Transportation Research and Analysis Computing Center

TRACC

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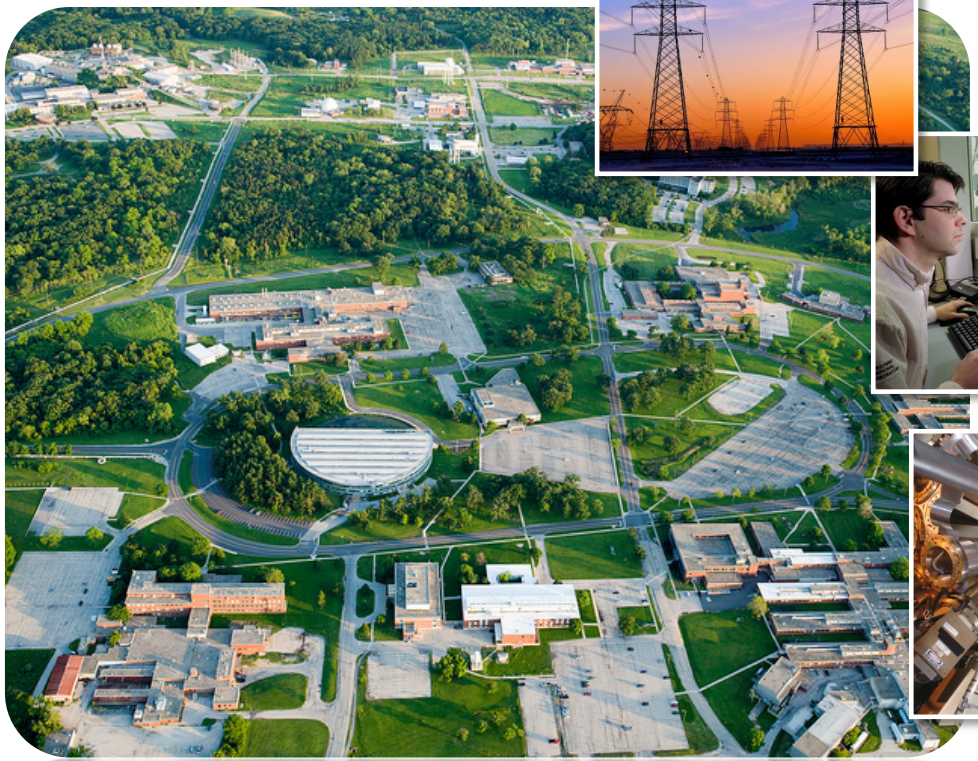
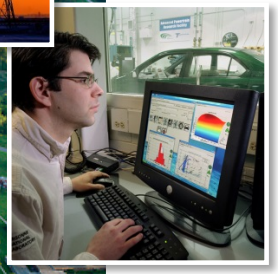
www.tracc.anl.gov

In cooperation with the U.S. Department of Transportation

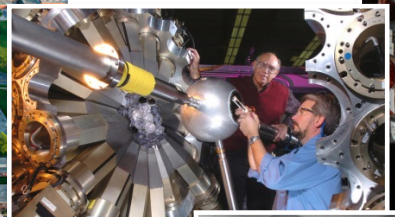
Argonne: One of DOE's Largest Research Facilities

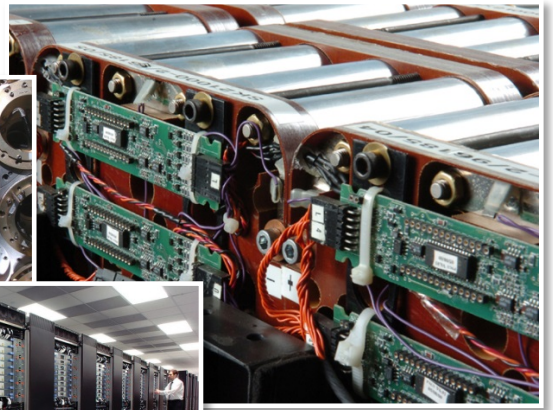




- Located 25 miles from the Chicago Loop, it was the first national laboratory, chartered in 1946

Argonne is managed by UChicago Argonne, LLC, for the U.S. Department of Energy's Office of Science.





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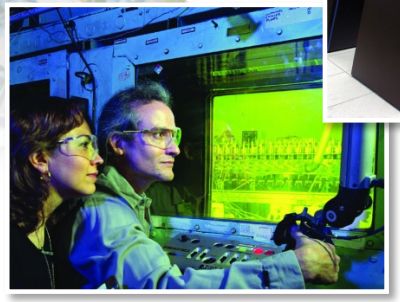
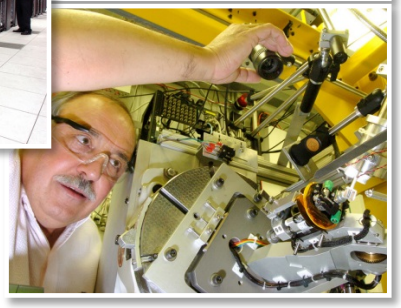
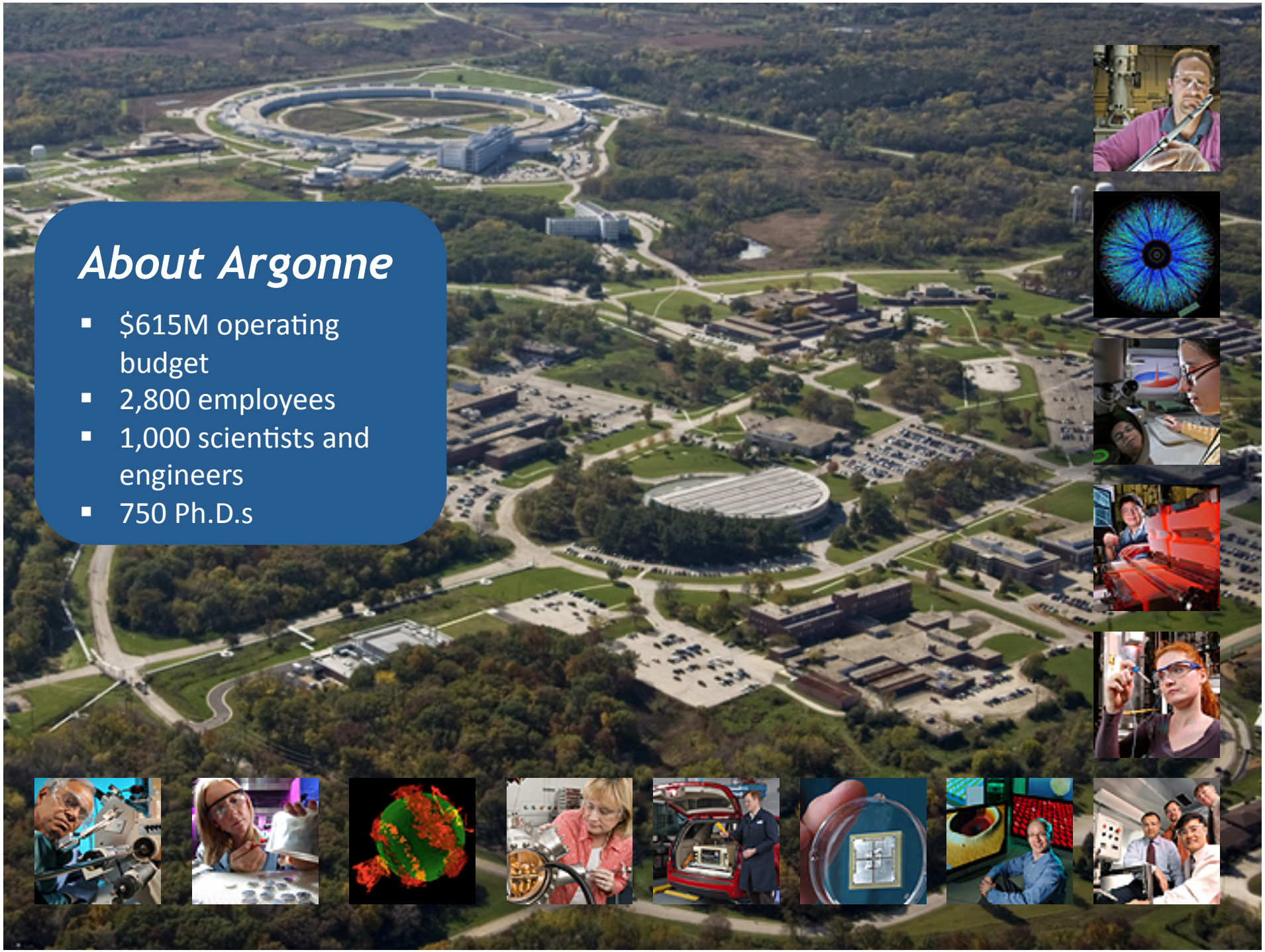


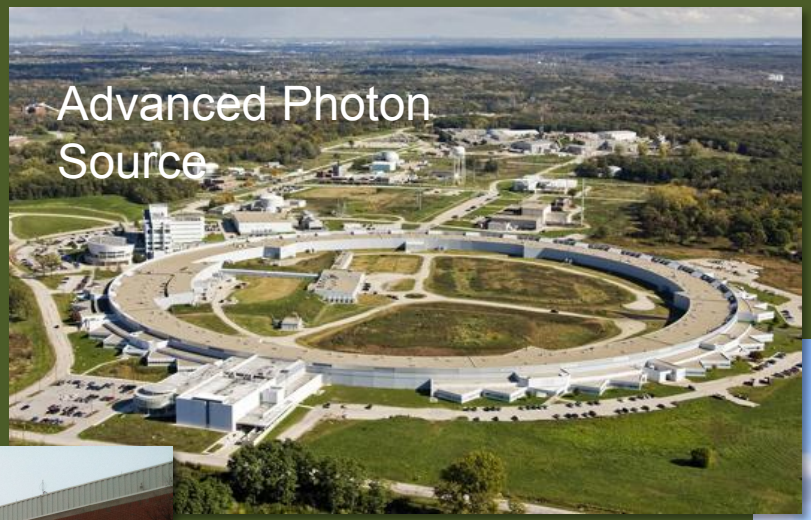




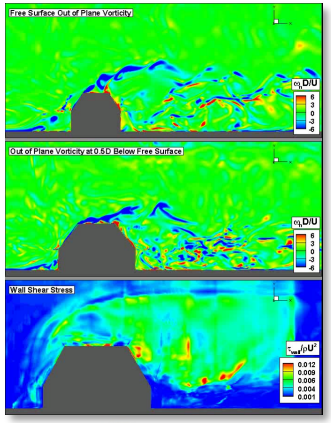
About Argonne

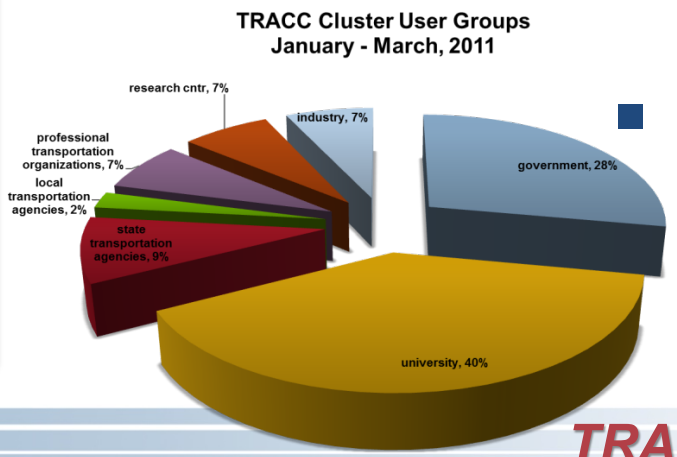
- $615M operating budget
- 2,800 employees
- 1,000 scientists and engineers
- 750 Ph.D.s

User Facilities at Argonne



The Transportation Research and Analysis Computing Center at Argonne National Laboratory





- A national user facility funded by USDOT to promote technology transfer from the national laboratory system to high priority transportation research projects
  - 130 users, 85% utilization
- Targeted research projects supporting essential USDOT computational research needs
- Sponsored research on advanced transportation simulations for evacuation planning
  - Illinois Department of Transportation
  - OEMC / City of Chicago

TRACC – A National User Facility to Meet USDOT Advanced Computation Needs

- USDOT and USDOE transportation research programs, private industry, and state and regional transportation agencies are moving to simulation-based design and analysis for improvements in efficiency, economics, and safety
- Higher fidelity analysis in areas such as crashworthiness, aerodynamics, combustion, thermal management, weather modeling, and traffic simulation require access to state-of-the-art computational and visualization facilities
- Argonne expertise in high-performance computing and transportation system analysis provides the basis for a national HPC user facility and a focal point for computational research for transportation applications

TRACC - High-Performance Computing for Transportation Research and Applied Technology

Aerodynamics

Culvert Modeling

Occupant Safety

TRACC's Clusters

Bridge Hydraulics

Crash Biomechanics

Traffic Modeling

Crashworthiness

Intelligent Transportation System

Bridge Structural Analysis

Transportation Data Archive

TRACC is a National USDOT Supercomputing Facility

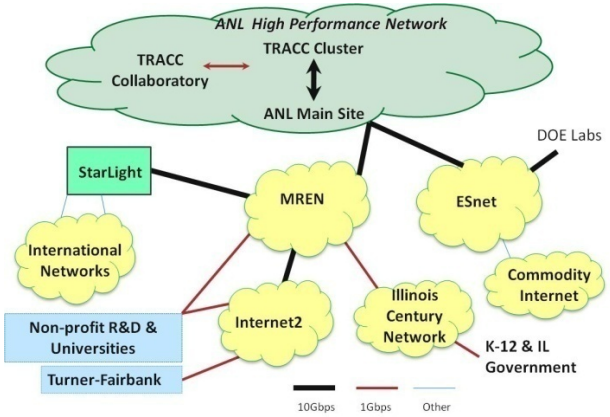
TRACC High Performance Compute Clusters

Zephyr

- 2944 cores, 184 16 core processors, 92 compute nodes
- 120 TB Lustre Disk Storage
- Shared 160 TB Archive/Backup Tape Storage

Phoenix

- 1024 cores, 256 quad core processors, 128 compute nodes
- 90TB Global Parallel File System Disk Storage
- Shared 160TB Archive/Backup Tape Storage



High-bandwidth connectivity is provided via the Argonne high-performance network to world-wide research and education networks (Internet2 and ESnet)

TRACC Collaboratory - Training, Meetings, and Digital Video Conferencing

TRACC Partner Organizations

- TRACC Partners
  - TRACC is linked to Federal and non-Federal research and development facilities, regional, state and city departments of transportation, and university transportation research centers
  - Federally sponsored USDOT partners currently include the Federal Highway Administration (FHWA) with its Office of Planning (OoP) and the Turner-Fairbanks Highway Research Center (TFHRC), and include the National Highway Traffic Safety Administration (NHTSA)

