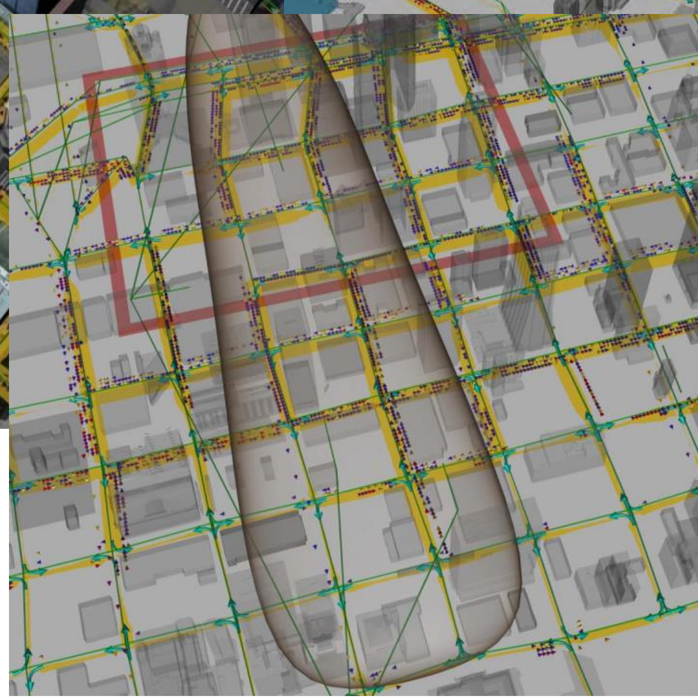
NCSA, under subcontract with TRACC, developed prototypes for advanced visualization for the USDOT transportation simulation code TRANSIMS. The development effort was codenamed Metropolis, and focused on efficient methodologies to store, retrieve, and display vast amounts of individual trajectory information as created by the TRANSIMS Microsimulator.

Initial implementations and prototypes are shown in this report to illustrate the capabilities. This includes screen shots of interactive applications and screen shots from video material developed for the project. For the interactive applications, performance was a major design criteria, due to the vast amount of data to be shown to the user.



For the video approach, new visualization paradigms are being explored to maximize the human understanding of the underlying concepts, results, and data objects.





An image from an evacuation scenario for downtown Chicago. This visualization indicates the area of the road network blocked to incoming traffic, and a cloud of material dispersing from the catastrophe site.

NCSA made specific enhancements that included the display of traffic signal activity; the display of the road occupancy data computed by the simulation; the display of the evacuation region as it developed over time; and the display of the disaster phenomenon (a cloud of particles released by an explosion) as it develops over time.

NCSA tested enabling contrasting simulations to be compared by displaying them simultaneously in one screen. To display traffic signal activity, they first consulted with researchers to understand the traffic signal activity data output from TRANSIMS. The traffic signal data described which directions traffic may move at different times; therefore, NCSA decided to represent signal activity with animated, arrow-like glyphs located at road intersections. NCSA selected a blue color for these glyphs, because this color was otherwise unused by the rest of the visualization. The glyphs are located underneath the road network and vehicle glyphs, to prevent collision, but are slightly thicker than the road network geometry to improve visibility. Creating these glyphs required adding a data-processing step to the visualization pipeline, which produced derived data in the form of a Maya scene file that was later incorporated into the final visualization. The evacuation region indicated a section of the road network that was closed to inbound traffic; this region expanded over the course of the simulation. In the visualization, this was represented as a closed polygonal outline, rendered as a thick red line above the road network.

TRACC researchers furnished NCSA with specific coordinates for this region, which were used to create the polygon. The disaster that caused the evacuation was assumed to be an explosion in the Sears Tower, which released an expanding cloud of harmful particles. In NCSA's visualization, this was represented by a semitransparent, cloud-like shape that smoothly expanded over time. The explosion occurred at a specific floor of the Sears Tower, from which the vertical position of the cloud was approximated. The visualization was then executed in Maya.

The project demonstrated various approaches to visualization, some of which were quite practical, and others which were too time-consuming and complex to be adopted by the transportation research community. As a result, future work consisted mainly of the expansion of the interactive OpenGL-based application.

January 2009 to March 2009

With around 28 different projects (and 64 individual users) after the first year of operations in production mode, the load on the cluster became quite significant. By March 2009, the load on the cluster exceeded 170,000 core hours. Supporting a larger number of users and diverse projects, a number of software packages were acquired or renewed. Also, a lack of memory for demanding applications cause a system upgrade for several machines to a total of 32GB (versus 4GB per machine on the normal nodes). The GPFS file system, a highly efficient and redundant parallel file system that is at the heart of the system, was more than half full. The general use of the cluster caused the first serious contention for users running their jobs, and discussions of possible software and hardware upgrades started.

Users also requested the acquisition of new powerful scientific codes that were purchase and made available in early 2009. These were in particular the Abaqus structural mechanics code used for crash analysis, and the TrueGrid Mesh Generator, also used in structural mechanics applications.

TRACC acquired a 21 token license from Simulia, the seller of Abaqus. The license included all of the major analysis products: (1) Abaqus/Standard, (2) ABAQUS/Explicit, and (3) one seat of ABAQUS/CAE, which provided a complete interactive environment for creating models, submitting and monitoring analysis jobs, and viewing and manipulating simulation results.

As users develop complex models, it was critical to provide model generation software that produces high fidelity meshes with computational accurate elements, that is, elements whose geometry have acceptable aspect ratios that ensure accurate results. As the validity of all computational analysis begins with a numerically sound discretization of the physical problem, CSM staff completed the evaluation of the TrueGrid® mesh generation software. TrueGrid uses projection algorithms that produce computational grids with well-formed quadrilaterals and hexahedrons. A license for one seat was obtained from XYZ Scientific Applications, Inc. (the developer of TrueGrid).

TRACC also added a High Definition video teleconferencing (HDVTC) system in March 2009. This

HDVTC was added to aid in the collaboration with Turner Fairbanks Highway Laboratory and University of Nebraska, the collaboration was between researchers doing work on Computational Fluid Dynamics. This system allows for 4 geographically distinct sites to collaborate via HDVTC. Additionally each participating site has the ability to share computer displayed (i.e. PowerPoint presentations, movies, applications, and desktop) content as part of the HDVTC stream. The system is still heavily in use at TRACC's new facility at Argonne.

As an outcome of a separate project with the Illinois Department of Transportation, Transportation Evacuation Scenarios, a visualization system called the LambdaVision developed originally for a University of Illinois/National Science Foundation project called Optiputer was evaluated for use by TRACC's research partners in the area of high resolution distributed visualizations. The LambdaVision, a 20 LCD Tiled display mini cluster, at TRACC, on loan from the University of Illinois, was capable of displaying images and movies at a 8000 x 4800 pixel resolution.

The simulations generated in TRANSIMS can generate movies at greater resolutions allowing for the researchers to visualize the results and to validate the available data for errors more efficiently. The technical staff of TRACC has developed a smaller, significantly more cost effective LambdaVision. This four (4) LCD tile display capable of 3840 x 2400 pixel resolution was built in March 2009.

TRACC also hosted an exhibitor's kiosk at the annual Transportation Research Board (TRB) Meeting on January 11th - 15th 2009 in Washington D.C. The kiosk display experienced significant traffic and proved to be a highly effective outreach mechanism to identify users of the TRACC computing and visualization facilities and establish collaborations in the key TRACC application areas of traffic simulation and evacuation planning, computational fluid dynamics for bridge hydraulics and computational structural mechanics applications.

New visualization work

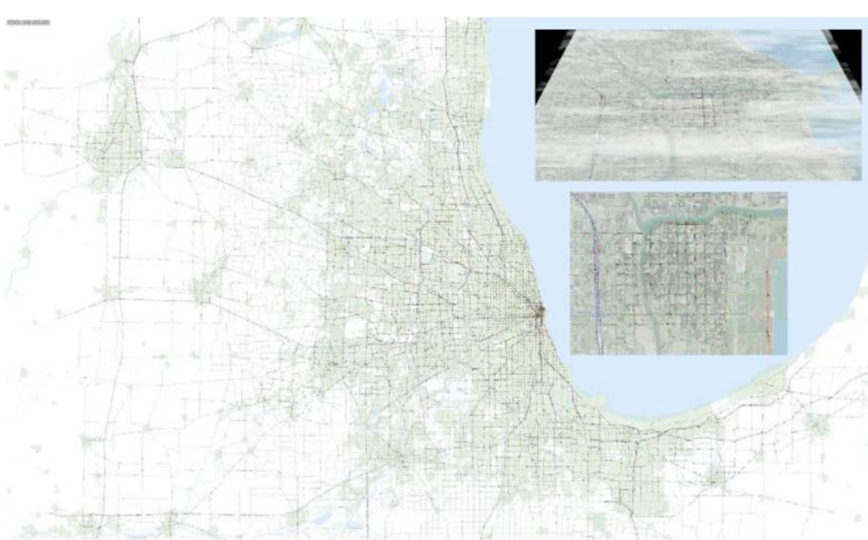
A number of users on the cluster contacted TRACC to learn more about our visualization techniques that were developed for TRANSIMS. Part of this was a consequence from training courses where the techniques were demonstrated to new users, and part of the interest came from people who had visited the TRACC booth at TRB in January 2009, where advanced visualizations were one of the most interesting details at the booth.

The visualization capabilities were improved for a number of reasons, one being experimentation with high definition displays at the TRACC Collaboratory that are now readily available (see above), with the hope that higher resolution displays would make it easier to find and identify network coding shortcomings, something that was successfully demonstrated when the tools were used to create animations of 4000 and 6000 pixels width, something that went by a magnitude beyond then available high definition standards. The advantage of using such technology was that the human visual system is very sensitive to identifying unusual patterns, while computers are very efficient in processing large amounts of data. Thus, being able to survey extremely large areas in great detail, problems with the network, such as misconfigured traffic signals, can be spotted easily, decreasing the turnaround time when fixing network coding.

Other aspects of this work targeted future expansion of this technology for integration with dispersion data. The idea was to create semi-transparent data layers on top of the traffic animation, in this simple case a varying level of simulated cloud cover. Clouds were chosen because simple algorithms exist to simulate clouds, and because dispersion data is expected to be made available in the form of graphical representations that may be similar to clouds and smoke.

The experiment dealt with creating realistic looking overlays by creating pseudo-3d views, and generating dark shadow under the clouds to enhance the 3d effects. A small demo movie was created to illustrate this technique.

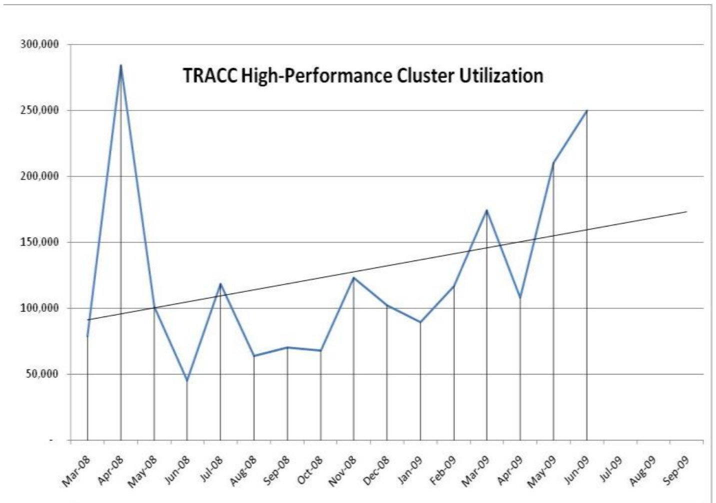
A much more detailed set of improvements were made when a group of transportation planners from Chicago 2016 (the team dealing with Chicago's bid to hold the Olympic Games in Chicago in 2016) was introduced to TRACC by Randy Blankenhorn, the director of the Chicago Metropolitan Agency for Planning. Intrigued by TRACC's visualization capabilities, the team from Chicago 2016 visited TRACC again and asked for a few attempts at improving existing capabilities, for example by creating side by side comparisons, closing certain lanes on certain streets to allow for Olympic traffic only, and similar techniques. The requests were used as the basis for revamping the entire visualization approach, which as a result was fully parallelized, and allowed now generally for pseudo-3d capabilities, and more importantly for spatial and temporal smoothing, leading to exceedingly smooth animations much improved over the videos that were demonstrated at previous shows, such as TRB.



The technology was quickly picked up by users and collaborators. The Buffalo TRANSIMS project used TRACC's animation techniques for all of their work. More importantly, users from AECOM working on the White House Area Transportation Study have picked up on this technique and have even found new visual paradigms showing, for example, the number of passengers in buses and trains in addition to the animation of vehicles. TRACC staff has spent time with developers from these agencies or companies to teach visualization techniques, and it can be considered a great success that these users were able to improve upon the system with a reasonably small amount of effort.

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:

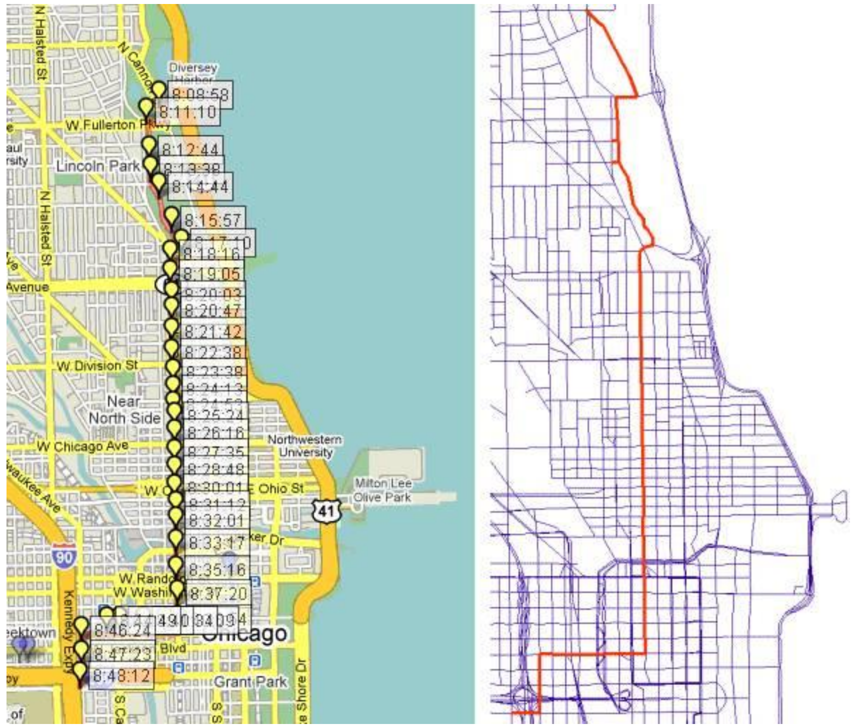
- Upgrade to High Definition projectors (in the large conference room) providing higher resolution images of models and simulations.
- Upgrade to PolyCom HDX8004 and PolyCom HDX9004 systems to provide High Definition quality, dual stream video and data (H.239) for videoconference sessions.
- Completion 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.

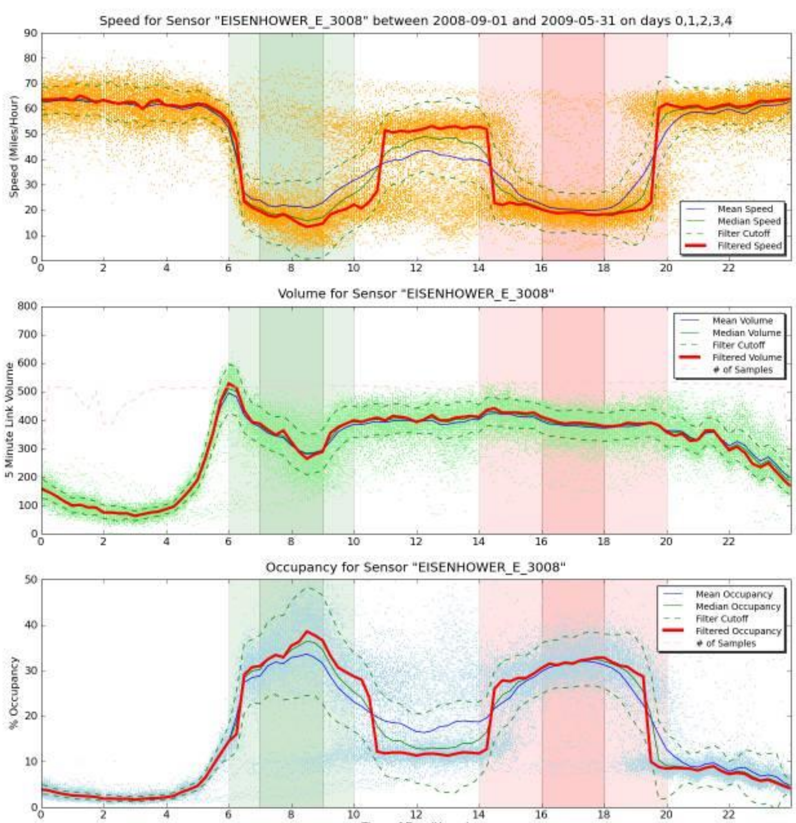
TRACC was also making excellent progress on the parallelization of TRANSIMS itself. A much improved methodology was implemented that resolved some of the limitations of previous approaches. The new methodology had numerous advantages over previous approaches, e.g. it had the potential for dynamic load 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.

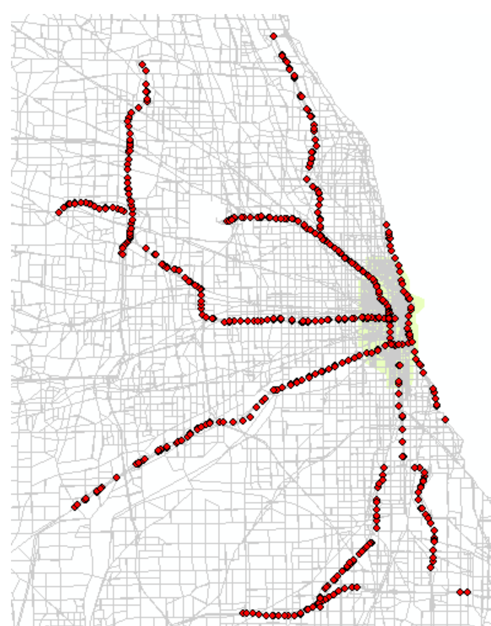


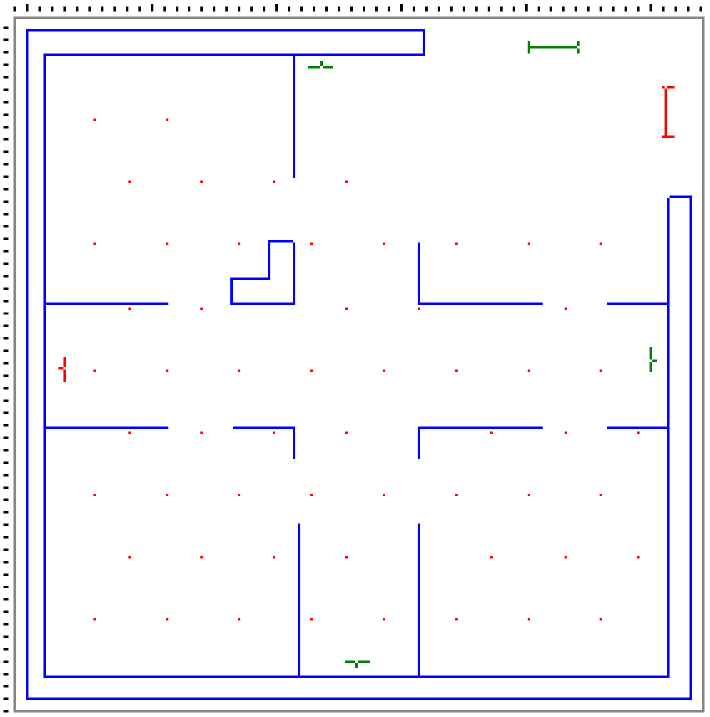
A major improvement of the model was based on the availability of Google Transit data from all regional transit authorities. Until then, TRANSIMS transit was of limited fidelity because detailed and precise scheduling information wasn't readily available. The Google Transit feeds, in combination with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

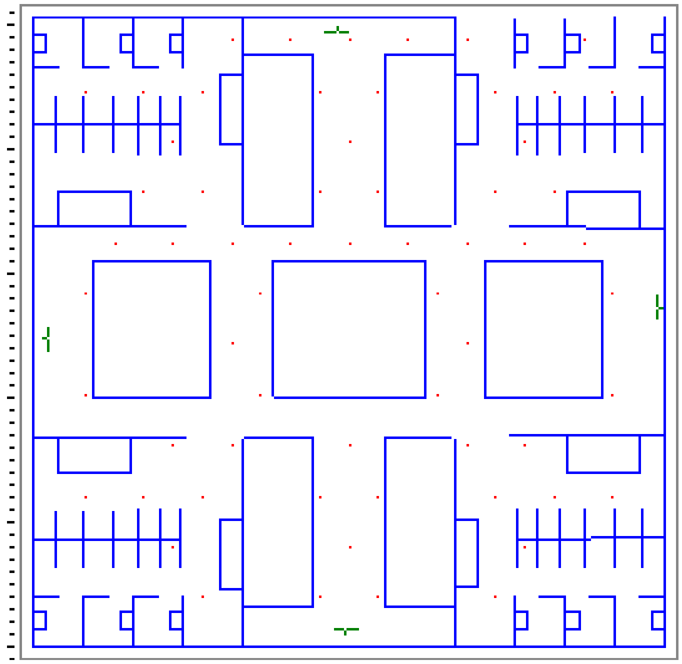
Starting earlier that year, TRACC started archiving 5 minute readings from approximately 800 sensors across the metropolitan Area, mostly on Interstate highways. The data allowed statistical analysis by time of day and was helpful for calibration, validation, and the development of more reasonable diurnal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





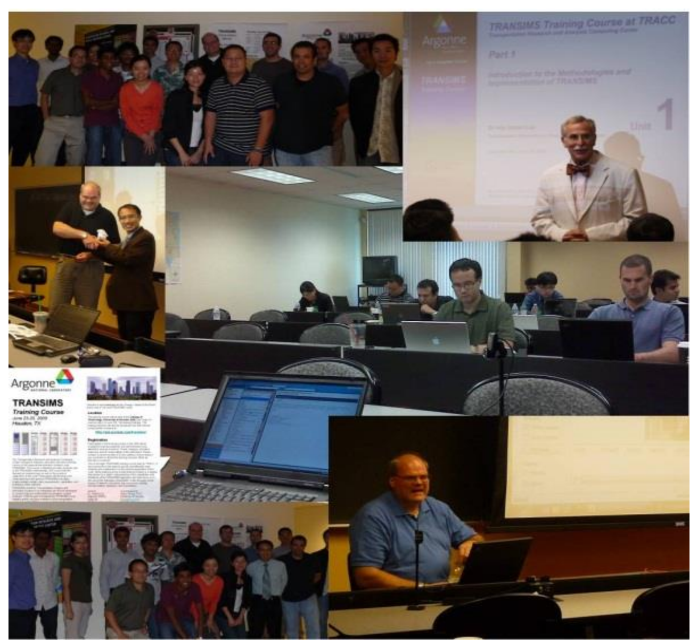


fully modeled, and when they park their associated vehicles in more realistic parking locations in the city.

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.

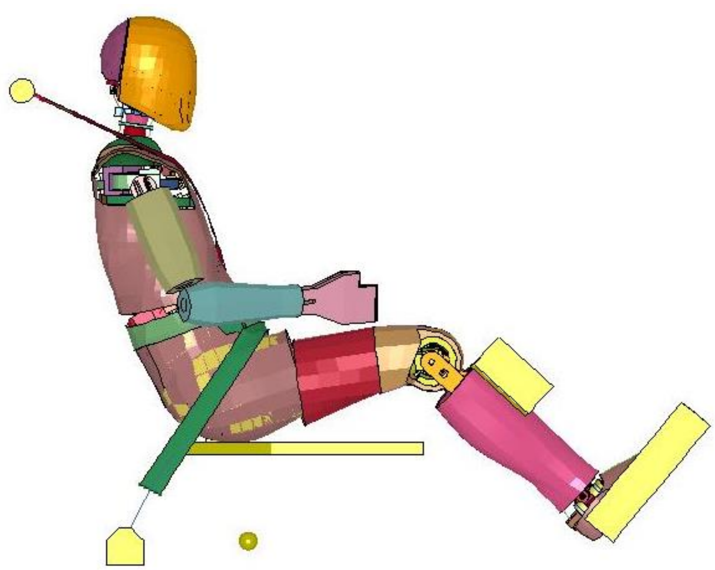
FHWA also started another round of proposals for the rollout of TRANSIMS, and TRACC users were supported in applying for funds from this program. The focus was on a few proposals that were of high interest for TRANSIMS users in general and for the Chicago Evacuation Study specifically.

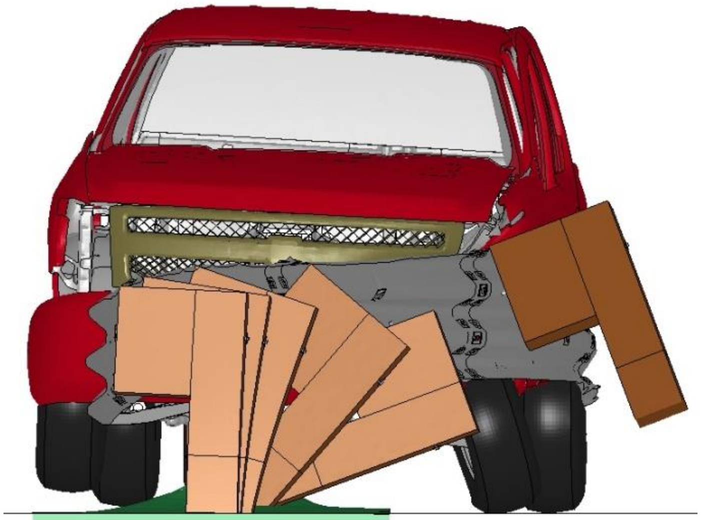
The Chicago evacuation project, separately funded by IDOT, ended in February 2009. Nevertheless, the work was being applied to develop advanced methodologies at this time, and to generalize some of the methodologies so that they can become applicable to other areas as well.

Computational structural mechanics

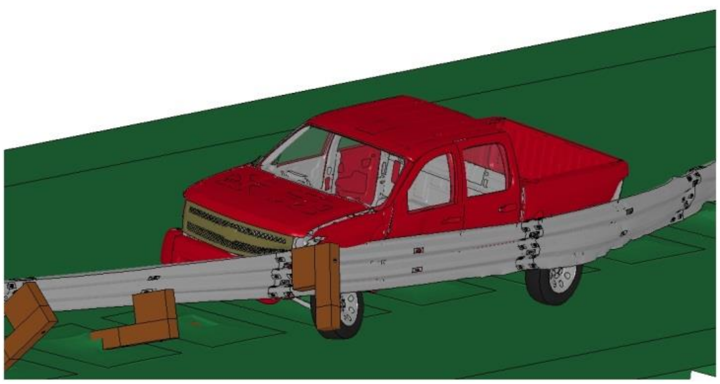
The use of TRACC cluster by the researchers from the computational mechanics area has grown in this quarter through the increased demand for LS-DYNA licenses from NHTSA, TTI, and new users from Florida State University. The researchers from NHTSA started their work on optimizing the occupant restraint 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



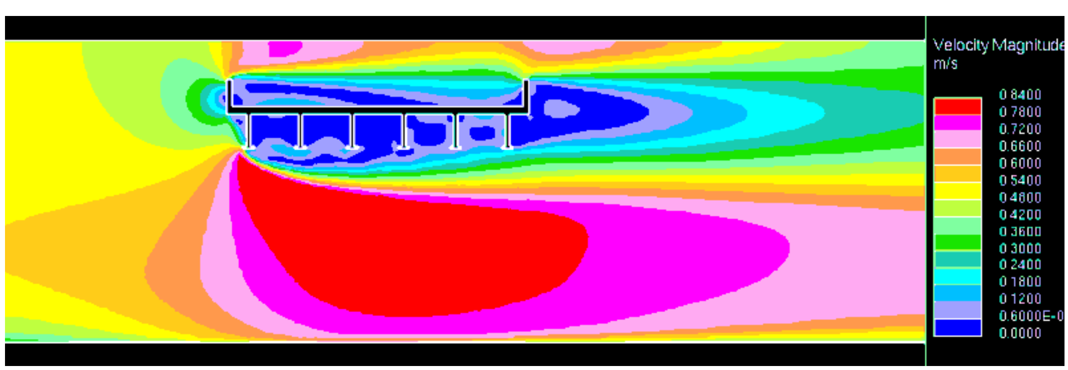
above mentioned guidelines was not necessarily going to perform under a higher impact speeds. TTI researchers were investigating the performance of certain roadway hardware under higher impact speed 137 km/hr (85 mph). Simulations were used to identify what type of devices were able to perform and what 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.

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

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.

July 2009 to September 2009

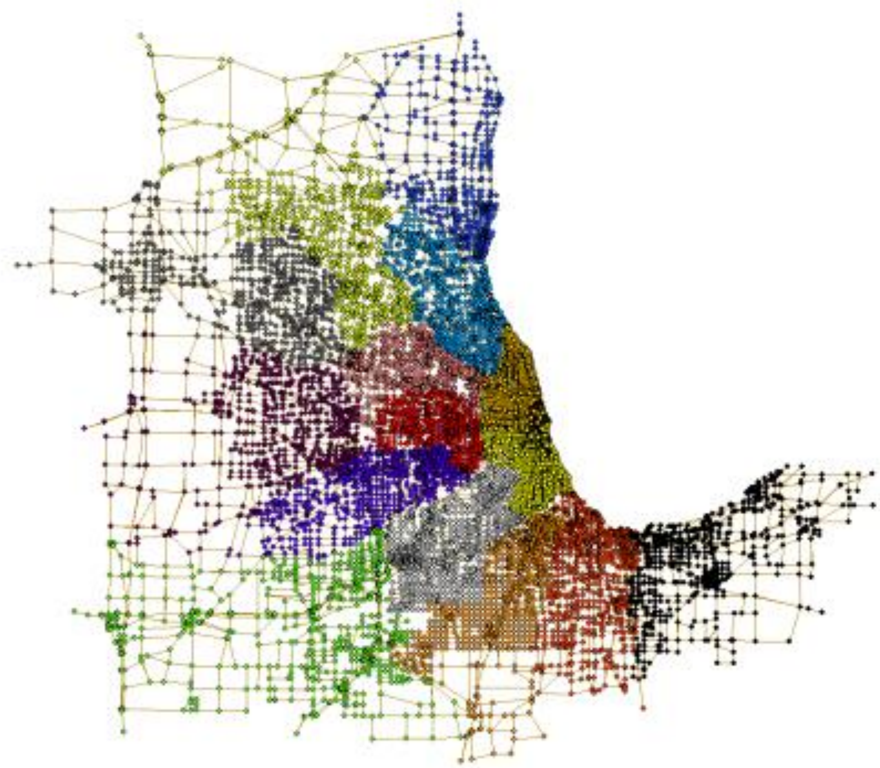
The number of users of the TRACC cluster increased to 91 from 29. Cluster utilization also increased during the quarter, peaking at approximately 85% in July. This substantial utilization also increased the mean wait time for users. Since utilization is expected to increase in the long term, TRACC initiated 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.

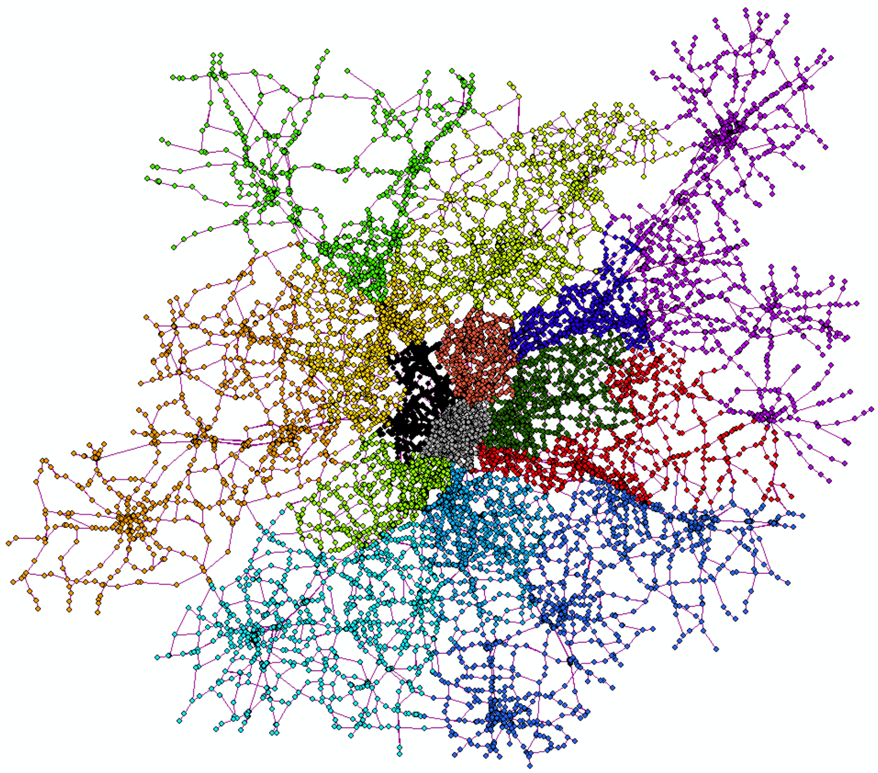
Transportation systems simulation

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 cate-



gories. 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

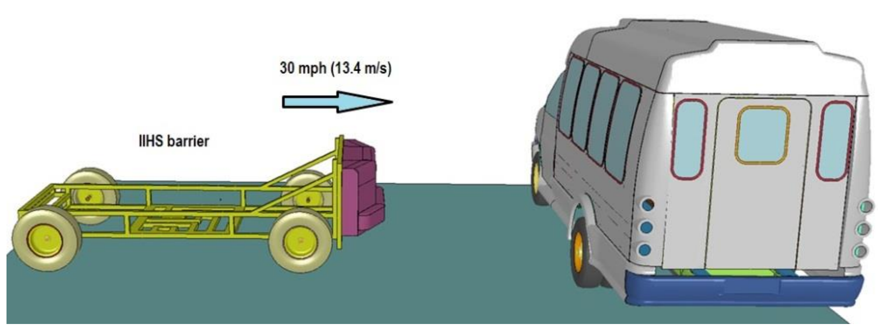
Building evacuation models were also further improved. Models were added for a typical shopping complex as well as typical residential buildings. Extensions to the modeling approach allowed for the differentiation of special populations, such as staff and elderly people. Based on these models, new methods 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.

