University Transportation Center for Underground Transportation Infrastructure (UTC-UTI)

Marte Gutierrez, Ph.D.
James R. Paden Distinguished Professor
Civil and Environmental Engineering
Colorado School of Mines
Golden, CO 80401
E-mail: mgutierr@mines.edu

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UTC – University Transportation Center for
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University Transportation Center for Underground Transportation Infrastructure (UTC-UTI)

- Tier 1 University Transportation Center (UTC) funded under the 2016 DOT UTC Competition.

- Addresses the FAST Act Research Priority Area: "Improving the Durability and Extending the Life of Transportation Infrastructure."

- Budget is $7.5 million for five years (2017-2022). 50% required cost match (in kind and/or cash).

- Participating Institutions: Colorado School of Mines (Lead Institution), California State University Los Angeles (Minority Serving Affiliate), and Lehigh University (Affiliate).

UTC-UTI builds upon the strong foundation of the Center for Underground Construction and Tunneling (CUC&T) at Colorado School of Mines (Dr. Mike Mooney, Director), and cements Mines as the leading place in the world for UC&T research and education.

ground
under
Center for Underground
Construction & Tunneling

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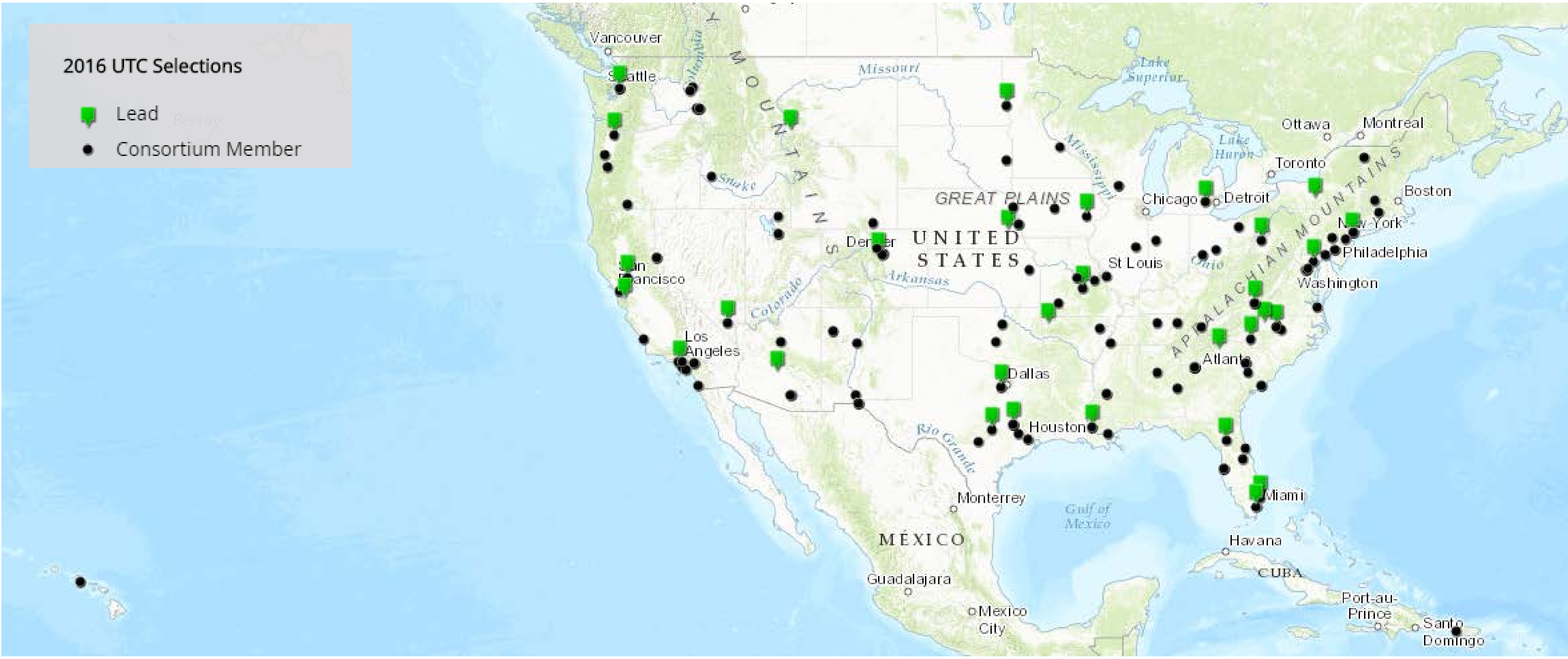
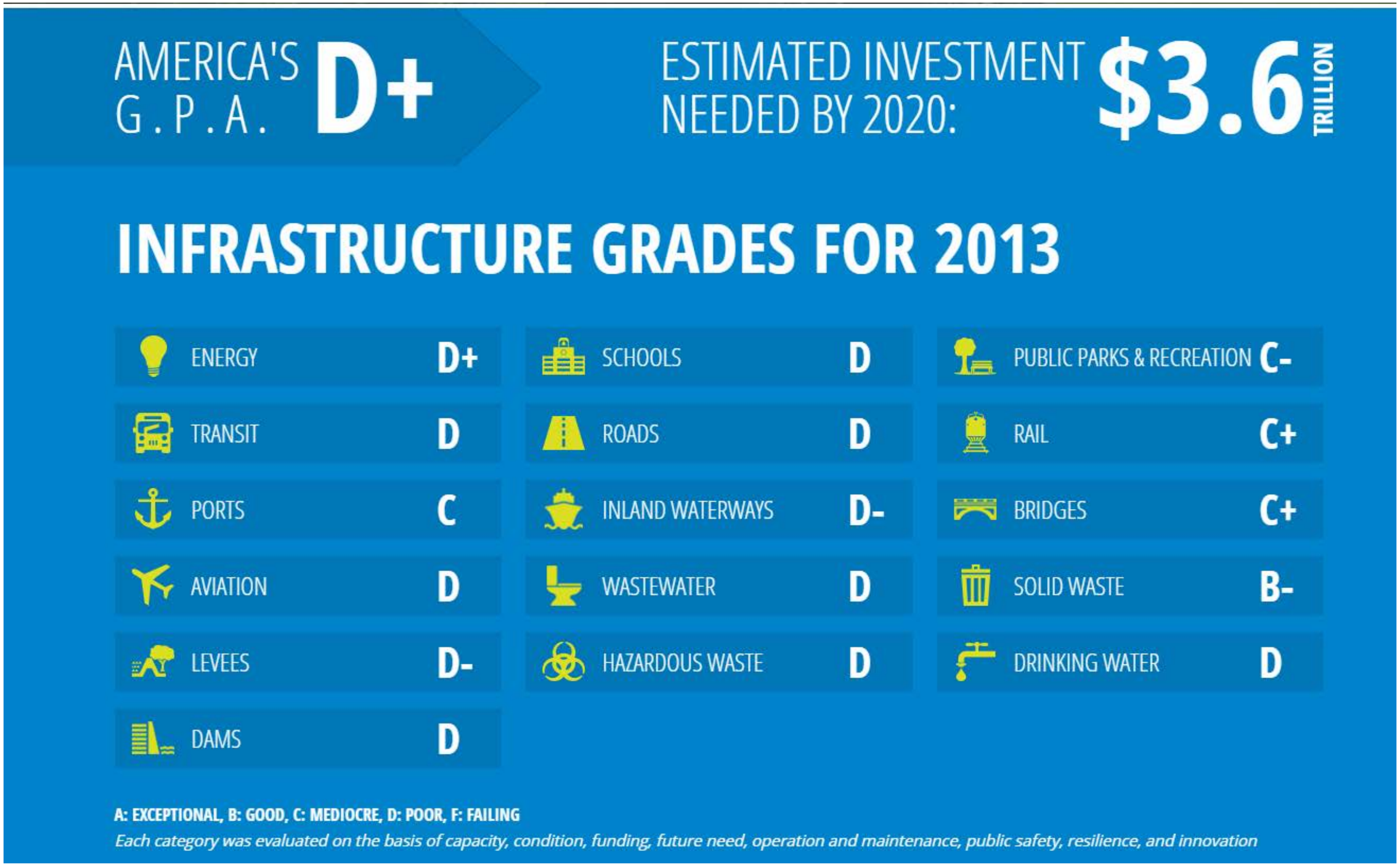
Locations of the 2016 UTCs



- 32 funded UTCs out of 212 applications.
- UTC-UTI is the first DOT Center at CSM.
- UTC-UTI is the first and only UTC focused on Underground Construction.
- CSM is the only Lead University for a UTC in CO.

ASCE Infrastructure Report Card



The FAST (Fixing America's Surface Transportation) Act

- Signed by President Obama on December 4, 2015 into law.
- The first federal law in over a decade to provide long-term funding certainty for surface transportation infrastructure.
- Authorizes $305 billion over fiscal years 2016 through 2020 for safety, public transportation, research and technology.
- Maintains focus on safety, streamlining of project delivery, and support for freight projects.
- Enables states and local governments to move forward with long term federal partnership for critical transportation projects.