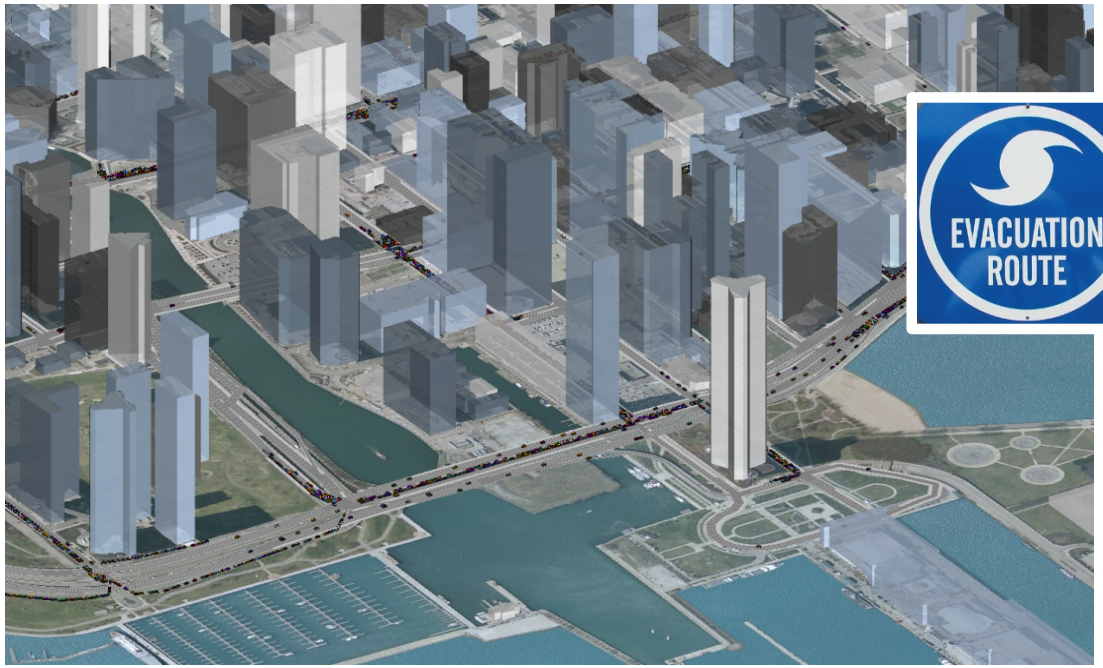
- Technology Development and Commercialization
  - Starting in FY2013, TRACC increased its emphasis on establishing cost-sharing research programs through sponsored research
  - A primary objective of DOE is to promote the economic interests of the United States
  - Partnering with organizations facilitates the development, transfer and use of Federally owned or originated technology by industry for public benefit
  - Sponsored research provides a mechanism to leverage DOE resources such as those of TRACC through partnering with industry

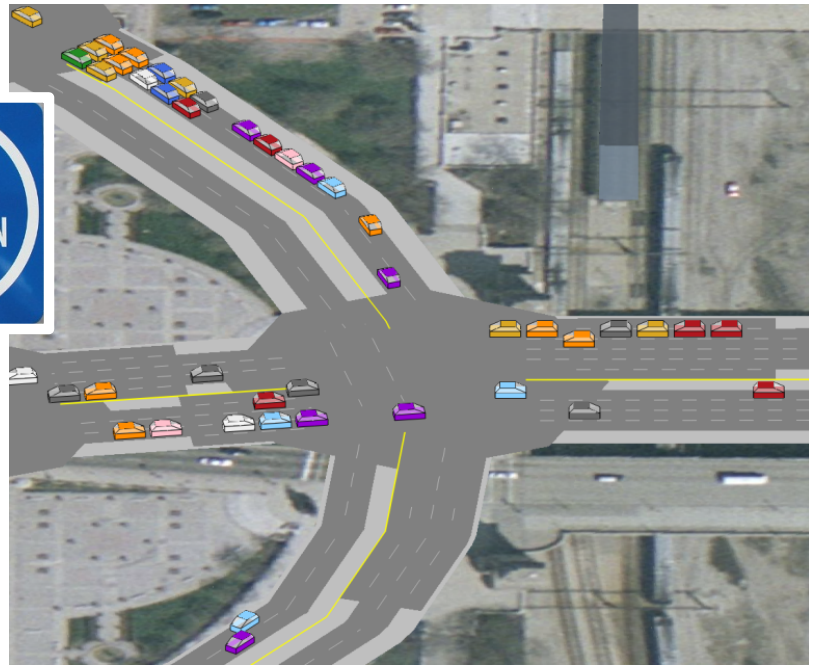
Current Focus Areas

- Traffic Modeling and Simulation and Emergency Transportation Planning
  - Chicago metropolitan area model using multi-modal simulation techniques
  - Collaboration with the Chicago Metropolitan Agency for Planning, the Illinois Department of Transportation, the Federal Highway Administration, and other federal agencies
- Computational Fluid Dynamics for Infrastructure Analysis
  - Hydraulics analysis of flow at bridges and culverts, flooding and scour, storm water runoff, laboratory flume, and field device flows
  - Wind engineering applied to roadside hardware and bridge aerodynamics
  - Analysis of salt spray and aerosol dispersion from trucks
- Computational Structural Mechanics for Transportation Applications
  - Vehicle crash analysis, roadside barrier impact, accident reconstruction and occupant response
  - Bridge dynamic response due to traffic loading, stay-cable response due to traffic loading and wind loading, stability of bridges with piers in scour holes, including fluid-structure interaction
- High-performance Computing Center
  - Two high-performance computing clusters
  - National and international network connectivity
  - Training and collaborative facilities

Argonne NATIONAL LABORATORY

Traffic Modeling and Simulation and Emergency Transportation Planning





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U.S. DEPARTMENT OF ENERGY

Transportation Systems Simulations at TRACC

TRANSIMS Activities

- Development of tools and methodologies to support a faster and more reliable modeling process
  - **Parallelization** and coordination of simultaneous execution of partitioned data sets
  - Adaptation of TRANSIMS to run effectively **on high performance computing** platforms
  - Development of high level tools such as network editors and **TRANSIMS Studio**
  - High performance **visualization** to aid in developing and debugging large complex transportation system models
  - **Training classes** to support new and advanced TRANSIMS users
- Development of a Chicago TRANSIMS model
  - Used as the basis for TRANSIMS **software and methodology improvement**s
  - Model is largely based on data and previous models from **CMAP**
  - The model is being shared with other research teams, e.g. IIT/CDOT

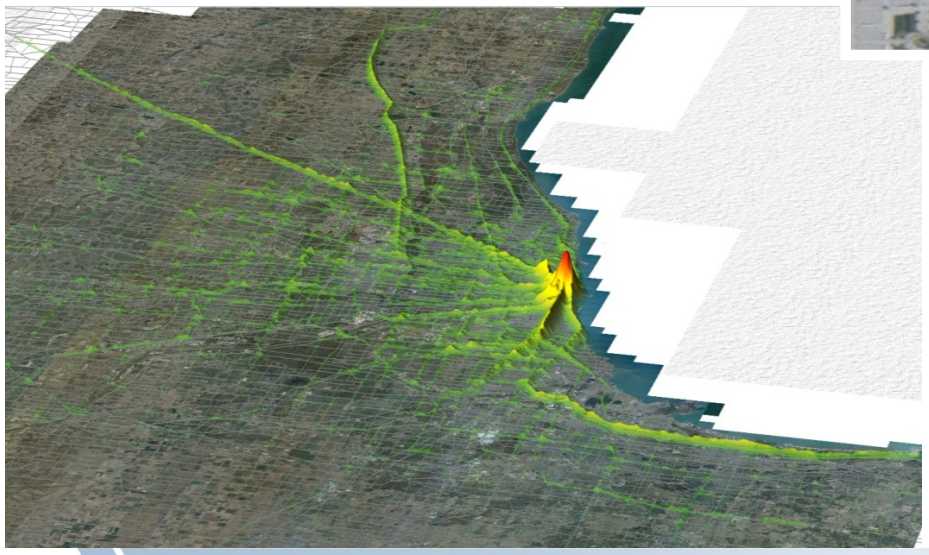
POLARIS Activities

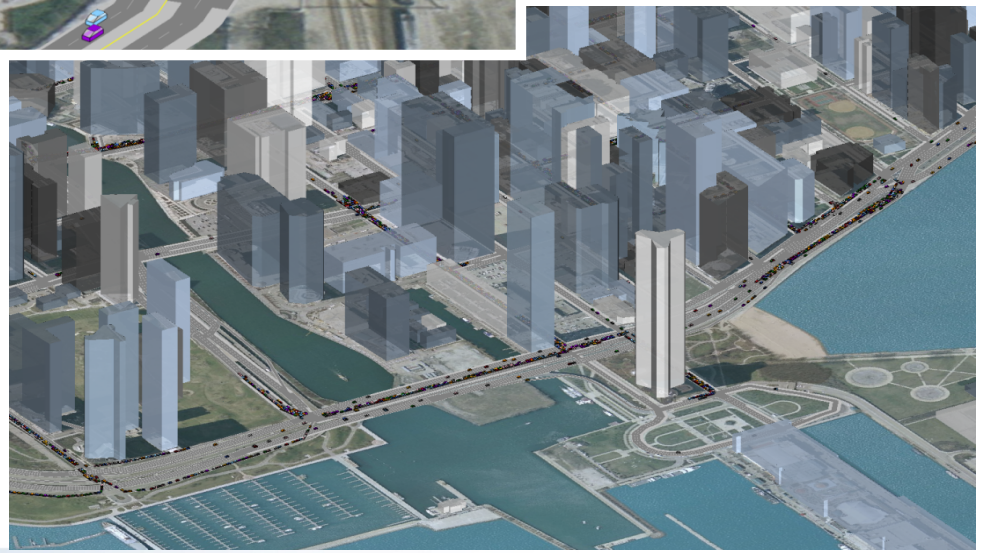
Planning and Operations Language for Agent-based Regional Integrated Simulation

- Mandates from FHWA:
  1. Model **Traffic Control Centers** and other **ITS Systems**
  2. Enhance Interoperability among Existing Tools
- Core Goals and Philosophies of the POLARIS Effort:
  - Develop Transportation Modeling Standards and Protocols
  - Create an **Open Source** Model Development Environment
  - Seek Out Opinions from and Actively Listen to the Transportation Community
  - Connect Sub-Communities with a **Common Modeling Language**
  - Offer Helpful Tools while Maintaining **Flexibility and Modularity**
- Repository of useful code and code fragments built using a standard methodology
  - Includes a library of common objects found in transportation models
  - Will be extended by users and other researchers

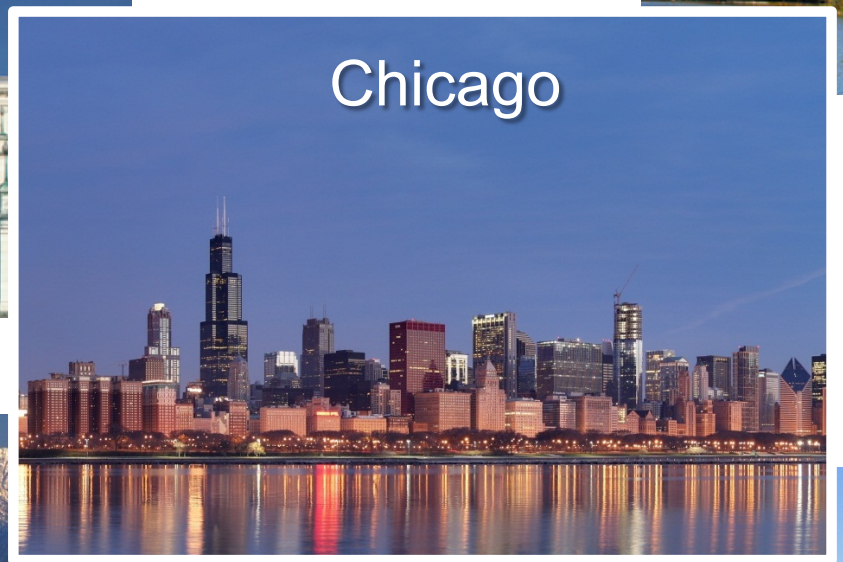
Transportation Systems Visualization

- Implementation of powerful visualization concepts to analyze complex computational simulations
- Effective visualization allows the human brain to detect simulation flaws or actual congestion problems





TRANSIMS Models at TRACC



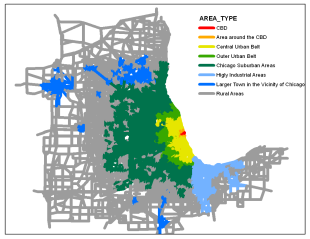
The 2011 RTSTEP Evacuation Simulation Team

TRANSIMS User Support and Training

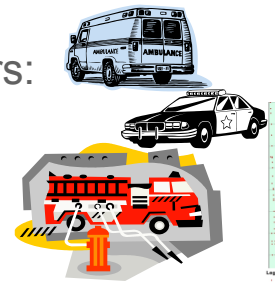
- TRACC is providing training courses on TRANSIMS and other subject areas to the transportation research community in the US
  - Training courses are offered approximately 10 times per year in varying locations
  - Participation is free, and training courses are broadcast over the Internet to reach additional users
- TRACC is holding additional training sessions on emerging capabilities through the Internet
- The goal is to build a strong community of expertise