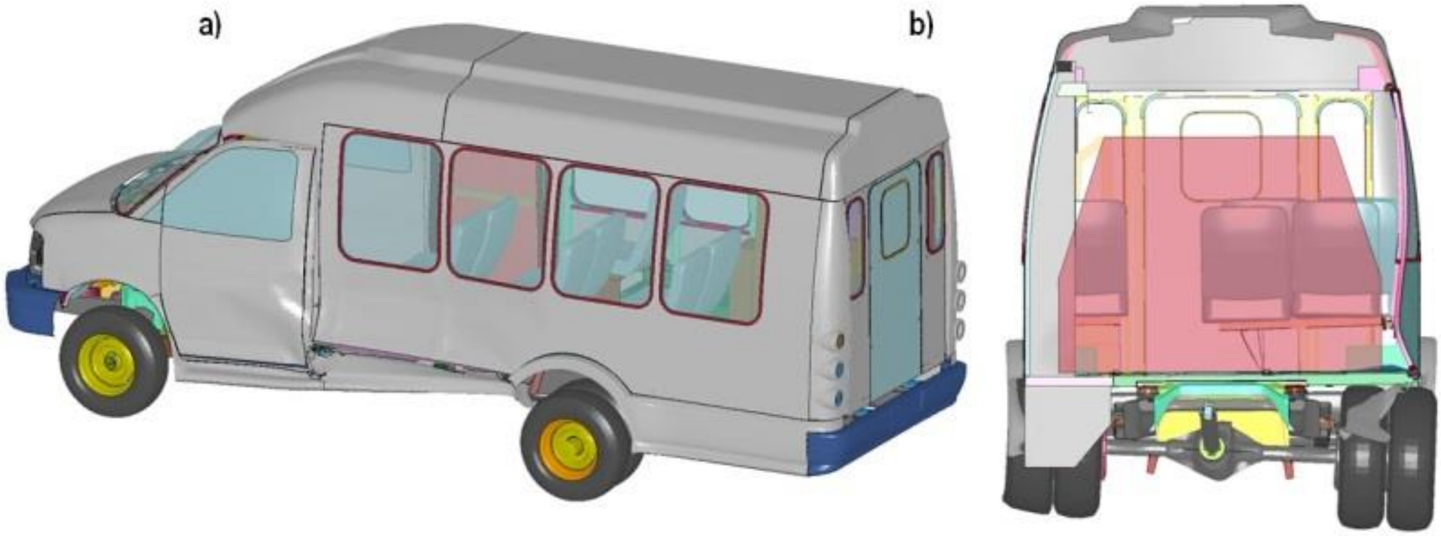
In the area of TRANSIMS evacuations, an extensive study was done to determine appropriate values for Microsimulator parameters which would best be able to describe a high congestion event. TRANSIMS employs the concept of "lost cars" to alleviate unrealistic congestion, which is often brought about due 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

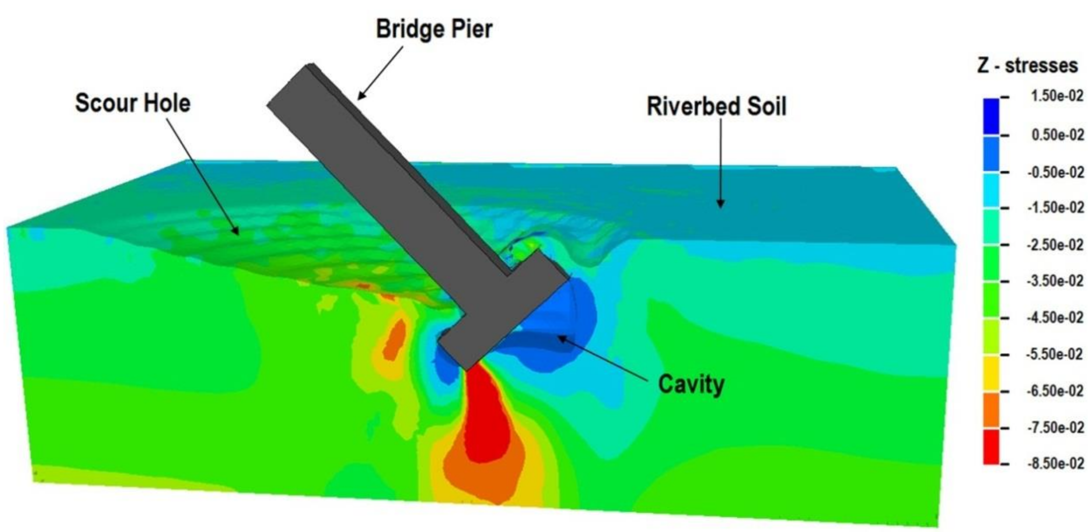
Extensive help was provided to the new users from Florida Agricultural and Mechanical University-Florida State University College of Engineering (FAMU-FSU). Research conducted at FAMU-FSU College of Engineering pertained to comprehensive crashworthiness and safety evaluation of paratransit buses. The 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.

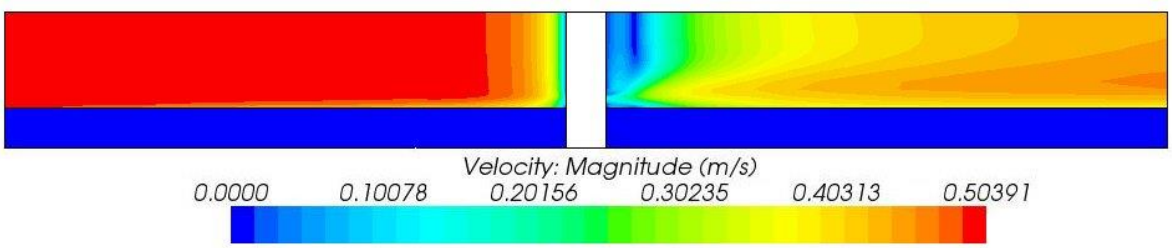


The National Highway Traffic Safety Administration (NHTSA) planned to expand the use of the TRACC cluster. NHTSA's Human Injury Research Division (HIRD) was doing a lot of work related to real world crash reconstruction. For reconstruction purposes, HIRD used two different software modules: MADYMO and 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.

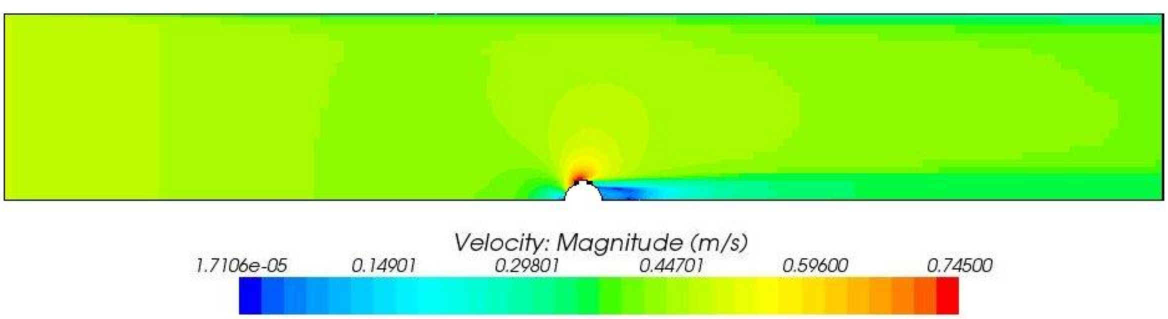
Computational fluid dynamics

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)

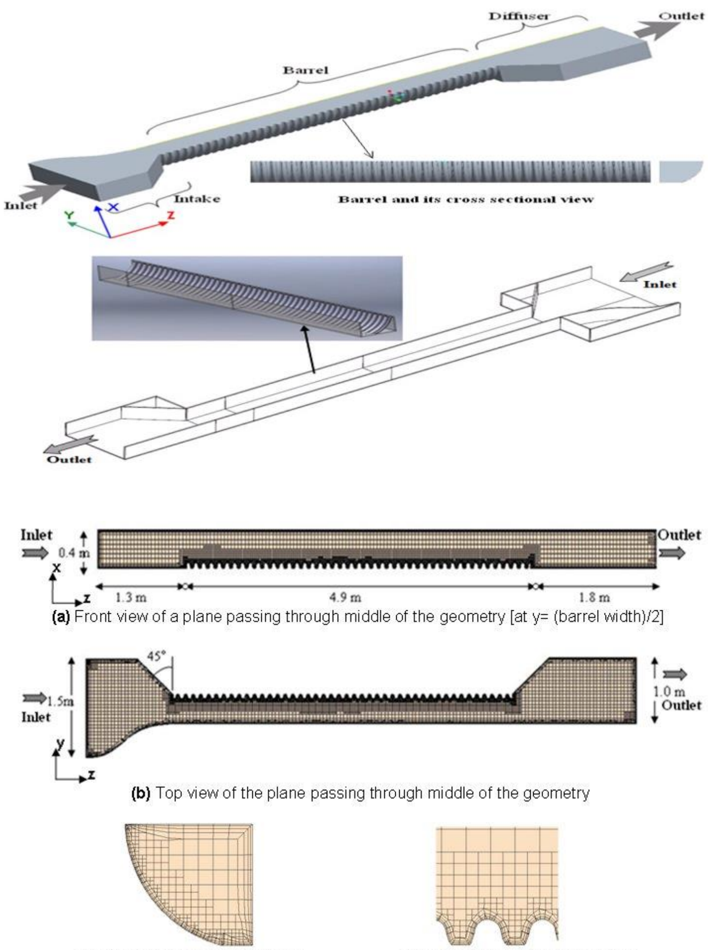


Scalar velocity contour at the interface (z = 1 mm)

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 experimentalists 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



(a) Front view of a plane passing through middle of the geometry [at y= (barrel width)/2]

(b) Top view of the plane passing through middle of the geometry

(c) Cross sectional view of barrel

(d) Enlarged view of corrugations

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.

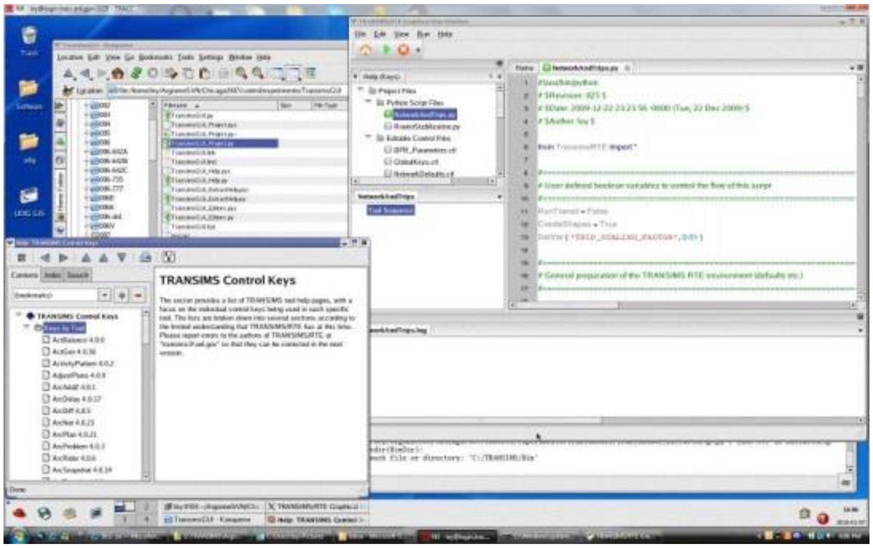
The training area can accommodate about twenty people. It was fully occupied. The general event area can accommodate more than thirty people, and it was used for students who participated at the TRACC site, and also served as a place to have small group discussions.

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.

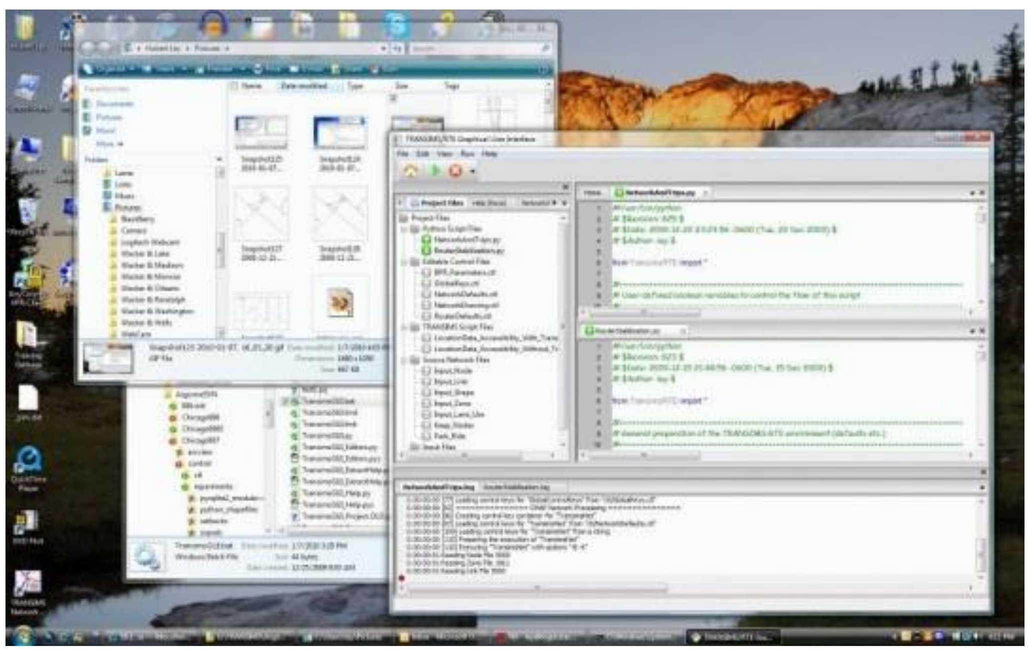
The group was also aware that the computational resources of HPC clusters that can be applied to large problems is growing very rapidly as computer hardware evolves and becomes more massively parallel at the chip and sub-chip level. Given the rate of advancement of computing hardware, the group also 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.

October 2009 to December 2009

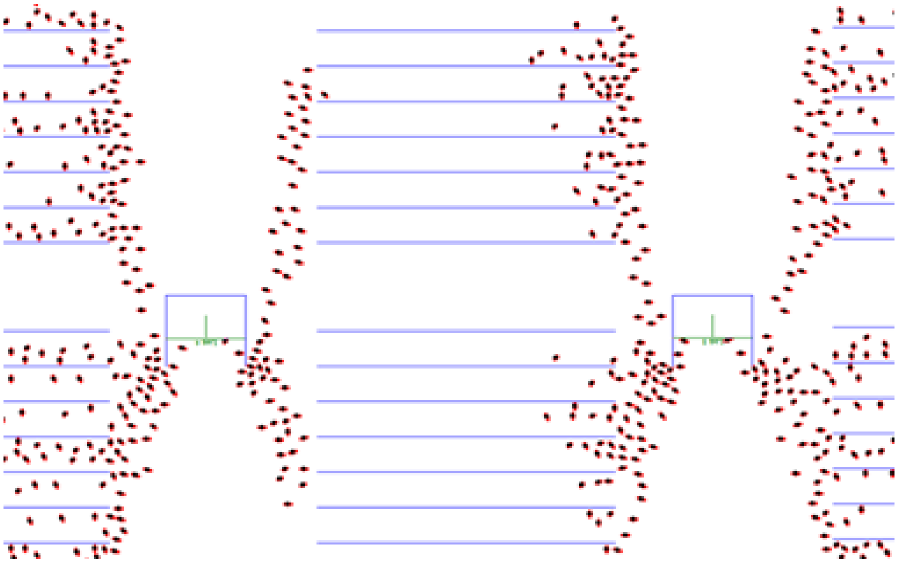
Because of the conclusion of the evacuation project that was implemented for the Illinois Department of Transportation, renewed emphasis was placed on



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



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



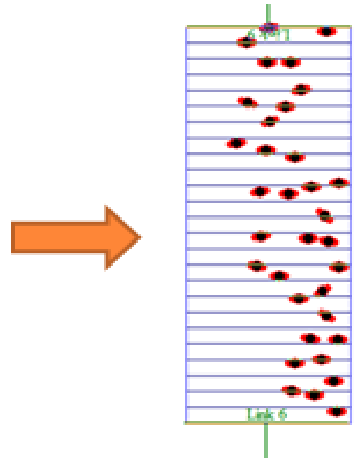
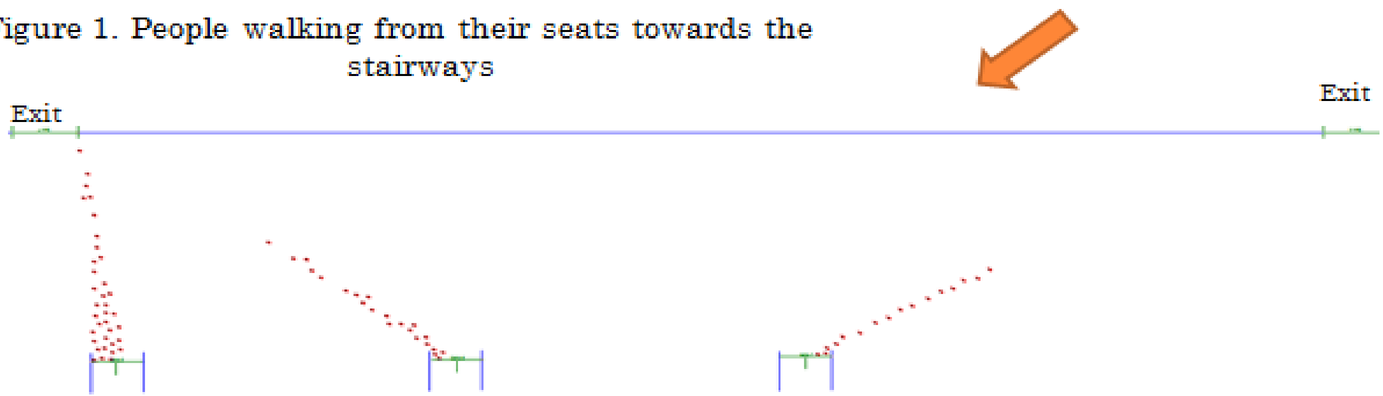
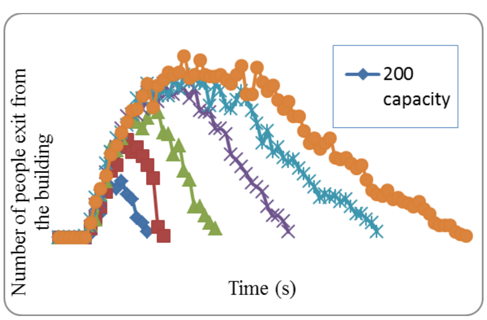


Figure 2. People walking down the stairs

Figure 1. People walking from their seats towards the stairways



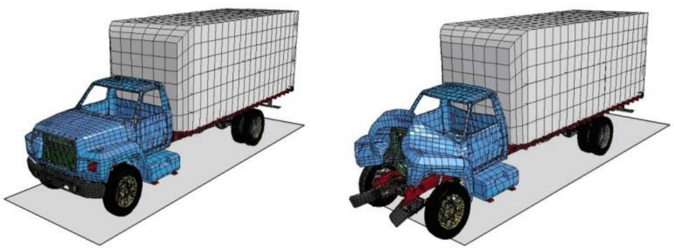
The team at Northern Illinois University also performed further studies of methodologies to appropriately model the pedestrian components of the evacuation model. A preliminary analysis was conducted using a dummy stadium configuration. The occupants are moving from their seats towards the stairways,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



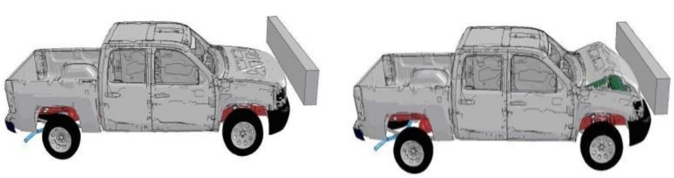
Another TRANSIMS training course was held on December 16 to 18, 2009. This was the ninth time that this course was presented. Feedback from former participants has shaped the content significantly and has made it more specific to the needs encountered by typical first time users. Most participants were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

Computational structural mechanics

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

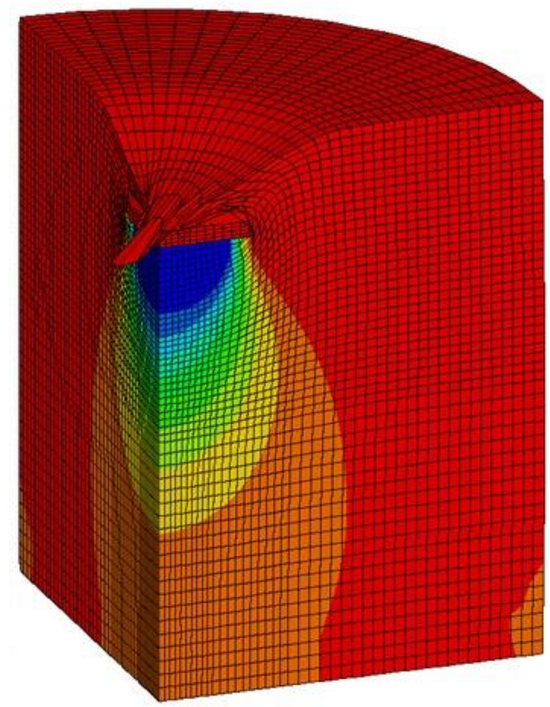


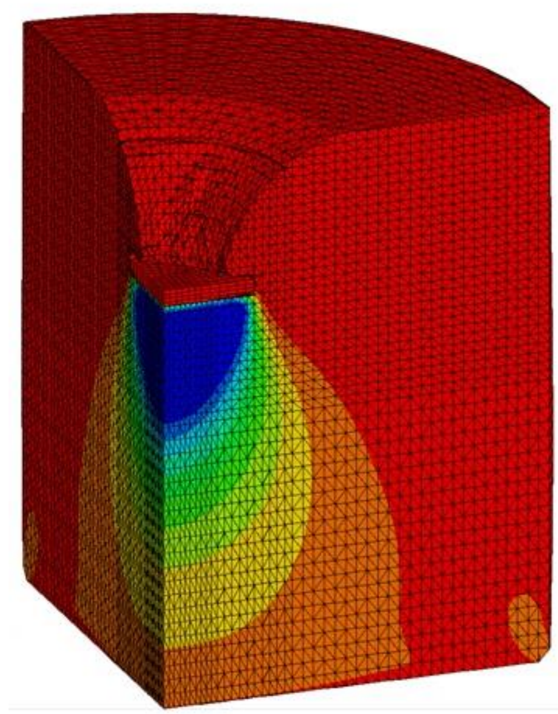
their work with MPP-DYNA on the cluster. Kineticorp was performing frontal impact simulations of vehicles using public domain FE vehicle models developed by National Crash Analysis Center (NCAC). The impact of a Ford Single Unit Truck into a rigid cylinder representing a tree and the low-speed frontal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

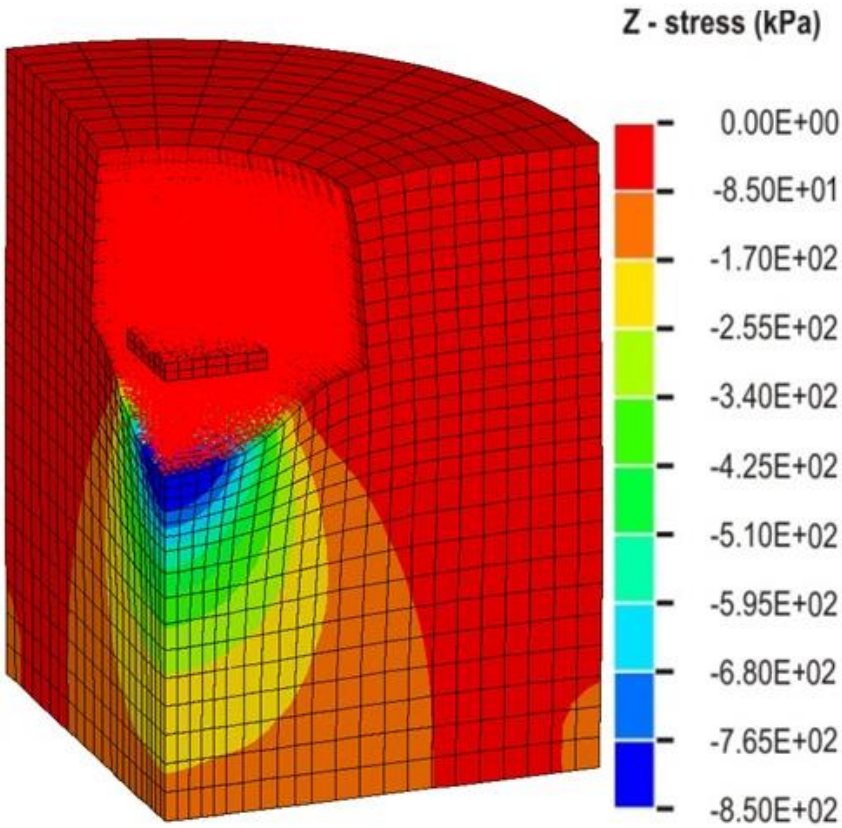


Collaborative research continued with Northern Illinois University in analyzing bridge stay-cables to parametric excitations. The study was performed previously on validating the LS-DYNA element formulations to represent cables in a finite element model of the bridge. In the current quarter research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

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





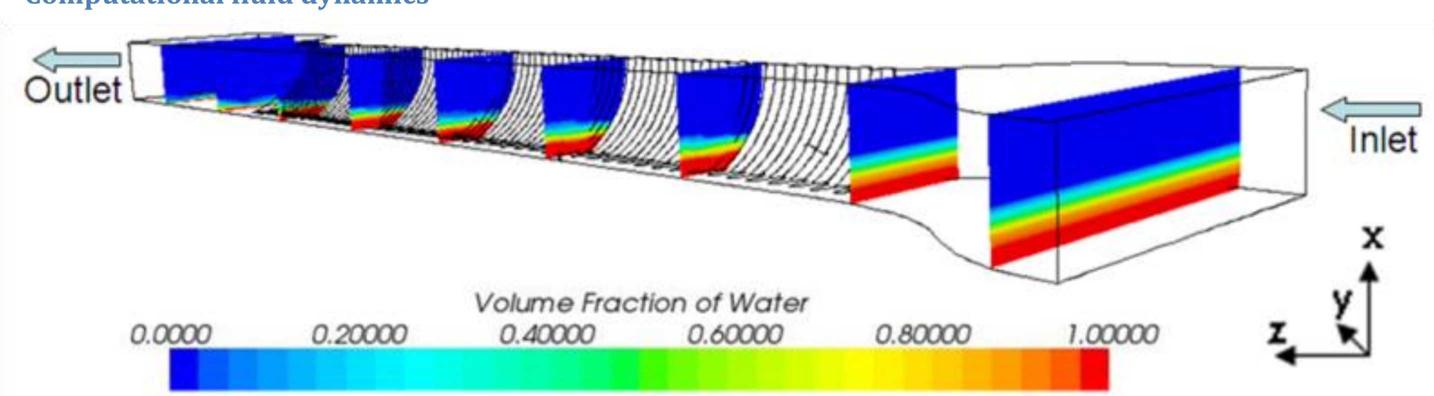


The University of Nebraska completed testing of the scour model in FLOW-3D on the TRACC cluster. They have an academic license for FLOW-3D use on the cluster that only allows U.N. staff and students to use it. In their initial evaluation of the FLOW-3D scour model, they found it to be useful for the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

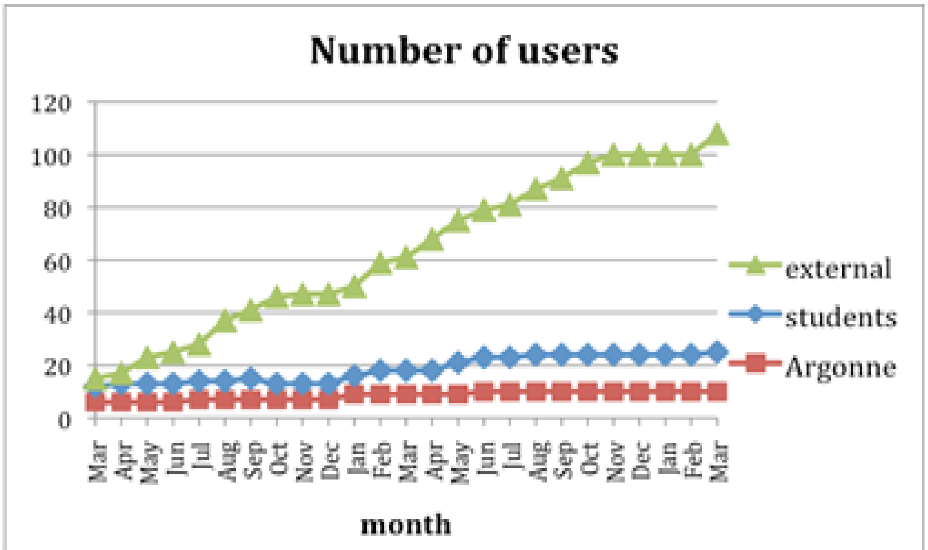
Based on the type of support that was provided to cluster users during this quarter and acquiring an in-depth knowledge of their needs and shortcomings, a report with recommendations for future training in the computational structural mechanics area was completed. Two training courses were scheduled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

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

Computational fluid dynamics



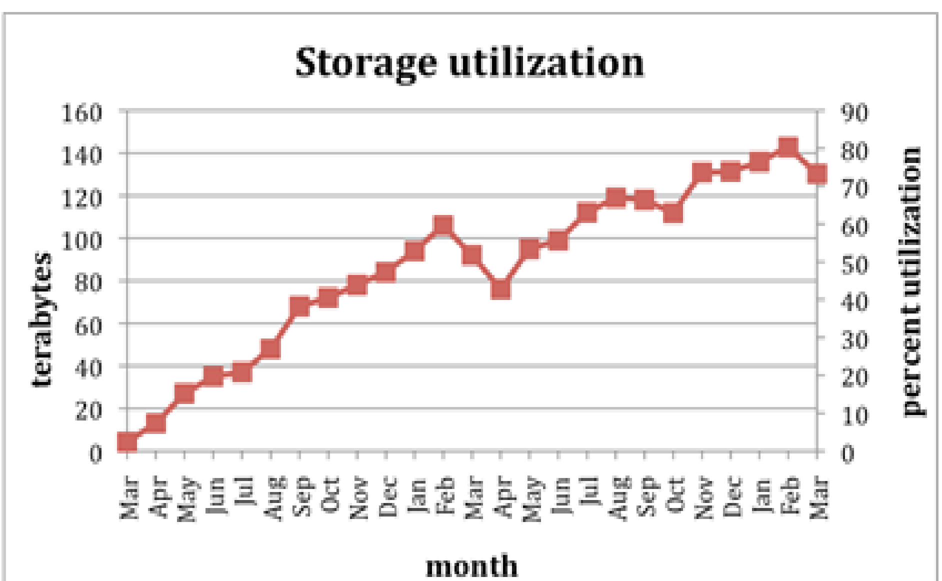
January 2010 to March 2010



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

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

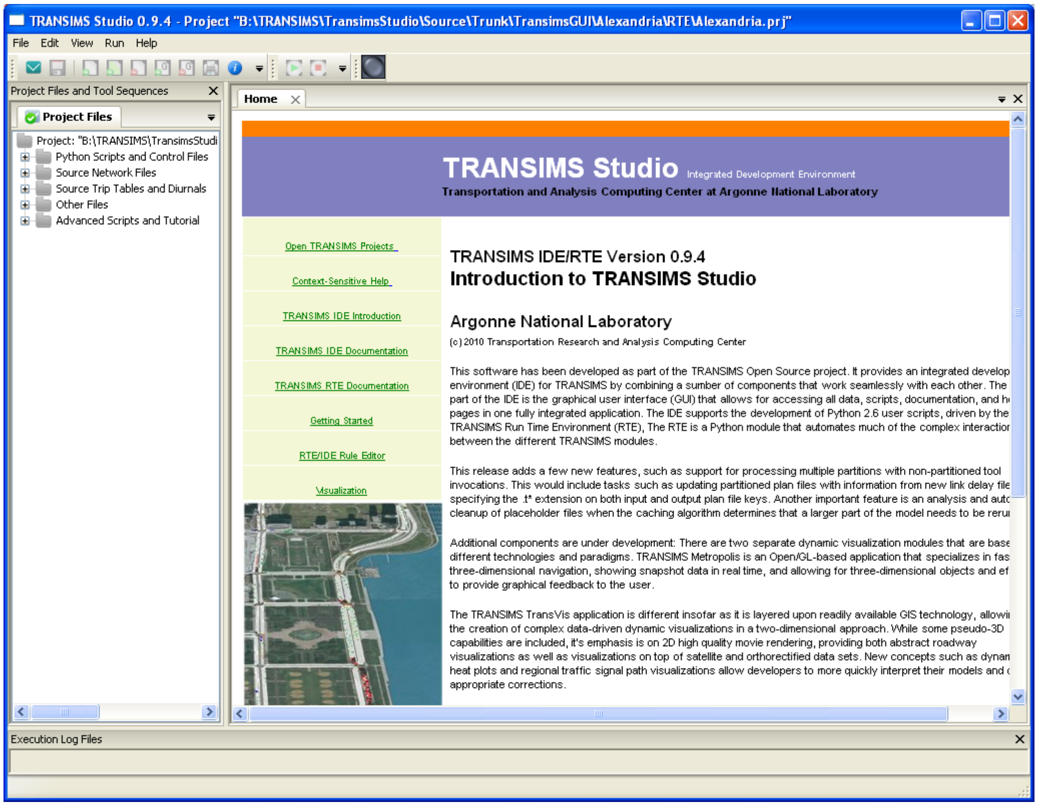
The number of users of the cluster increased over this quarter to 108, 10 of whom are Argonne employees, 15 students working directly with Argonne, and 83 external government and academic users. Cluster utilization continued to rise after the CPU upgrades, and for March reached 74% of the current cluster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



Transportation systems simulation

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

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



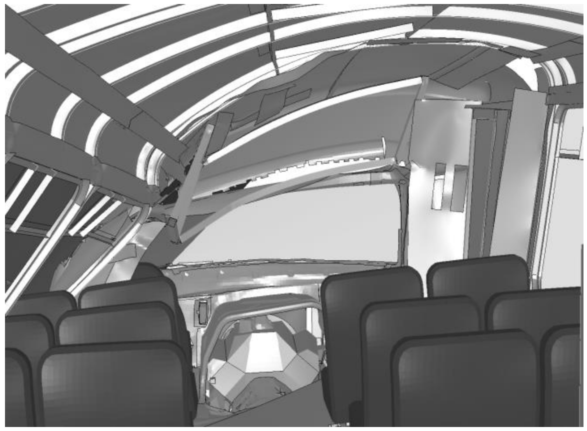
recent workshop showed large interest in this new software, and many more users were expected to actively use this application. It has also become an excellent training tool and was adopted by a team from the Illinois Institute of Technology to learn about TRANSIMS for their own separately funded TRANSIMS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

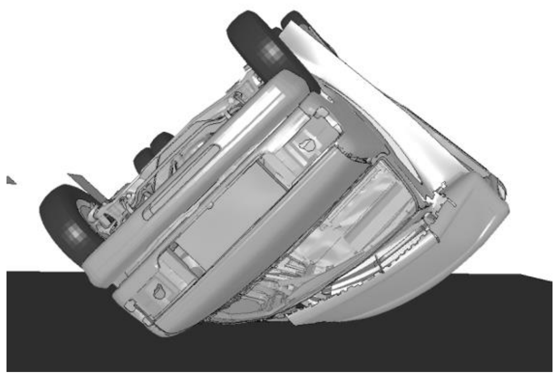
TRACC held a workshop on TRANSIMS applications and development on April 7 to 9, 2010. This was a unique meeting for the TRANSIMS community with high interest from a large mix of participants from FHWA, research centers, universities, and consulting companies. It was also the first meeting where many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

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

Computational structural mechanics

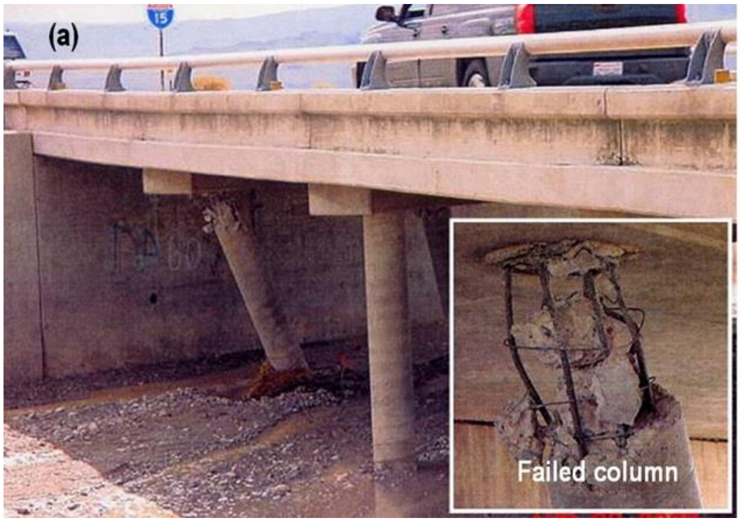
FAMU-FSU College of Engineering was working on the project titled: “Best Practice Guidelines for Construction of Paratransit Buses”. The project was a continuation of two previous research projects conducted for the Transit Office of the Florida Department of Transportation. Experiences gained from those studies helped FDOT in development of the Crashworthiness and Safety Assessment Standard for Paratransit Buses, which became effective in August 2007. In this quarter FDOT conducted a full scale rollover test at the Florida Department of Transportation’s (FDOT) facility located in Tallahassee, Florida. The test was conducted on a Champion Challenger bus with a 158 inch long chassis. The purpose of this test was to acquire data to be used in the validation of a previously developed finite element model by current TRACC employee Dr. Cezary Bojanowski. Selected pictures from the test and the equivalent simulation are shown below. The experiment together with conducted simulations has proven credibility of the FE models and applied modeling techniques. TRACC staff performed an additional study on multi-objective optimization of the bus structure subject to rollover and side impact test simulations. Linear ANOVA and Sobol’s Indices were used to identify and rank the most relevant elements of the structure for the objective functions considered.