Motivation for UTC-UTI

- Increased urbanization, population density and traffic congestion demand greater investments in underground transportation infrastructure (UTI) for highways, roads, railways, transit, parking and lifeline conveyance.
- Many areas in the US and the world are increasingly finding that underground transportation is one of the few options available.
- Underground transportation offers many positive aspects to long-term sustainability.
- Future UTIs will be deeper, larger, more complex, and will be for multiple uses.
- Many of existing UTIs in the US are beyond nominal expected life, and are in need of repair, retrofit or upgrade.
- New UTIs involve expensive and complex construction. Many instances of UTI projects have encountered major problems.
- Maintenance, retrofit and extension are costlier for UTIs than for other forms of transportation.

Underground transportation offers many positive aspects to long-term sustainability particularly in urban areas:

- Reducing traffic congestion and travel times.
- Reducing fossil fuel use and emissions.
- Positively affecting land use and development by reducing urban sprawl and traffic noise, and preserving landscape and biodiversity.
- Increasing the resilience of communities by providing reliable service safe from natural and anthropogenic hazards.

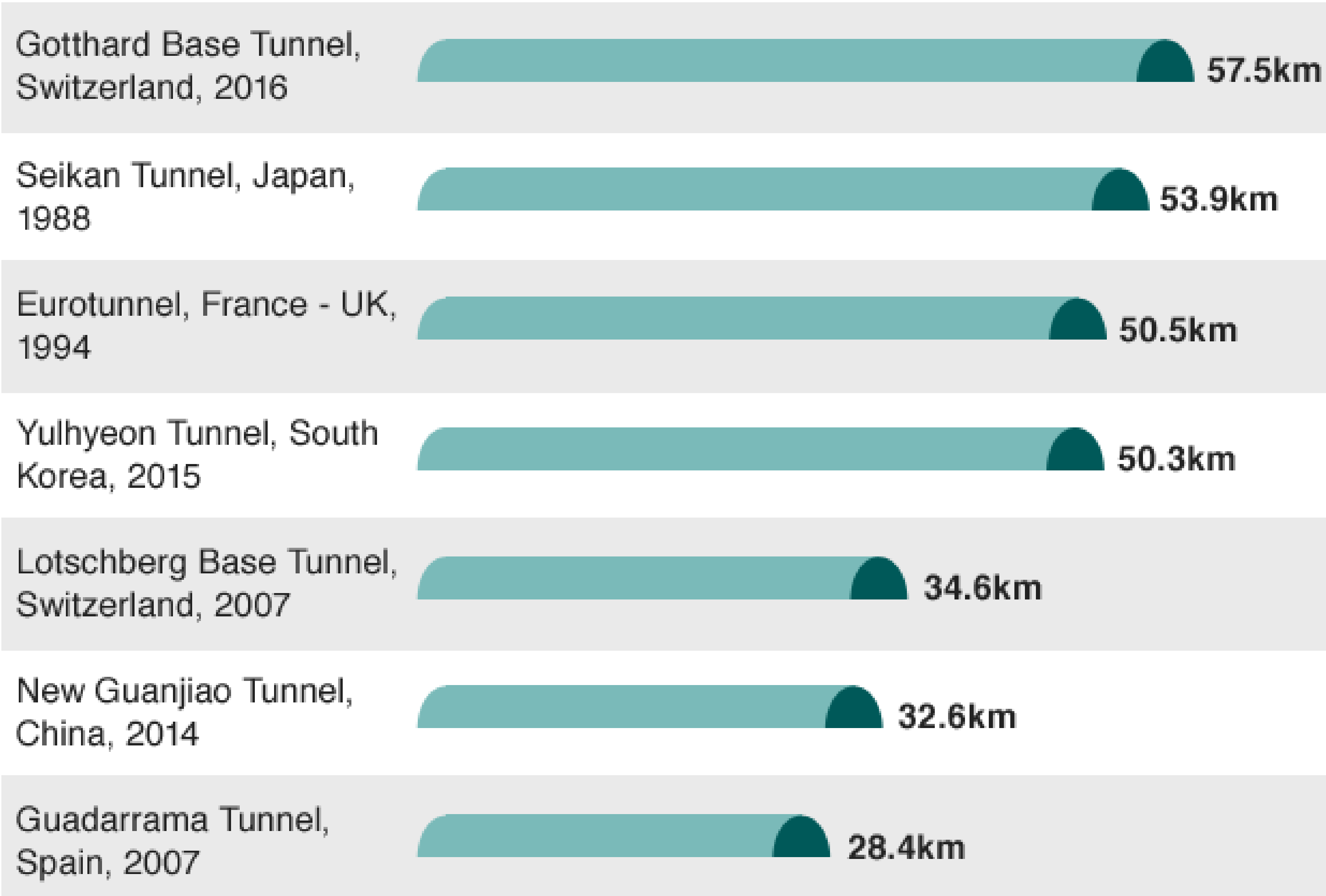
Many areas in the US and the world are increasingly finding that underground transportation is one of the few options available. Examples:

- **San Francisco Bay Area**: MUNI Central Subway, Silicon Valley Rapid Transit, Trans Bay Terminal…
- **Seattle:** Alaskan Way Viaduct, Downtown Seattle Transit Tunnel (DSTT), Sound Transit 3, …
- **New York City**: East Side Access, Second Avenue Subway, Number 7 Line Extension, ..
- **Washington, DC**: Dulles Transit Extension, Orange Line Extension, Silver Line Extension, Georgetown Tunnel and Inner Loop, …

- Future underground transportation infrastructure will be deeper, larger, more complex and will be for multiple uses.

The seven longest tunnels in the world

For trains and cars



Source: BBC

Gotthard Base Tunnel: World's Longest and Deepest Rail Tunnel

Gotthard Base Tunnel

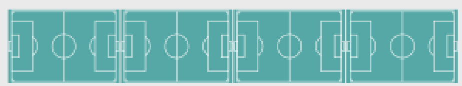
Construction time **17 years**

Length **57.1km**

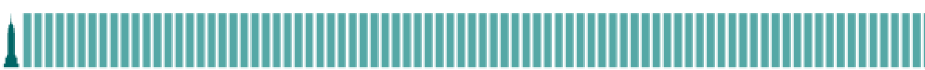
Cost **$12,500 million**
Equivalent to Nicaragua's gross domestic product

People employed **2,600**

Length of the drilling machine **410m**
Equivalent to four football fields



Amount of concrete used **4,000,000 cubic metres**
84 times the Empire State building



Maximum freight amount **377,000 tonnes per day**
or 15,080 shipping containers

Source: BBC

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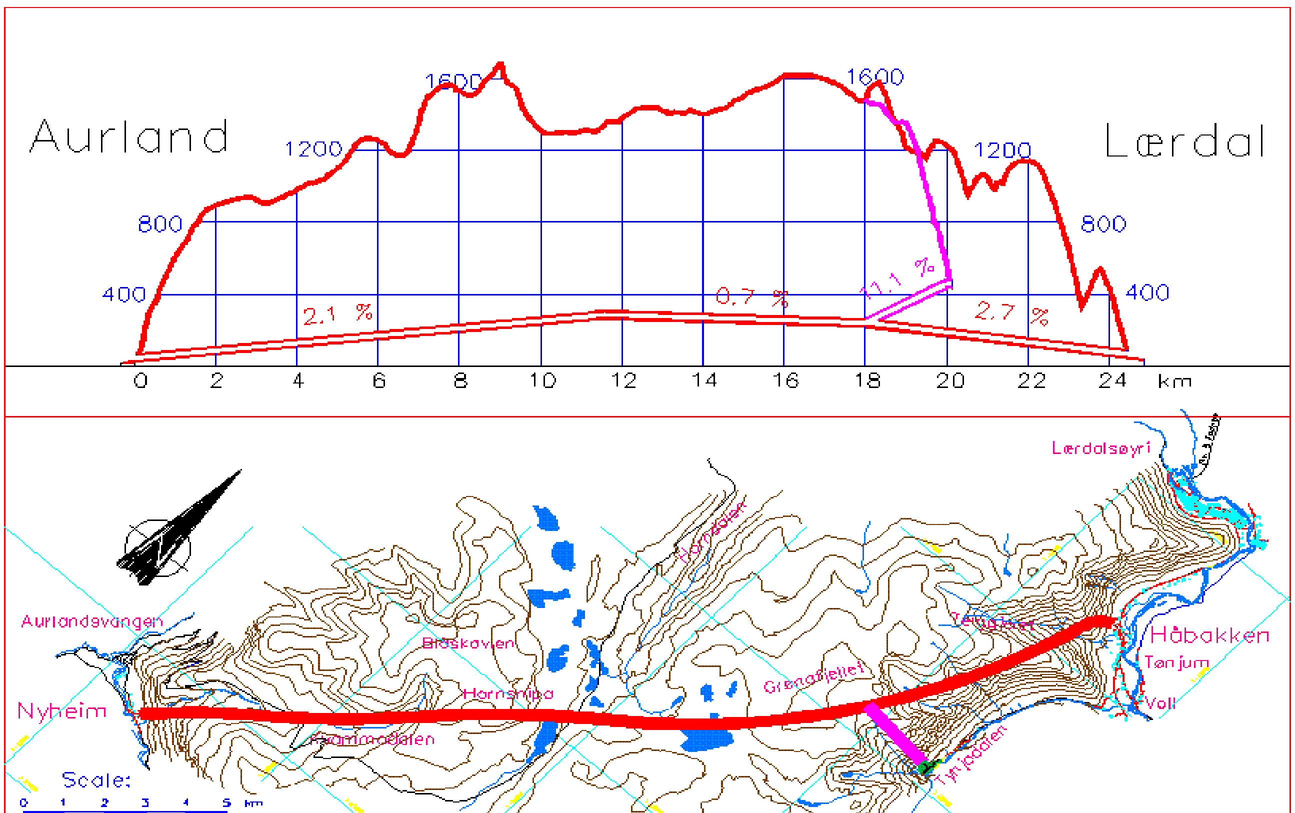
Lærdal Tunnel, Norway