RTSTEP - Regional Emergency Evacuation Planning

Regional Planners

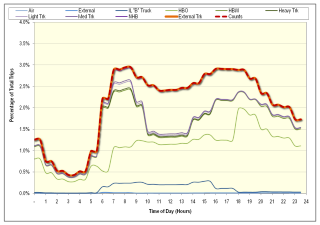


First Responders: Federal State City

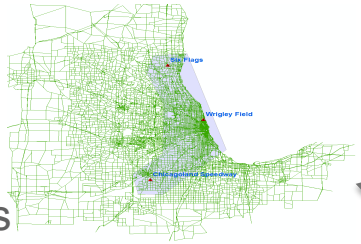


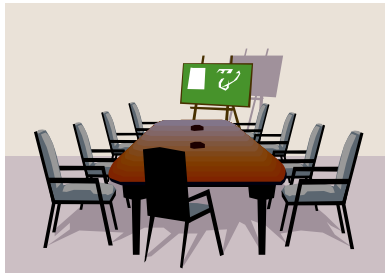
Realistic High Fidelity Simulations

Dynamic Transportation Models

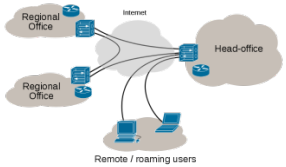


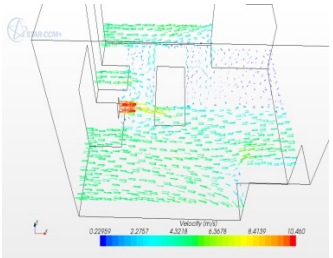
Case Studies and Specific Scenarios





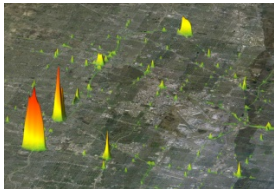
High Speed Networks





Advanced Dispersion Models

High Performance Computing



State-of-the Art Visualization Techniques

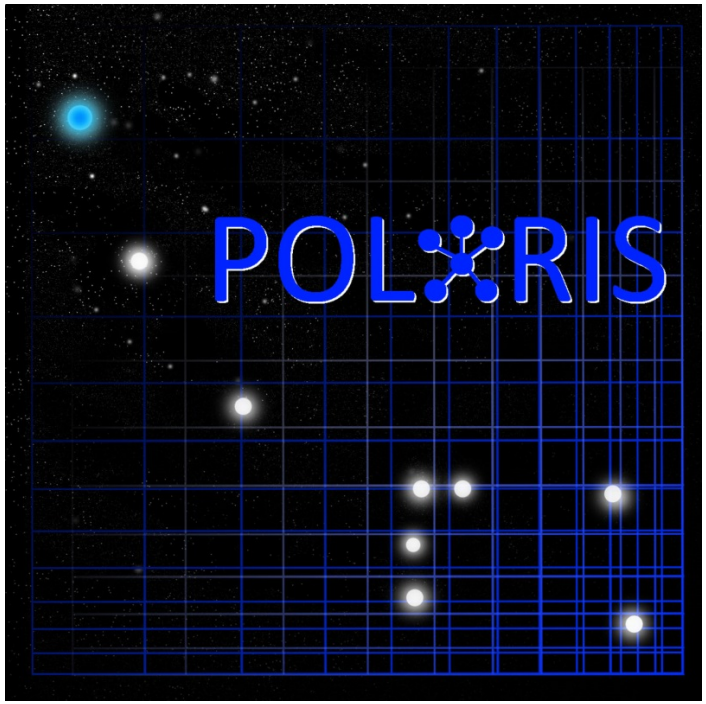
Advanced Training Courses

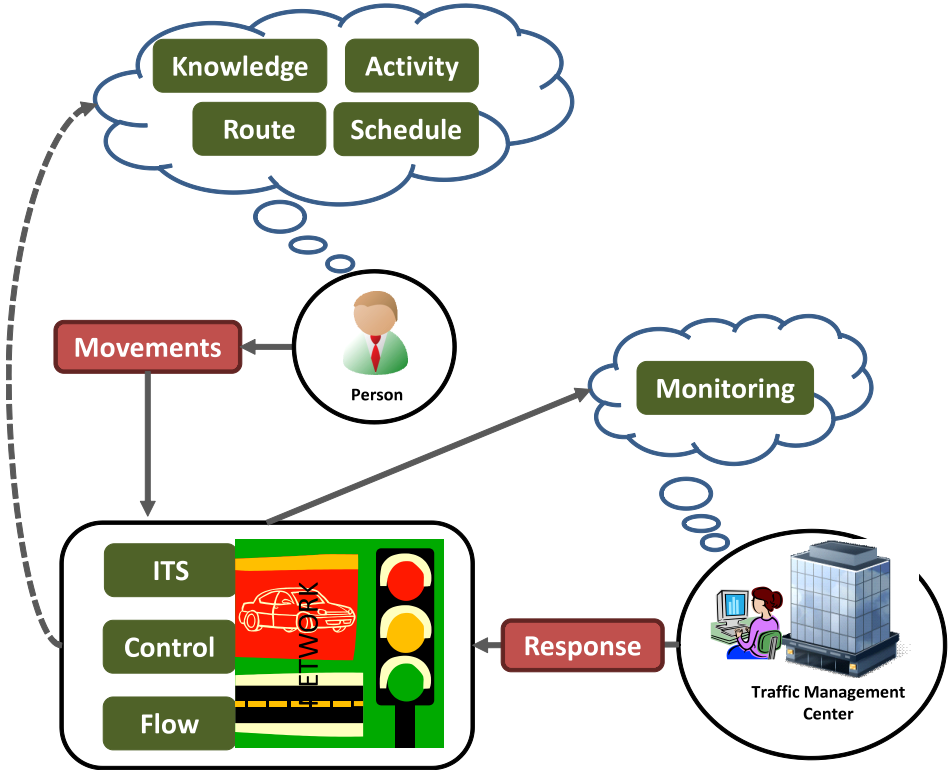
Comprehensive Data Sources

Application of High Fidelity Agent-Based Transportation Simulation Tools at TRACC

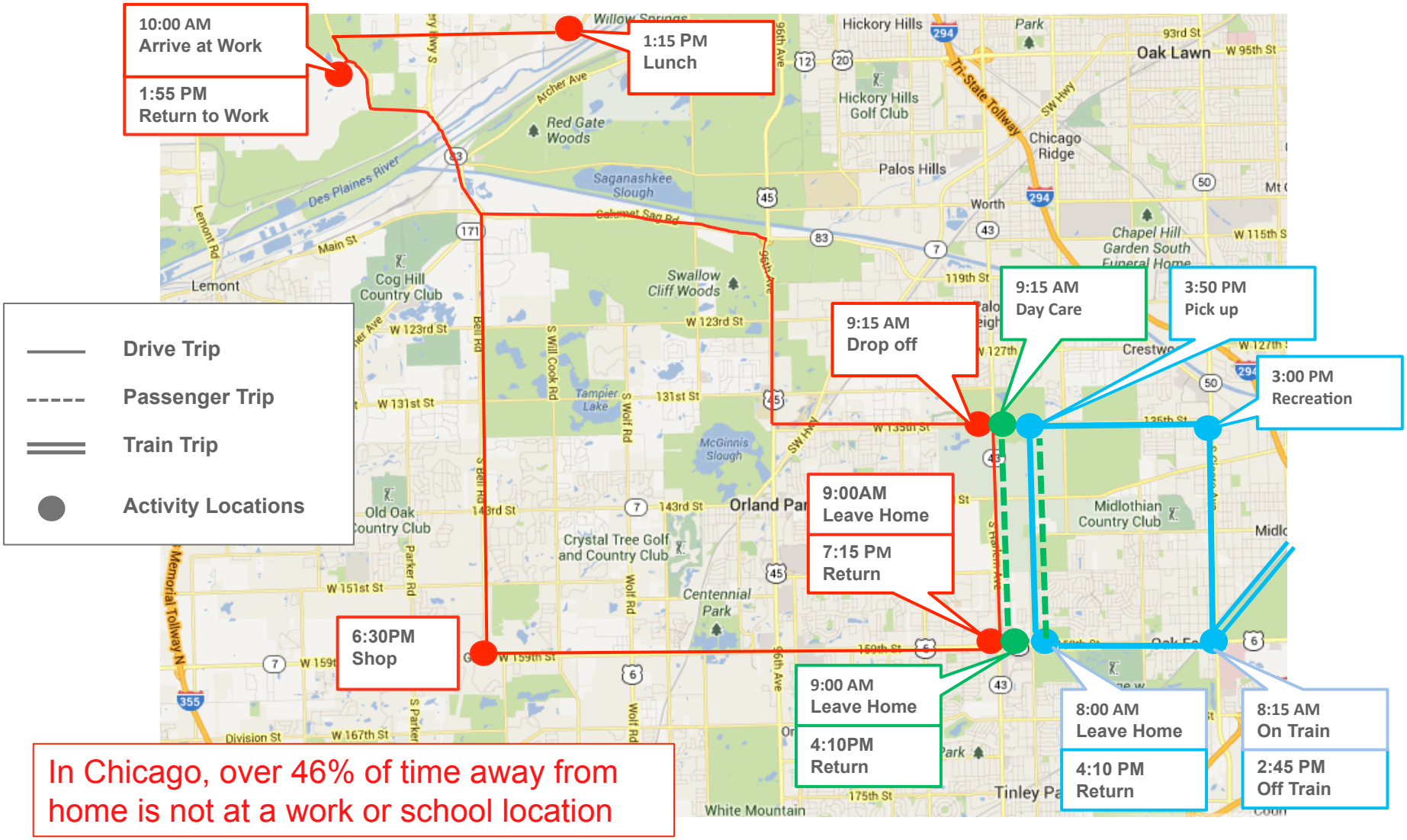
Integrated Transportation Model (POLARIS)

- Agent based Approach
- Traveler is in the "center"
- All aspects of the traveler's day are modeled explicitly in a single model



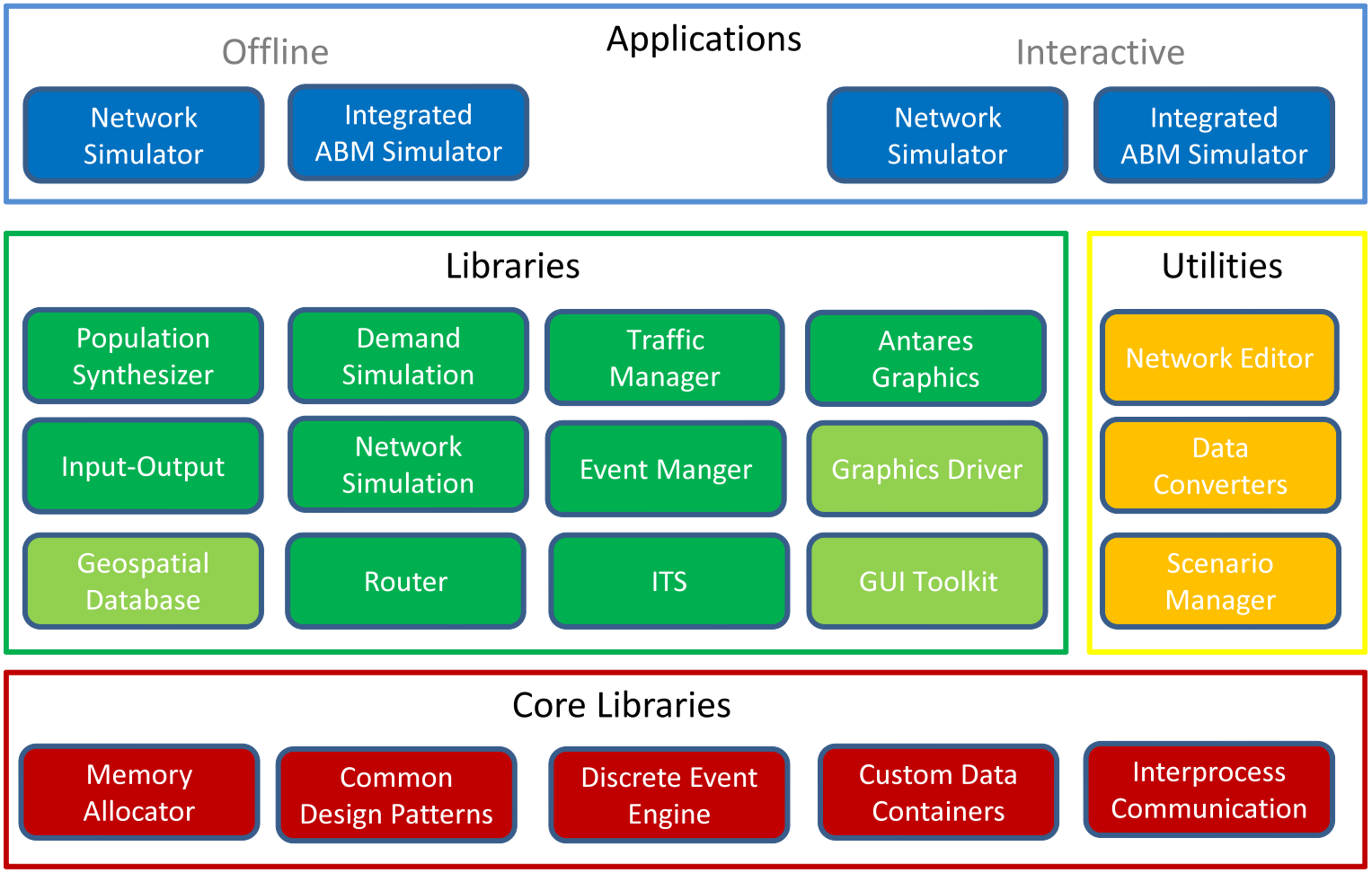


Activity Travel Patterns

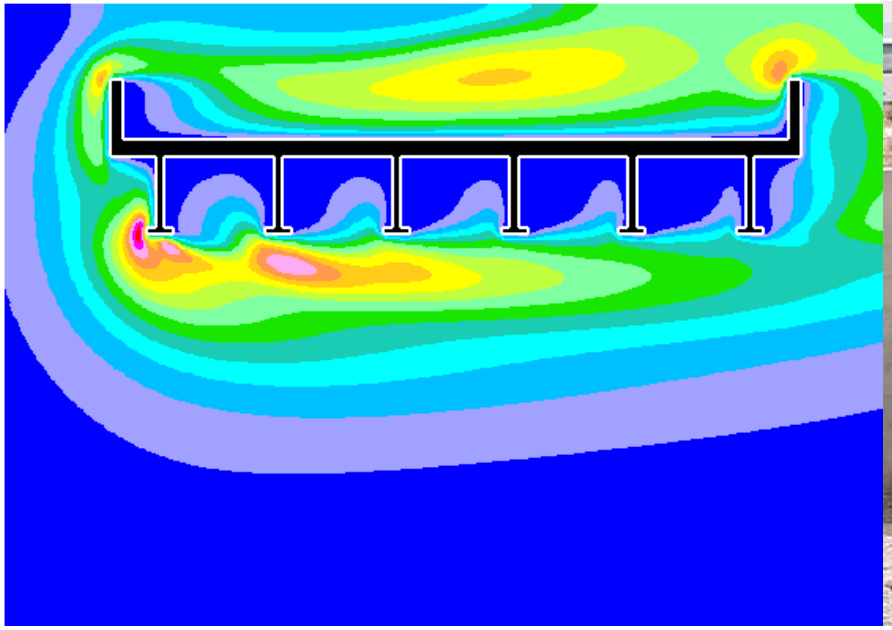


In Chicago, over 46% of time away from home is not at a work or school location

POLARIS Transportation Systems Modeling Suite



Computational Fluid Dynamics for Infrastructural Analysis



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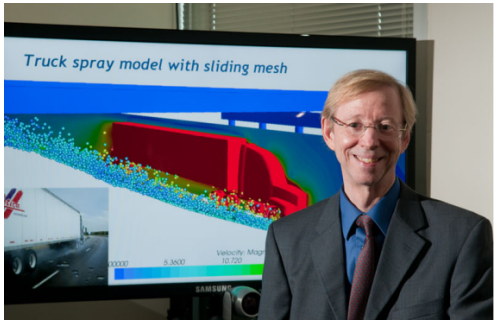
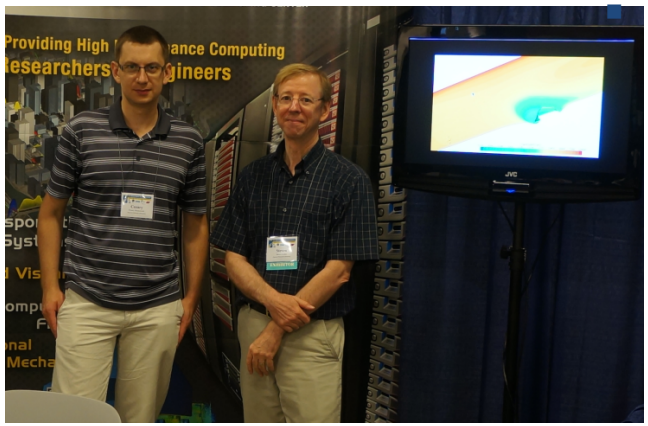
Computational Fluid Dynamics and Computational Structural Mechanics



- Commercial applications such as LS-DYNA and CD-adapco STAR-CCM+ scale well on TRACC clusters

- Based on proven and reliable commercial models, **cutting edge research** involves the addition of crucial modeling capabilities such as
  - **Sediment erosion** at bridge pier and abutment foundations
  - Parametric vibrations in **bridge stay cables**
  - Many more …



High priority **transportation-related issues are "messy"** and need robust and well-calibrated methodologies in the hands of many agencies and consulting companies

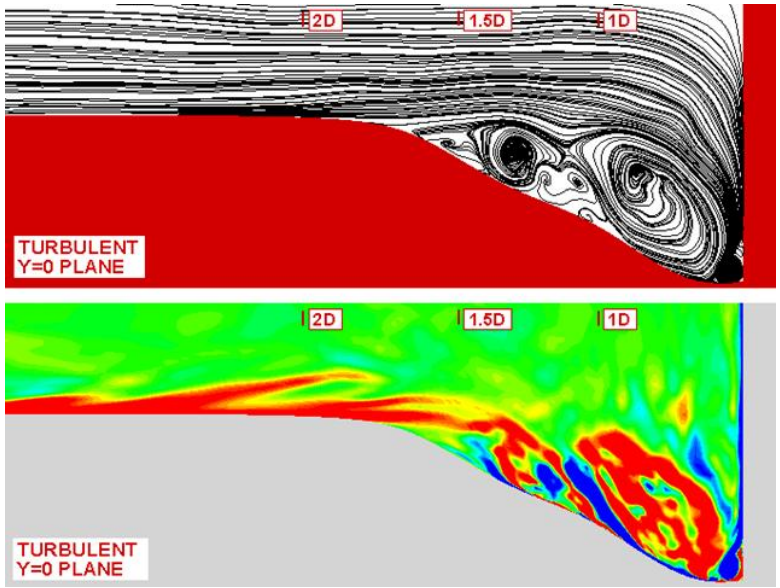
- TRACC provides a **platform that is substantially larger** than existing platforms available to transportation researchers
- TRACC focuses on **calibration and validation** of cutting edge modeling approaches