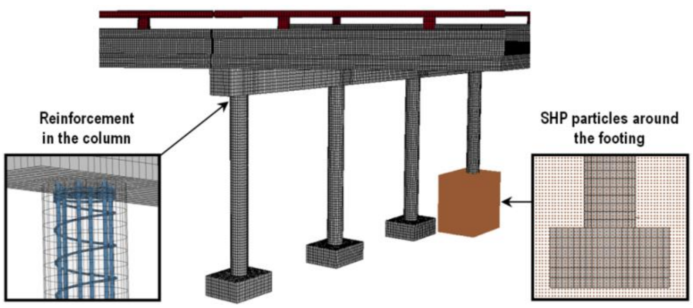




The number of TRACC cluster users in the area of computational structural mechanics was increasing. New users from Worchester Polytechnic Institute and Clemson University were assigned TRACC Cluster accounts. Worchester Polytechnic Institute planned to use the TRACC cluster to study the propagation of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

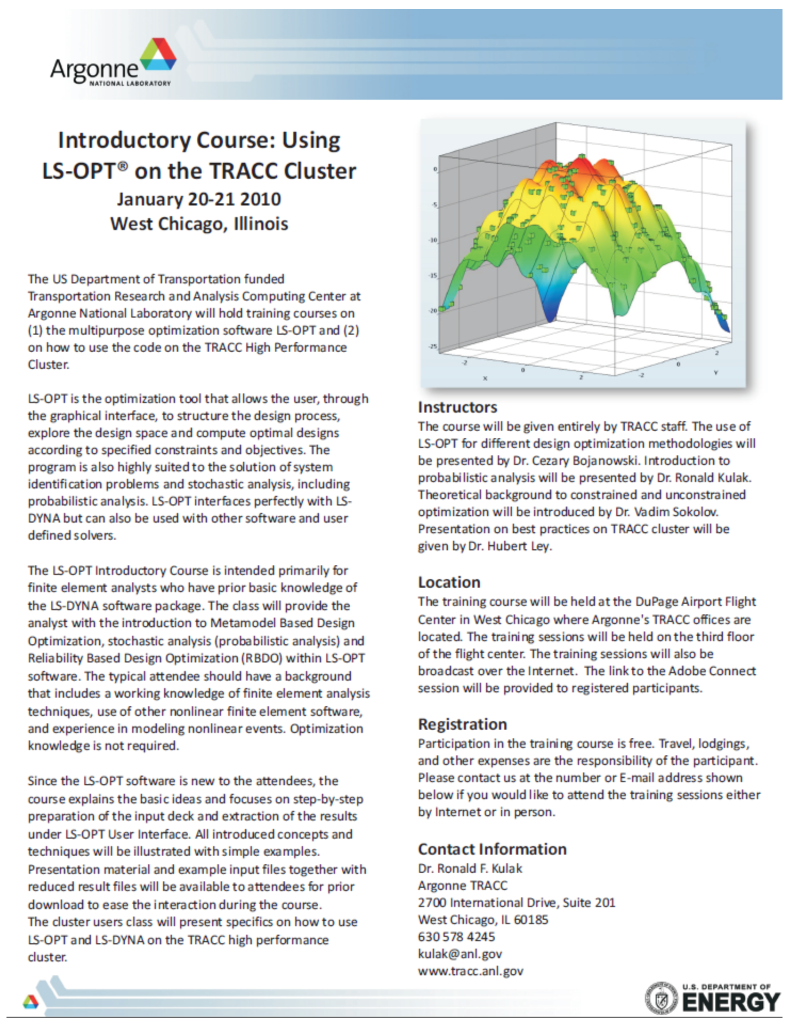
TRACC CSM staff continued the work on developing a multiphysics approach to evaluate the stability of bridges with piers in scour holes. Once the most suitable method of soil-structure interaction modeling was chosen, the next step in the research was to apply it to reconstruct a real life problem of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





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

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


Argonne NATIONAL LABORATORY

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

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

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

The LS-OPT Introductory Course is intended primarily for finite element analysts who have prior basic knowledge of the LS-DYNA software package. The class will provide the analyst with the introduction to Metamodel Based Design Optimization, stochastic analysis (probabilistic analysis) and Reliability Based Design Optimization (RBDO) within LS-OPT software. The typical attendee should have a background that includes a working knowledge of finite element analysis techniques, use of other nonlinear finite element software, and experience in modeling nonlinear events. Optimization knowledge is not required.

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

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

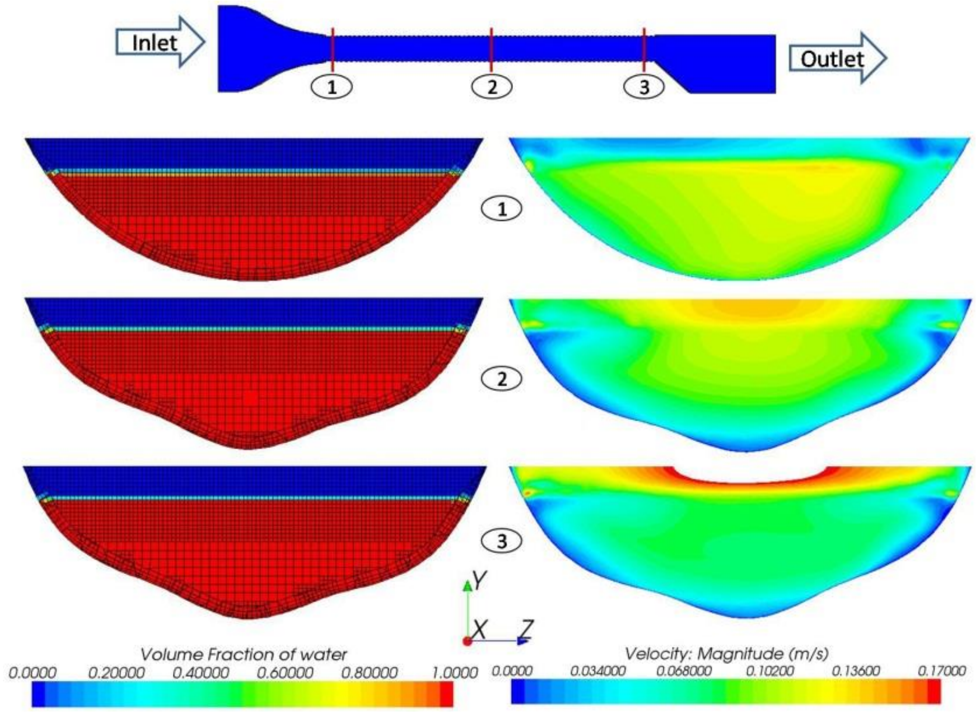
Location
The training course will be held at the DuPage Airport Flight Center in West Chicago where Argonne's TRACC offices are located. The training sessions will be held on the third floor of the flight center. The training sessions will also be broadcast over the Internet. The link to the Adobe Connect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

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

Contact Information
Dr. Ronald F. Kulak
Argonne TRACC
2700 International Drive, Suite 201
West Chicago, IL 60185
630 578 4245
kulak@anl.gov
www.tracc.anl.gov

U.S. DEPARTMENT OF ENERGY

Computational Fluid Dynamics



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

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

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

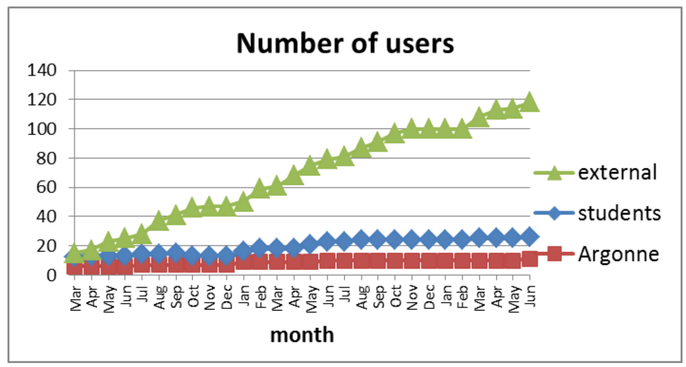
Work on development of training materials and new tutorials for a CFD training course based on STAR-CD was completed in March, and the first offering of this course was conducted on March 15-17, 2010. Experience with the previous STAR-CCM+ CFD training course and feedback from trainees indicated that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

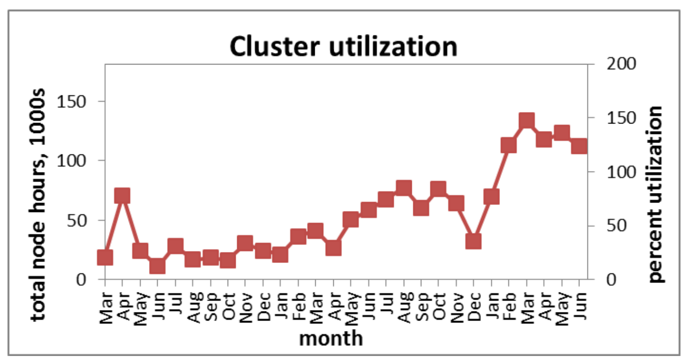
remote participants to get hands-on experience with the software by working on the tutorials as a learning vehicle during the class. Additional material on the use of the TRACC cluster was added.

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

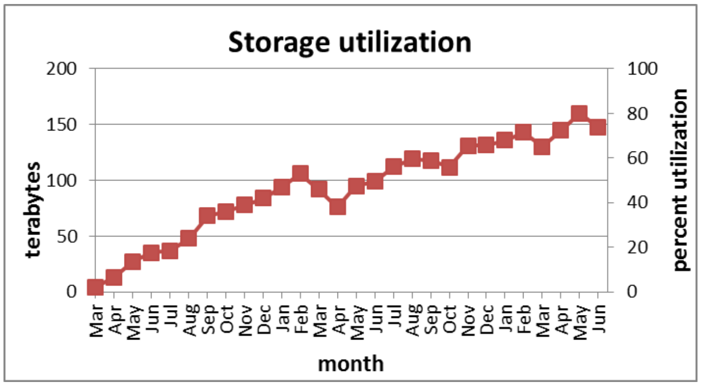
A major advantage of using the videoconferencing for CFD training appears to be that a training class can be composed of several small groups of participants at different locations, when participants in the small groups cannot afford to travel to a central location for a course and when instructors cannot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

April 2010 to June 2010





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



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

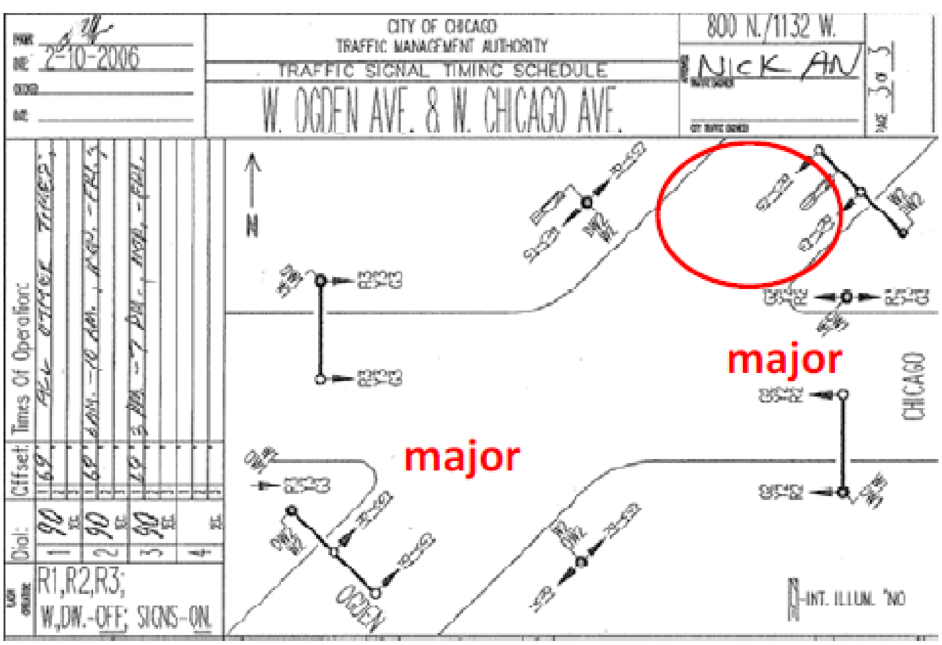
Transportation systems simulation

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

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

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

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



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

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

TRANSIMS

Training Course at LSU

Agenda

Wednesday, May 26, 2010

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

Thursday, May 27, 2010

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

Friday, May 28, 2010

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

Location

The LTRC Transportation Training and Education Center (TTEC) is located at 4099 Gourrier Avenue at the southern end of LSU's campus.

For information on Baton Rouge accommodations, please visit: http://www.visitbatonrouge.com

Internet Broadcast

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

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

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

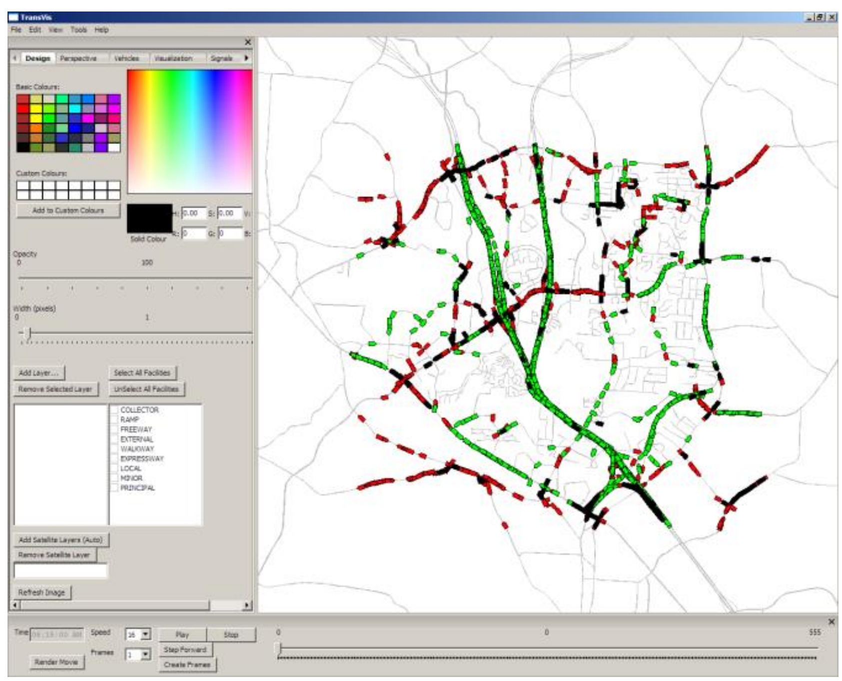
AECOM was collaborating with TRACC on several projects at the time. The major collaboration areas included TRANSIMS software development and maintenance, TRANSIMS training sessions and utilization of TRACC for TRANSIMS project applications. AECOM was leading the development of TRANSIMS Version 5.0 while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

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

Advanced visualization

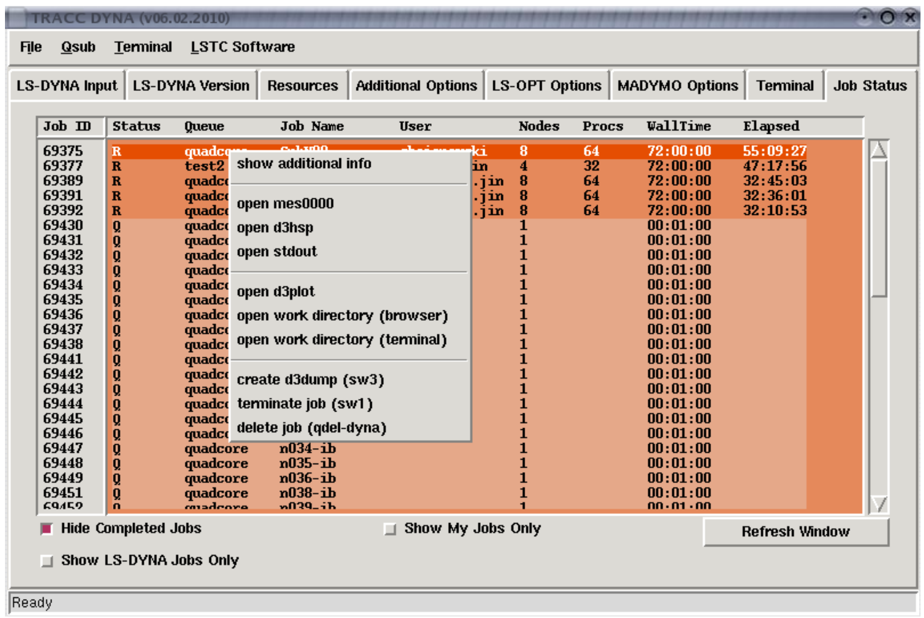
A major addition to the capabilities of TransimsVIS was the creation of high definition animations using a new waypoints feature. Users were able to bookmark positions in time and space, which could be returned to at a later time. This feature was extended to save a series of waypoints at fixed intervals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

Computational structural mechanics



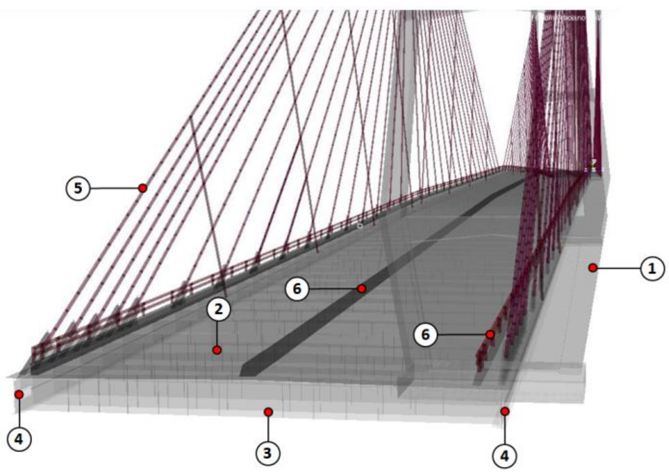
At the request of NHTSA, TRACC was expanding its computational mechanics code offerings to include MADYMO/modeFrontier. NHTSA was interested in greatly expanding its accident reconstruction efforts, and in order to do this, NHTSA needed to use MADYMO/modeFrontier on TRACC's cluster. In the current quarter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

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



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

In order to implement the work done by Northern Illinois University students to a real bridge, TRACC CSM staff developed a FE model of the Bill Emerson Memorial Bridge. This is a cable-stayed bridge connecting Missouri's Route 34 and Route 74 with Illinois Route 146 across the Mississippi River. The choice of the bridge was made primarily upon the availability of the geometry, material properties, and experimental data for the natural frequencies of the bridge structure. A validation study was performed on the model through comparison of calculated and experimentally obtained first seven natural modes of vibration and associated with them frequencies. The model was judged as valid and was made available to NIU for implementation of their work.

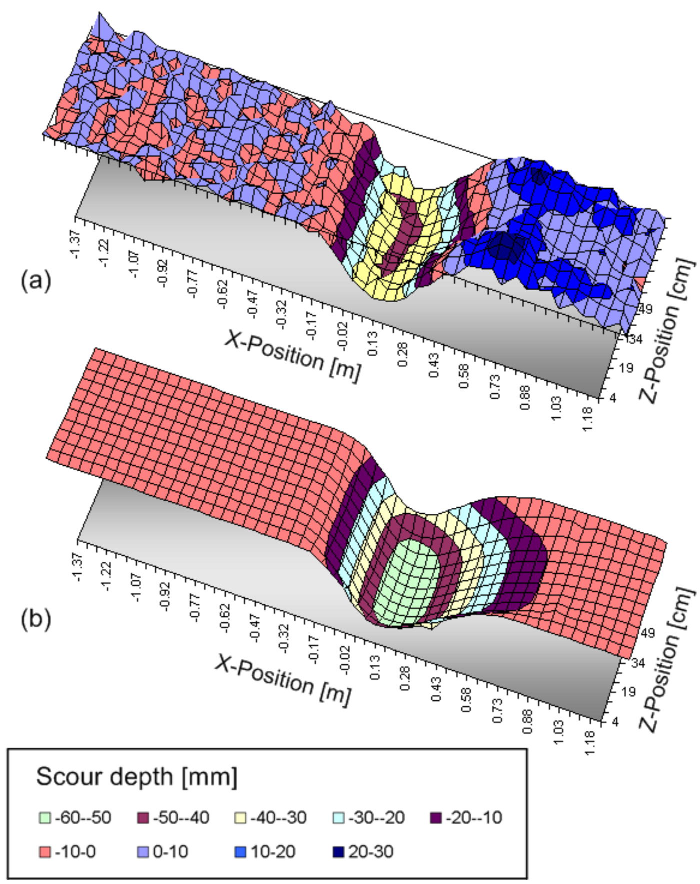


The research and development performed by the Computational Structural Mechanics staff has resulted in the current reporting period in two papers that were accepted by the 11th International LS-DYNA Users Conference in Dearborn, MI:

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

Computational Fluid Dynamics

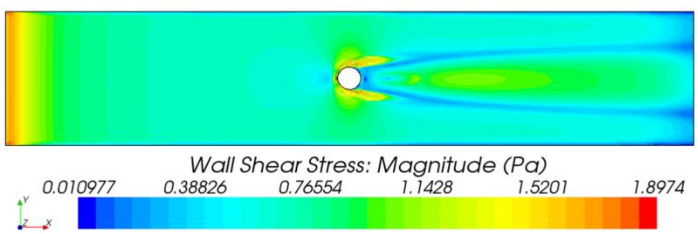
In the third quarter work on the computational procedures for two approaches to managing bed displacements as a function of bed shear stress and moving the entire mesh as a consequence to preserve mesh quality continued. The first effort uses STAR-CD to displace the soured bed. The displaced surface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



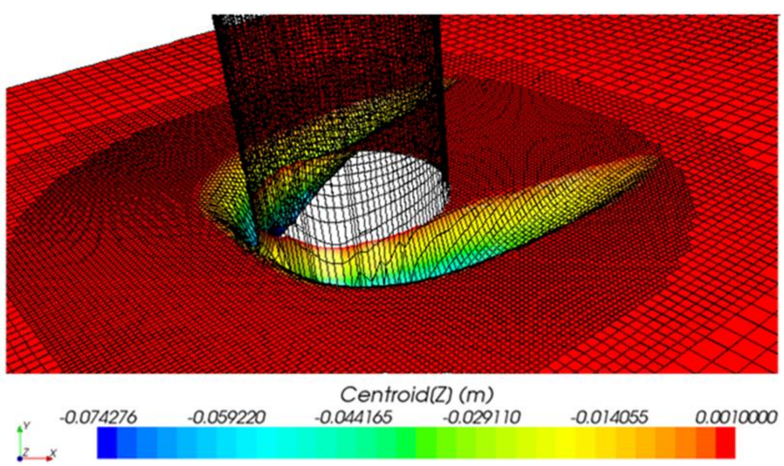
because it was a first demonstration that 3D scour effects observed in laboratory experiments could be computed with commercial CFD software.

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

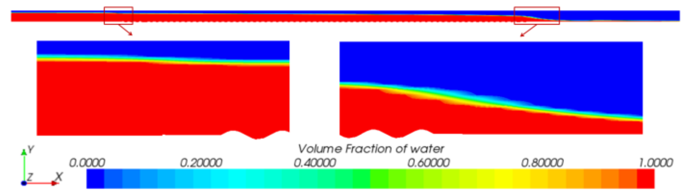
Initial tests on the 3D scour around a cylindrical pier

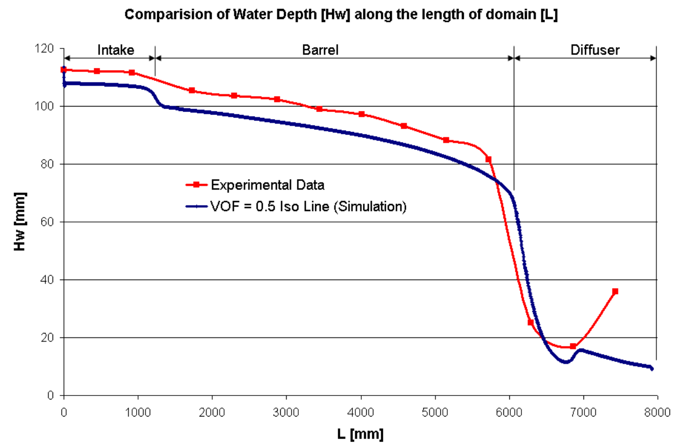


indicated that the procedure worked well, and scour hole depth was close to that predicted experimentally. However, the scour hole shape was much steeper than that observed in experiment. Additional physics models would be required to do better.

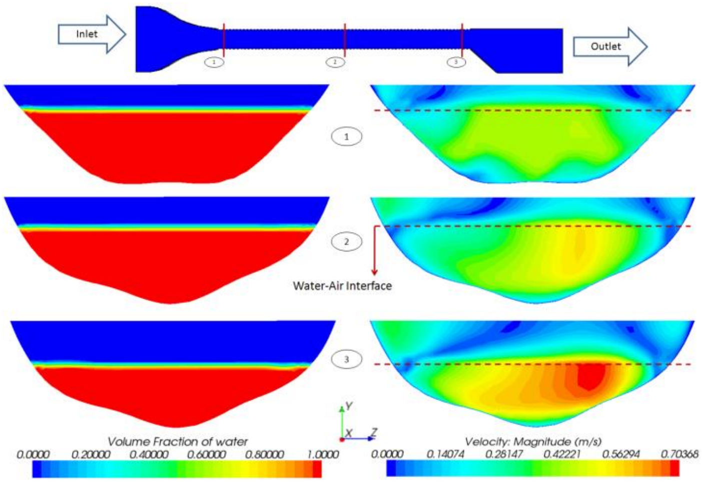


In culvert modeling, two experiments were modeled. One had the flap gate at the exit completely down and the other used a flap gate angle of about eleven degrees. The position of the flap gate at the exit in combination with the pump rate controls the flow rate through the culvert. With the flap gate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

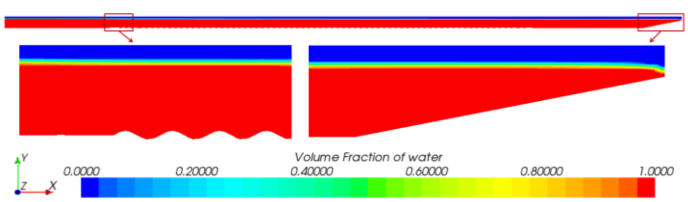




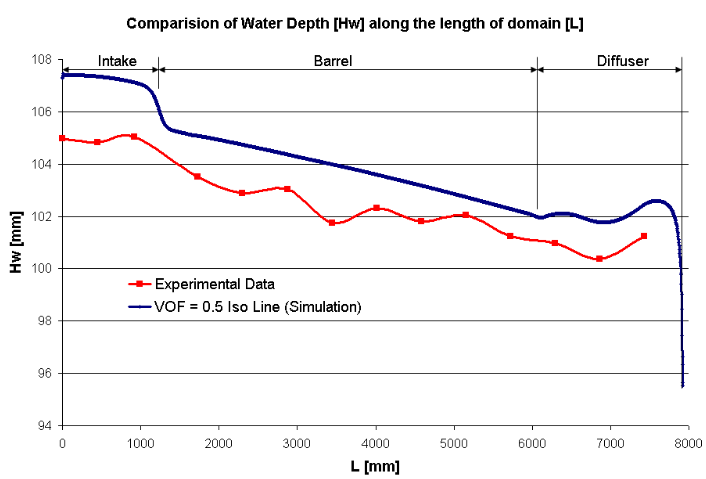
The model also showed that the asymmetric diffuser section at the outlet produced an asymmetric velocity profile in culvert barrel that extended more than halfway upstream to the barrel inlet. This impact of the outlet diffuser geometry was not obvious to flume designers, and requires costly particle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



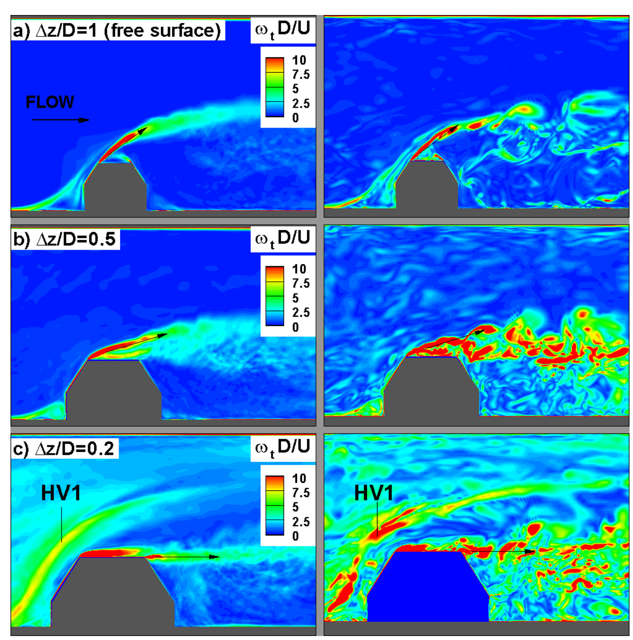
In the second case analyzed with the flap gate at 11 degrees, the water level in the flume diffuser did not drop off, which also match the experimental behavior.



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



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



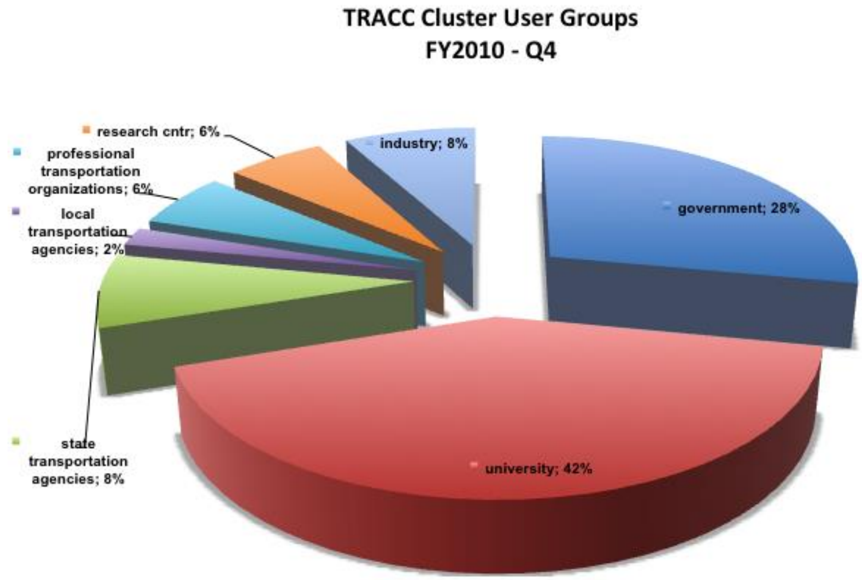
July 2010 to September 2010

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

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

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

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



Transportation systems simulation

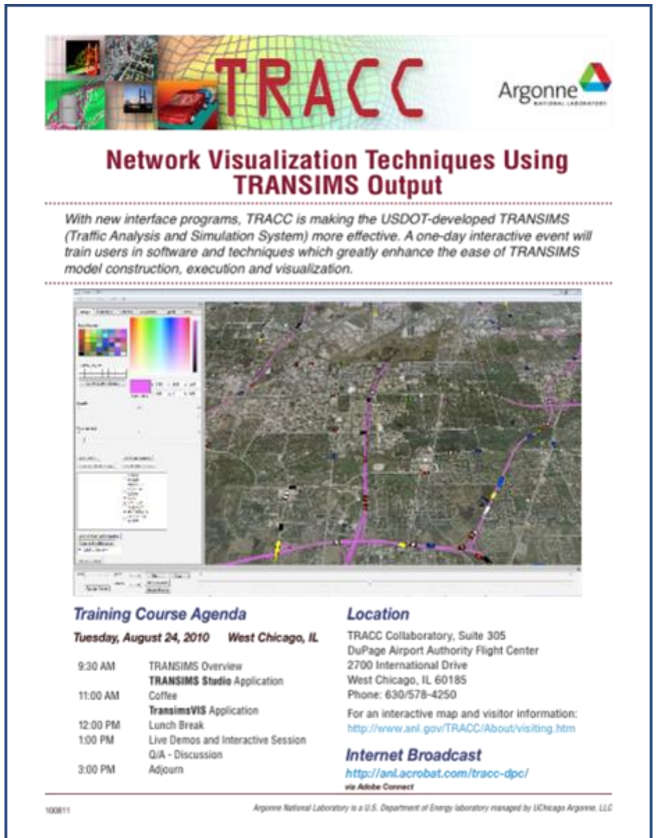
TRACC rolled out additional elements of its TRANSIMS Studio to AECOM, RSG, IIT, CMAP, and the City of Moreno Valley. Assistance was given to AECOM to get TRANSIMS Studio running on the TRACC cluster for their Jacksonville, FL model. Additional support was given to ensure that TransimsVIS was able to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

Chicago regional models.