Areas of CFD Application

- Bridge scour during floods
- Hydrodynamic forces on bridges during floods and storm surges
- Salt spray from trucks on bridges using weathering steel
- Culvert flow capacity and fish passage
- Aerodynamic forces on bridges and road side hardware
- Other hydraulic and aerodynamic problems

Current CFD Collaborative and User Projects

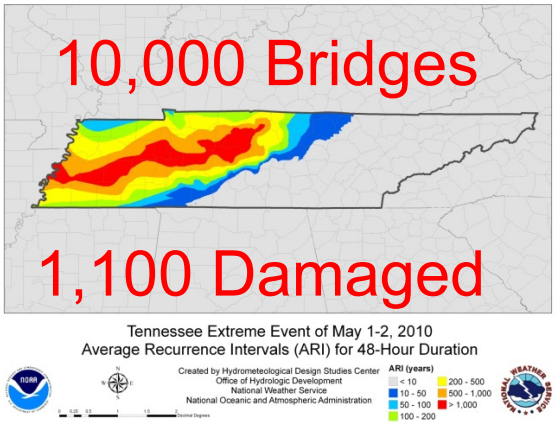
- Hydraulic Forces on Bridge Structures and Scour in Floods
  - FHWA Turner Fairbank Highway Research Center (TFHRC)
  - University of Nebraska
  - University of Iowa
  - Argonne National Laboratory
- Investigation of Bridge Pier and Abutment Scour Using Large Eddy Simulation (LES)
  - University of Iowa



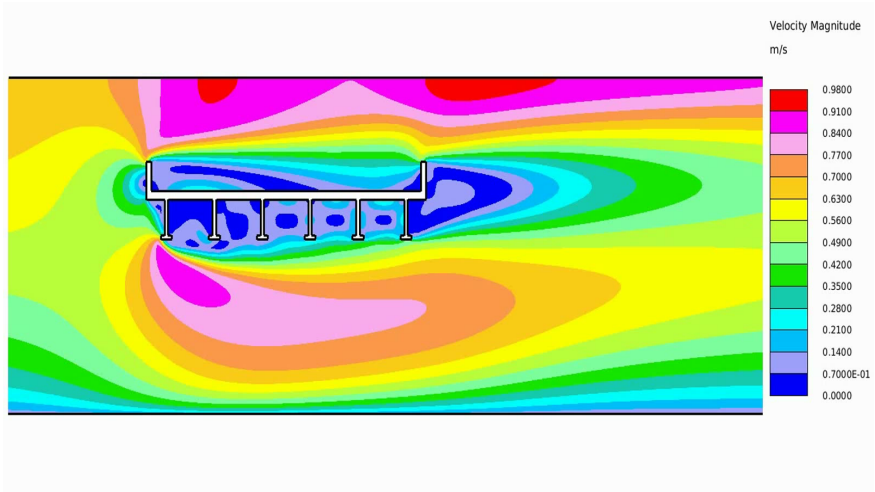
Flow in a scour hole in front of a pier

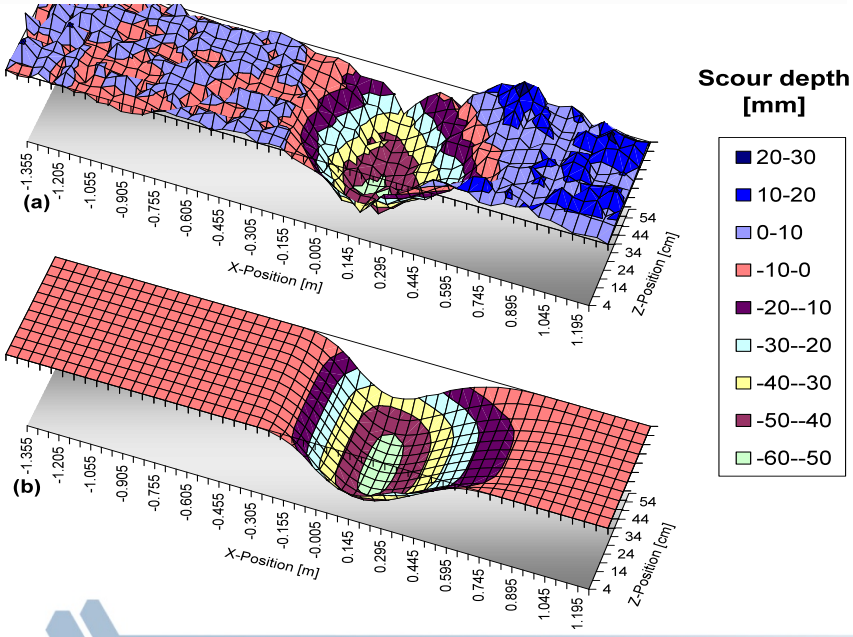
- Wind Loads on Highway Signs, Traffic Signal Structures, Bridge Cables, others
  - Argonne and TFHRC
- Salt Spray from Trucks on Weathering Steel Bridges
- Flow and Fish Passage through Culverts
  - TFHRC, Argonne, University of Nebraska

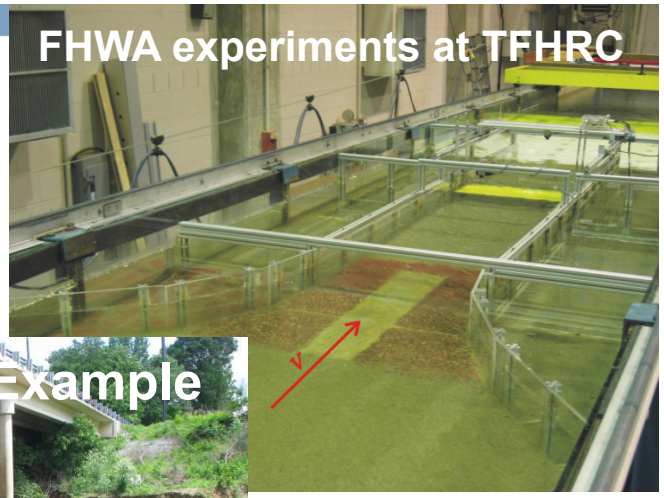
Tennessee May 2010 Superflood – 1000 Year Event



CFD - Turner Fairbank Highway Research Center, NIU, Argonne



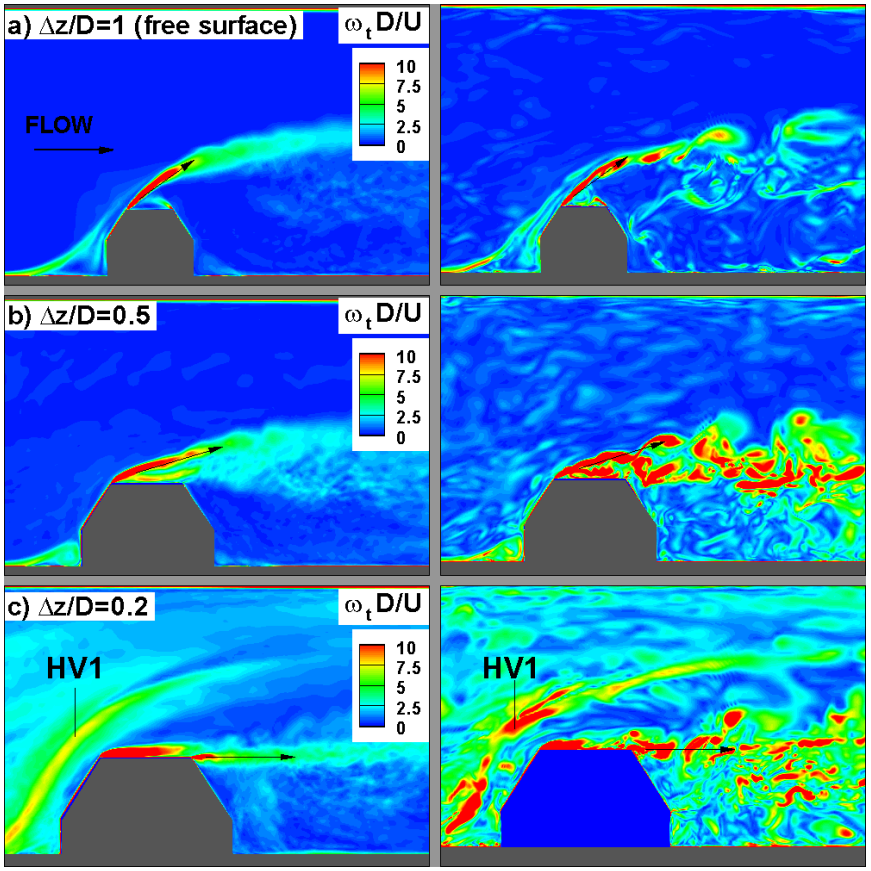


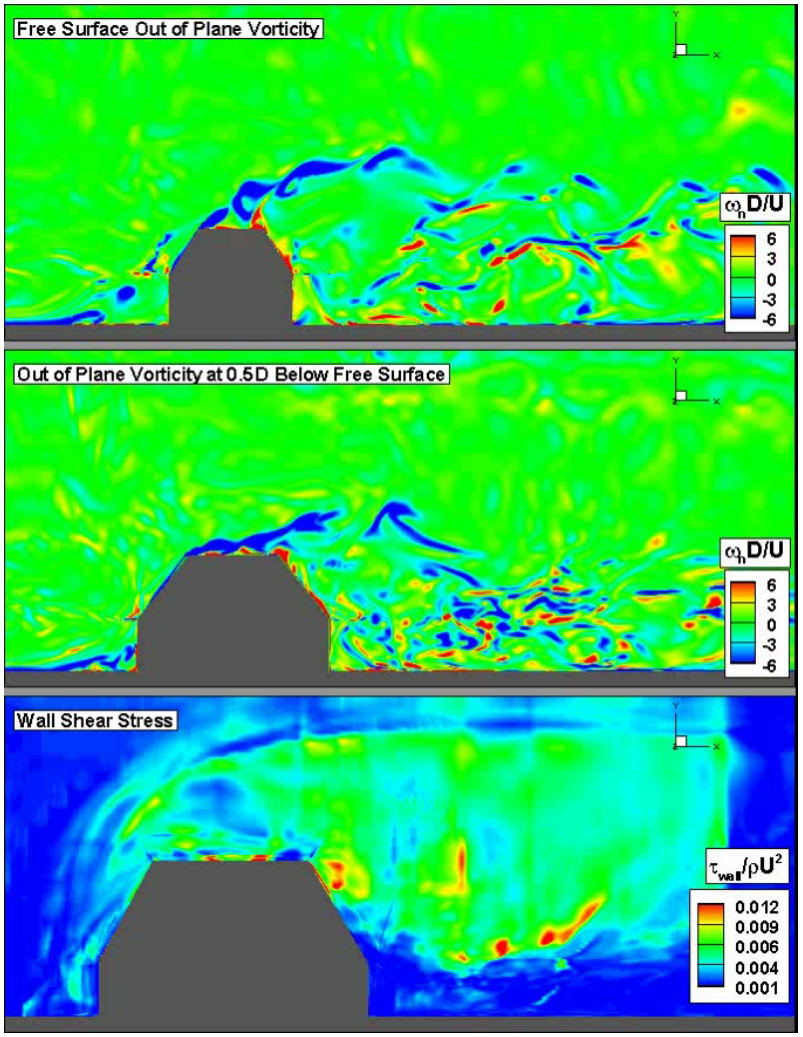


- Formation of scour holes in sediment under bridges during flood events
- Critical shear stress models to model the pickup of sediment and formation of holes
- Calibration of small models and scaling to a wide variety real world geometries
- Development of improved engineering guidelines for bridge inspectors and regulators

Cutting Edge CFD Analysis Platform at TRACC for Cluster Users

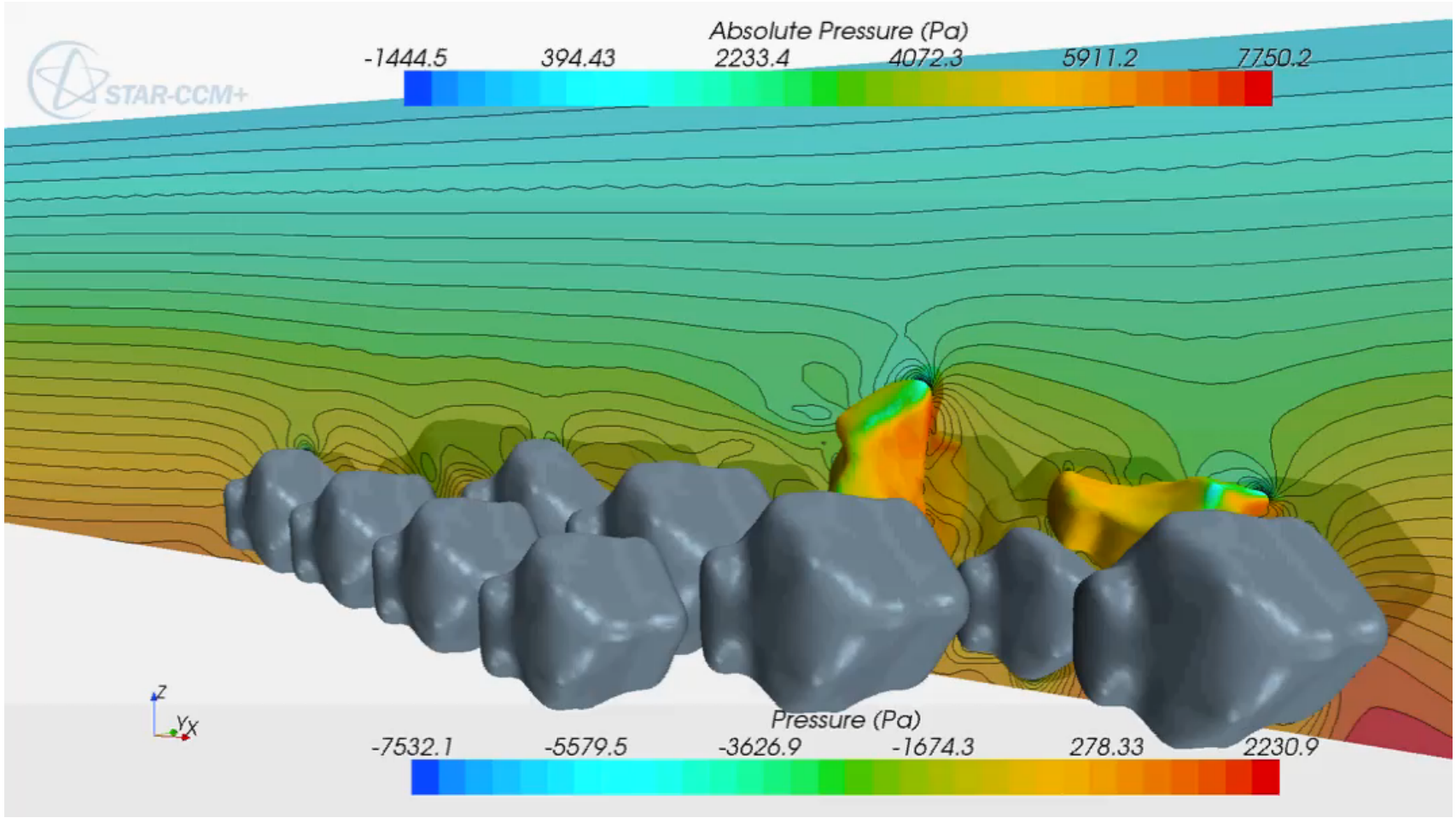
TRACC is providing a platform for cutting edge analysis, such as large eddy simulation, to provide much more detailed analysis results from CFD software in the transportation research area