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

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

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



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

Computational Fluid Dynamics

Outreach at the 2010 National Hydraulic Engineering Conference

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

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

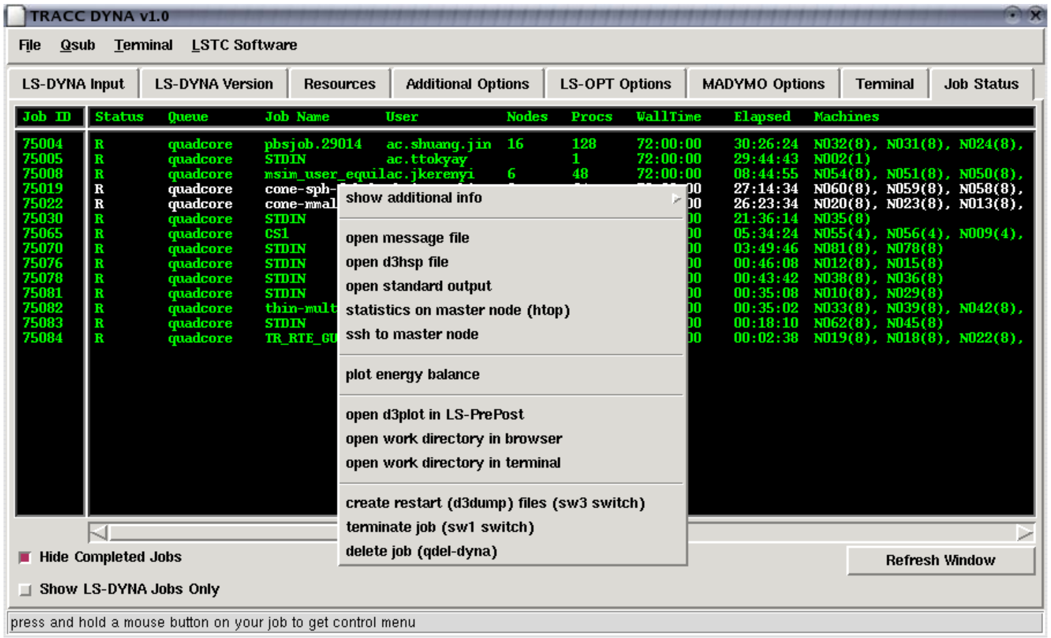
Computational Fluids Dynamics and Computational Structural Mechanics staff at TRACC developed a collaborative research proposal to perform computational mechanics research and development in areas of interest to the Aerodynamics Laboratory and the Hydraulics Laboratory at TFHRC and to provide computational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

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

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

Computational structural mechanics

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



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

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

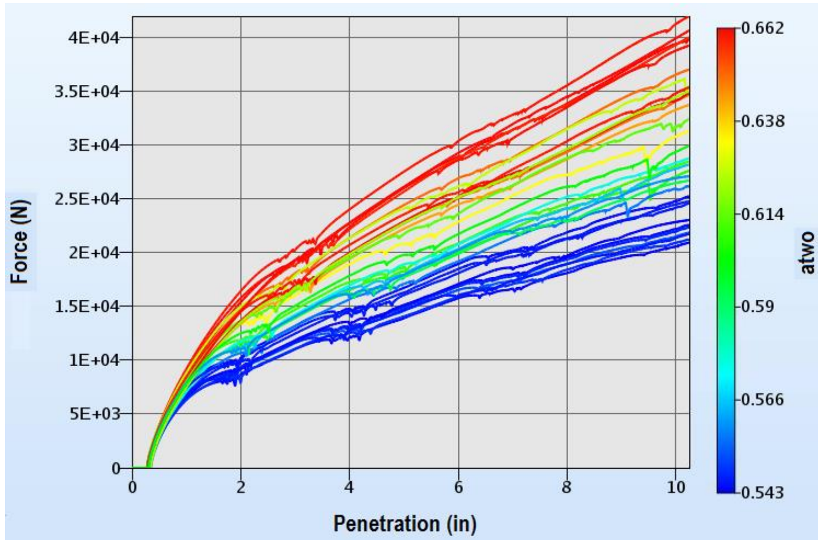
FAMU-FSU was still the most active collaborator in the CSM research area. The initial FE models of the buses that were used by FAMU-FSU were developed by current TRACC staff member Dr. Cezary Bojanowski when he was still a student at FSU. Extensive consultation was provided to FAMU-FSU College of Engineering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

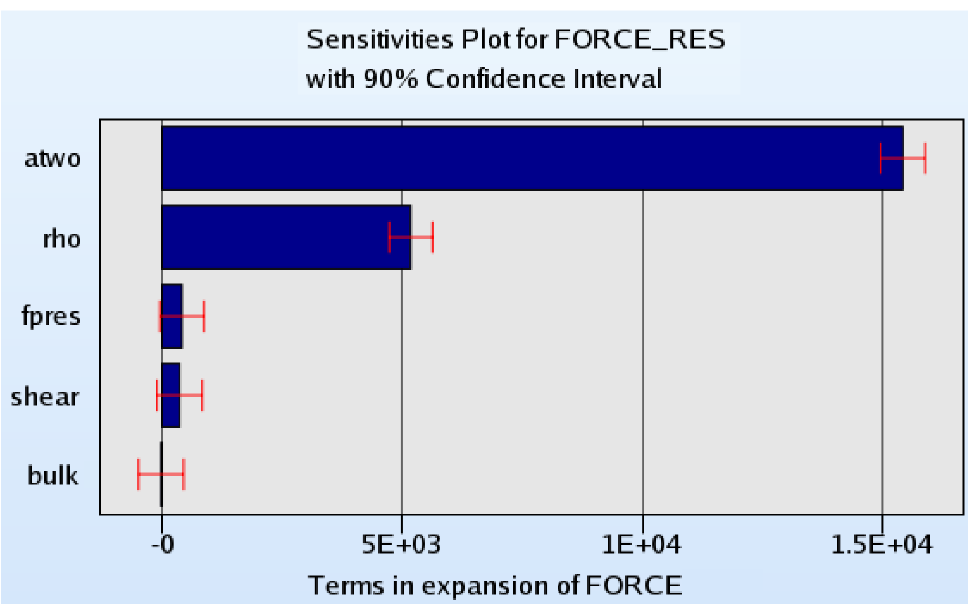
ECE-R66 defines a full scale dynamic rollover procedure as a basic approval experiment. Expanded version of the ECE-R66 is presented in Florida Department of Transportation (FDOT) Standard, which was developed as a Crash and Safety Assessment

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

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

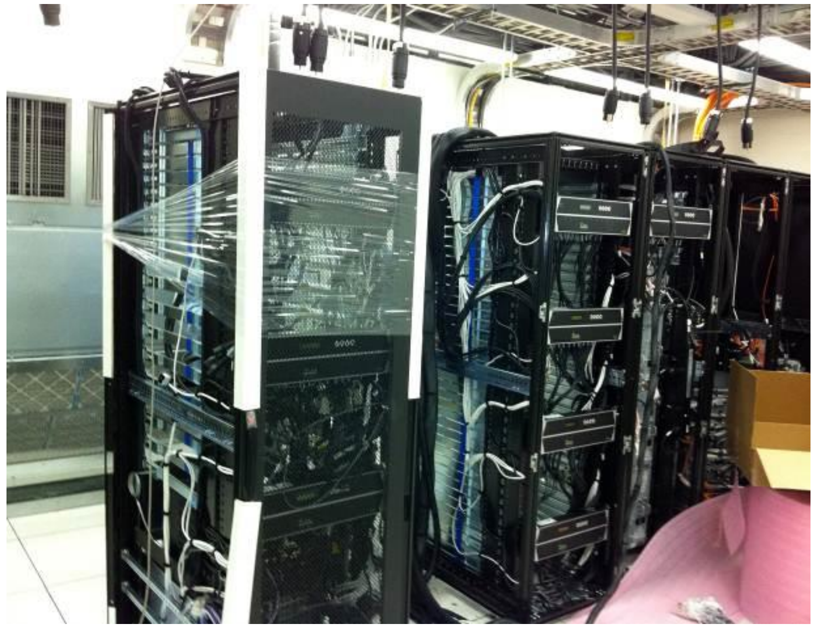
In order to implement the work done by Northern Illinois University students to a real bridge, TRACC CSM staff developed a FE model of the Bill Emerson Memorial Bridge. During this quarter, vehicle-bridge interaction was studied in more detail and simulations of traffic loading on the bridge have been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





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

October 2010 to December 2010



The major change in TRACC's operation in December 2010 was the move of the facilities (as well as the high performance computing system) to the Argonne National Laboratory site, located near Lemont, IL. TRACC's location at the DuPage Airport Flight Center had always been a temporary solution, and had been initially envisioned as being a driving factor in establishing the DuPage National Technology Park close to this location in West Chicago. With the economic downturn of previous years, as well as decreased interest by partner universities in investing in the research park, the decision of operating TRACC at a remote facility were re-examined, and senior Argonne management decided to provide a suitable location for TRACC onsite. TRACC's offices were now located in building 222 close to Argonne's main entrance, and the high performance computing cluster system was relocated to an ideal computer room in Building 240, co-located with some of the fastest computers in the world. This placement ensured state of the art support, and full integration into one of the most secure but widely accessible network environments in the United States.

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

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

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

Despite the move, the TRACC facility still hosted two training sessions during the quarter. This included a training class in the computational structural mechanics area and a workshop on the Highway Ca-

pacity manual. Other meetings were held in cooperation with the Chicago Metropolitan Agency for Planning as part of their outreach programs.

Transportation systems simulation

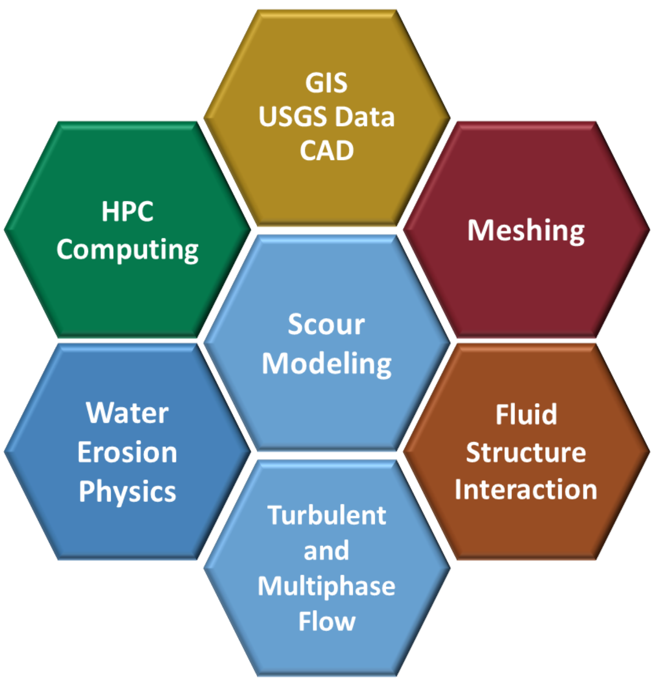
A major event in the area of transportation systems simulation and evacuation planning was the commencement of the RTSTEP project with the City of Chicago. The project had been proposed to the City two years earlier, and the development of a contract that the City of Chicago, the University of Chicago,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

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

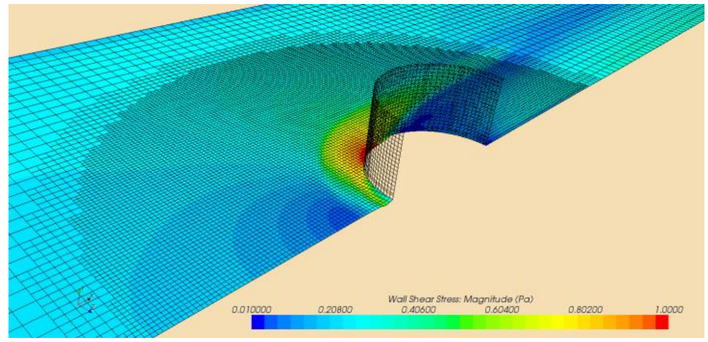
Computational Fluid Dynamics

Scour Analysis

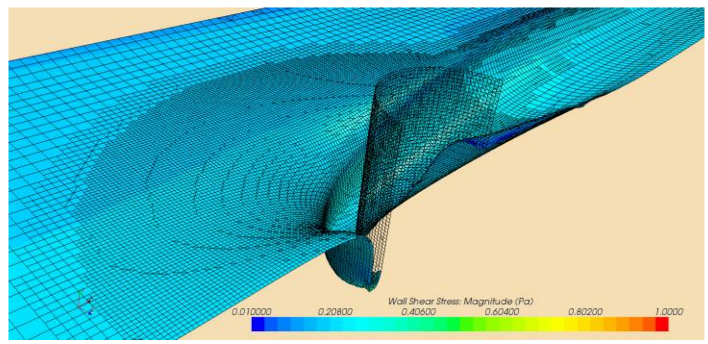
Analysis of three-dimensional scour processes at real bridges was recognized to be a complex multidisciplinary problem that included several research topics beyond just the CFD that included turbulent and multiphase flow with water erosion physics: it's successful development also relied on the new area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



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



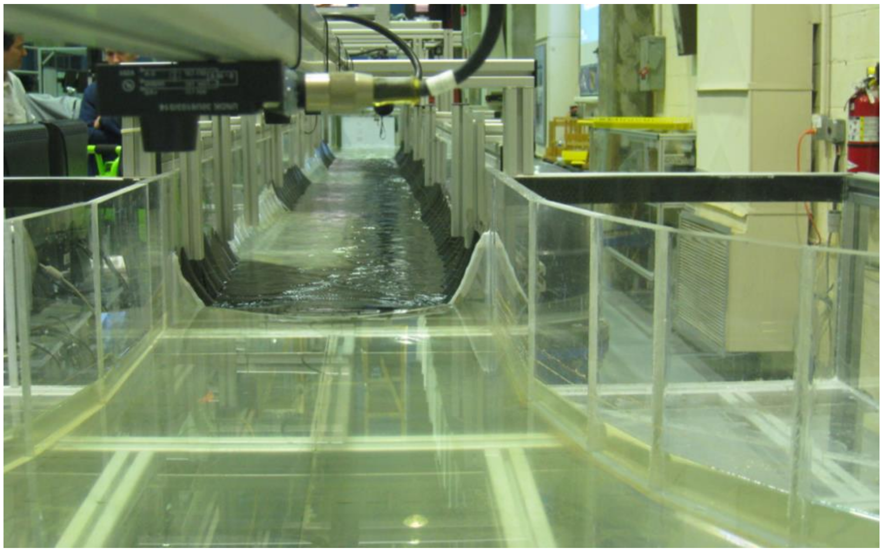
Sand bed shear stress distribution near the start of the scour process around a cylindrical pier. The critical shear stress for initiating motion of sand on the bed is approximately 0.18 Pa.



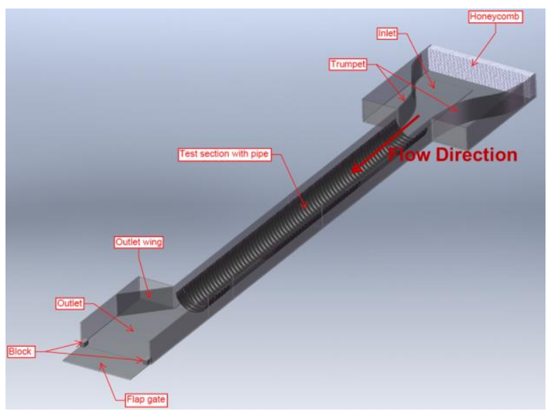
A symmetric half of scour around a single pier was computed, and although the scour hole was clearly too steep for conditions of non-cohesive sand sediment, the complex procedure to compute the evolution of the scour hole through a large series of automated computer runs with remeshing over a time period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

Culvert Analysis

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



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

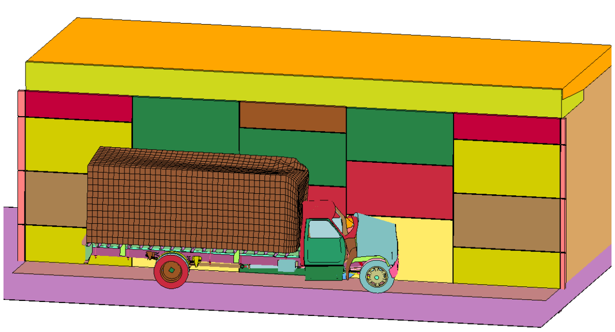


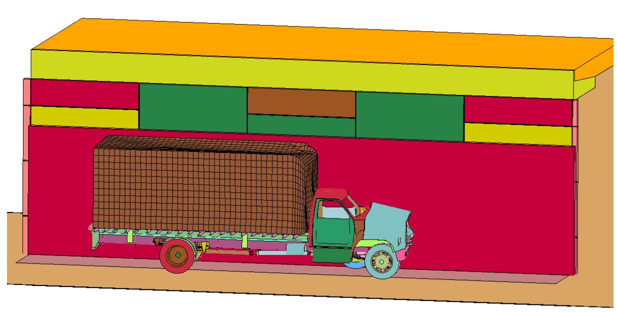
Computational structural mechanics

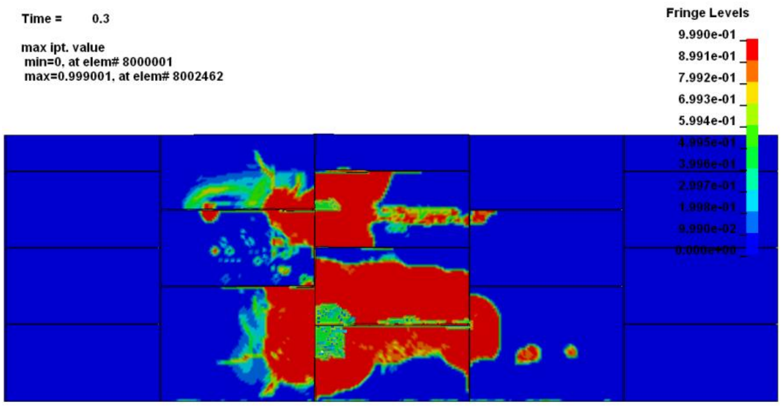
The TRACC cluster, Computational Structural Mechanics staff, and cluster administrator continued to provide computational and support resources to an expanding user base of DOT researchers using computational structural mechanics tools to address design and safety issues. Two new Computational Structural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

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

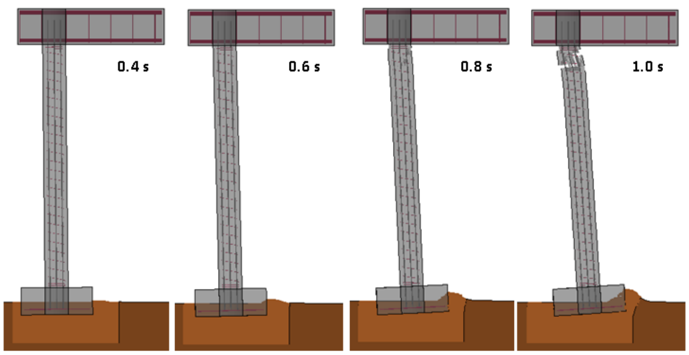
TRACC staff continued work evaluating the most efficient numerical multi-physics approach for modeling bridge stability for bridges with supporting piers embedded in scour holes. A second set of published data for soil penetration tests was located and favorable comparisons between experimental test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







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



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

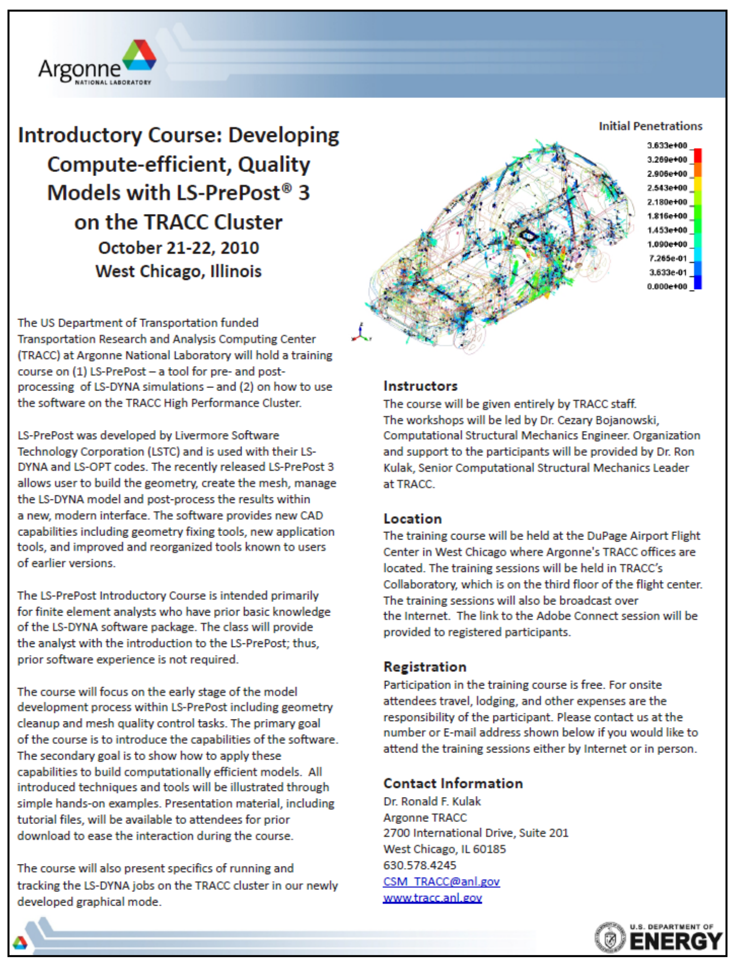
In this quarter, the CSM group gave an Introductory Course*: Developing Compute-efficient, Quality Models with LS-PrePost® 3 on the TRACC Cluster*. The training was held October 21-22, 2010 at TRACC in West Chicago with interactive participation on-site as well as remotely via the Internet. The training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

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

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

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

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


Argonne NATIONAL LABORATORY

Introductory Course: Developing Compute-efficient, Quality Models with LS-PrePost® 3 on the TRACC Cluster
October 21-22, 2010
West Chicago, Illinois

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

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

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

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

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

Initial Penetrations
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3.269e+00
2.906e+00
2.543e+00
2.180e+00
1.816e+00
1.453e+00
1.090e+00
7.265e-01
3.633e-01
0.000e+00

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

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

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

Contact Information
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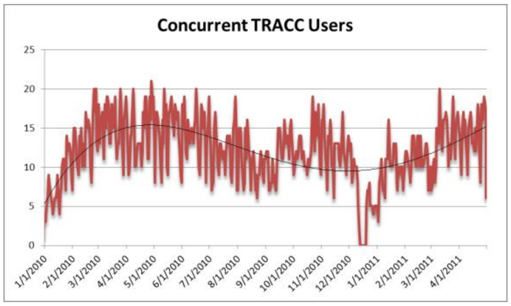
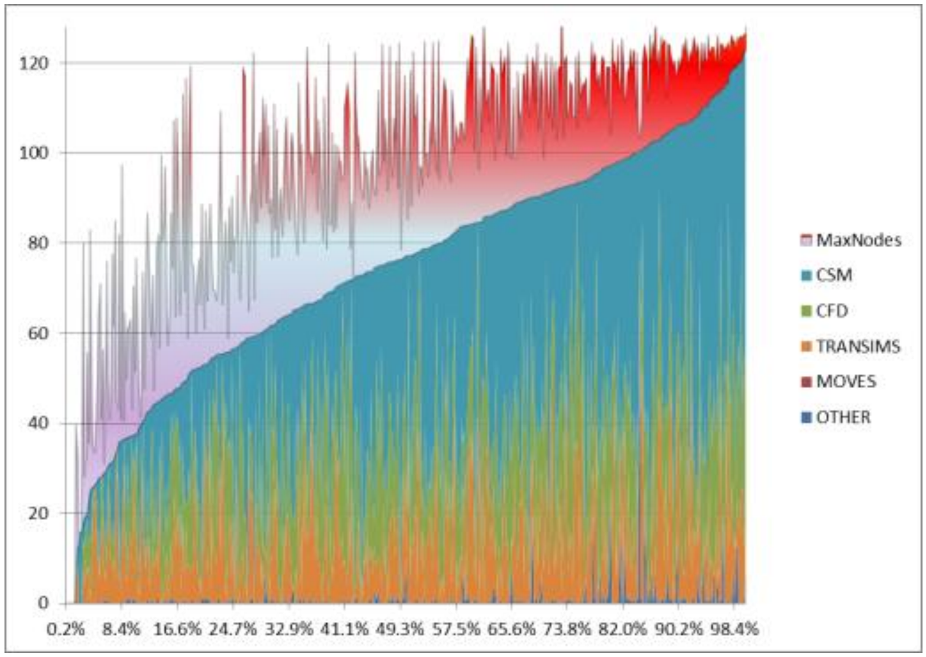
www.tracc.anl.gov

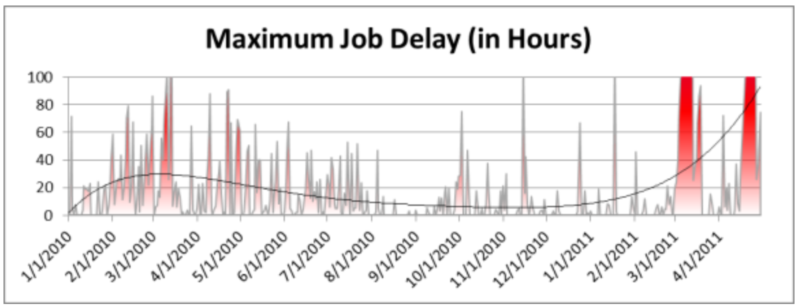
U.S. DEPARTMENT OF ENERGY

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

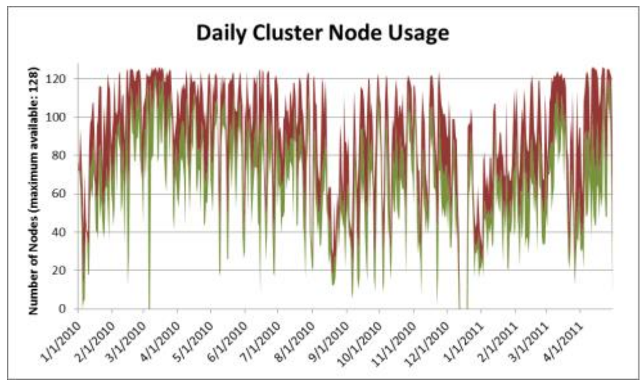






fact that the TRACC cluster is a limited resource that was being used for relatively large jobs as well as for interactive work, a long term load average beyond 70% significantly reduces the user experience and was detrimental to effective project performance. For example, peak waiting times for larger 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.

Argonne NATIONAL LABORATORY

TRANSIMS

Training Course

January 19-21, 2011

Argonne, IL

The Transportation Research and Analysis Computing Center at Argonne National Laboratory will hold a training course on the regional transportation analysis code TRANSIMS. The course is targeting both analysts new to the TRANSIMS methodology and those who had a previous experience working with TRANSIMS, and covers both the theoretical underpinnings as well as the practical application of the code. Participants will develop a full understanding of the general TRANSIMS principles, implementation details, data requirements, capabilities, and limitations of the software.

TRANSIMS (short for Transportation Analysis and Simulation System) is an integrated set of tools developed to conduct regional multimodal transportation system analyses. With the goal of establishing TRANSIMS as an ongoing public resource available to the transportation community, TRANSIMS is made available by the Federal Highway Administration under a NASA Open Source Agreement and is therefore readily available to the community.

The software is compatible with regular Windows and Linux desktop or server systems, but can also make use of high performance computing systems such as the TRACC cluster, a 1024 core Linux system with 240TB of disk space and extremely fast network connections across the United States. This cluster is generally available to researchers in the US transportation community and is currently being used for TRANSIMS traffic simulation, emergency evacuation modeling, computational fluid dynamics for bridge analysis, and structural mechanics codes to determine crashworthiness and structural integrity of highway components and vehicles.

Location

The training course will be held at the main campus of **Argonne National Laboratory, building 222** (see maps on reverse side).

Registration

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

This is the twelfth TRANSIMS training course held by TRACC. It has evolved from the need to quickly and efficiently train students and collaborators in the practical application of the code. While addressing the fundamental principles to a degree that allows for a better understanding of the capabilities and limitations of the TRANSIMS approach, the main focus is on the use of the individual components. It also focuses on the issues of network conversion, trip conversion, routing, microsimulation, feedback, and visualization. ***This year, participants will also gain experience in the new TRANSIMS studio application. Therefore use of a laptop while attending the lectures is highly encouraged.***

Instructors:

Dr. Hubert Ley, Dr. Kuilin Zhang, Michael Hope and Dr. Vadim Sokolov
Argonne TRACC, 9700 S. Cass Ave, Argonne, IL, 60439
630 252-5200, TRANSIMS@anl.gov
David Roden*,* Senior Consulting Manager
AECOM, 2101 Wilson Boulevard, Suite 800, Arlington, VA 22201
703 340-3069, david.roden@aecom.com
Dr. Zongzhi Li*,* Associate Professor, CAE
Illinois Institute of Technology
Coordinator, Transportation Engineering Program and Infrastructure Engineering and Management Program
Transportation Engineering Infrastructure Engineering and Management
Office: AM 102 3201 South Dearborn Street Chicago, Illinois 60616
312 567-3556, lizz@iit.edu

TRACC
Transportation Research and Analysis Computing Center
at Argonne National Laboratory

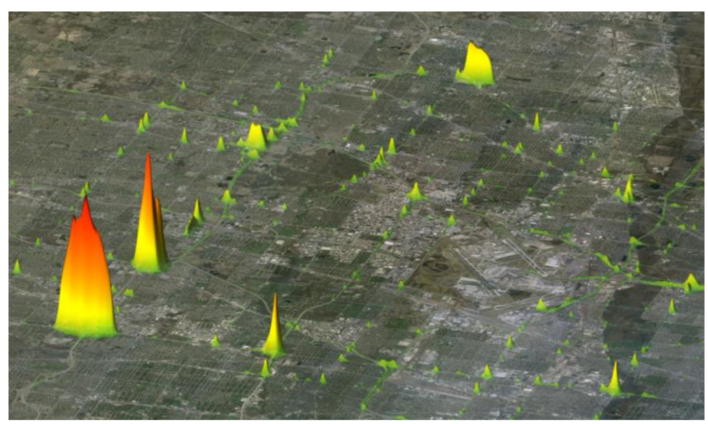
UChicago Argonne LLC

www.tracc.anl.gov

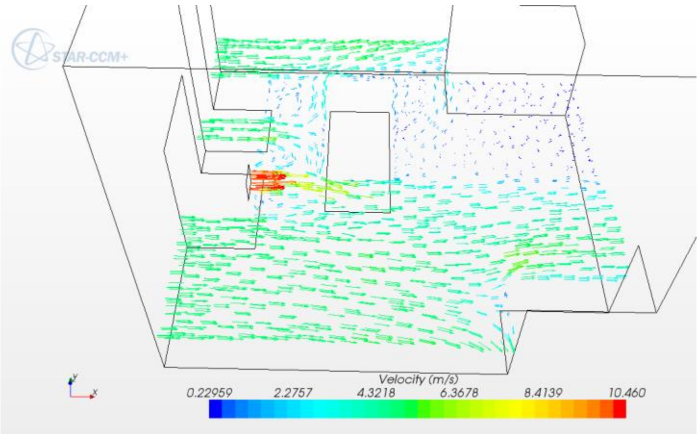
A U.S. Department of Energy laboratory managed by UChicago Argonne, LLC

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.

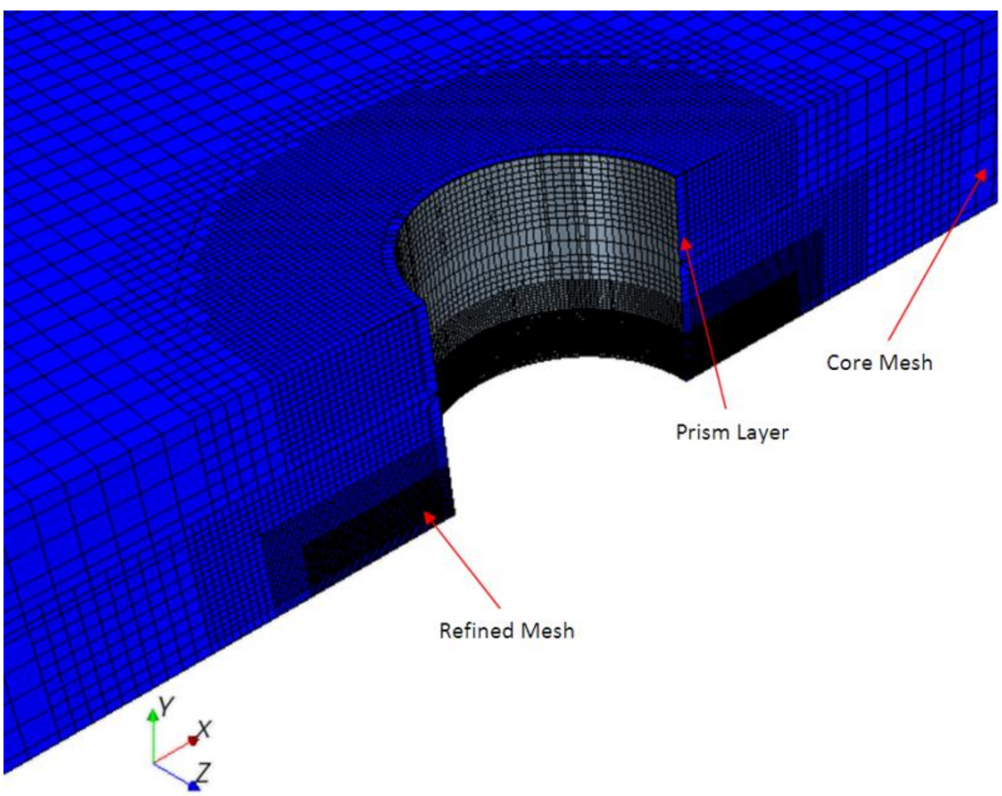
Computational Fluid Dynamics

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.

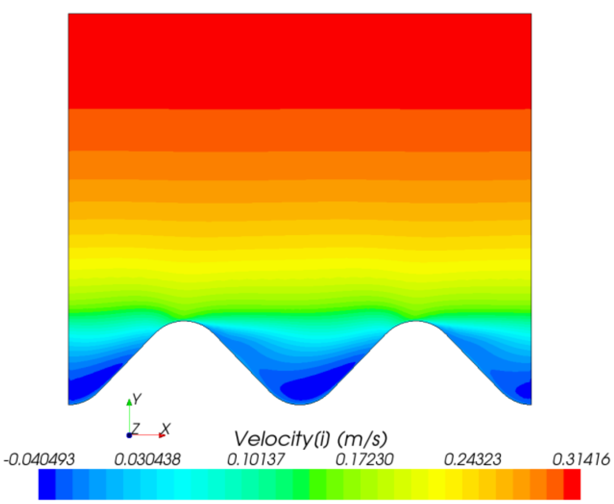
Culvert Modeling

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.



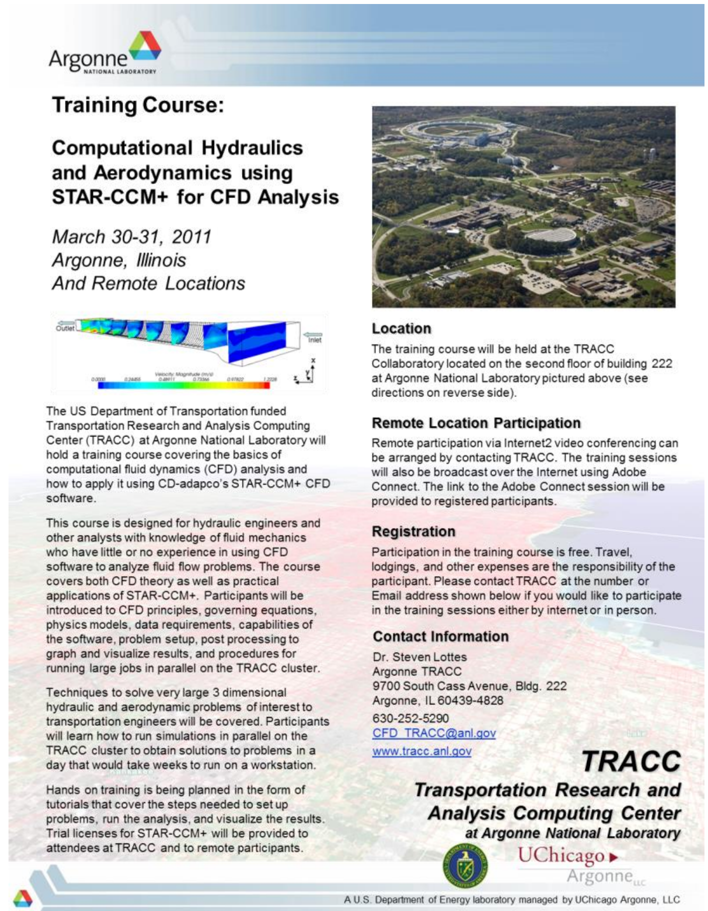
The objective of the new culvert analysis project was to develop approaches to CFD modeling of culvert flows and to use the models to perform analysis to assess flow regions for fish passage under a variety of flow conditions. The flow conditions to be tested with CFD analysis were defined in the tables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

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

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TRACC
Transportation Research and Analysis Computing Center
at Argonne National Laboratory

UChicago
Argonne LLC

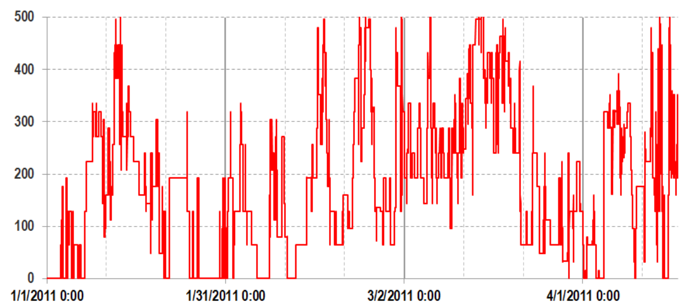
A U.S. Department of Energy laboratory managed by UChicago Argonne, LLC

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

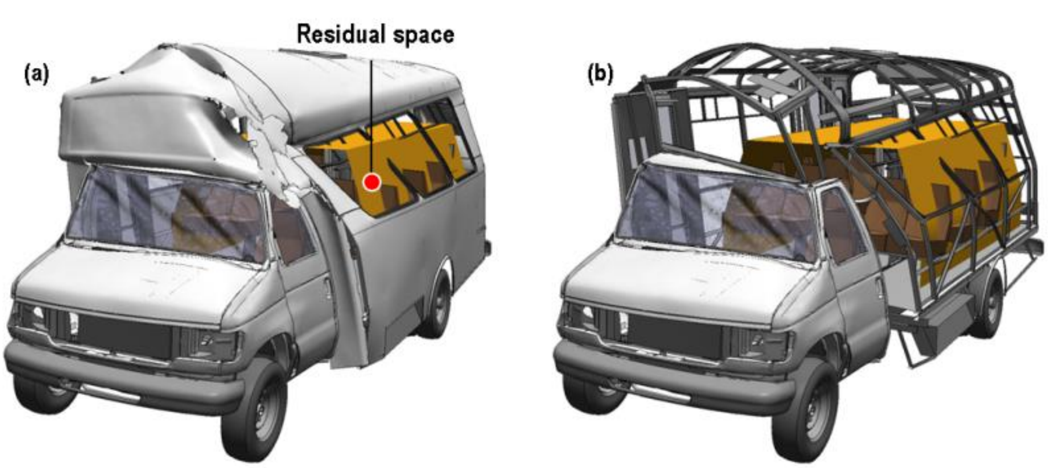
a free surface as in open channel hydraulics flows, analysis of the flow of 80 mph wind past a pair of road signs in close proximity, a method for modeling fully developed flow through culverts using cyclic boundary conditions, computing the forces on a flooded bridge deck, and a method for transient 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.

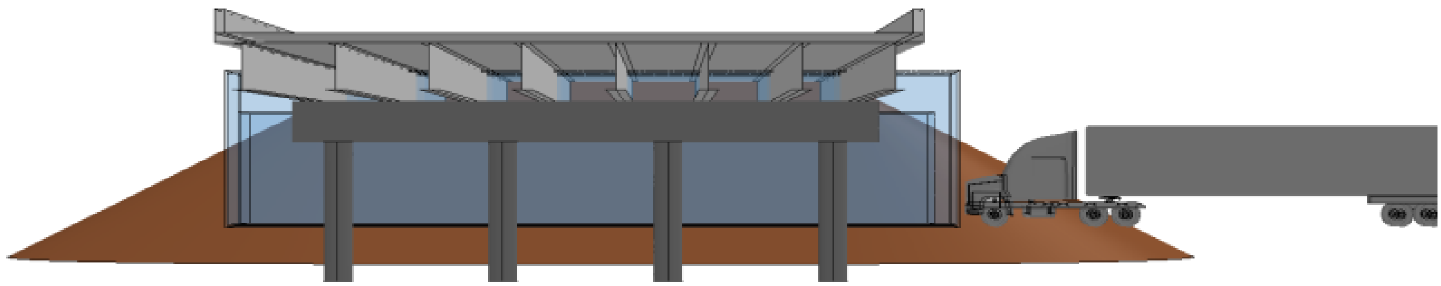
Computational structural mechanics

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.

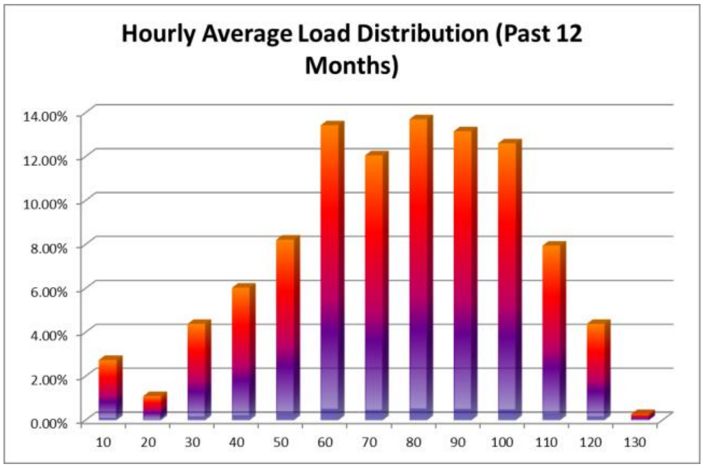
In this quarter, three papers submitted to the Transportation Research Board (TRB) Annual Meeting Committee, Washington, D.C., 2011 were presented at the conference. The new work performed by CSM staff in the current quarter was accepted for presentation and publication at international conferences:

- 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

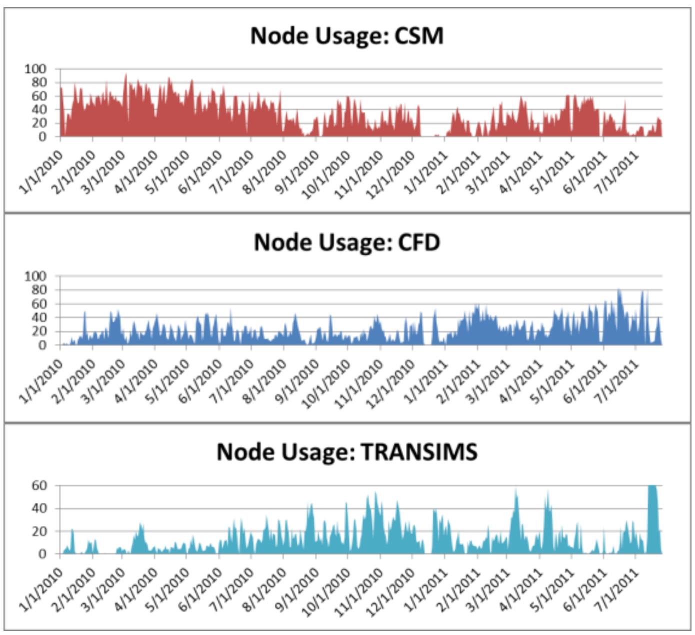
For the 3rd quarter of FY2011, the cluster was particularly heavily used, with an average utilization of about 67% for April, 66% for May, and 63% for June 2011. More significantly, the average of daily maximum usage was 91%, 82%, and 87% respectively. These numbers are important because they reflect 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.



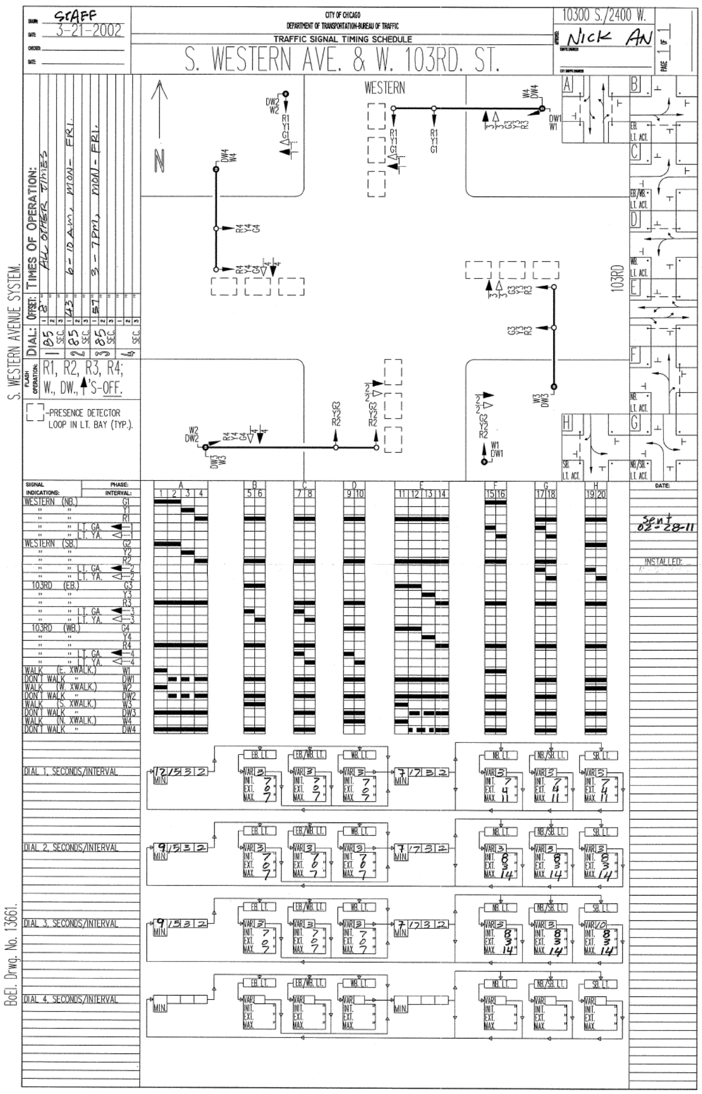
The total number of individuals having active accounts at the time was about 130. This included project supervisors and individuals that did not actively run jobs. They may have used the cluster interactively, uploaded and downloaded data files, or used other TRACC resources such as source file archives 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

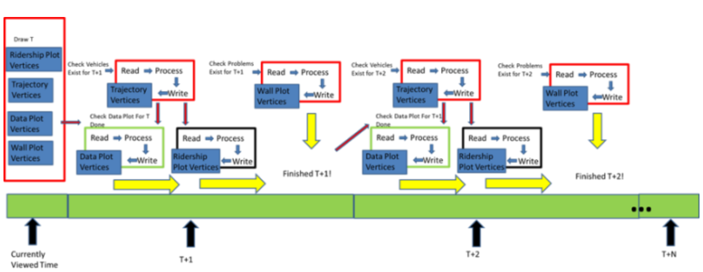
The RTSTEP project, a $2M project involving about 25 collaborators at Northern Illinois University, the Illinois Institute of Technology, the Chicago Metropolitan Agency for Planning, the City of Chicago, and AECOM, a large consulting and engineering company, was in full operation by the summer of 2011. 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.

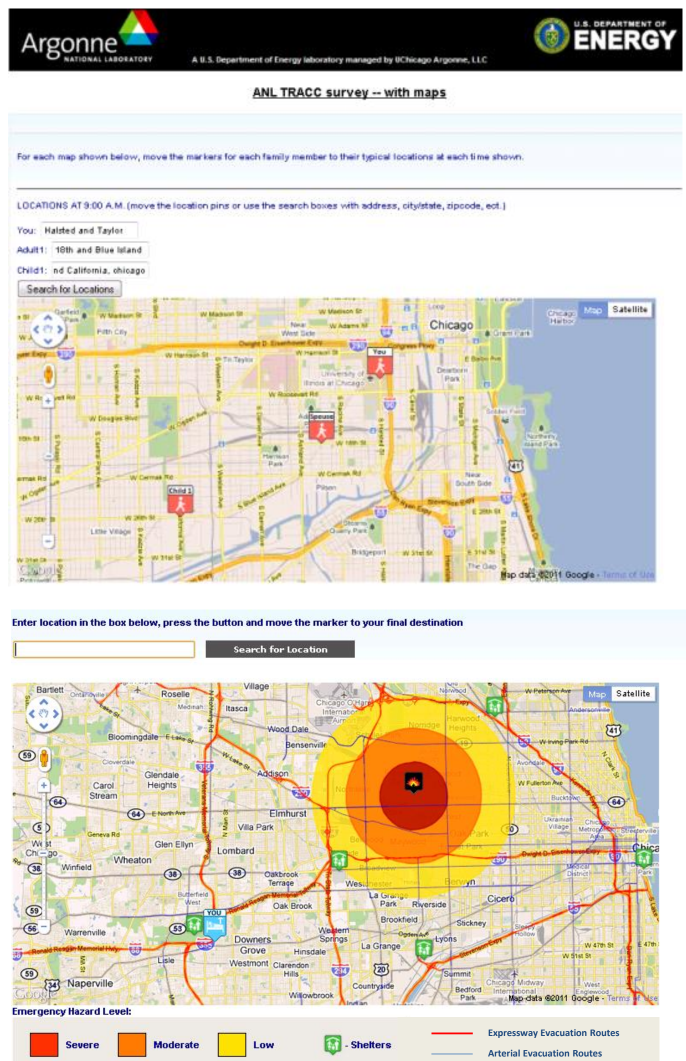
A team of IIT students also worked on detailed traffic signal models for hundreds of intersections in the City of Chicago. They interpreted engineering drawings for phasing and timing of traffic signal systems and translated the information into appropriate model data sets.



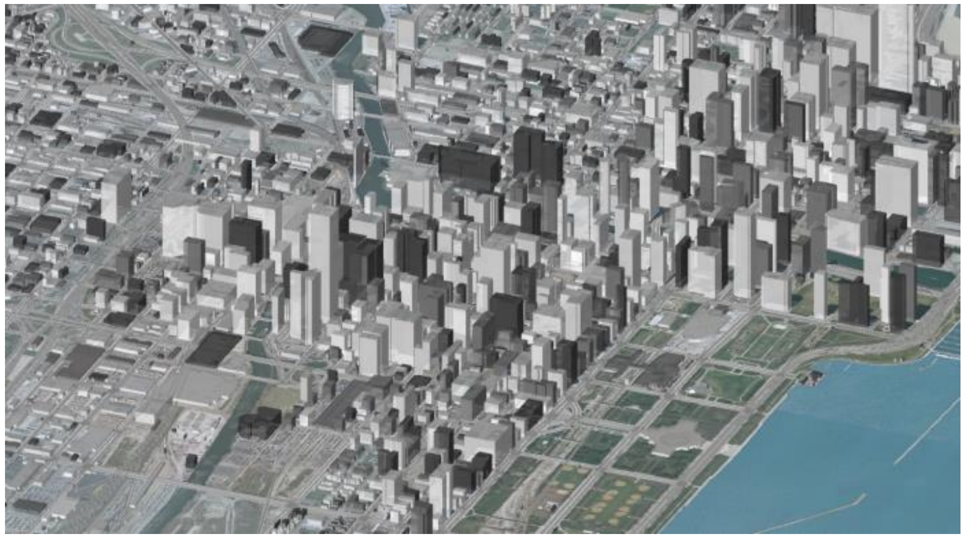
The projects involved many different pieces of software that had to be developed, integrated, and tested thoroughly. AECOM took the lead on TRANSIMS tools, Argonne developed the visualization and execution frameworks, and the universities supported this work with specialized capabilities and data pre-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



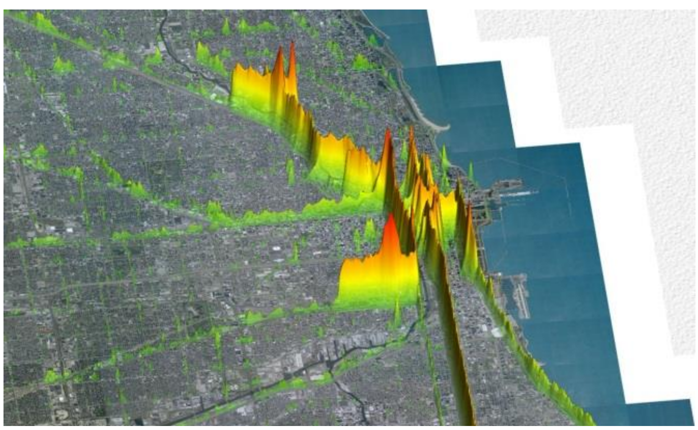
Also, a planned evacuation decision survey was implemented. The survey was designed as a stated choice survey which was to be completed by a random stratified sample of individuals in the Chicago region. The survey collected basic demographic information on the respondents, as well as the locations of 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.



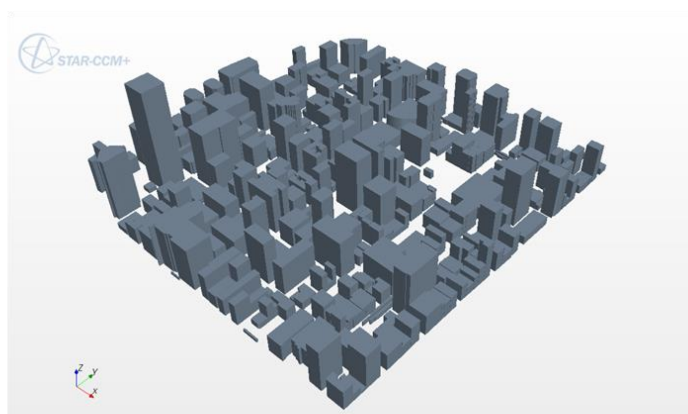
Development continued on both the TransimsVIS and TransimsEDT applications. The TransimsVIS development was done as part of the RTSTEP project.



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.

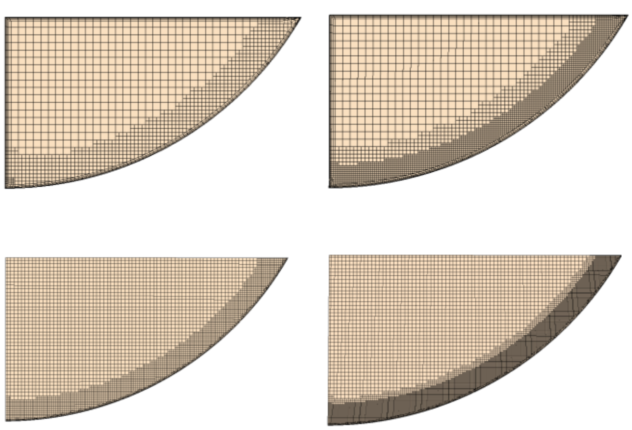


In a real radioactive dispersion event, the plume was expected to be composed of not only multi-component gases but also of multiple phase particles. Therefore a multi-phase flow model was added to the plume model. This was accomplished in Star-CCM+ by redefining the model with an addition of a Lagrangian 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

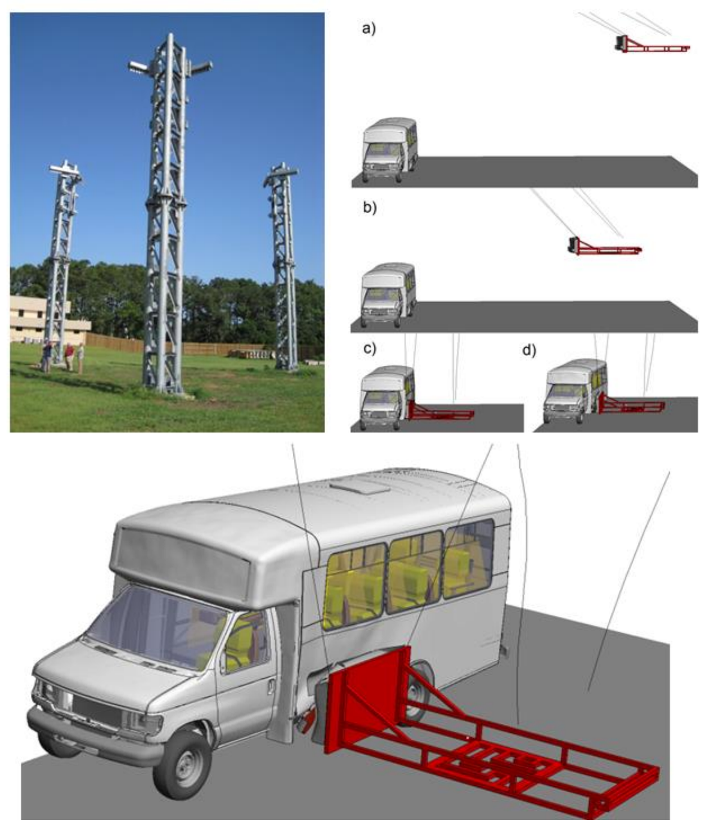
Work on two additional physics models needed in the pier scour model was begun during the quarter. In the previous formulations the scour process eroded the bed directly downward in alignment with the gravity vector. This approach is fine when starting from a flat bed when the slope of the scour hole 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.

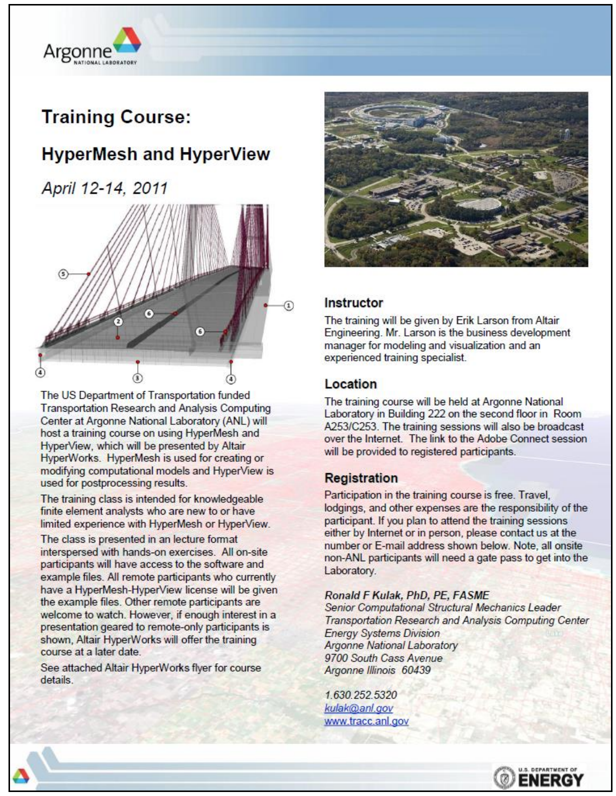


Work on developing credible models for making reliable predictions of the response of bridges and their components to blast loading has continued. Previously, LS-DYNA capabilities were utilized to simulate the transient response of stay cables in a long span cable stayed bridge (Bill Emerson

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

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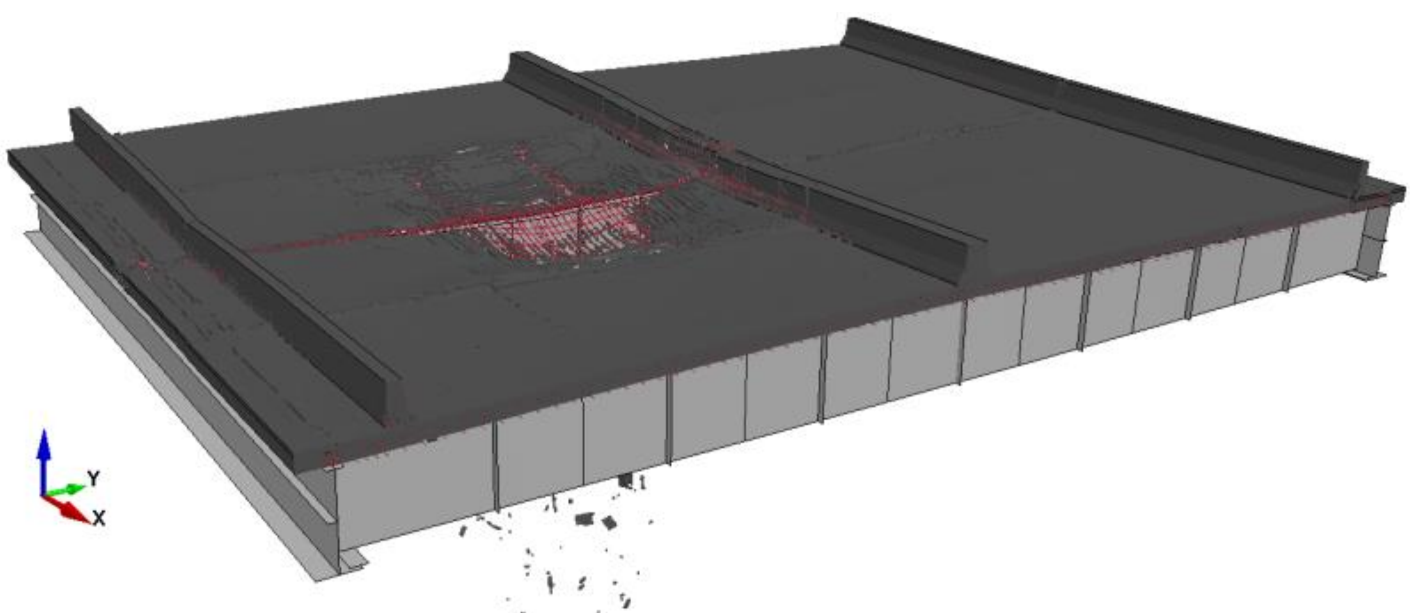


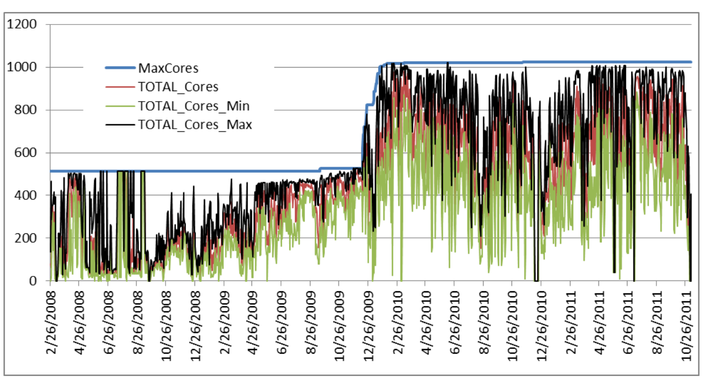
Strasbourg, France, May 23-24, 2011.

July 2011 to September 2011

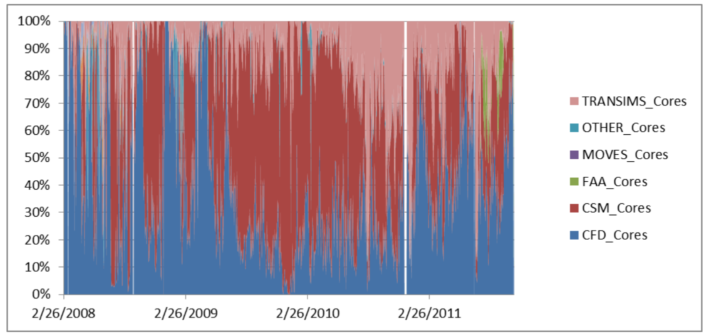
TRACC expertise with videoconferencing and remote collaboration has led to a leading role at Argonne for the deployment of such technologies throughout the laboratory, in particular to reduce travel and cut down both on costs and greenhouse gas emissions. This activity also significantly reduced the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



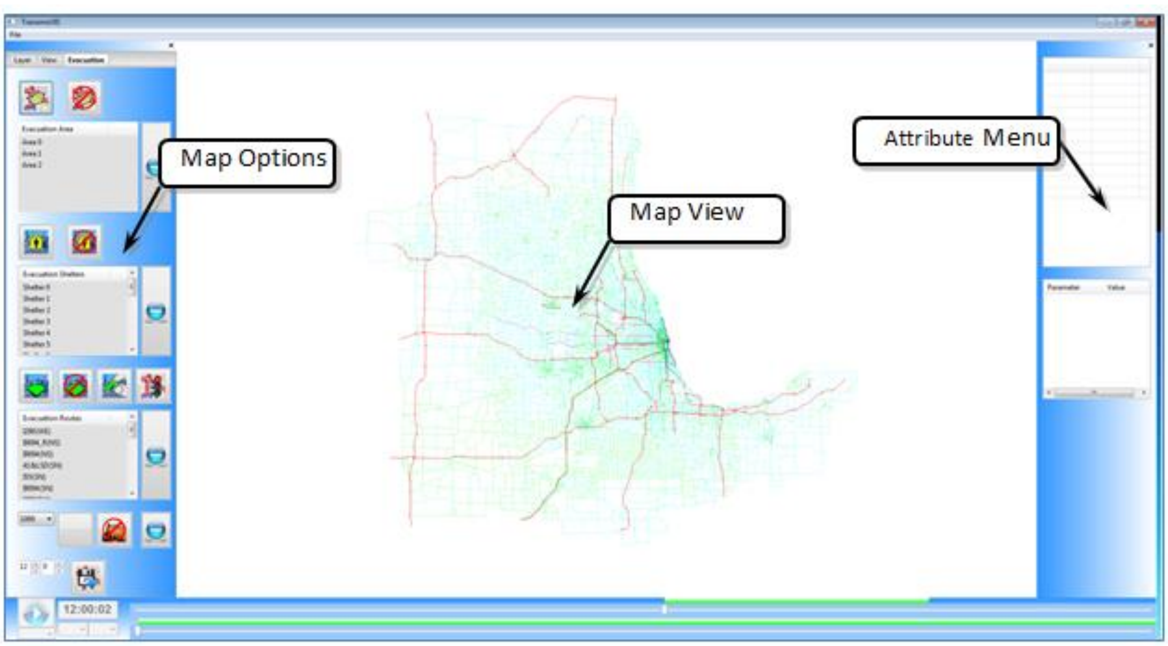
Transportation systems simulation

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.