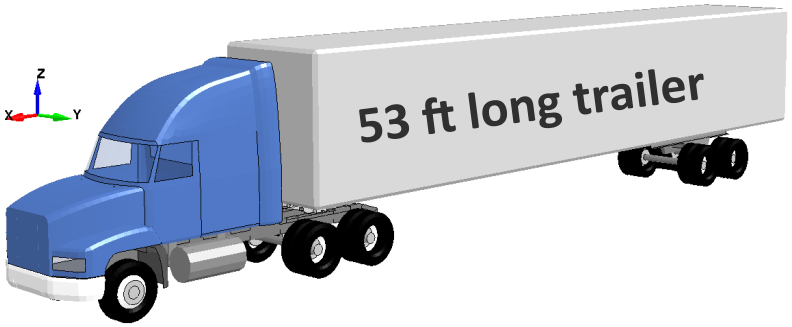
Modeling road salt spray at weathering steel bridges

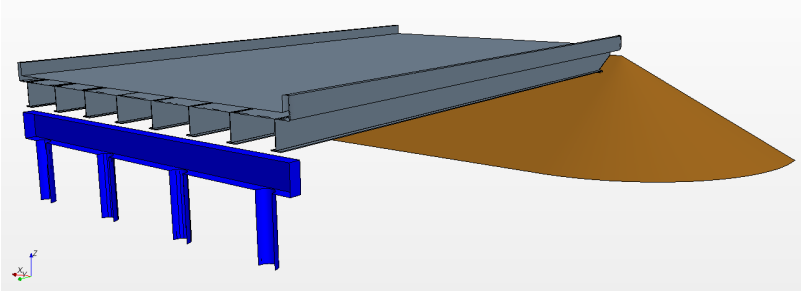
Riprap Foundation Armor Failure During Flood Flow Using Advanced FSI Coupling Between STAR-CCM+ and LS-DYNA Developed at Argonne



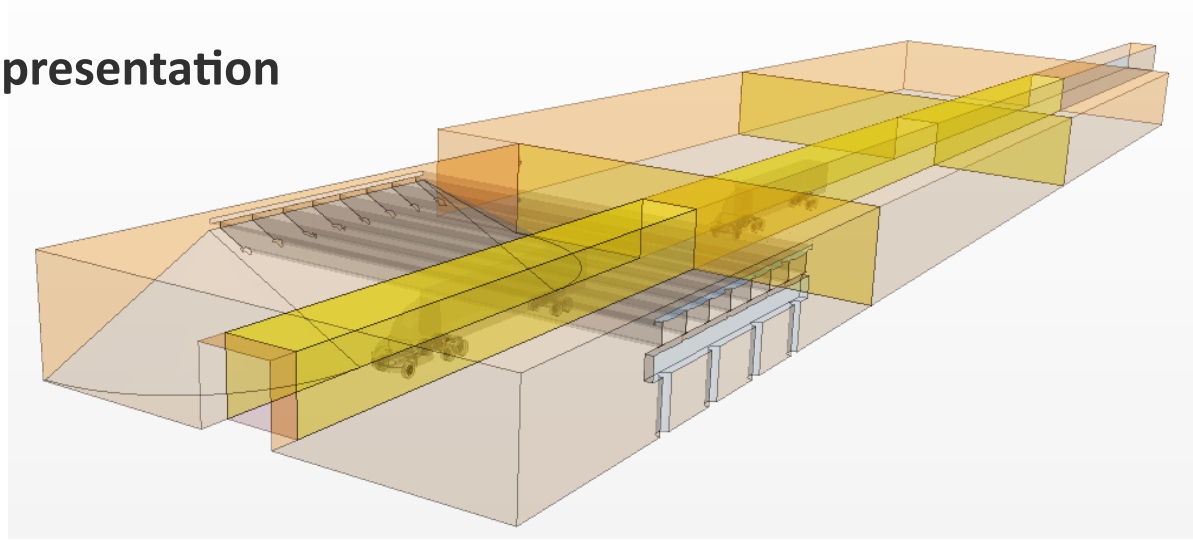
CFD model

- Truck Model Based on Mack CH 613 Tractor
- Bridge geometry based on blueprints
- Motion model based on sliding mesh concept
- Particle injectors located on curb side tire treads – to reduce computational cost

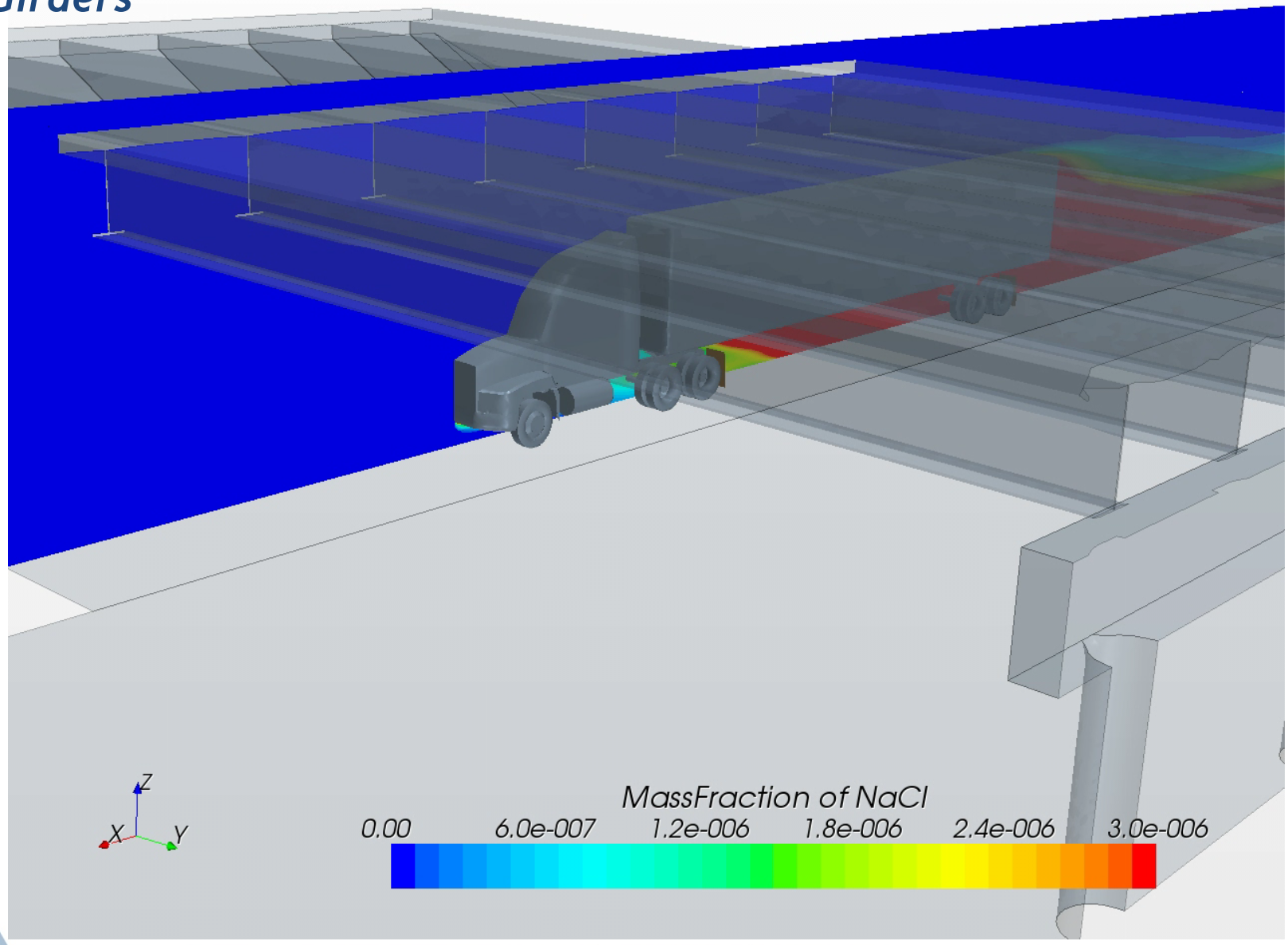




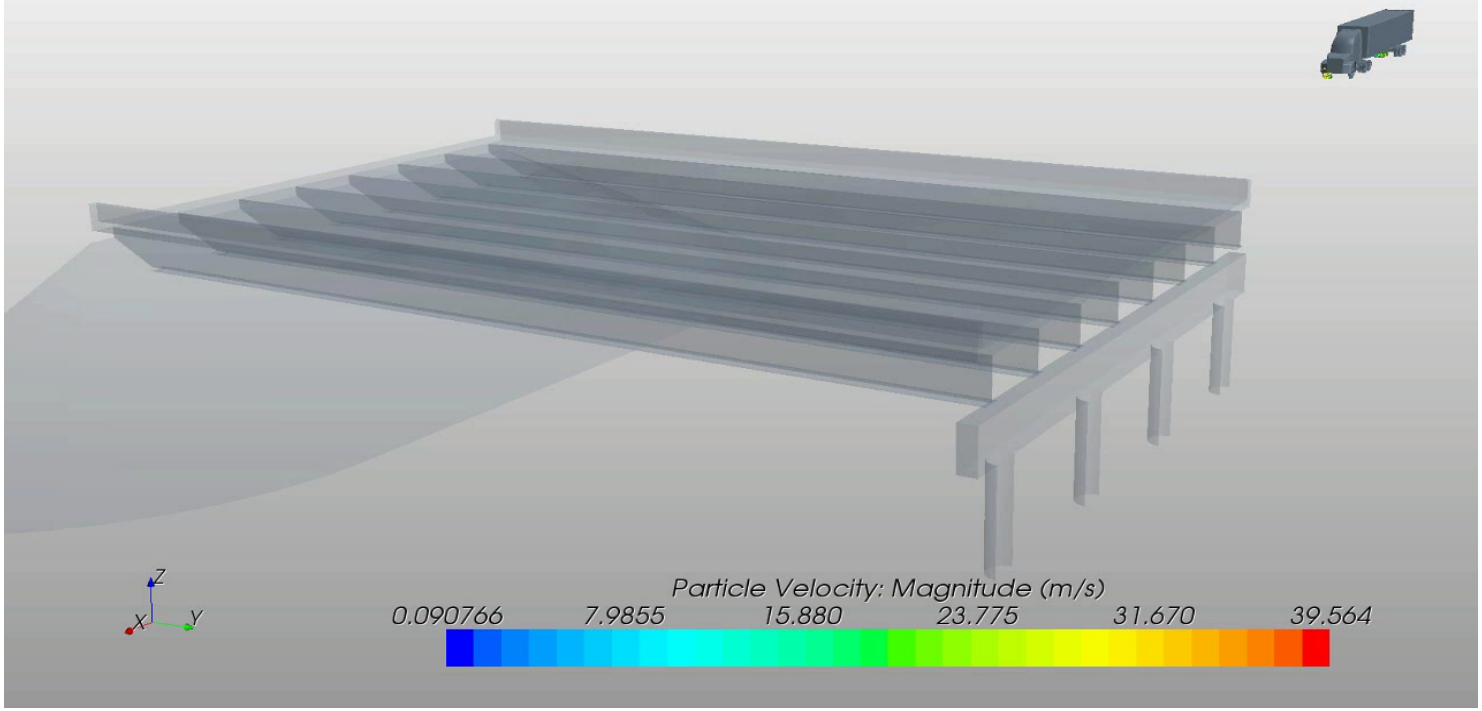
CFD representation



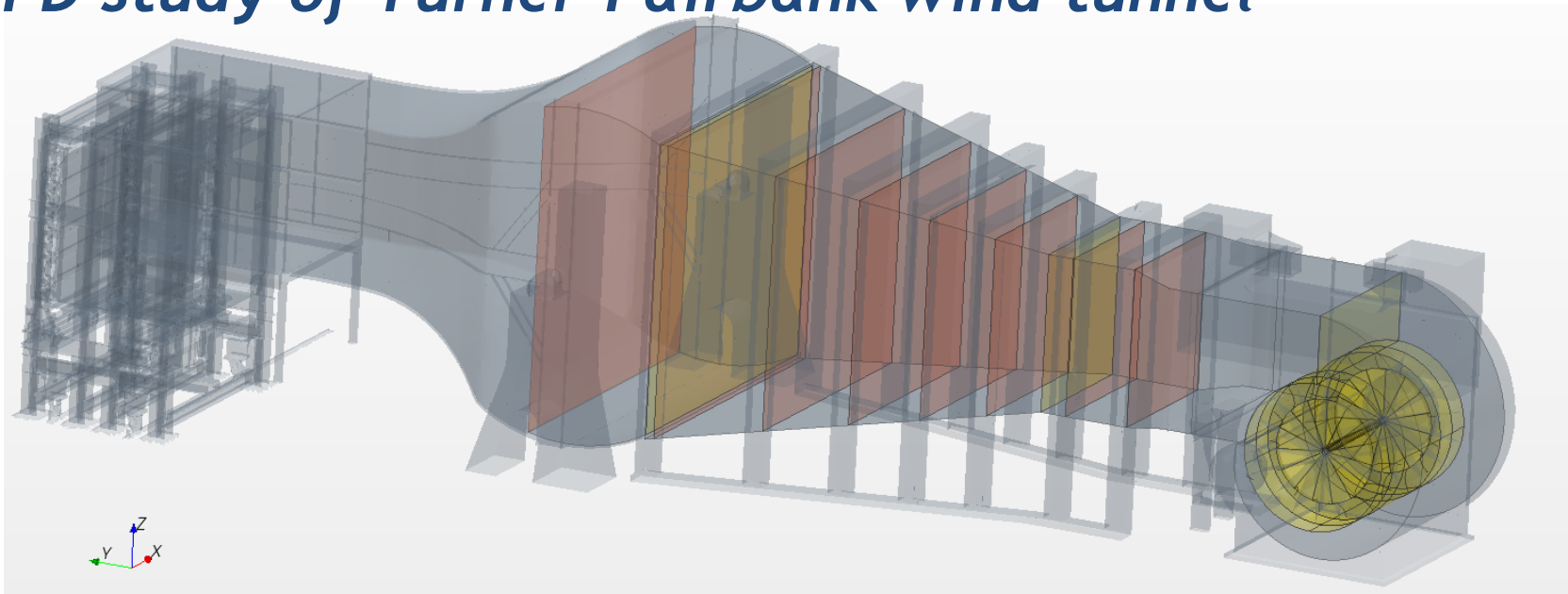
Simulation Of Salt Dust Picked Up By Trucks & Carried To Bridge Girders



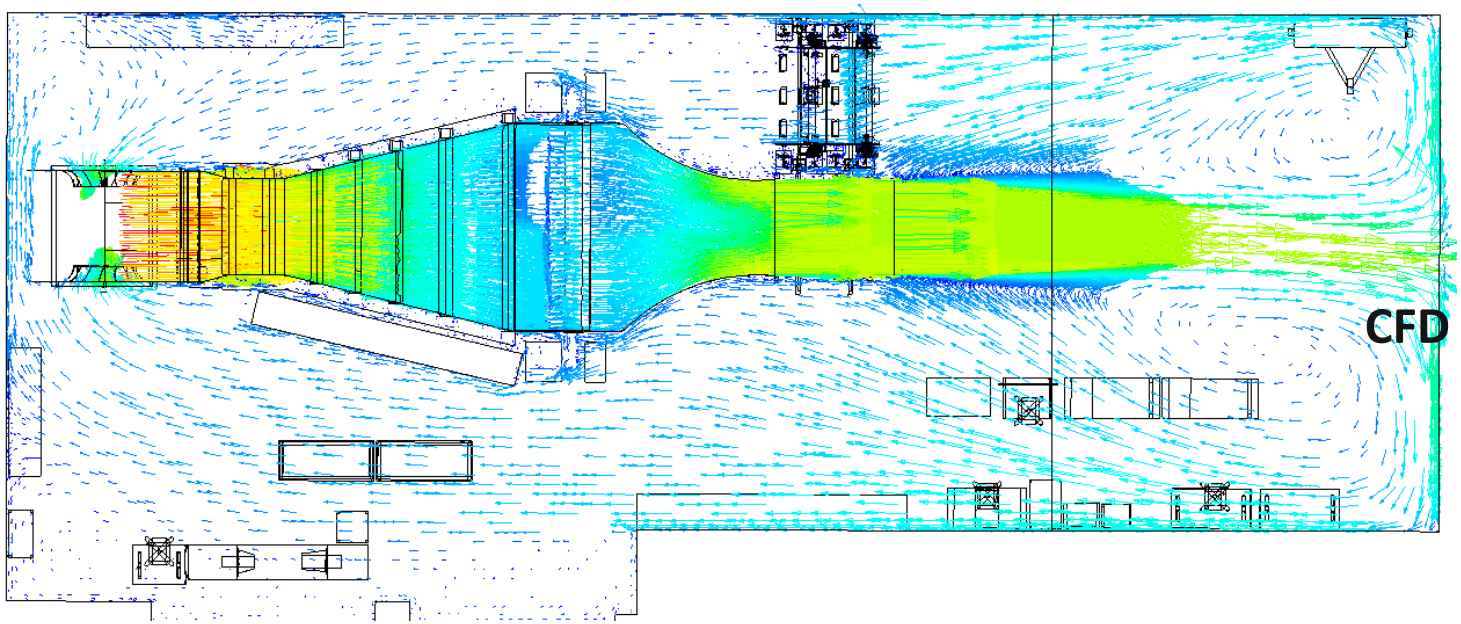
Computer Modeling and Analysis of Truck Generated Salt Spray under Bridges



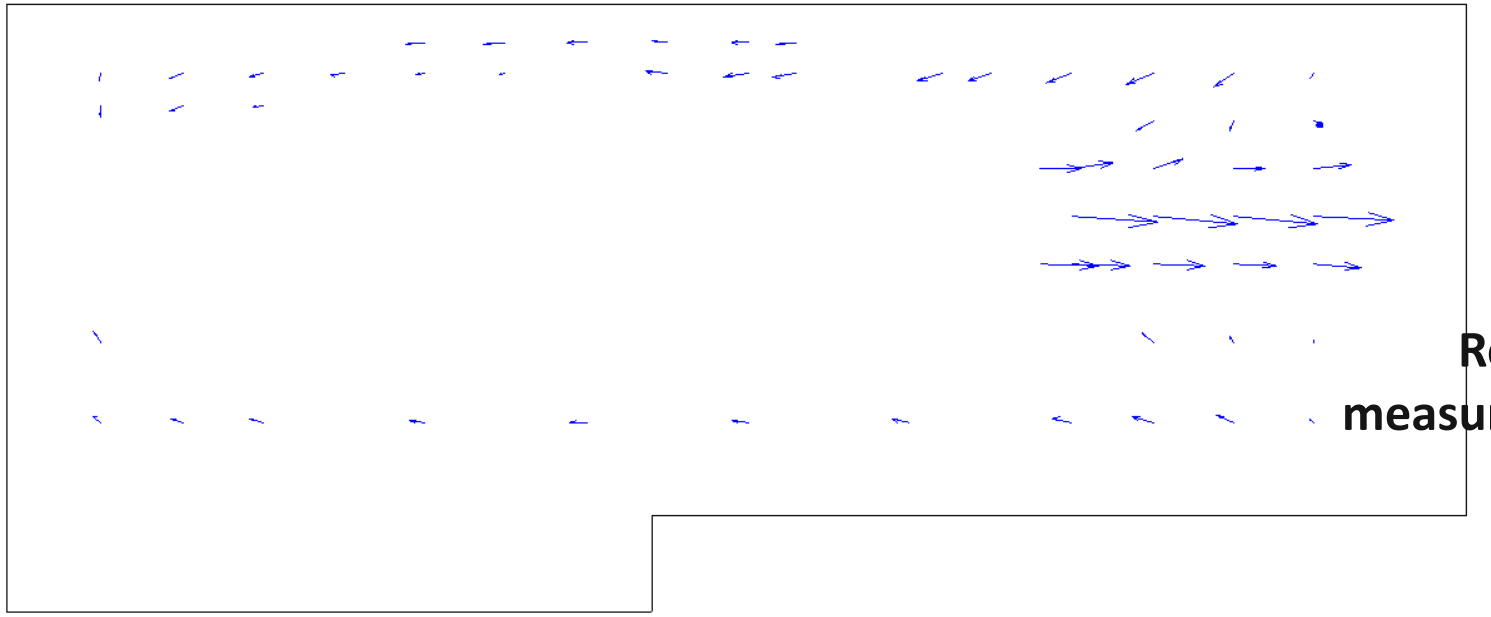
CFD study of Turner-Fairbank wind tunnel



Velocity distribution across the room



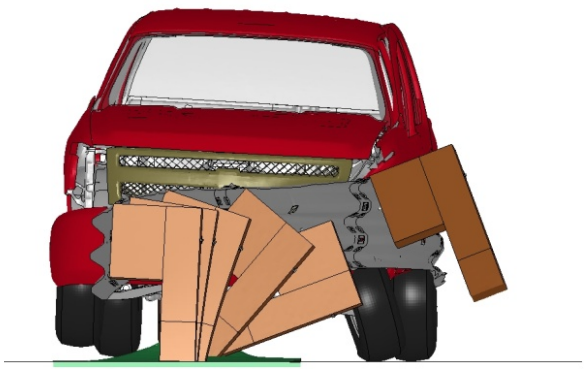
CFD Analysis

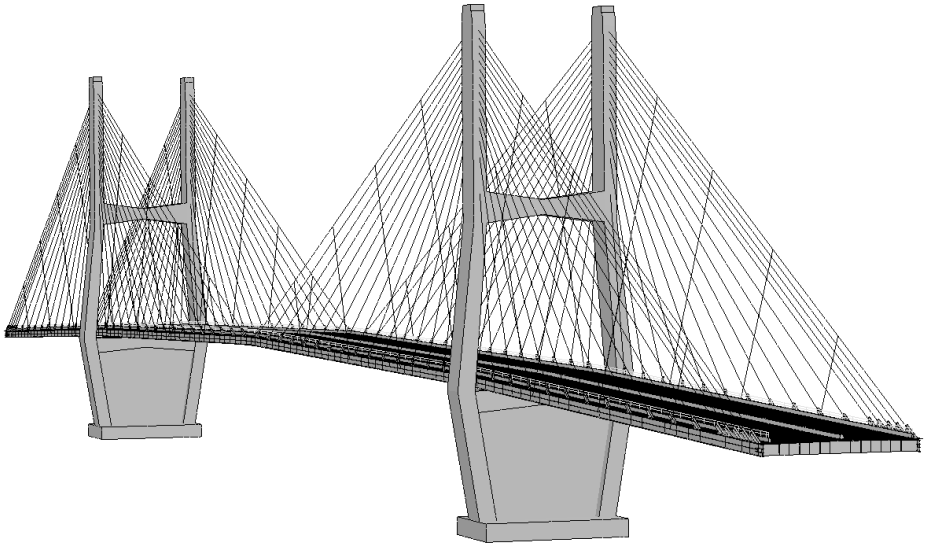


Real measurements

Argonne NATIONAL LABORATORY

Computational Structural Mechanics for Transportation Applications





In cooperation with the U.S. Department of Transportation

U.S. DEPARTMENT OF ENERGY

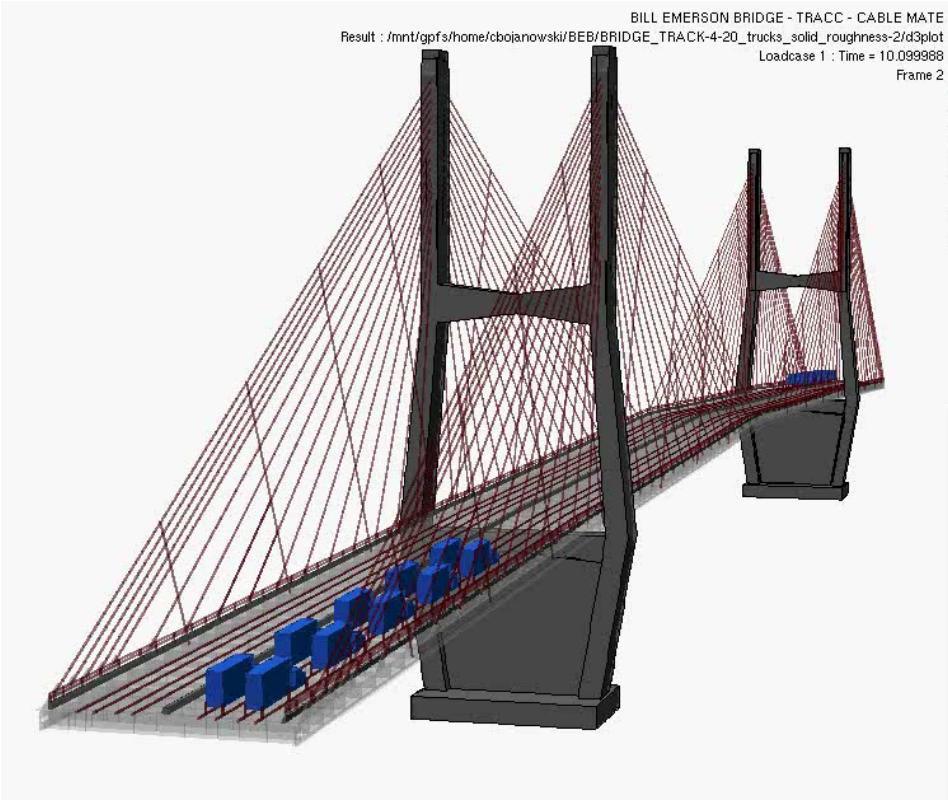
Computational Structural Mechanics Areas of Application

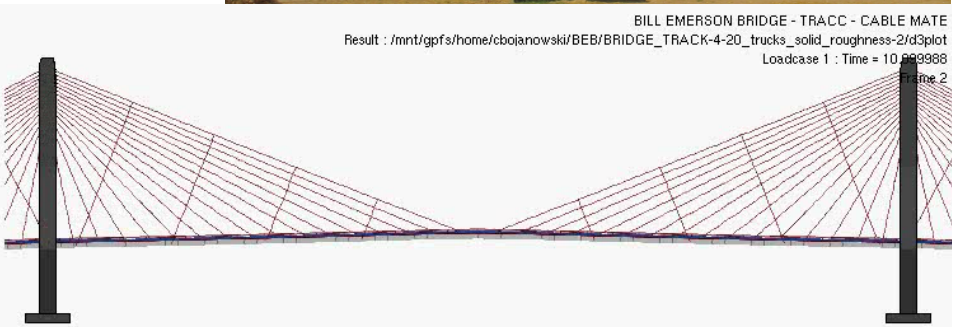
- TRACC's expertise:
  - Transportation Structures:
    - Analyzing extreme loadings on bridges (wind, earthquake, blast)
    - Stability of bridges in flood conditions using multi-physics approach
  - Vehicle Crashworthiness:
    - Supporting several crash related research projects
  - Fluid-Structure Interaction:
    - Analysis of transient deformations of structures resulting from action of surrounding fluid

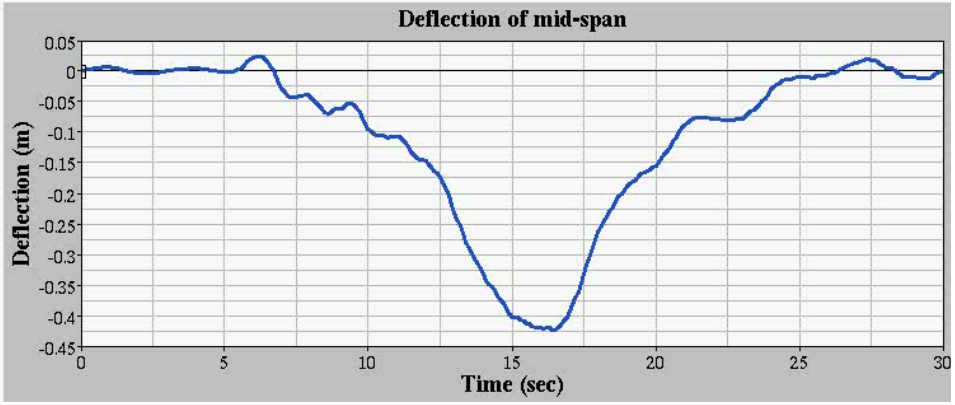
- TRACC's current users:
  - National Highway Traffic Safety Administration (NHTSA) - occupant safety assessment and crash biomechanics
  - University of Virginia - crash biomechanics
  - Florida State University - bus crashworthiness analysis

TRACC: Multi-purpose High Fidelity Bridge Models

- Integrated analysis
- Traffic load on bridges
- Wind forces on deck and cables
- Dynamic interaction with vehicles



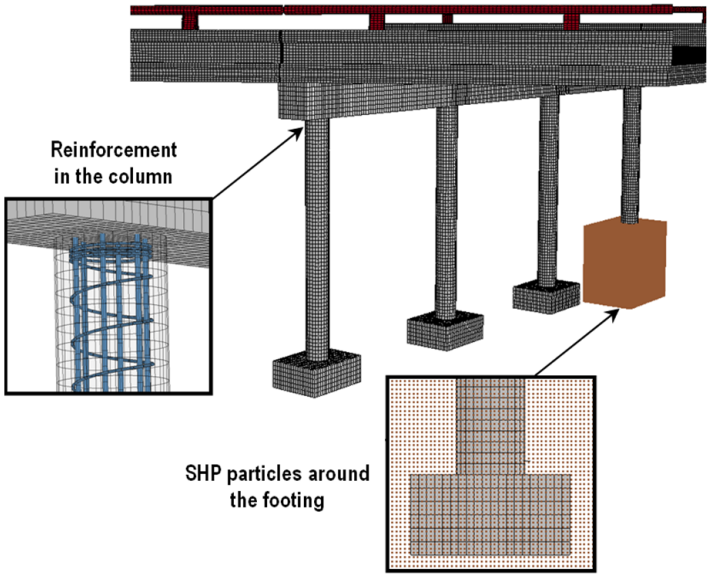




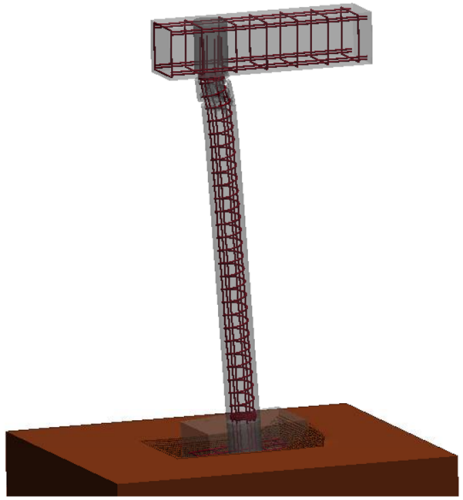
TRACC: Soil-Structure Interaction Example

- Develop simulation capabilities for modeling bridge pier failure during riverbed scour that occurs during flash floods