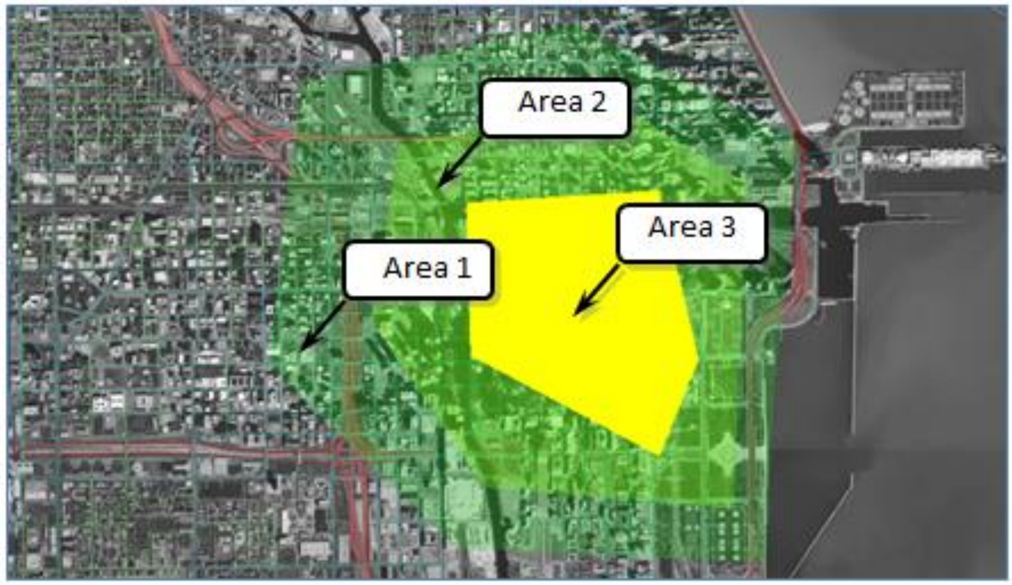
By March 2012, TRACC, AECOM and IIT finished much of the work on the network supply model, correcting insufficiencies and introducing a number of network enhancements. A large number of modifications were made to the network. Large sections of I-294, I-90, I-290, I-355, I-88, I-57, I-55, I-65 and I-80 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.



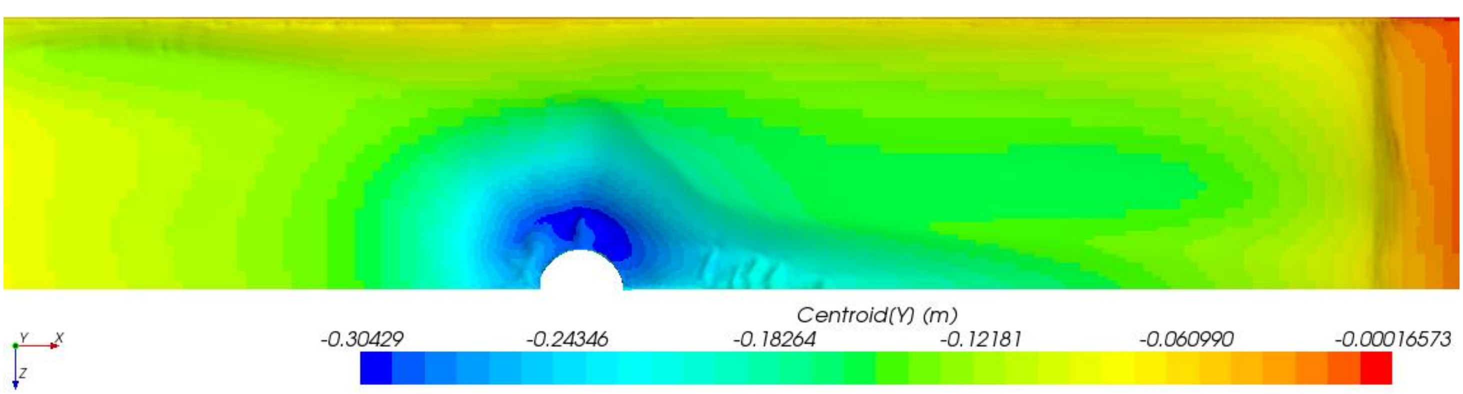
Finally, toll data was refined in the normal day model for the metropolitan region. In the previous revision, the tolls were the same for trucks and passenger cars, while they are different in real life. Previously, there was no distinction between express (for I-PASS users) and cash lanes. The accurate 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

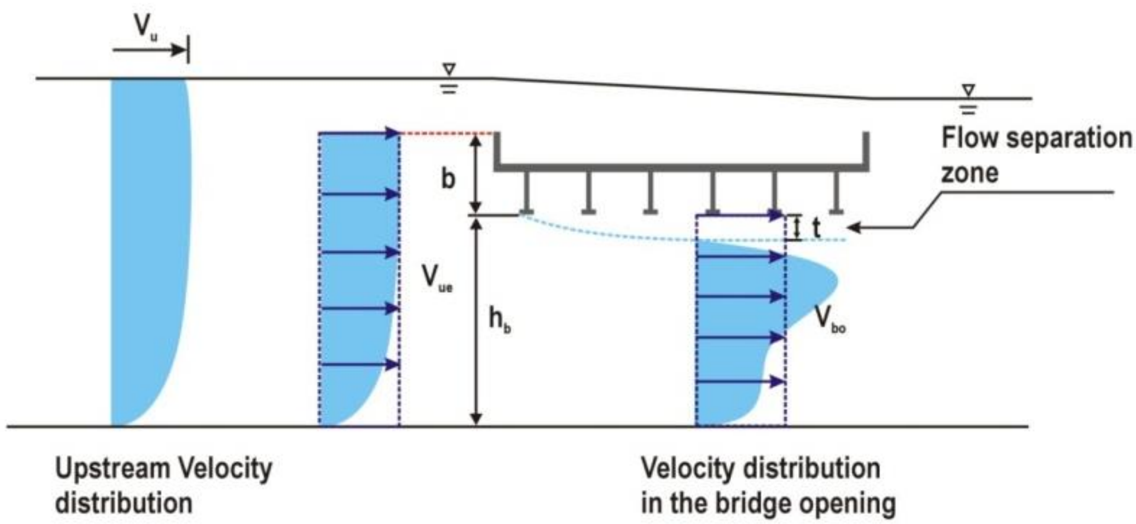
Most on the work on the visualizer for TRANSIMS and RTSTEP was finished at this time. The software became a fully interactive tool that allowed users to configure evacuation scenarios, start the TRANSIMS runs to execute the actual simulation, and then start the visualization component that allows for 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.

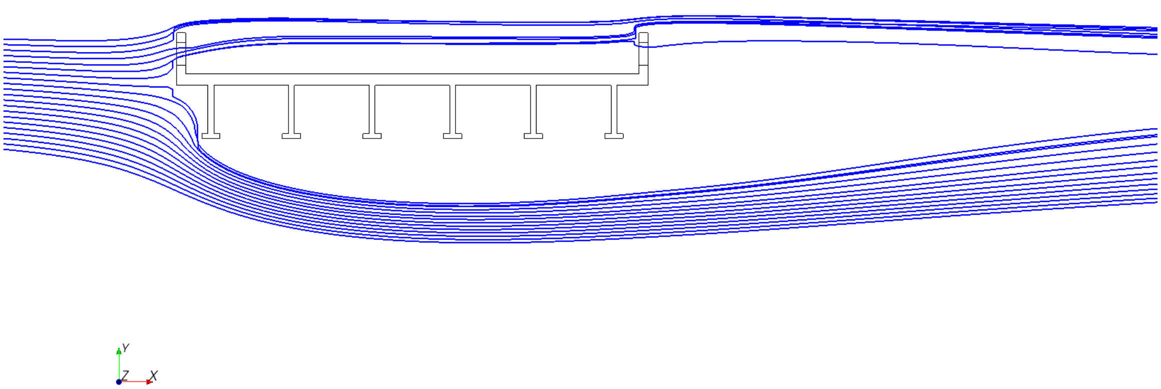
Computational Fluid Dynamics

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



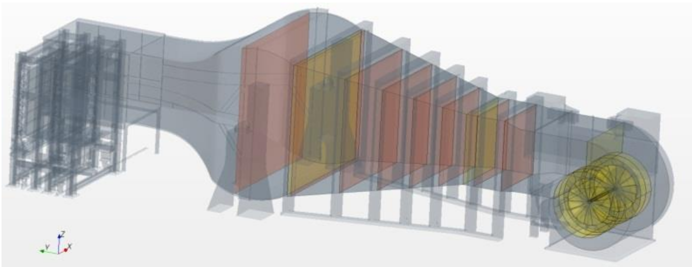


defined field functions for the model was published in a quarterly report, the software needed to pause the computation, do periodic remeshing, and restart it in an automated series of incremental series of CFD computations to compute the scour process are available from TRACC upon request.

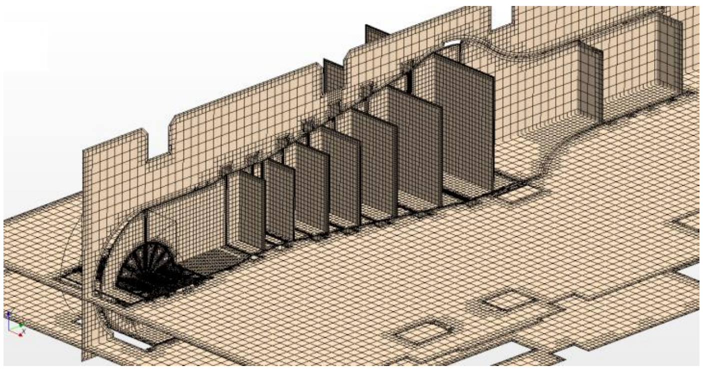
The completion of this work was a major success in the scour modeling effort at TRACC. It provides a methodology to compute three dimensional scour at the cylindrical pier bridge foundation structure. The primary methods of the model are not limited to cylindrical piers and therefore can be extended 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.

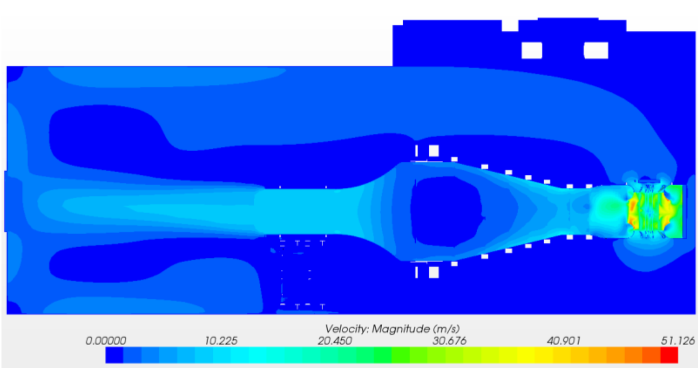
An analysis of the wind tunnel laboratory at TFHRC was begun to aid in planning and possibly modifying room equipment locations in preparation for a new series of experiments. CAD data files defining the wind tunnel were provided by TFHRC.



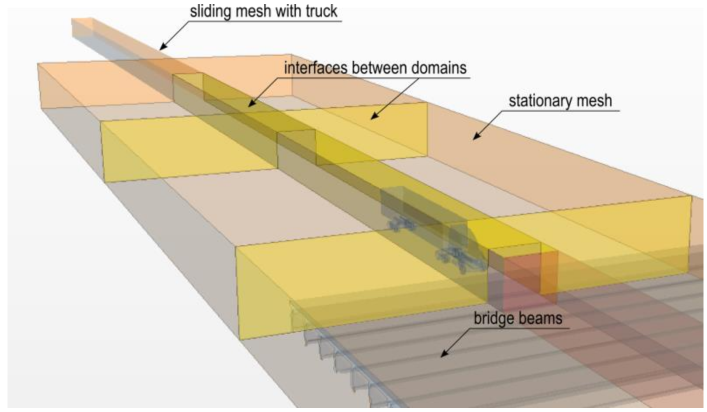
An initial computational mesh was developed for the wind tunnel in place with the laboratory room geometry, but without the details of all of the furniture and additional equipment in the laboratory. Test bridge sections are hung from a stand downstream of the wind tunnel exit, and therefore it is important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

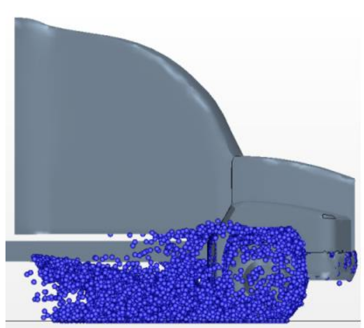


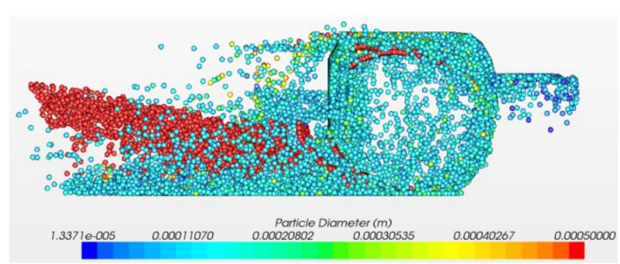
A CFD approach to the modeling of truck generated salt spray was initiated. The work was part of a project to identify better guidelines for the use of weathering steel in bridges in regions of the country where roadways are salted during snow and ice storms. The technique of using a sliding mesh was 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.

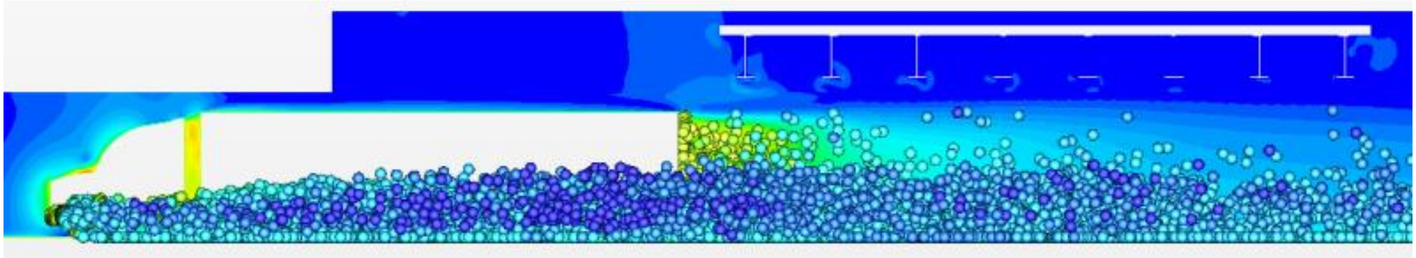


An initial investigation of injecting droplets from tire surfaces and using Lagrangian droplet transport models to track the paths of droplets coming off the truck were also performed. Part of this work was in identifying from the literature and CFD analysis the size ranges of droplets that would be 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.



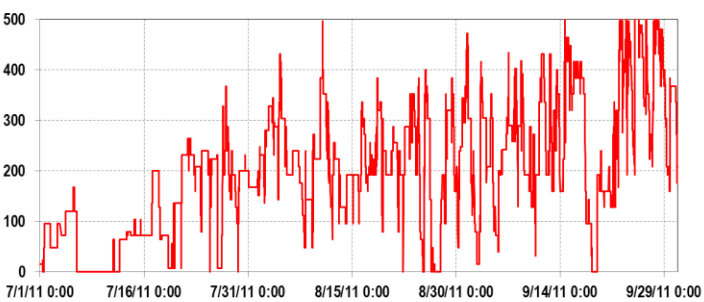




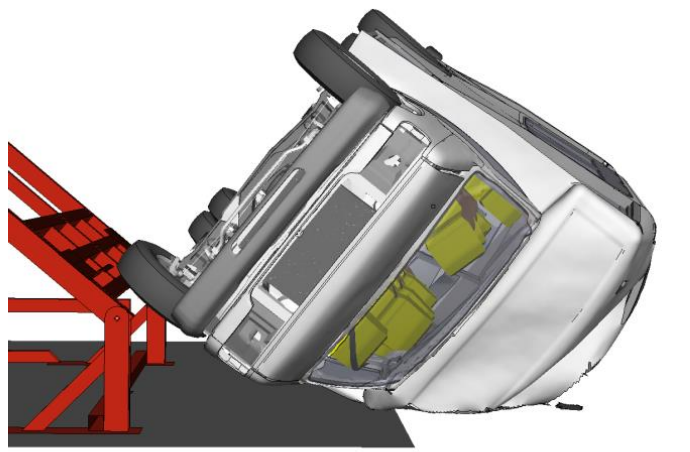
Because the flow in the truck wake did not carry a significant number of droplets up to bridge beam height in initial testing, other factors that could influence droplet transport to the bridge bean height were planned for investigation in the following quarters.

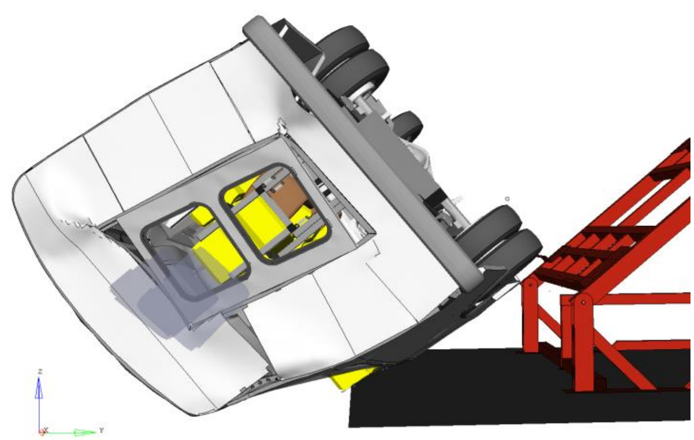
Computational structural mechanics

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.



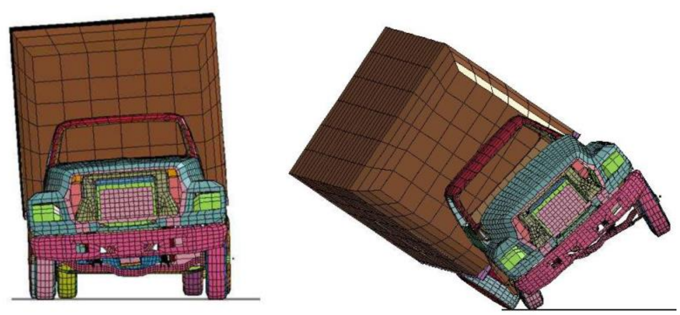
In the recent quarter FAMU-FSU researchers were working on finalizing their year-long project and preparing the final reports. A significant number of simulations were performed in order to validate their FE models before they are delivered to the sponsors at Florida DOT. Previously conducted full rollover 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

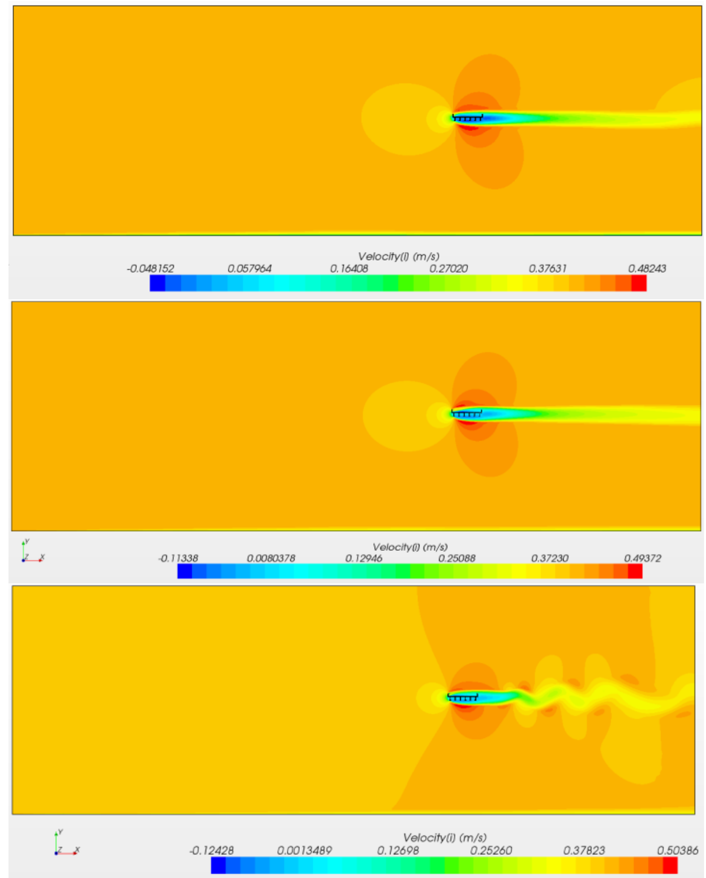
Scour Modeling

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:

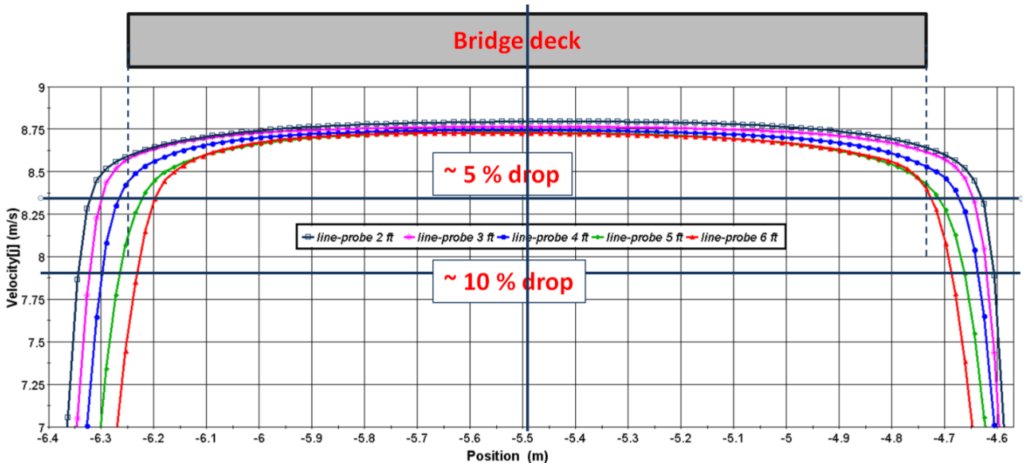
- A lab scale model (deck height of 0.058 m and domain of 2 m x 6 m)
- 10 times the lab scale model (deck height of 0.58 m and domain of 20 m x 60 m), and
- 100 times lab scale model (deck height of 5.8 m and domain of 200 m x 600 m)



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

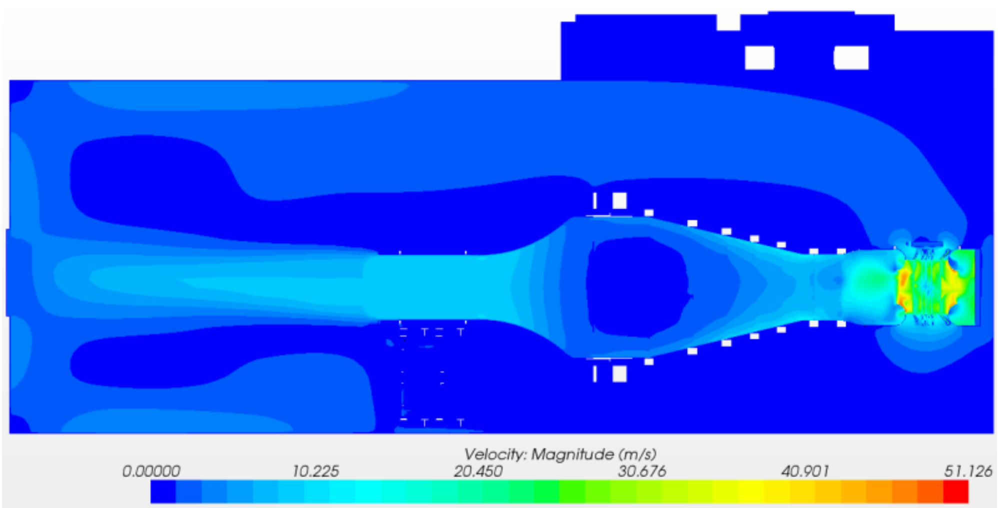
The full scale 100x model had an unsteady wake using an unsteady k-epsilon turbulence model. Using a turbulent Reynolds number defined with the eddy viscosity, μ_t, in the wake region, that Reynolds number was around 35 for the 10x scale up and increased to near 500 for the 100x, full scale case. Under 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

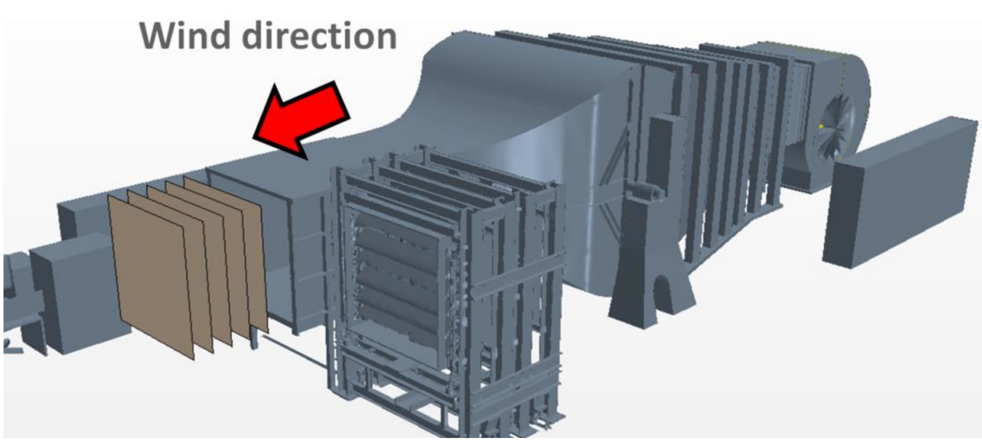
The model of the wind tunnel laboratory was completed with inclusion of the major pieces of furniture in the room. The primary test section for wind effects on scale bridge deck models and other model structures is located in the immediate downstream of the outlet of the wind tunnel in the room. Uniformity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

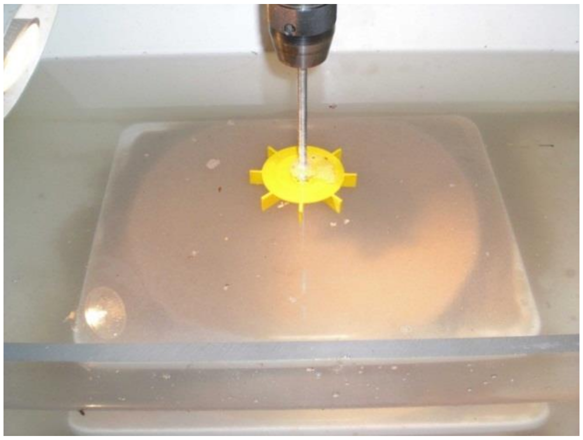


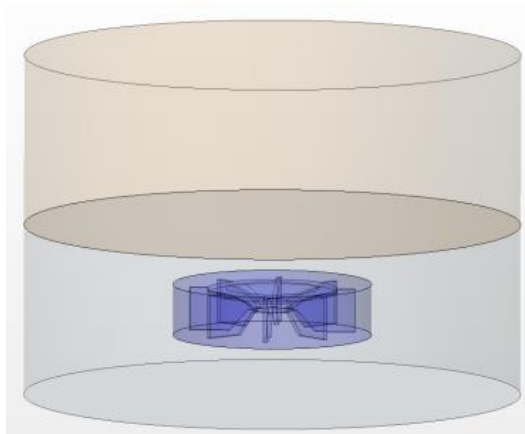
Primarily due to the asymmetric placement of the wind tunnel in the room, return air flow in the completed simulations was shown to be slightly asymmetric, and the air jet leaving the tunnel turned slightly to the side of the room with more open space.

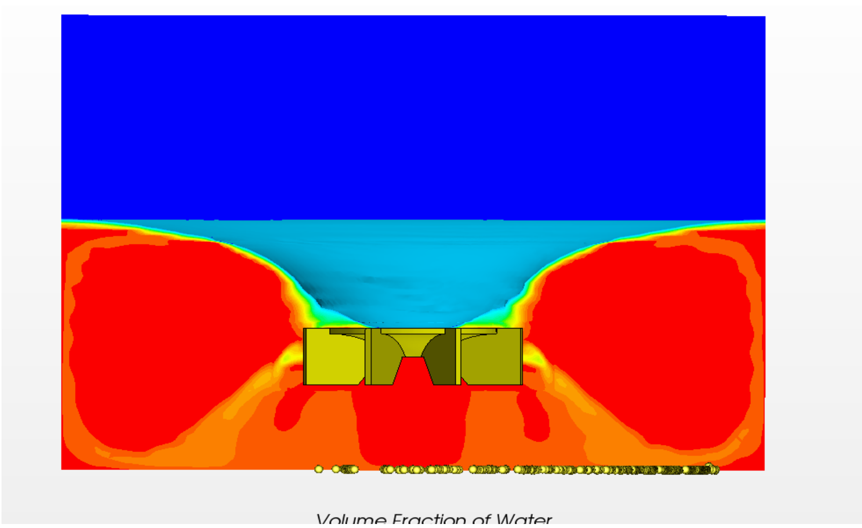
The analysis showed that a wide model bridge deck placed in the test section would be exposed to different wind velocities by a few percent at the ends of the model deck. Based on these results, scientific staff at Turner-Fairbank decided to measure air flow at a set of points in the test section and 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.

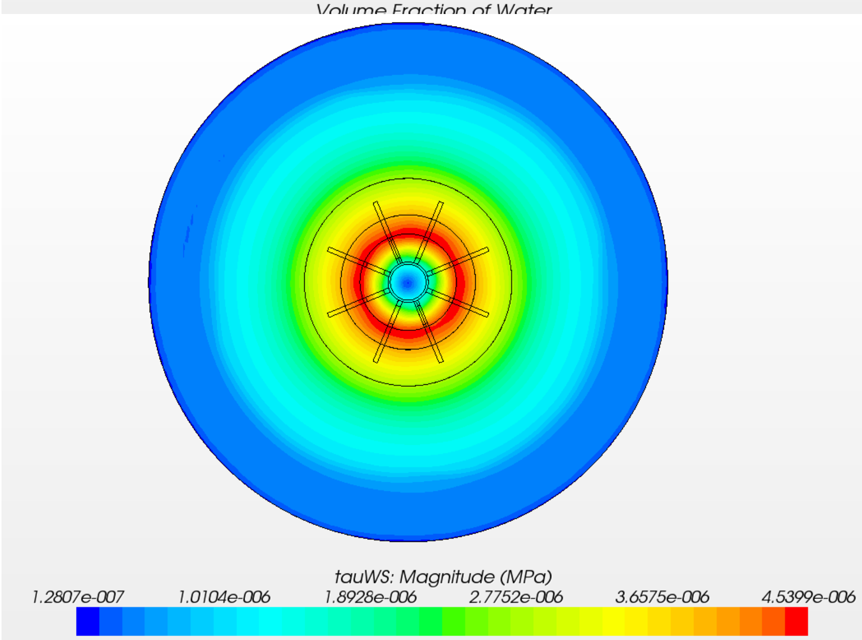
The Turner-Fairbank laboratory began working on a device that could be placed on a riverbed and used to generate a variable amount of shear stress to determine the shear required to erode sediment without disturbing the sample by removing it from the riverbed. CFD modeling was used to investigate several 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-









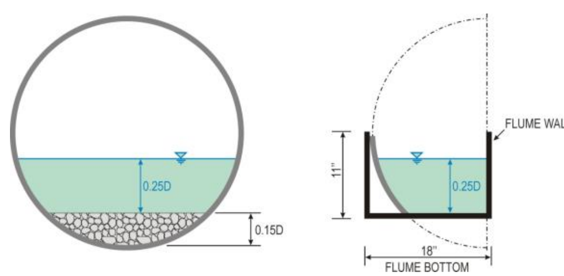


peller on a drill and testing it in a tray of sand where it appeared to function reasonably well.

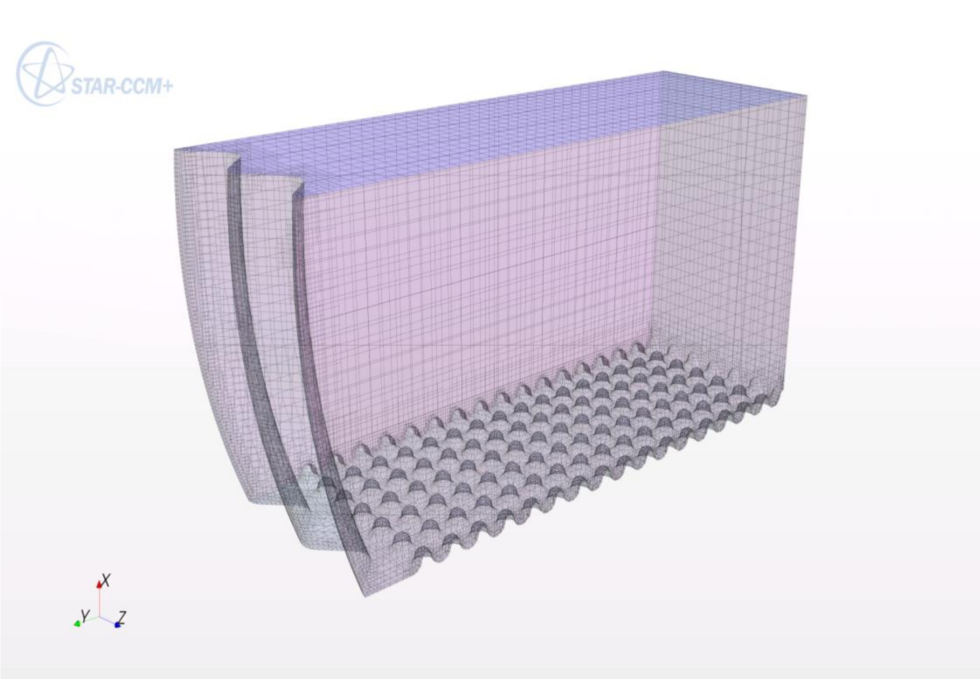
Modeling of this concept showed that the propeller would generate high shear in a ring pattern with a peak in the shear stress at some radial distance from the center of the propeller. In a shallow pan, nearly all of the sand in the middle was thrown to the sides in experiments. However, in a deeper 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.

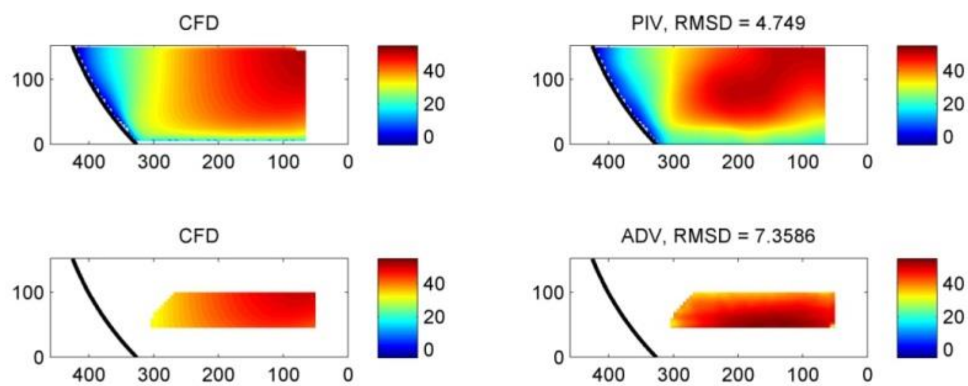
Modeling of culvert flow for fish passage

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





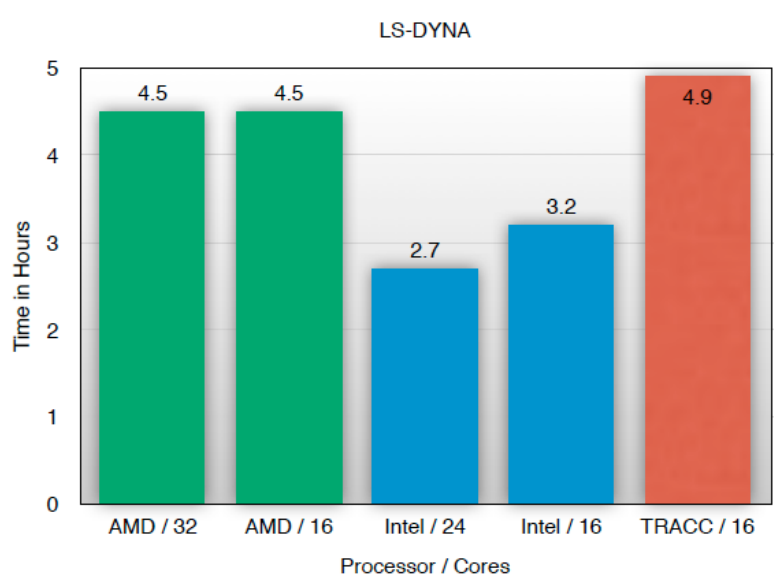
sufficiently well to be used for engineering purposes in improving design for fish passage. CFD cross section velocity predictions were within the range of experimental uncertainty of particle image velocimetry (PIV) and acoustic Doppler velocimetry (ADV) measurements.