Finite Element model of Bridge



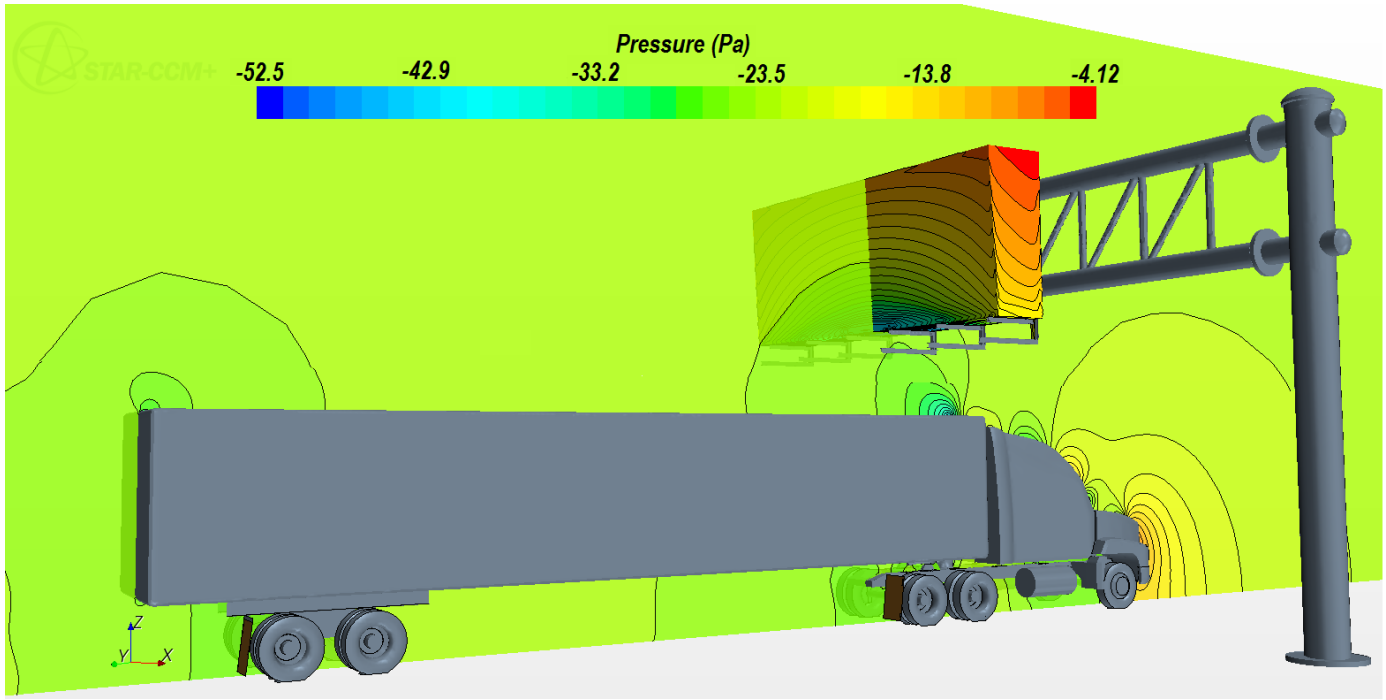
Failed column due to lateral load

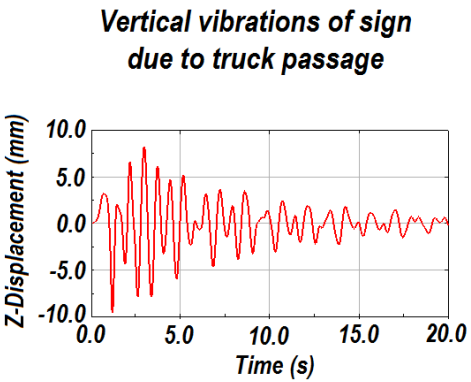


- Use hybrid formulations (Lagrangian plus Smooth Particle Hydrodynamic) to simulate the failure of a bridge pier to hydraulic loading during flood events
- Soil-structure interaction treatment with large deformations

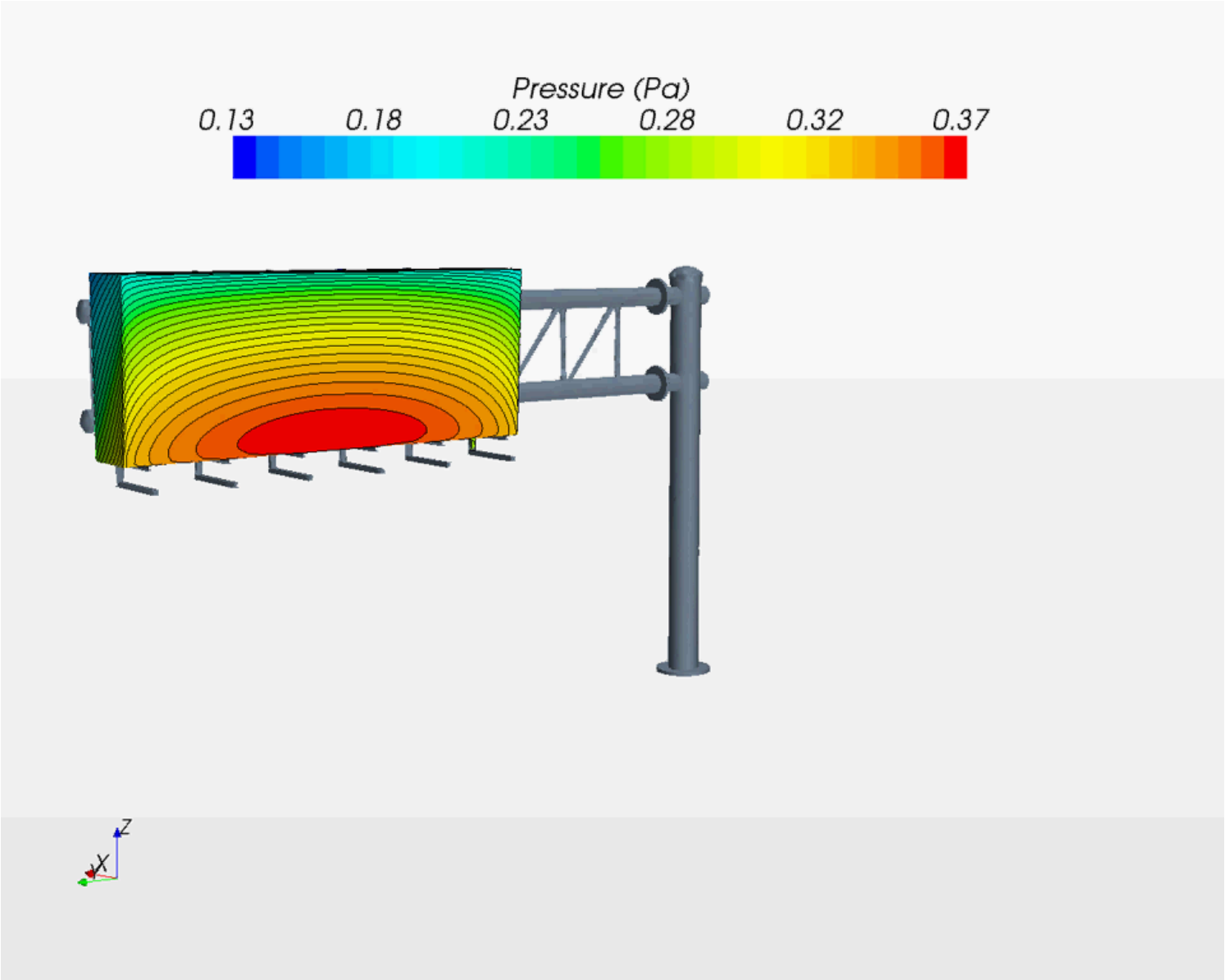
TRACC: Road Sign vibration due to truck passage CFD and CSM coupling example

- Developing coupling methods between STAR-CCM+ (fluid mechanics code) and LS-DYNA (structural code) for fluid-structure interaction (FSI) problems
- Analyze transient vibration of signs due to the passage of trucks





CFD Study on Sign vibration due to passing trucks



TRACC: Road Sign Vibration Due to Truck Passage CFD and CSM Coupling Example

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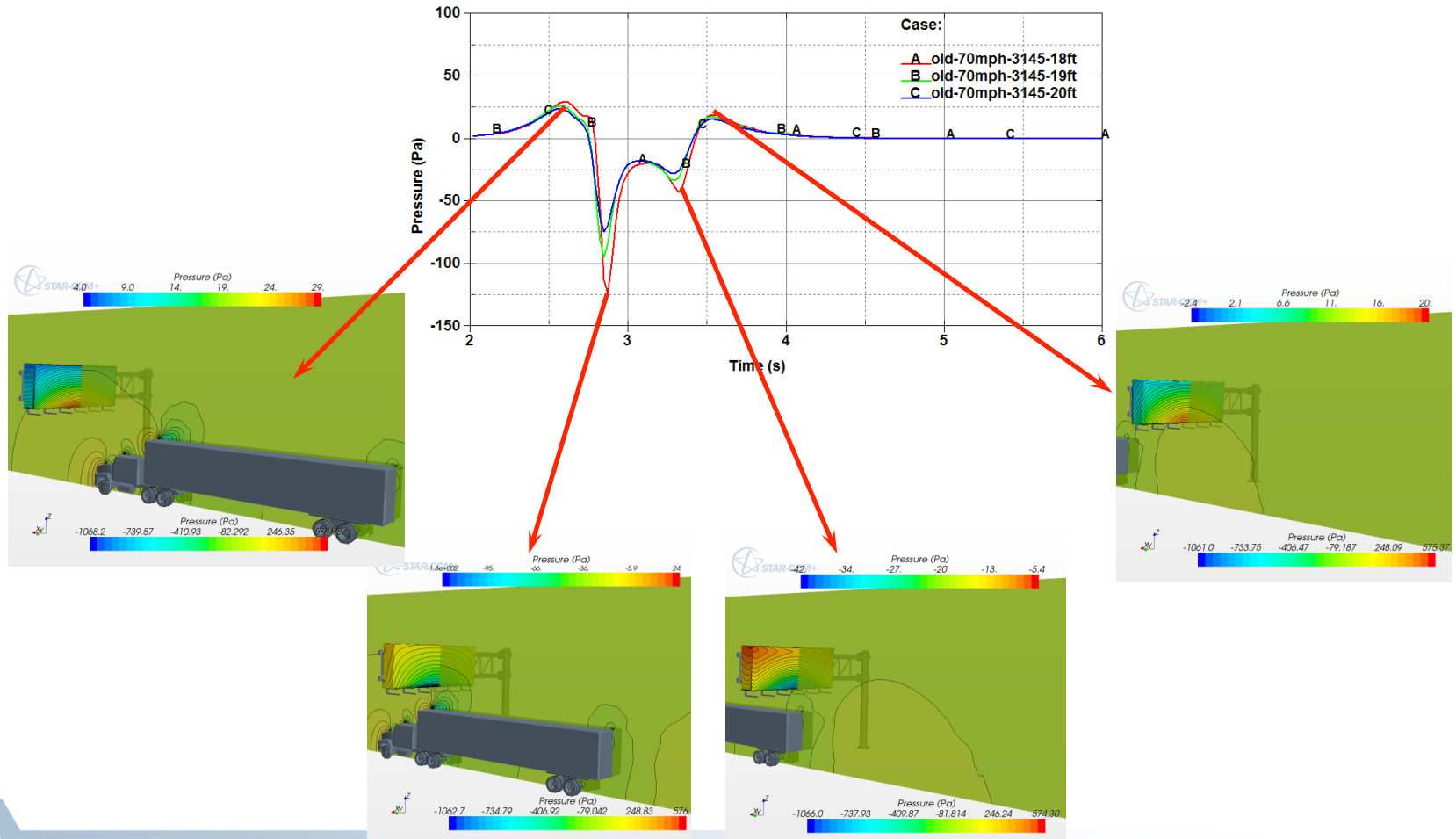
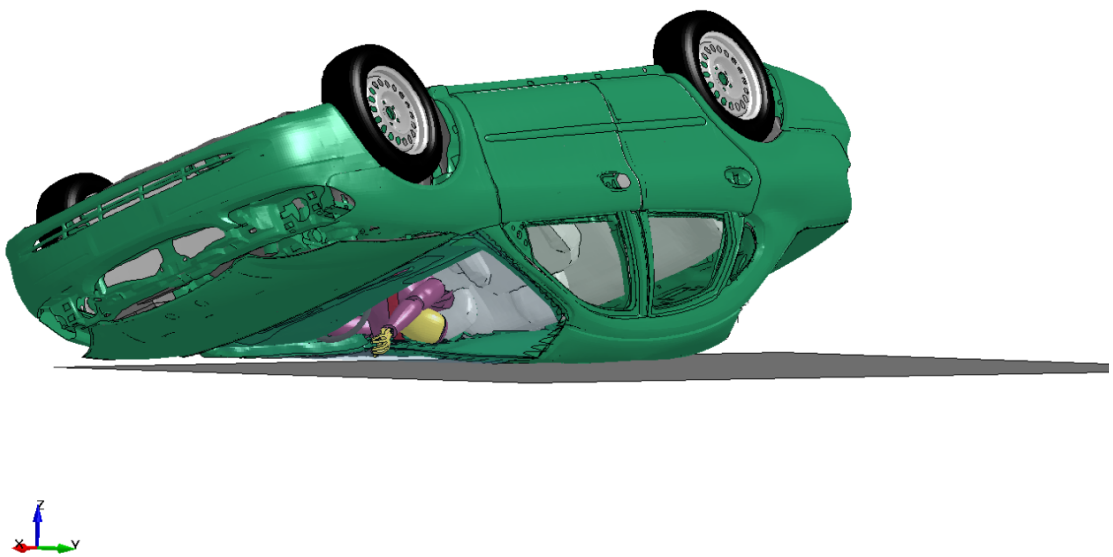
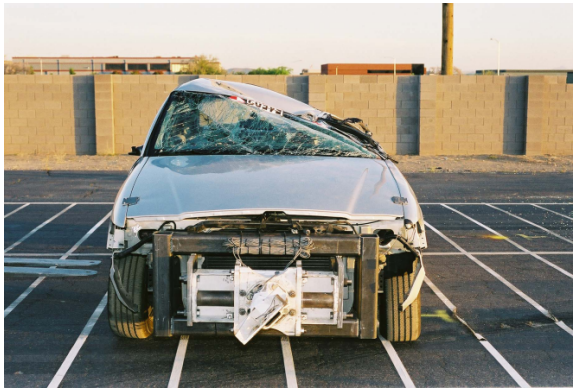


TRACC Users' work: NHTSA - Controlled Rollover Impact System

- CRIS provides a repeatable test technique for evaluating roof-to-ground impact in a vehicle rollover event
- NHTSA is using TRACC resources to supplement expensive experiments with multiple crashworthiness simulations

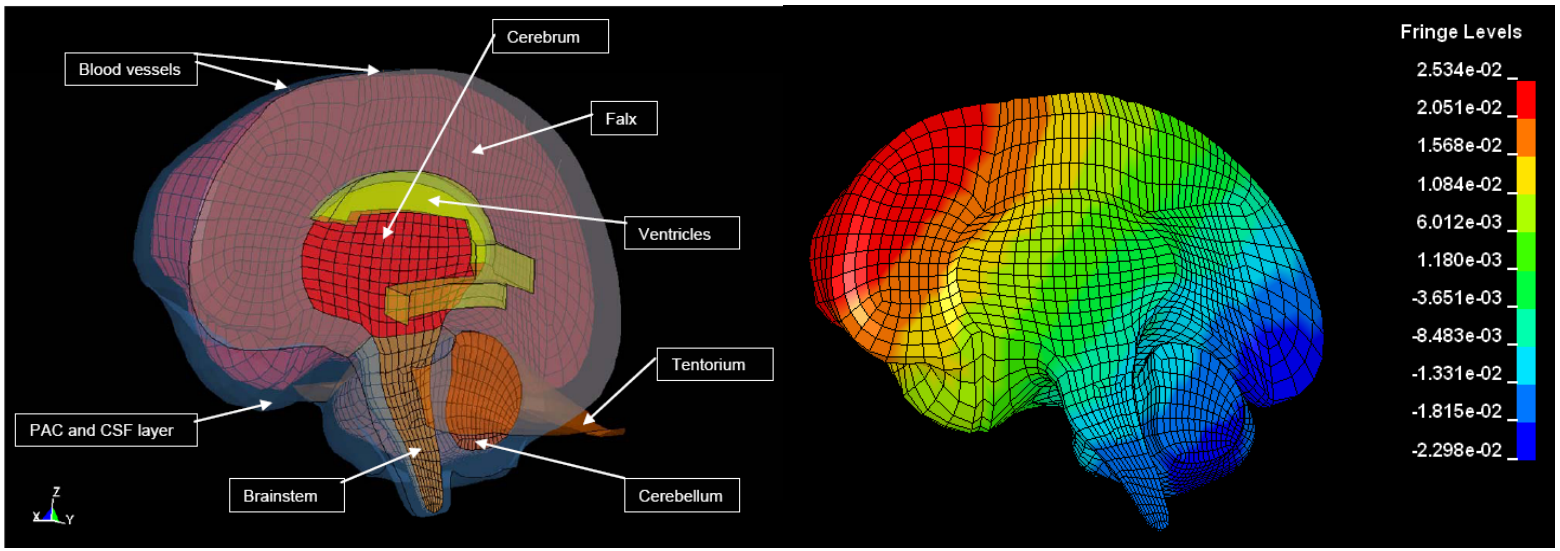
THOR dummy inside Ford Taurus FE model





TRACC Users' Work: NHTSA - Traumatic Brain Injury (TBI)

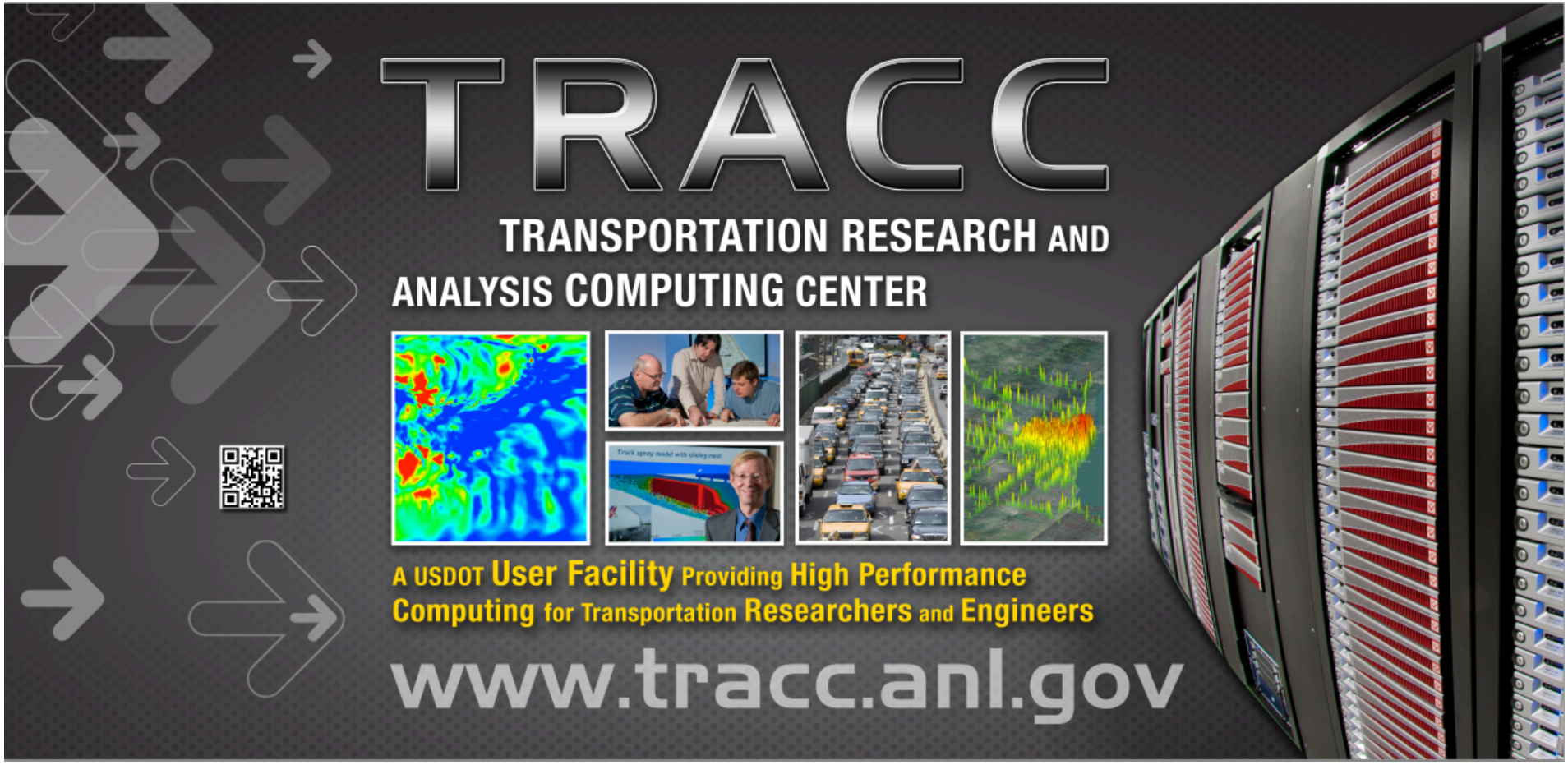
- Motor vehicle crashes remain one of the major causes of TBI in the US only second to falls.
- Finite element models have proven to be viable tools to better understand the biomechanics of TBI.
- Probabilistic analyses are being performed to identify important random variables and their effect on response distributions.
- Defining Characteristic: Small FE model, short compute time but hundreds of runs.



Computing, Networking, and Training and Collaborative Facilities

In cooperation with the U.S. Department of Transportation

TRACC'S Computing Facility



TRACC High-Performance Cluster Computers

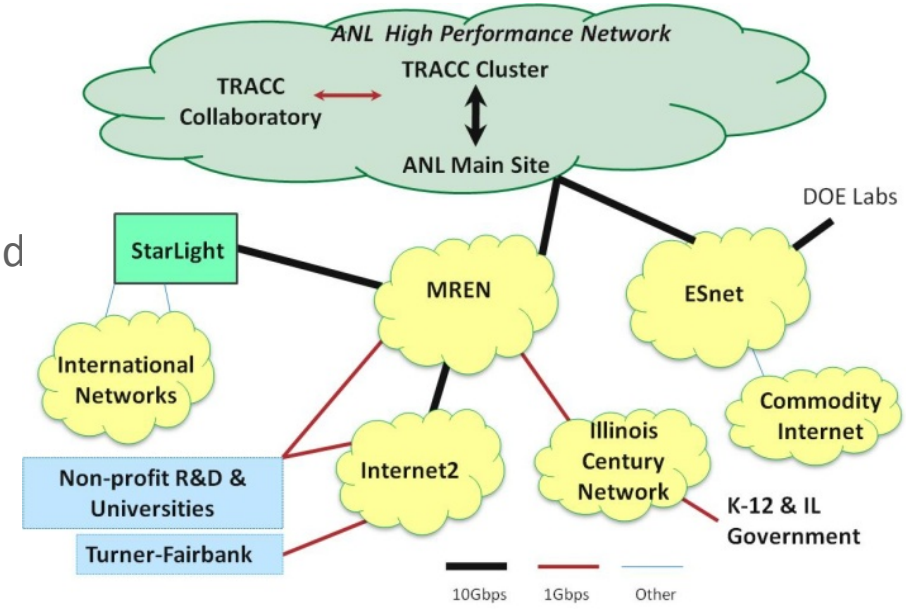
Zephyr

Item/Cluster	Zephyr	Phoenix
Nodes	92	128
Processors per node	2	2
Total Processors	184	256
Processor Type	AMD 6273, 16 core, 2.3 GHz	AMD 2378, quad core, 2.4 GHz
Cores per Processor	16 (8 modules each capable of executing 2 integer or 2 floating point operation)	4 cores each capable of executing 1 integer or 1 floating point operation
Total Cores	2944	1024
RAM per node	88 nodes at 32 GB, 2 at 64 GB, & 2 at 128 GB	124 nodes at 8 GB and 4 at 32 GB
RAM Speed	1600 MHz	667 MHz
Disk storage per node	One TB	200 GB
Login Nodes	2	3
Administrative Nodes	2	2
Application Node (Sandbox)	1	0
Statistics Gathering Node	1	1
I/O Nodes	1	4
Ethernet Interconnect	Gig-E/Dual 10 Gig uplink	Gig-E/Dual 10 Gig Uplink
Infiniband Interconnect	QDR 40 Gbps	DDR 20 Gbps
File System Usable Storage	Lustre-based, 120 TB/RAID6 storage	GPFS-based, 90TB formatted capacity
OS	CentOS/Linux 6.2	Red Hat Enterprise Linux 4.8
Tape Storage and Backup	Shared 160 TB Tape Library	

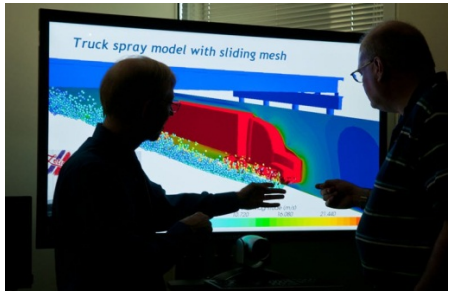
Phoenix

TRACC Network Connectivity

- TRACC is a part of the Argonne advanced fiber optic-based network



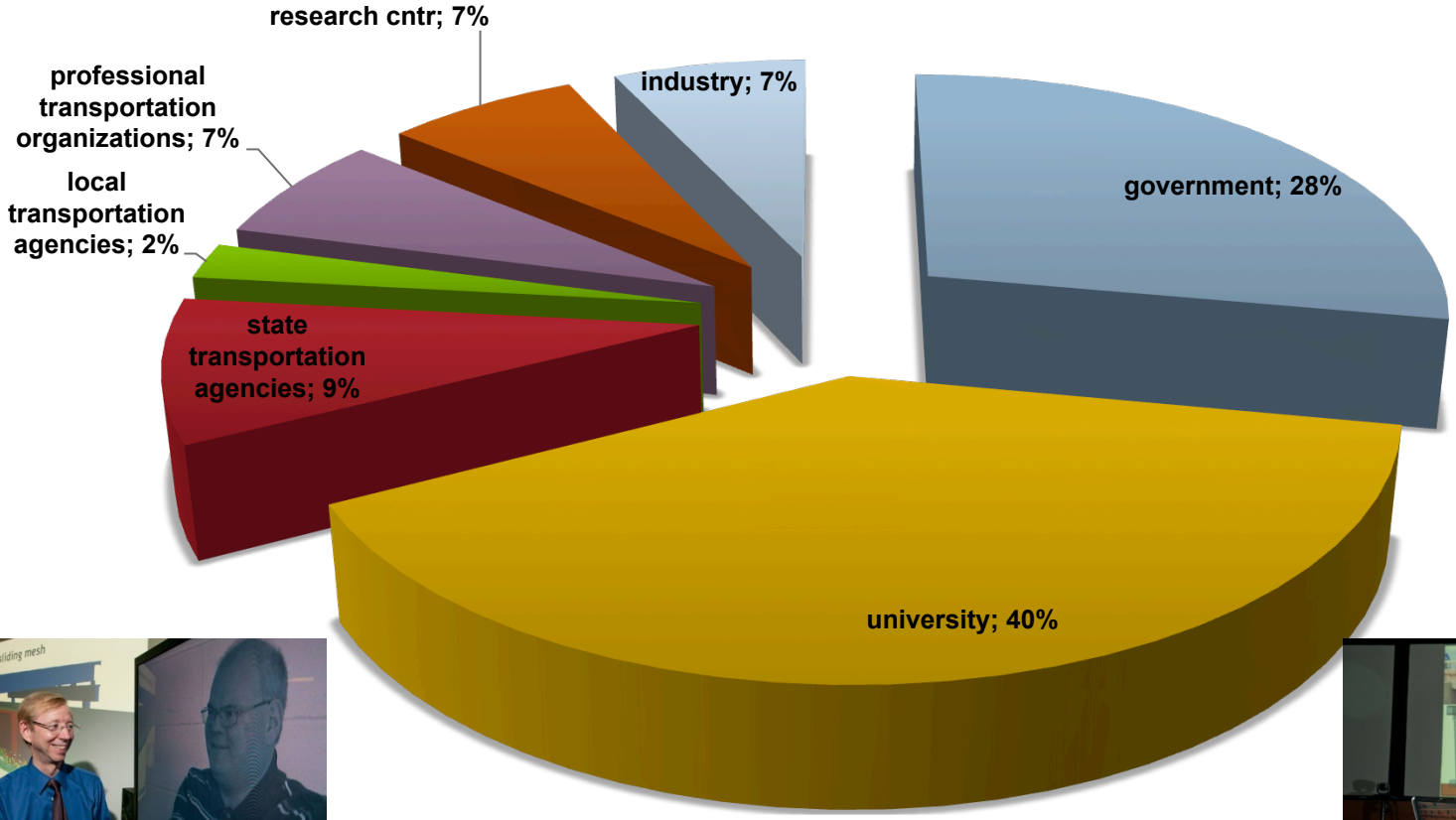
- TRACC, via the Argonne network, has network access to university, federal, state and local, and commercial transportation research centers world-wide via:
  - The Department of Energy network (ESnet)
  - The Metropolitan Research and Education Network (MREN)
  - The research and education network, Internet2
  - StarLight, an international network connection point



TRACC User Profile

TRACC Cluster User Groups

January - March, 2011

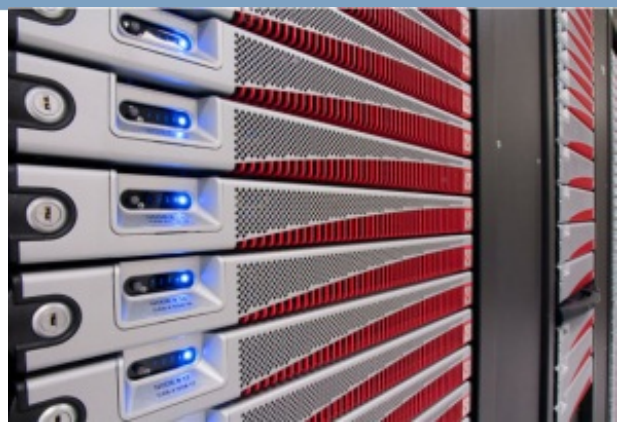


TRACC Training and Collaboration Facilities

Collaborative conferences, meetings and training with geographically distributed participants utilizing:

- High-speed network access to global research and education networks
- Video Teleconference systems
  - Web conferencing
  - High-Definition multi-point video and data sharing
- Large (60 person) Demonstration and Collaborative Training area
- Multimedia and Videoconferencing enabled conference room
- Two units, each capable of providing eight-site videoconferences

The TRACC Team



- Management
  - Hubert Ley (Director), Penny Kolpacki
- Operations
  - Larry Amiot, Joe Reitzer
- System Administration
  - Waldemar Nowakowski, Bob Schmitt
- Current Targeted Technical Disciplines
  - *Structural Mechanics*
    - Cezary Bojanowski
  - *Fluid Dynamics, Aerodynamics*
    - Steve Lottes,
  - *High Fidelity Transportation Simulations*
    - Vadim Sokolov, Michael Hope, Joshua Auld, Bo Xu
- Key USDOT Partners
  - Federal Highway Administration (FHWA)
    - Office of Planning (OoP)
    - Turner-Fairbank Highway Research Center (TFHRC)
  - National Highway Traffic Safety Administration (NHTSA)