Computational structural mechanics

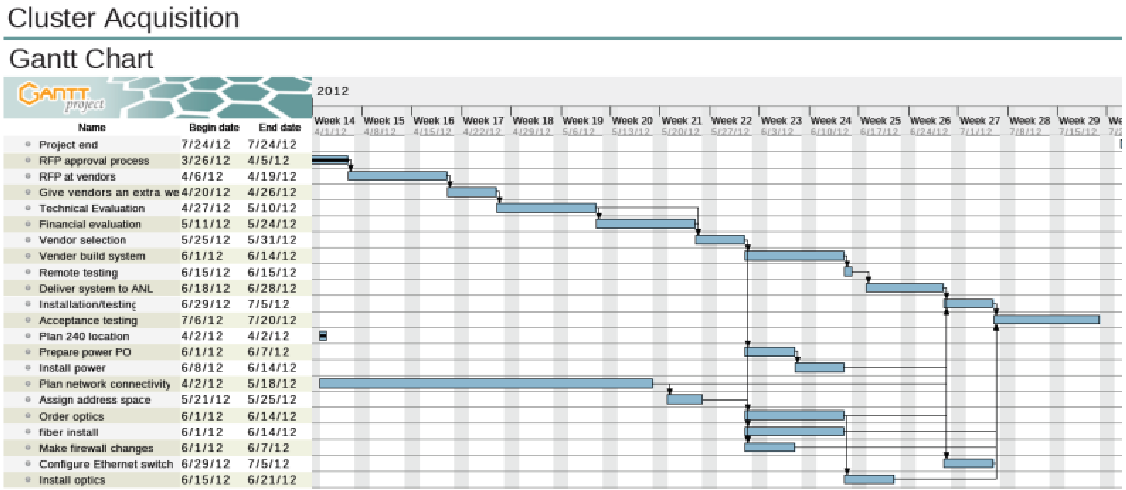
In preparation for increasing collaborator demands for computing resources, TRACC was considering acquiring another high performance cluster computer. The purchase decision for the cluster hardware configuration depended on many metrics: performance, cost, delivery, compatibility, etc. Since several 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.



January 2012 to March 2012



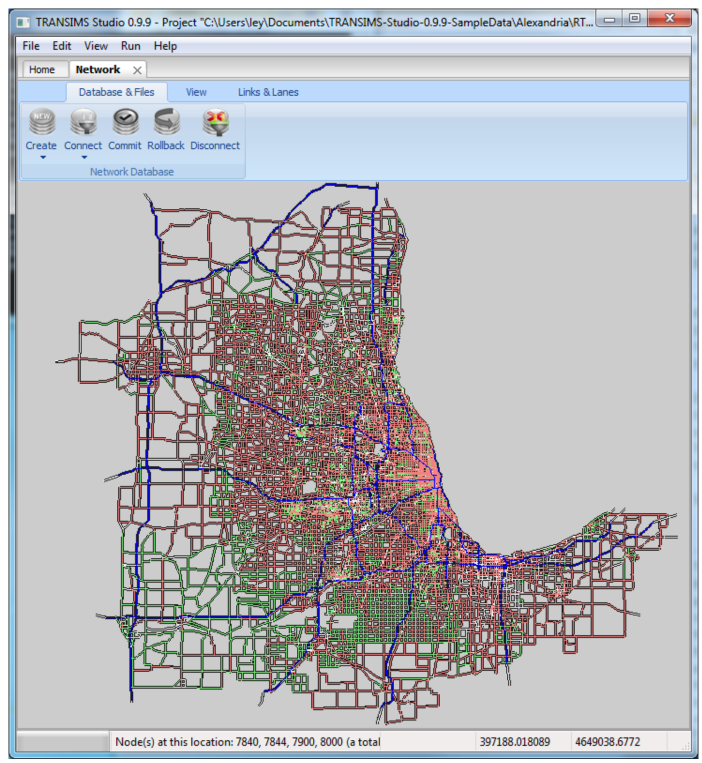
With the upcoming close-out of the grant funding TRACC's operation, new funding opportunities were pursued, and sufficient funding was secured from several projects to continue the operation of TRACC as USDOT's largest supercomputing facility for transportation research without relying on the congressional grant. The computing resources established at TRACC to support this mission are highly utilized, and TRACC developed a plan for upgrading the supercomputing facility to meet the demand of upcoming projects, both for the use by external users as well as the work on new interagency agreements with USDOT.

The new sponsors of TRACC's continued operation rely heavily on TRACC's computing resources, and a request for proposals was developed to upgrade the supercomputer at TRACC with modern hardware and additional storage capacity. The RFP was sent out at the end of January 2012, and a total of 7 vendors responded with proposals by the end of February.

Visualization and graphical user interfaces

The RTSTEP project for the City of Chicago provided much of the recent funding for the visualization tasks at TRACC. This work has been finalized in November 2011, and while some of the work on the visualization software continues in support of other TRACC users, the team is currently focusing on the development of fundamental software libraries for transportation modeling. The visualization task is expected to regain importance as new users start making use of the existing TRANSIMS capabilities, and will be an integral part of the generalization of TRACC's effort in developing future flexible transportation simulation solutions for USDOT and specifically FHWA.

The work was also introduced to hundreds of emergency responders and other interested parties at a series of demonstrations at various locations throughout Illinois, Wisconsin, and Indiana. The following is a list of specific demonstrations and training activities held since November 2011.



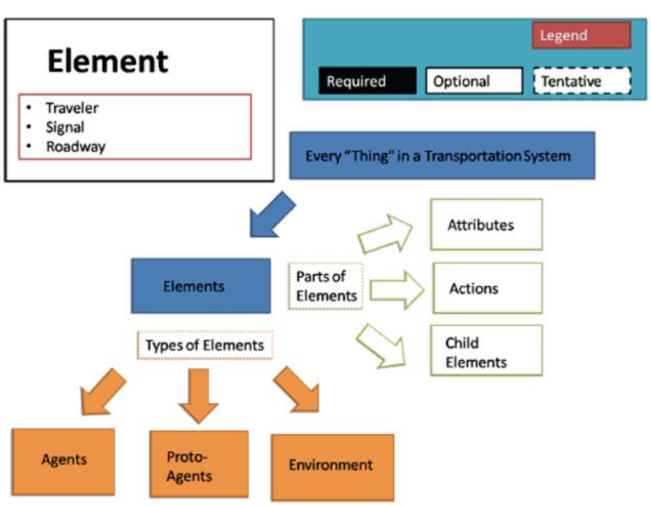
Development of a new network editor for TRANSIMS and POLARIS has started as well. The concept is based on an underlying relational database implemented in Sqlite3, as well as integration of the network editor into the current version of TRANSIMS Studio.

Emphasis is placed on efficiency of the editing process because a lack of an appropriate network editor for TRANSIMS has been found one of the major drawbacks for adopting this software.

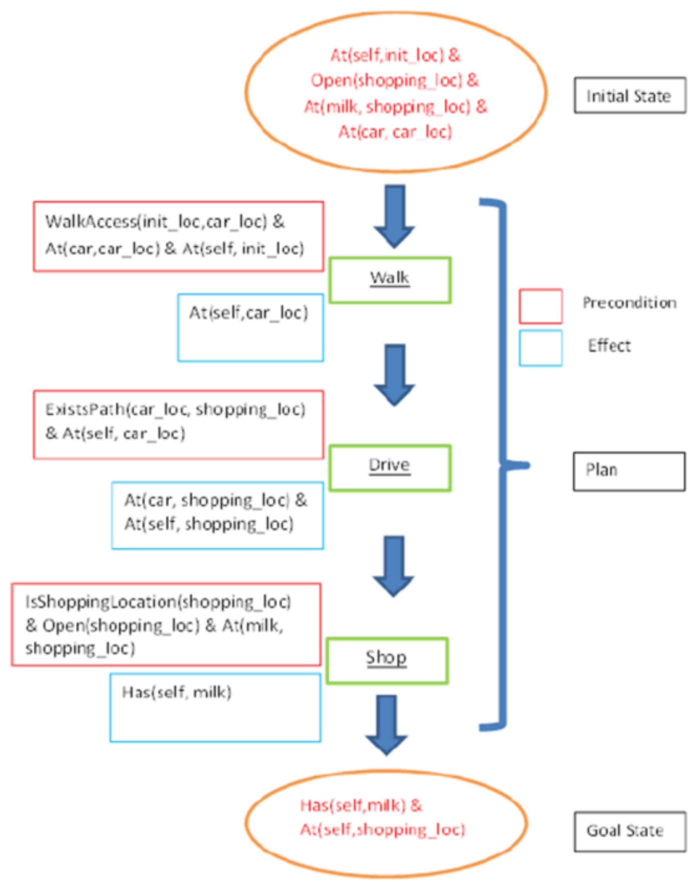
Like TRANSIMS Studio, the network editor is being developed in Python, but is highly efficient due to the database design as well as the use of Cython and OpenGL for using advanced graphics card capabilities readily available in most computers today.

Polaris Development

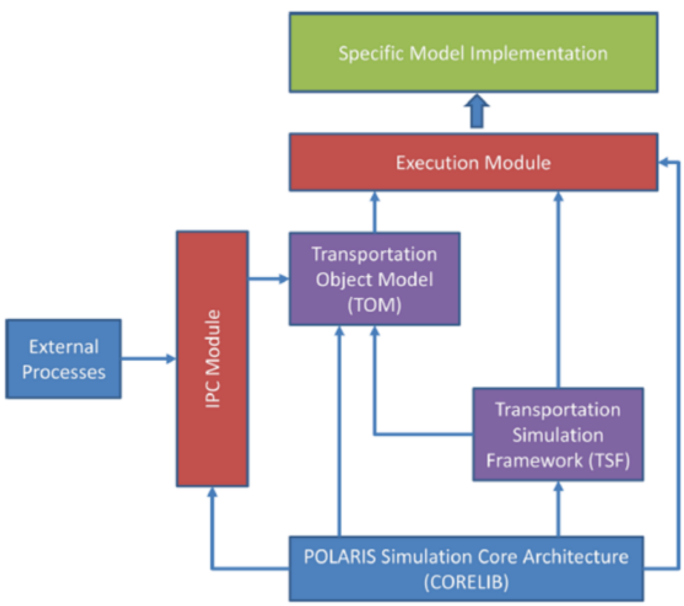
The needs of the transportation planning community are extremely varied and change over time as the modern transportation system becomes more complex with advances in technology. In addition, each planning group has different needs, as each must solve a slightly different planning problem or a similar planning problem on different transportation systems (one group may be concerned with regional emissions whereas another will be concerned with testing charging stations). Owing to these two constraints and historical evidence from the efficacy of comprehensive models such as TRANSIMS, it is apparent that developing an all-encompassing "mega" model, which is inherently inflexible, is not a tenable approach. It is unlikely developers would be able to conceive of every possible need the software must address using a minimalistic set of data at the software creation stage.



Despite having a large body of research, there is relatively little work being done to unify the modeling concepts produced by the transportation research community. Research is often conducted on specific aspects of the transportation system without an eye for how it fits into the larger picture. For example, a new car following simulation routine might be developed which is fast and effective, however there is no way for the routine to be "slotted in" with all other components necessary such that its merits can be realized (or perhaps challenged) on a system-wide scale. Unification is brought about largely through the efforts of private tool developers such as PTV, Quadstone, and Caliper who do not necessarily hold the same set of motivations as an open research community. The Transportation Research Board's Strategic Highway Research Program (SHRP 2) has funded several research projects (e.g. C04, C10, and L04) to develop methodologies to integrate user response and travel demand models in network simulation procedures in light of existing demand and network modeling tools. However, these efforts were still not part of a fully integrated modeling environment.



The concept of simulation remains a potent tool in the transportation planning arsenal. A simulation allows a modeler to create a virtual representation of a complex system and observe how it behaves, ultimately enabling the succinct summarization of system-wide behavior. Traditionally in a transportation Four Step Model, simulation is conceived of as a "one-shot" tool: given these set of inputs, "show me what happens during this given day". This approach is generally understood to be invalid in isolation, the main question being, "does the system represent a 'normal day' (most common) case?" This is typically ensured by performing an iteration loop to stabilize all "actions" of the transportation system members. Once it is reasonably well assumed that this case is met, it is determined that the simulation is a reasonable analog for reality. Performance measures are drafted off of this model (or case studies involving this model) and synthesized with other criteria to make a decision. However, this procedure is notably destitute of describing the inherent variation in the system - a highway might be determined to be optimal for the "normal day", but under different weather conditions or days of the week there may have been a far better alternative. Therefore, the typical model of "one shot" transportation needs to evolve to be able to describe this variation.



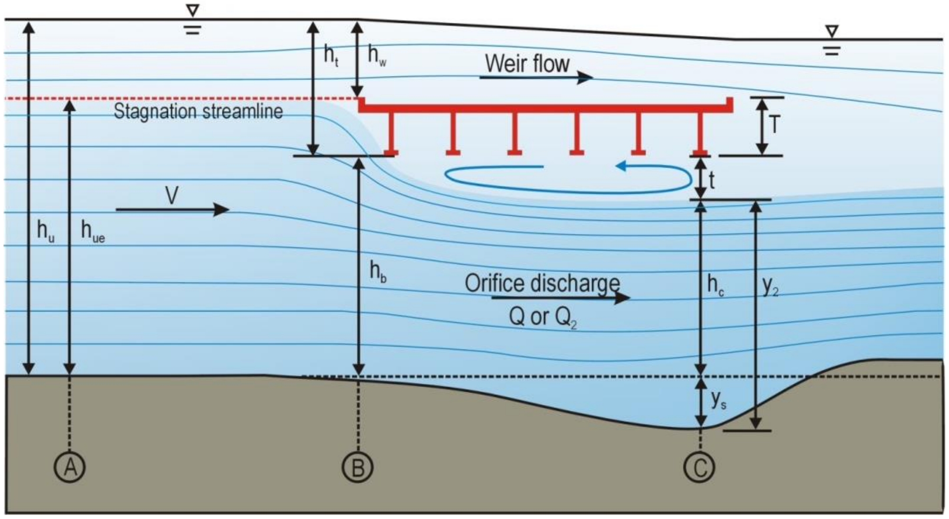
The technological utilization and awareness of advanced research within the transportation community can be somewhat lower compared to others such as the agent-based modeling or artificial intelligence communities. Implementing many complex and high resolution techniques are met with skepticism as it is generally understood that a transportation system simulation has the potential to be very computationally intensive. However, computing continues to advance rapidly and performing ambitious simulations is not the challenge that it once was if the software is appropriately designed. In this same vein, there is a burgeoning of new data sources (highway blue tooth sensors, online wiki-style road networks, traffic social networks, etc.) which, if properly utilized, provide clarity and validation to the entire modeling process while expediting model construction. As transportation planning moves steadily into the realm of utilizing simulation-based modeling, it begins to hold more and more in common with other simulation heavy fields such as the artificial intelligence and agent-based modeling communities. Thus, it is becoming increasingly important to review and apply the literature and techniques of these related fields.

Based on the above needs, TRACC conceptualized an "ideal tool" which was not attainable at the time, but would serve as a guide for how to take development steps in the right direction. In an ideal case, what was needed was an adaptable transportation model that could be used in a variety of contexts and with various types of available data - one which could be supported easily and connected with other major efforts in the transportation modeling community. In the hands of a typical planner - the model should allow them to describe the type of problem they are trying to solve, the important performance measures needed to assess success, and feed in relevant data they have easily available. The model should run quickly and allow the planner to examine the results allowing them to review outputs targeted at the performance measures and the core decision which needs to be made. If the modeler had other tools at their disposal, they should be able to run them and easily integrate their results to enhance the decision making process such that it becomes more comprehensive and better informed.

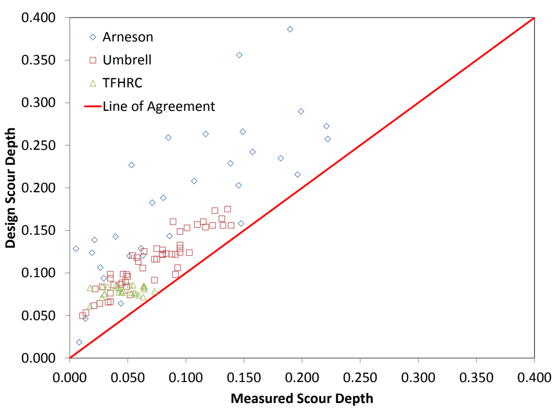
This conceptualization formed the basis for the development of tools and methodologies for the Polaris project, a project that will likely continue into FY 2014.

Computational Fluid Dynamics

Work on the new design equation for pressure flow scour for the fifth edition of Hydraulic Engineering Circular No. 18, Evaluating Scour at Bridges was completed and submitted for publication. Development of this updated design equation used a new approach by incorporating CFD analysis into the de-



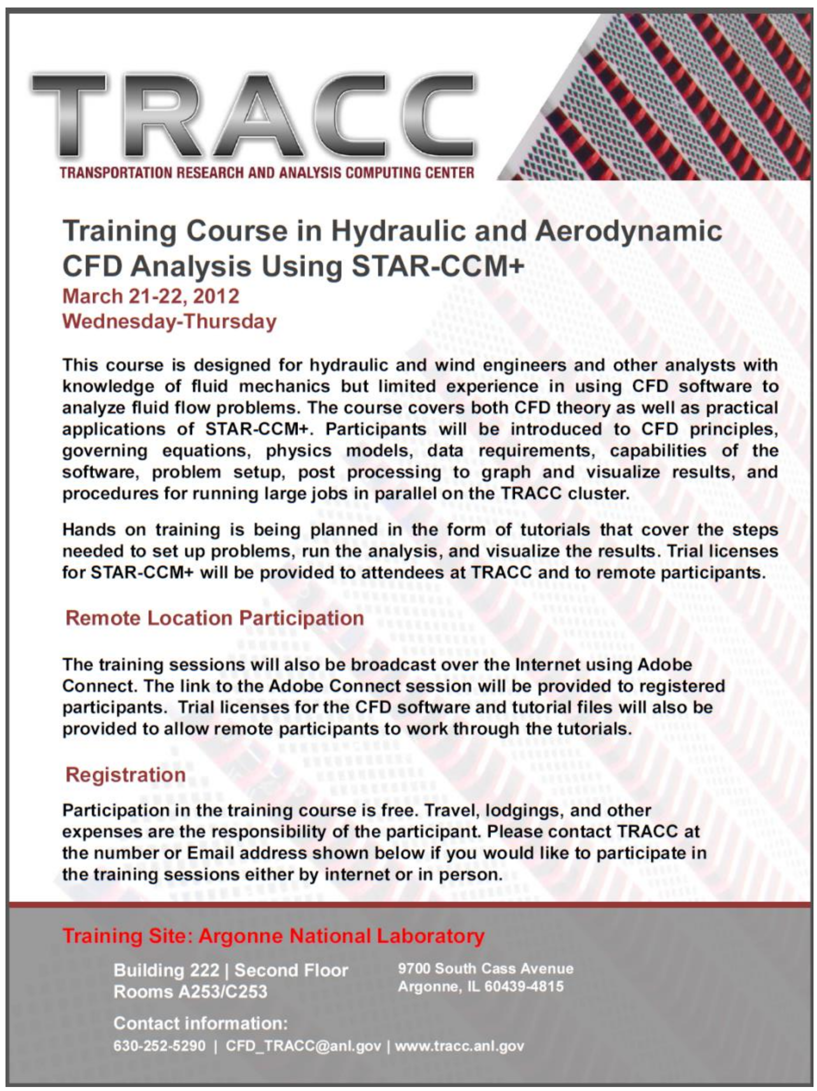
velopment of the equation. While the new design equation for evaluation of scour under inundated bridge decks during floods is still an algebraic correlation using a best fit to laboratory data sets plus a safety factor, CFD was used to guide the formulation of terms in the equation that would have physically correct trends as flood flow water depth increased and the geometry of the bridge was varied. The CFD analysis was also used to ensure that the new design equation exhibited the correct behavior at the extremes of conditions.



A comparison of laboratory data against the prediction of the design equation scour depth with safety factor has no under prediction of scour and a very large percentage of the data points clustered near the line of agreement.

Technology Transfer

The second training course in the application of CD-adapco's STAR-CCM+ CFD software transportation related problems was conducted on March 21-22, 2012. The course evolved to be nearly entirely hands on tutorials that focus on the latest techniques for solving problems in hydraulics and wind engineering. Two new tutorials were developed for the March training, and the mesh morphing was expanded to include a scour model. A number of the problems of interest include motion of objects in the flow domain and the need to have a moving and in some cases a deforming mesh. These types of problems are some of the most challenging to set up and solve. The two new tutorials focused on these techniques. One included a propeller in a water reservoir with a free surface. The other used sliding meshes to move a truck model under a bridge at 60 mph to analyze the distribution of droplet salt spray on bridge beams coming off of the tires on salted wet roads. These tutorials provided training in newly developed models



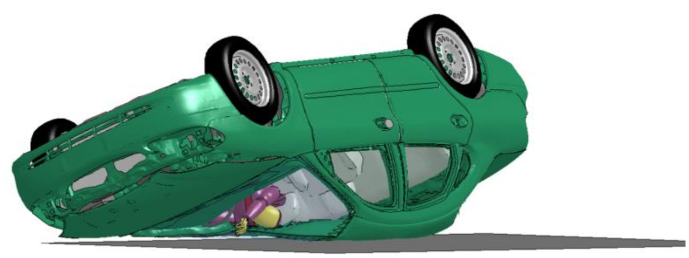
that are a focus of ongoing research to the attendees.

Participants were provided with trial licenses and software by CD-adapco to work on the tutorials during the training days and experiment with the software for about two weeks after the course. Course attendees included TFHRC research staff, state DOT researchers, professors, and students from several universities. About fifteen people attended at the TRACC facility and about an equal number participated online via Adobe Connect.

Computational structural mechanics

The Transportation Research and Analysis Computing Center (TRACC) has obtained a Work for Others contract with the National Highway Safety Administration (NHTSA) Vehicle Safety Research to provide assistance to NHTSA's ongoing projects starting in FY2013. The work will be performed by the CSM researchers of TRACC under an inter-agency agreement between the U.S. Department of Transportation and the U.S Department of Energy.

For the past five years, NHTSA has been using TRACC's HPC computer and participating in computational structural mechanics training classes. NHTSA mainly used the LS-DYNA software package: LS-DYNA (multiphysics solvers), LS-OPT (optimization tool) and LS-PrePost (pre- and post-processing tool). NHTSA crash analysis researchers were early users of the TRACC cluster and have become the most active users of TRACC's 500 core LS-DYNA software license. The large core-license-pool allows NHTSA to minimize the time needed to obtain simulation results and, thus, expand modeling variations that must be considered to ensure credible treatment of crash events while meeting critical project deadlines. The purposes of this project were (1) to enhance future cooperation between NHTSA and TRACC and (2) to secure NHTSA's access to TRACC's high performance cluster, LS-DYNA and TRACC's staff expertise.

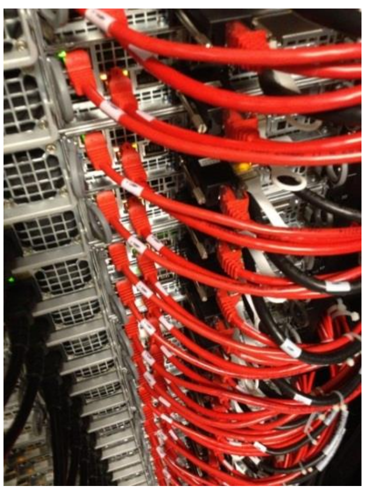


The CRIS dynamic test was developed by Exponent® Engineering and Scientific Consulting and Ford Motor Company to study roof-to-ground behavior during a vehicle rollover. NHTSA had performed simulations of the CRIS Test using a coupled code approach in which LS-DYNA® (Livermore Software Technology Corporation/LSTC) was coupled to MADYMO®(TASS Engineering). The physical test was performed using a 1999 Ford Crown Victoria and Hybrid III 50th dummy. However, because there was no finite element model available for the Crown Victoria, the NHTSA numerical simulations used a finite element model for a 2000 Ford Taurus as a surrogate and a MADYMO Hybrid III 50th dummy. Because of issues associated with code couplings and dealing with two software vendors, NHTSA has tasked TRACC with performing simulations that use dummy models that are directly attainable from LSTC. LSTC had at that time two Hybrid III 50th models available: a coarse model and a fine model.

The first task that TRACC has been asked to work on is to use LSTC Hybrid III 50th dummy models in the finite element model of the 2001 Ford Taurus and to compare the response of the dummy (as measured by neck forces and neck moments) to the response obtained by NHTSAs simulations that used the MADYMO Hybrid 50th dummy model. The work was initially contracted for two fiscal years.

April 2012 to September 2012

A new cluster computer for TRACC was acquired from Atipa Technologies in the third quarter of FY1012. The Request for Proposals was prepared in early April with the delivery of the system at the end of June. The system has been named Zephyr, and is now in full production operation at TRACC.

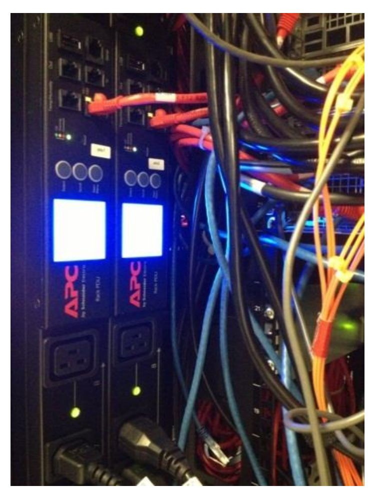


With 92 computing nodes, each node having two 16 core AMD Interlagos 6276 2.3 GHz processors with a minimum of 32 GB of RAM, the system has the potential of providing TRACC's users the ability to run large, high core count jobs and at faster speeds than possible with Phoenix (the previous TRACC cluster). Inter-process communication was much enhanced with the system's 40 Gbps, QDR Infiniband message passing network.

During the Functional Acceptance testing, TRACC ran LS-DYNA R6 with OpenMPI from Livermore Software Technology Corporation. Using four nodes, the benchmarks ran nearly twice as fast on Zephyr as it did on Phoenix without any system optimizations. This is largely due to a more efficient CPU architecture, faster memory, and faster Infiniband interconnects. With CentOS 6, the latest MPI libraries and compilers, it is expected that TRACC's users will see a significant increase in performance in job execution. Applications not using MPI will also benefit from the 32 CPU cores each compute node provides.

Zephyr Cluster Configuration:

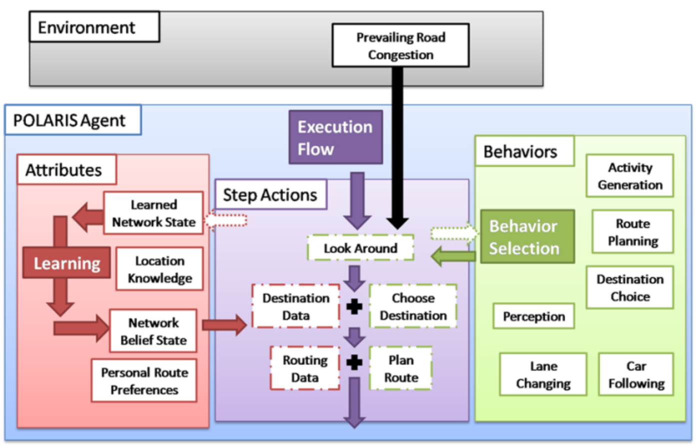
- 92 computing nodes each with two AMD Interlagos 16 core 2.3 GHz processors (32 cores per node, 2944 cores total)
- Arranged in three queues
  - 88 nodes with 32 GB of memory (1GB per core)
  - 2 nodes with 64 GB of memory (2GB per core)
  - 2 nodes with 128 GB of memory (4GB per core)
- 120 TB of Lustre-based user storage in a redundant RAID6 configuration
- High-speed 108 port fat-free QDR Infiniband connectivity
- 240 ports of Gigabit Ethernet connectivity
- Dual 10Gbps connectivity to Argonne and external networks
- Infiniband interconnectivity between the new cluster (Zephyr) and the old cluster (Phoenix)
- Two administrative servers
- One I/O server
- One monitoring and statistics gathering server
- One application server that can be used for user code development (sandbox)



All nodes run Linux using CentOS 6.2.

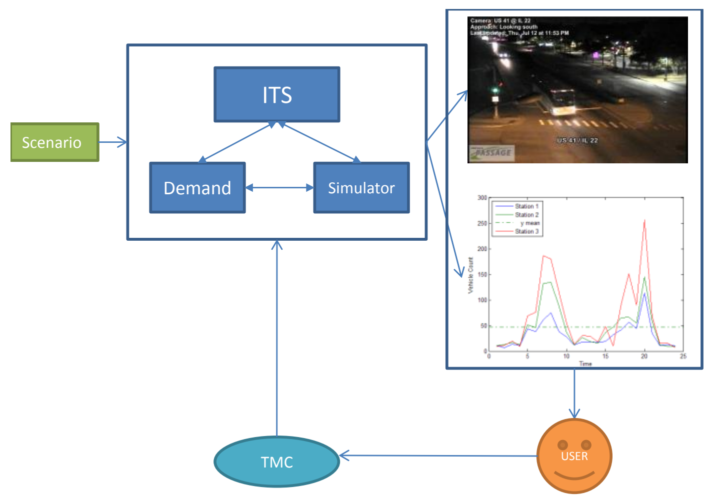
Polaris and transportation systems simulations

There are several confluent factors in the transportation community which have influenced the development of a new kind of tool to answer questions about the transportation system. Historically, existing transportation-related models have looked at different aspects of the transportation system (travel demand, traffic flows, emissions, etc.) independently from each other. When the realization developed with the transportation community that these phenomena needed to be modeled in an integrated manner, attempts were made to link these unrelated models into a unified system. The integrated solutions produced have frequently been either inflexible, non-modular, or low performance. There was a need for the different models to inter-operate with one another to answer these questions about a transportation system, but transportation models generally lacked a common framework to do so in a straightforward manner.

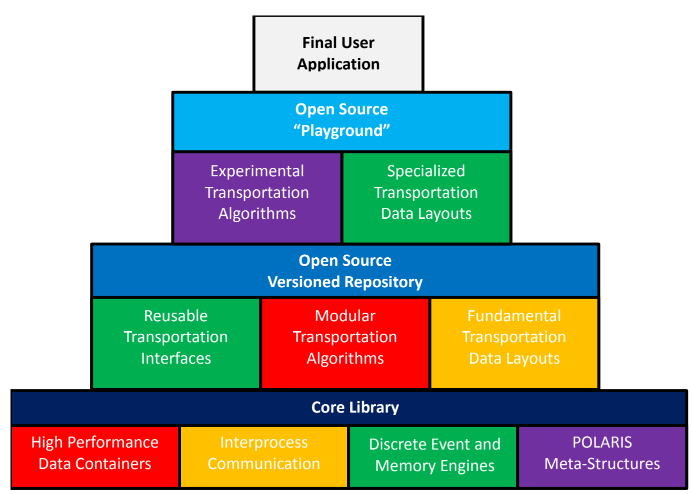


The framework being developed to address these needs is called: POLARIS (Planning and Operations Language for Agent-based Regional Integrated Simulation). It has two major conceptual components. The first is a high level agent-based modeling language targeted specifically at transportation - a minimalistic set of concepts, building blocks, and symbols that can be utilized to succinctly describe all possible elements of a transportation system. The second is a framework and SDK (software development kit) that facilitates the development, execution, and review of a model written in such a language.

The user community envisioned for POLARIS is broad, including those from a wide variety of transportation research disciplines and those involved in all phases of the transportation model development process from design to application. Transportation researchers will use POLARIS to test and validate theories in an integrated environment quickly and easily as well as refine and expand the transportation ontology model. Integrated transportation model developers would utilize POLARIS to weave together disparate model components developed by researchers and bring in new technologies in addition to connecting existing models of interest. Transportation modelers will apply models created by the integrated model developers and solve real world problems using POLARIS. Software developers working in the transportation arena will work to improve performance and increase usability as well as utilize the low level libraries to aid in functional programming or memory management tasks.



The design philosophy of the POLARIS modeling framework is founded on several tenets which serve to maximize ease of use and flexibility. First, give developers tools which will ease their model development efforts, however do not force them to be used.

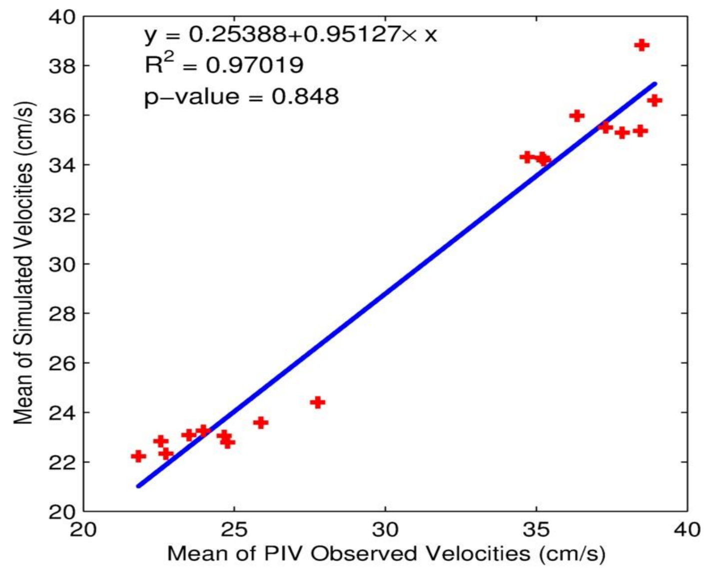


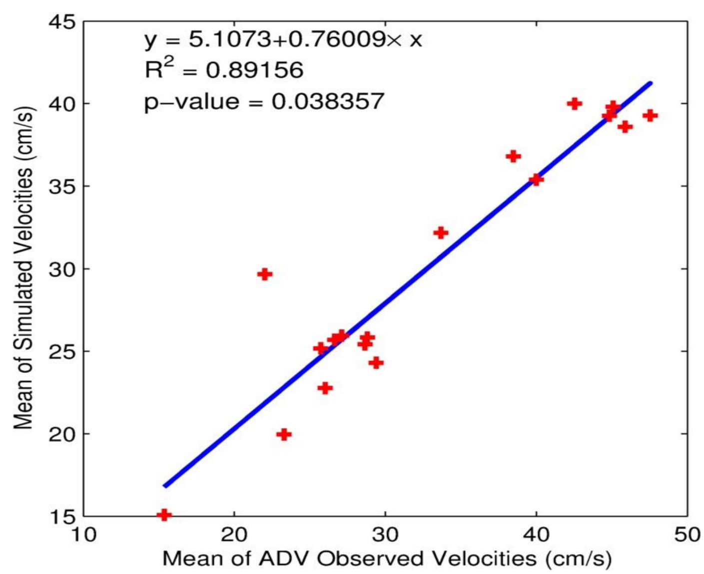
This is a common philosophy in many programming languages, advanced features are offered, but so are the low level concepts needed to assemble competitive features from scratch if the user is dissatisfied with the default implementation. Next, suggest to developers standardized symbols and structure which can be used to facilitate communication within their model components as well as among other models. A simple example is a term such as *location* (intersection, transit stop, point on a street, parking lot, etc.), nearly every software package has its own version (likely with nearly identical implementation) of the same concept; in POLARIS, this concept is defined once and any applications written using it would use this same definition. This means that any developers wishing to interface with any POLARIS application need only look at one central place in POLARIS to understand what location means in software terms. Next, using a fixed API, abstract low level details from high level ones such that core developers optimizing low level operations can work independently of researchers implementing high level concepts. This is a common thread in many well-engineered software APIs, it allows a model developed in POLARIS to be able to achieve high performance as well as re-usability, code clarity, and short development times. Finally, and perhaps most importantly POLARIS is founded on an ontological base which allows for extreme modularity. Within the POLARIS ontology, extremely complex components of the transportation system (such as human travelers) are broken down to their atomic parts and re-organized in a hierarchy. This is done to a degree such that a customized component created by one developer can understand another customized component created by another developer through understanding the more primitive (and more standardized) ancestry of the other component. As an example, consider a router: regardless of which algorithm is used internally, a user should be able to count on the fact that it will deliver, as a minimum, the path from a start location to an end location on a given type of network.

Computational Fluid Dynamics

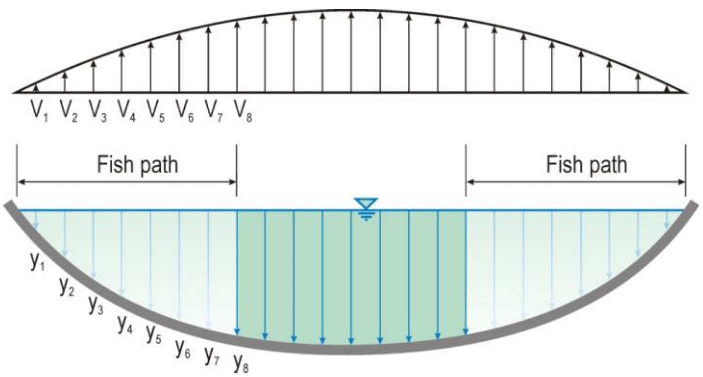
Fish Passage through Culverts

Work on the development of applying CFD analysis to improve culvert design procedures was completed. Integrating the results of the work into existing culvert design guidelines remained to be done, but that work would be completed by other engineers. The CFD predictions of distribution of cross section in a given culvert flow under normal conditions that should allow for fish passage were shown to be within the range of uncertainty of PIV and ADV measurements at the laboratory scale.

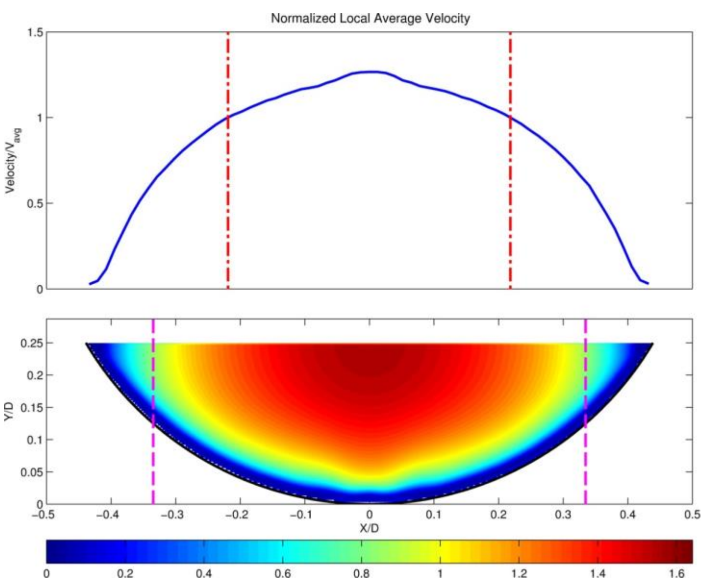




In the original concept the maximum velocity through a culvert would be at the center and decrease toward the sides of the culvert. Therefore, if normal flow was too fast at the centerline for fish passage, knowledge of the cross section velocity distribution would allow for the identification of a shallower region toward the sides of the culvert that would be slow enough to allow for fish passage, depending on the species of fish.



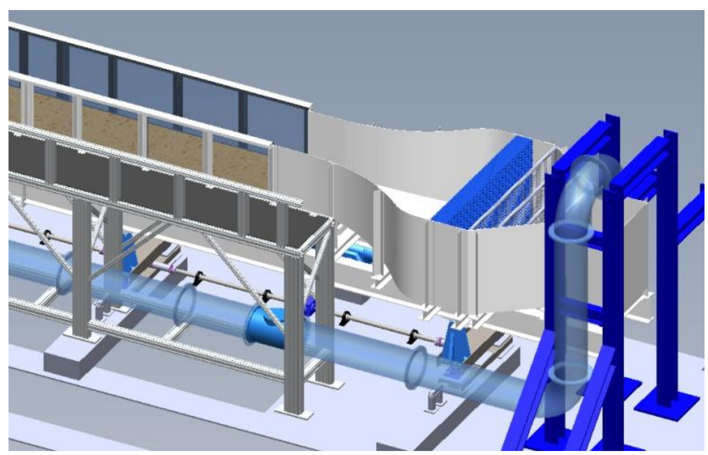
For large fish, there is also a minimum depth required for fish passage. In cylindrical culverts without gravel on the bottom the curvature makes the depth increasingly shallow toward the sides, and therefore for the larger fish species there is also a limiting position toward the sides beyond which fish cannot swim through.

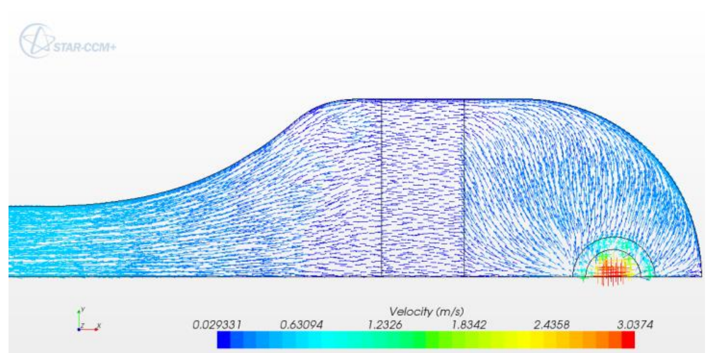


A Ph.D. degree was awarded to a University of Nebraska researcher for this work. The extensive CFD validation against laboratory experiment and parametric flow analysis over a size range of culverts from laboratory scale to a size that was far too large to test in a laboratory demonstrated viability of CFD analysis in this application and that CFD analysis could be extended to practical analysis that is beyond what can be accomplished in a hydraulic laboratory.

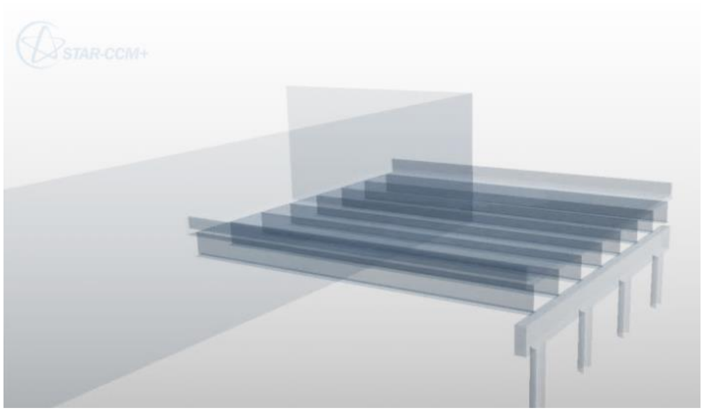
New Flume Design for the Hydraulics Laboratory at TFHRC

The large tilting flume at TFHRC will be replaced with a high-speed flume with a live-bed scour testing capability. The flume consists of several sections. The test section is a straight channel with a depression that can be filled with bed material. A long stretch of straight channel is provided before the test section to allow the development of a proper boundary layer for the test section. An inlet that may include a main pipe reception, a diffuser, and a trumpet is connected to the long straight section to feed a well-conditioned flow into the channel. An inlet needed to be designed to provide a sufficiently uniform velocity profile at the entrance of the long straight section. CFD simulation was employed to optimize the geometry to accomplish the desired flow condition under high discharge rate. This project demonstrated that CFD can be used to improve and optimize experimental equipment.

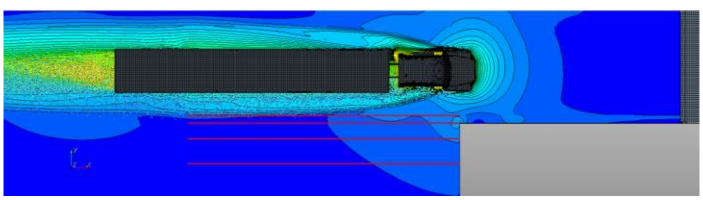




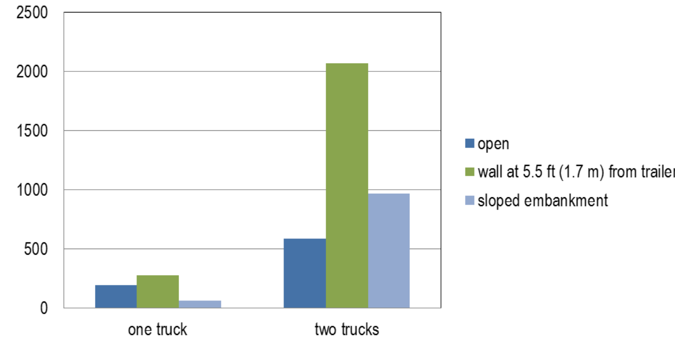
Modeling of Truck Generated Salt Spray under Bridges



Vertical walls were expected to confine salt spray from trucks and cause more of the spray to be transported to beam level where it could cause corrosion. In the CFD simulations the high concentrations of droplets were observed to remain with the truck wake, and for modern trucks, the aerodynamic design of the truck cab successfully keeps the wake small and close to the truck to minimize drag and improve fuel economy. A number of tests were run changing the abutment wall from very near to the truck to several meters away. As the distance between wall and truck decreased, more droplets were transported to beam level, however, this effect was small compared to other factors such as following traffic and wind.



The effect of traffic was found to be significant. Trucks are often observed in pairs on highways. When a lead truck suspends a large number of salt laden droplets up to a level not much above mid trailer height, very few of those droplets would reach beam height without the influence of wind or a following truck. When a second truck travels through a low level salt droplet laden wake generated by a lead truck, the second truck was observed in CFD simulations to divert the droplets both around the truck and up and over the streamlined cab and then the trailer where eddies above the trailer could easily carry them up to the beam level.



Cumulative plot presenting number of parcels at the bridge beam level in basic cases

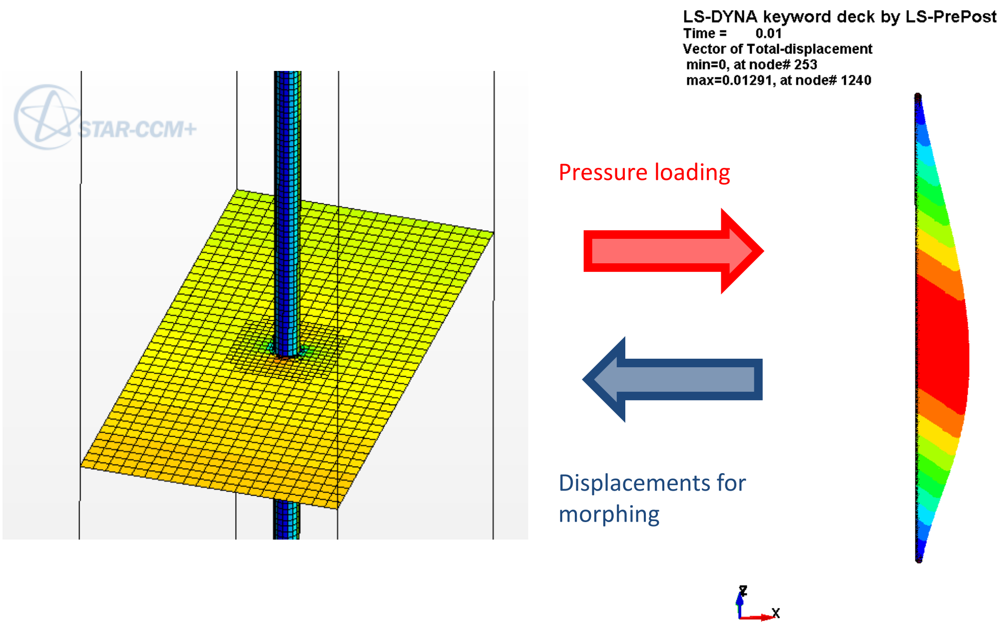
This project vividly demonstrated the value of CFD simulation in improving the understanding of very complex phenomenon. The visualization capabilities available for advanced CFD software is part of the key in achieving insights into the many things that can influence salt droplet transport from the street to weathering steel beams, possibly increasing corrosion to unacceptable rates.

Multiphysics Coupling of STAR-CCM+ and LS-DYNA for Bridge and Cable Analysis under Wind Loading

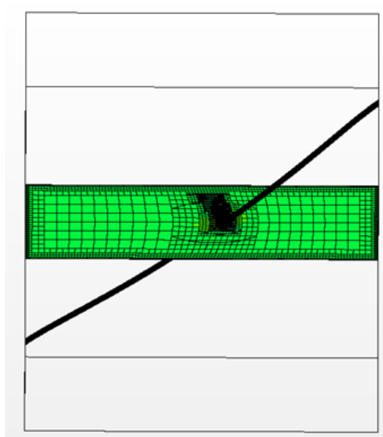
Work on multiphysics modeling of bridge cable vibrations was started. Vibrations of the cables can be categorized as a Fluid Structure Interaction (FSI) problem where air (fluid) induces vibrations of the cable (structure) and the vibrating cable disturbs the flow of the air. FSI problems are still regarded as a cutting edge research area and there is no single established approach to treat these problems. Also there is currently no easy choice of software capable of solving flow around bodies, especially those with complex geometry, that undergo large deformations without significant development and setup effort by the user. However, to some degree multiphysics problems can be handled by the following commercial software:

- COMSOL
- ANSYS
- ABAQUS
- LS-DYNA
- STAR-CCM+

The problem of cable vibration involves not only addressing FSI itself but also large elastic deformations of cable. Although fluid codes like STAR-CCM+ can handle some FSI problems, this one is out of its cur-



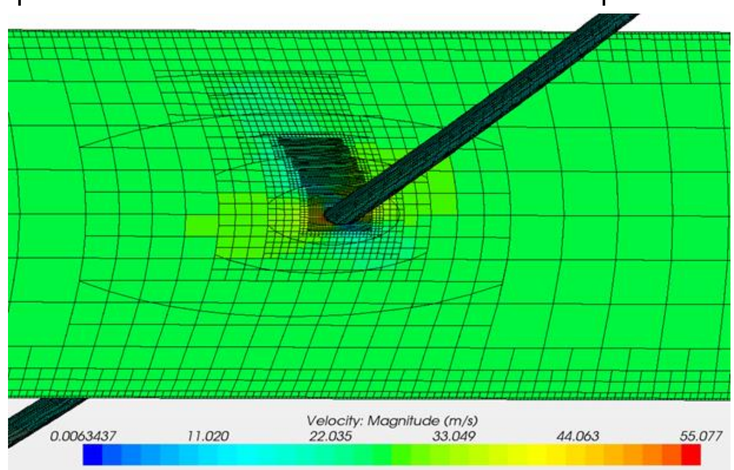
rent scope. LS-DYNA and ABAQUS can handle large deformations of structures but their fluid flow capabilities are limited. A recently released LS-DYNA CFD solver was not well tested yet and it also is not in use by a large community of users. The most reliable option for this type of problem appears to be the coupling of two solvers - a widely used and well tested CFD solver to solve the flow field and a similar major CSM software to solve for displacements.



The problem of coupling the two different types of software involves transfer of the results between two codes and (what is most difficult) mapping the results from one computational grid to another. The structural code requires usually a different type of mesh than the fluid code and as a result interpolation between the surfaces is required. CD-adapco has developed two way coupling algorithms for STAR-CCM+ and ABAQUS (Also they are currently working on two-way coupling with the NASTRAN structural solver). That seems to be the purest approach to coupling as it reduces user interference in the data exchange process. However, TRACC currently doesn't have an ABAQUS license (due to low usage by external users and associated high license cost).

A more generic way of coupling through user scripting and automatic results mapping within STAR-CCM+ is also available. This approach only requires that the external structural solver accepts NASTRAN result files and is able to produce NASTRAN based displacement output files.

A simple example of a straight vertical cable subject to a 60 mph wind load was studied as a test case to establish the steps required in the coupling process. Geometry files that include the pressure loading on surfaces produced by STAR-CCM+ are translated using Python scripts to LS-DYNA input format. The coupling procedure passes the pressure loading from STAR-CCM+ to LS-DYNA and displacements from the deformed model computed in

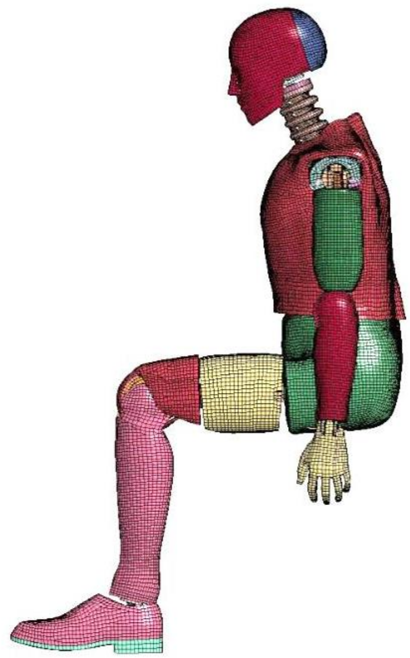


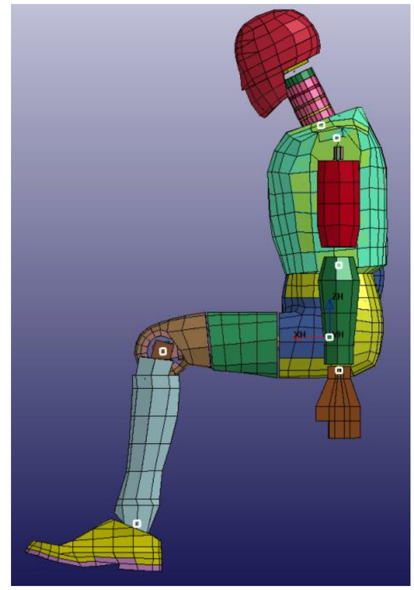
LS-DYNA are passed back to STAR-CCM+ for the next iteration. The deformed object displacements computed in LS-DYNA are used to displace surfaces in STAR-CCM+ and morph the mesh to maintain computational cell quality.

Wind induced vibration of stay cables in bridges remains a subject of considerable interest to the federal highway administration, bridge engineers, and bridge owners. This problem is complex, and both laboratory and analytical research on it are difficult to conduct. The work that was successfully begun on coupling state-of-the-art CFD software with CSM software to analyze this problem provides a major example of research that is being done at TRACC for

USDOT that cannot be done at other USDOT facilities. The effort requires a high level of multidisciplinary expertise in CFD, CSM, and super computing systems, and the supercomputing facilities to perform the analysis.

Computational structural mechanics





Work on the WFO project with NHTSA has been greatly advanced in this quarter. A feasibility study was performed to see if both LS-DYNA vehicle and dummy finite element models could be used to simulate a CRIS test and assess the response of the Hybrid III 50th dummy – in particular, the head and neck response. Both dummy models have been tested: simplified FAST HIII model and the detailed NCAC HIII dummy model. The dummies were positioned in the Ford Taurus car model and the restraint systems were fitted to the body of the dummies. Adjustments to the Ford Taurus model have been also made to reflect the weight and inertia differences between the Taurus and the vehicle used in the experiment – Ford Crown Victoria.

Two metrics were defined by NHTSA for judging the model performance: neck force and neck moment. Comparison between simulation and experimental results showed favorable agreement in peak magnitude and shape. However, these agreements were obtained with an adjusted roll angular velocity that resulted from a number of unknown initial conditions in the experiment. A list of missing parameters needed for more credible simulations has been assembled and forwarded to the sponsors for their feedback. The further work will focus on better matching of the experimental input and output quantities. The goal of this study was to provide a base model that can be subsequently used for an extensive sensitivity study on the test conditions.

Organizations and Users with Access to the TRACC HPC Clusters

3-D Numerical Simulation of Direct-Injection, Mixture Formation and Combustion in a Hydrogen Engine			
	ES Division, Argonne		
		Scarcelli, Riccardo	***User***
	US DOE Engines and Emissions Control Technologies		
		Singh, Gurpreet	***Cognizant Engineer***
A Microstructure-Based Modeling Approach to Characterize Asphalt Materials			
	Michigan Department of Transportation		
		Staton, John	***Cognizant Engineer***
	Michigan Technological University		
		Barak, John	***Cognizant Engineer***
		Colbert, Baron	***User***
		Dai, Qingli	***User***
		Lu, Haizhu	***User***
		Ng, Kenny	***User***
		You, Zhanping	***Cognizant Engineer***
Analysis and Design of Roadside Safety Features for Safety Performance			
	Texas Transportation Institute		
		Abu-Odeh, Akram Y.	***User***
		Bligh, Roger P.	***Cognizant Engineer***
		Sheikh, N.M.	***User***
Analysis of THOR-NT Dummy for Vertical Impact Environments			
	NASA Langley		
		Annett, Martin S.	***Cognizant Engineer***
	Virginia Tech		
		Putnam, Jacob	***User***
		Untaroi, Costin	***User***
Application of Chaos Theory Analysis to Structural Health Monitoring of Cable-Stayed Bridges			
	FHWA NDE		
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Application of TRANSIMS for Highway Work Zones			
	FHWA OoP		
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	Western Michigan University		
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Assessment Of Occupant Kinematics in Rollovers; Rollover Crash Analysis			
	NHTSA HID		
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Bridge Hydraulics - Analysis Support for Hydraulics Research in Transportation Applications			
	TFHRC		
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		Guo, Junke	***Cognizant Engineer***
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		Zhai, Yuan	***User***
Bridge Scour Modeling Using CFD			
	California Department of Transportation		
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CFD Analysis of Outlet Modifications to Improve Highway Pipe Efficiency at Peak Flows			
	Maine Department of Transportation		
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CFD Modeling of FDOT's Sediment Erosion Rate Flume (SERF)			
	Florida Department of Transportation		
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Chicago Business District Evacuation (IDOT)			
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Chicago North Side Water Reclaimation Plant Studies			
	TRACC, Argonne		
		Lottes, Steven A.	***Cognizant Engineer***
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CMAP Activity-Based Model			
	CMAP		
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		Stratton, Matt	***User***
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	FHWA OoP		
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Computational Mechanics Research and Support for Aerodynamics and Hydraulics at TFHRC			
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	TRACC, Argonne		
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Computer Aided Mix Design (CAMiD) Technical and Analysis Support for Advanced Computational Needs -- Bituminous Mixtures Laboratory at FHWA Turner-Fairbank Research Center			
	FHWA OoP		
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	TFHRC		
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CRIS Test Modeling			
	NHTSA		
		Kruszewski, Piotr Mateusz	***User***
Design-oriented Scoured Foundation Modeling for Bridge Performance Analysis			
	University of Missouri-Kansas City		
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Determining Wheel-Soil Interaction Loads using a Meshfree Finite Element Approach			
	NASA JPL		
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Development and Evaluation of Climate Metrics for Aviation based on Climate-Chemistry Modeling Analyses			
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Development and Improvement of Roadside Safety Barriers			
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Development of TRANSIMS Models to Evaluate Traffic Management Plans for Special Events and Construction Projects in the Chicago Business District			
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Development of TRANSIMS Software for use in Parallelization of TRANSIMS			
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Development of TRANSIMS Tools and Methodology for the Atlanta Metropolitan Area			
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Development of TRANSIMS Visualization Software Metropolis			
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Electromagnetic Shock Absorber			
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Evaluation of Thor Dummy FE Model in Crash Environments			
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FHWA Signal Processing, Data Analysis and Computational Modeling for Highway Applications			
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Geosynthetic-Reinforced Soil Integral Bridge System; Scour Countermeasure Design; Deformation Analysis of Bridge Supported on Shallow Foundations			
	FHWA OoP		
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Impact of Wide Base Tires on Pavements - A National Study			
	FHWA IR&D		
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Improvements of LS-Dyna Models for Off-Road Traffic Accident Analysis			
	Kineticorp		
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Inner Nozzle Flow characterization of Biodiesel from Different Feedstocks			
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		Lottes, Steven A.	***Cognizant Engineer***
	US DOE EERE Vehicle Tech Prog		
		Stork, Kevin	***Cognizant Engineer***
In-situ Load Rating of Highway Bridges			
	University of Virginia		
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Investigation of Bridge Pier and Abutment Scour Using Large Eddy Simulation			
	University of Iowa		
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		Miyawaki, Shinjiro	***User***
		Tokyay, Talia Ekin	***User***
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Investigation of Impact Factors for FDOT Bridges; and the Best Practices in Construction of Paratransit Buses			
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Investigation of Occupant Injury Mechanism in Vehicle Small Overlap Impacts			
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Investigation of Occupant Response in Vehicle Crash			
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		Poulard, David	***User***
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Investigation of River Flow and Transport Processes Using High Resolution Eddy Resolving CFD Simulations			
	South Florida Water Management District		
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	TRACC, Argonne		
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Large Eddy Simulation of Interaction of Turbulent Flow with a Porous Media			
	TRACC, Argonne		
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Large Scale Evacuation Planning with Microscopic Traffic Simulation			
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Management			
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Modeling Hot Mix Asphalt Compaction - Technical Support for Pavement Design and Performance Modeling Team			
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Modeling Soil-Structure Interaction in the Presence of Large Soil Deformations			
	TRACC, Argonne		
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Moreno Valley TRANSIMS Transportation Modeling/ITS			
	FHWA OoP		
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MOVES (Motor Vehicle Emission Simulator), Modeling emissions from on road vehicles			
	EPA Office of Transportation and Air Qualilty		
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MOVES Air Pollutant Emission Analysis for the GREET Model			
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NCAC Finite Element Models Assessment			
	George Washington University		
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NHTSA Human Injury Research Division			
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Nonlinear Analysis of Cable-Stayed Bridge Cables			
	Northern Illinois University		
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Numerical Investigation of Single Point Incremental Forming			
	Northwestern University		
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		Huang, Ying	***User***
Open Channel Flow, Bridge Hydraulics, and Bridge Scour			
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Picoscopic Modeling of Transportation Systems			
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RTSTEP: Regional Transportation Simulation Tool for Evacuation Planning			
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SACOG TRANSIMS Implementation			
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SANDAG Activity-Based Model			
	SANDAG		
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SIMon Brain Model			
	NHTSA HID		
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Simulation Analysis of an Integrated Model System for the Region of Southern California Association of Governments			
	SCAG		
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Simulation of Bridge Pier Failure from Flood Loading			
	TRACC, Argonne		
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Snowdrift Mitigation			
	University of Iowa		
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Software Testing			
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SToRM-Cluster; Computation River Hydraulics and Transfer			
	USGS		
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Structural Performance of Flexible Pavements			
	Louisana TRC		
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Structural Testing Laboratory Computational Mechanics Research; Finite Element Modeling of Highway Structures			
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Study of Erosion Mechanisms at Piers of Rectangular Shape using Eddy Resolving Techniques and use of the Databases for Improvement of RANS Scour Models			
	TFHRC		
		Kerenyi, Kornel	***Cognizant Engineer***
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Study of the Rate of Deterioration of Bridges and Pavements as Affected by Trucks			
	Clemson University		
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Temecula Traffic Circulation Analysis of Alternate Networks			
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	Moreno Valley		
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Time Domain Fatigue Simulation of Metals			
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Traffic Simulation of St. Louis Transportation Network for Earthquake Impact Assessment			
	Newmark Civil Engineering Laboratory		
		Elnashai, Amr S.	***Cognizant Engineer***
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Transient Structural Dynamics of Bridges Subjected to Traffic, Seismic and Blast Loadings			
	TRACC, Argonne		
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TRANSIMS Configuration Control, Testing, Automation, and Software Release			
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TRANSIMS Evacuation Traffic Models of New Orleans and Houston			
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TRANSIMS Technology and Tools development technical assistance for the development Buffalo USA/Canadian Region cross-border model.			
	USDOT		
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TRANSIMS Traffic Simulation Software Development/Parallelization			
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Update LA DOTD Policy on Pile Driving Vibration Management			
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Using TRANSIMS to Quantify the Impacts of Planned Transportation Projects on Congestion and Air Quality			
	Georgia Regional Transportation Authority		
		Davis, Curt	***User***
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Vehicle Stability under High Winds			
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Wind Loads on Highway Sign and Traffic Signal Structures			
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Advanced Degrees Awarded to Graduate School Students for Computational Fluid Dynamics Work Done on TRACC High Performance Computer Clusters on Problems of Importance to the FHWA Turner-Fairbank Highway Research Center and U.S. DOT

1. Bishwadipa Das Adhikary, “Flow and Pressure Scour Analysis of an Open Channel Flow Having an Inundated Bridge Deck under Various Flooding Conditions,” M.S. Thesis, Northern Illinois University, July 2008
2. Dipankar Biswas, “Development of an Iterative Scouring Procedure for Implementation in CFD Code for Open Channel Flow under Different Bridge Flooding Conditions,” M.S. Thesis, Northern Illinois University, June 2009
3. Afzal Bushra, “Computational Fluid Dynamic Analysis of Hydrodynamic Forces on Inundated Bridge Decks and the Effect of Scaling,” Ph.D. Thesis, University of Nebraska, November 2009
4. Bhaskar Rao Tulimilli, “Development of a Three-dimensional Scouring Methodology and its Implementation in Commercial CFD Code for Open Channel Flow Over a flooded Bridge Deck,” M.S. Thesis, Northern Illinois University, June 2010
5. Phani Ganesh, Development of Three-Dimensional Iterative Methodology Using a Commercial CFD Code For Flow Scouring Around Bridge Piers, M.S. Thesis, Northern Illinois University, October 2010
6. Vishnu Vardhan Reddy Pati, “CFD Modeling and Analysis of Flow through Culverts,” M.S. Thesis, Northern Illinois University, October 2010
7. Zhaoding Xie, “Theoretical and Numerical Research on Sediment Transport in Pressurised Flow Conditions,” Ph.D. Thesis, University of Nebraska, July 2011
8. Chris Edwards, “3-D Mesh Morphing Iterative Methodology for Flow Scouring Around Bridge Piers Implemented in a Commercial CFD Code,” M.S. Thesis, Northern Illinois University, August 2011
9. Yuan Zhai, “Time-Dependent Scour Depth under Bridge-Submerged Flow,” M.S. Thesis, University of Nebraska, May 2010
10. Yuan Zhai, “CFD Modeling of Fish Passage in Large Culvert and Assistance for Culvert Design with Fish Passage,” Ph.D. Thesis, University of Nebraska, July 2013

Dr. Steven Lottes, Argonne TRACC, served on the thesis committees for Bishwadipa Das Adhikary, Dipankar Biswas, Bhaskar Rao Tulimilli, Phani Ganesh, Chris Edwards, and Vishnu Vardhan Reddy Pati.

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Advanced Degrees Awarded to Graduate School Students for Computational Structural Mechanics Work Done on TRACC High Performance Computer Clusters on Problems of Importance to the U.S. DOT

1. Rohan Patil, "Stability of Single-Unit Truck under Wind Loading", M.S. Thesis, Northern Illinois University, December 2011, directed by Abijith Gupta
2. Francesco Lucas Fisher, "Design of a Semi-Active Controllable Electromagnetic Shock Absorber", M.S. Thesis, Northern Illinois University, December 2011, directed by Abijith Gupta
3. Eduardo E. Taft Ford, "Dynamic Interaction Between Heavy Vehicles and Highway Bridges", M.S. Thesis, Florida State University, October 2010, directed by Jerry Wekezer
4. Bharathi Vannemreddy, "Aerodynamic Vibrations of Stay Cables of a Cable Stayed Bridge", M.S. Thesis, Northern Illinois University, August 2010, directed by Abijith Gupta
5. Srihari Vannemreddi, "Numerical Modeling of Stay Cables and Stay Cable Bridges" , M.S. Thesis, Northern Illinois University, August 2010, directed by Abijith Gupta
6. Sharnie Earle, "Evaluation of Dynamic Load Allowance Factors for Reinforced Concrete Highway Bridges", M.S. Thesis, Florida State University, April 2010, directed by Jerry Wekezer

Dr. Ronald F. Kulak served on the thesis committees for Rohan Patil, Francesco Lucas Fisher, Bharathi Vannemreddy, and Srihari Vannemreddi

Dr. Cezary Bojanowski served on the thesis committees for Rohan Patil, Francesco Lucas Fisher, and Srihari Vannemreddi. He also advised to Eduardo E. Taft Ford and Sharnie Earle on their thesis.

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