- World's longest road tunnel
- Length = 24.5 km



Eiksund Tunnel, Norway

- World's deepest undersea tunnel
- 290 m below sea level
- 7.7 km long
- 16,000 m^2 of shotcrete
- 1,300 tons of explosives
- 5 million blast holes

Many of the existing UTI in the US are beyond nominal expected life and in need of repair or becoming functionally obsolete. Examples:

- Boston's Callahan Tunnel built in 1961.
- Amtrak's 104-year old Hudson River tunnels.
- Amtrak's tunnels in Baltimore and Potomac with tight curvatures and clearances that force trains to slow down to 30 mph.
- It is estimated that shutdown of train services along the Northeast Corridor alone can cost up to $100 million a day from congestion, productivity and other losses.

Even some newer project are rapidly deteriorating. Example:

The Cumberland Gap twin-bore tunnel in the Appalachian Mountain.

- Built in the 1990s for $290 million.
- Tunnel carries about 22,500 vehicles bi-directionally per day. About 10% of the traffic is trucks.
- Already needed major repairs in 2007 and 2012 due to approximately 7,400 ft^2 of pavement surface having voids beneath ranging from 0.5 to 40” deep.
- Closure for repair will entail cost of $1.1 million per day due to traffic delays.

Many instances of underground construction projects that have encountered major problems. Examples:

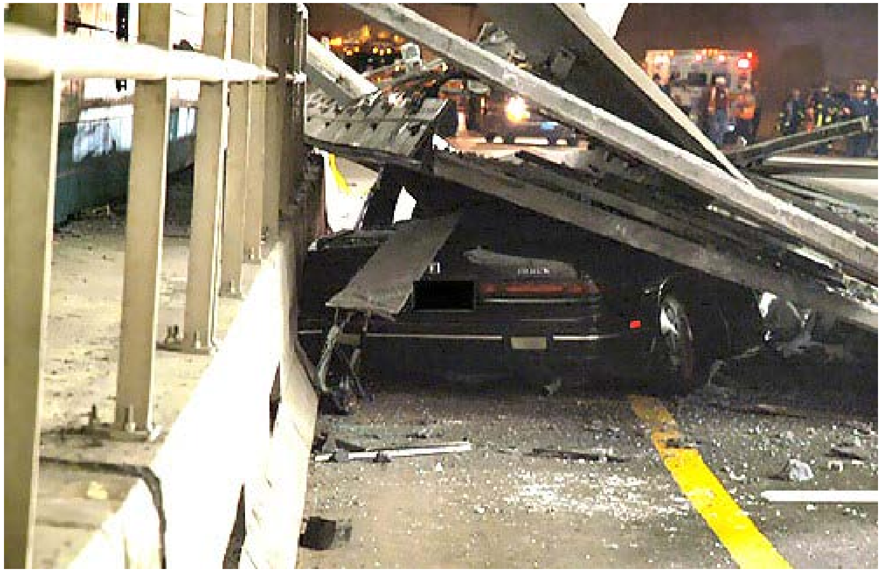
- “Big Dig” Central Artery/Tunnel project that incurred huge cost escalation from an initial estimate of $2 billion to a final cost $24 billion, and delay of completion of 11 years,
- 1994 Heathrow Airport Tunnel Collapse,
- 2003 Shanghai Metro Line 4 collapse in China,
- 2004 Nicoll Highway collapse in Singapore, and
- 2007 Sao Paulo 100-ft deep shaft collapse.

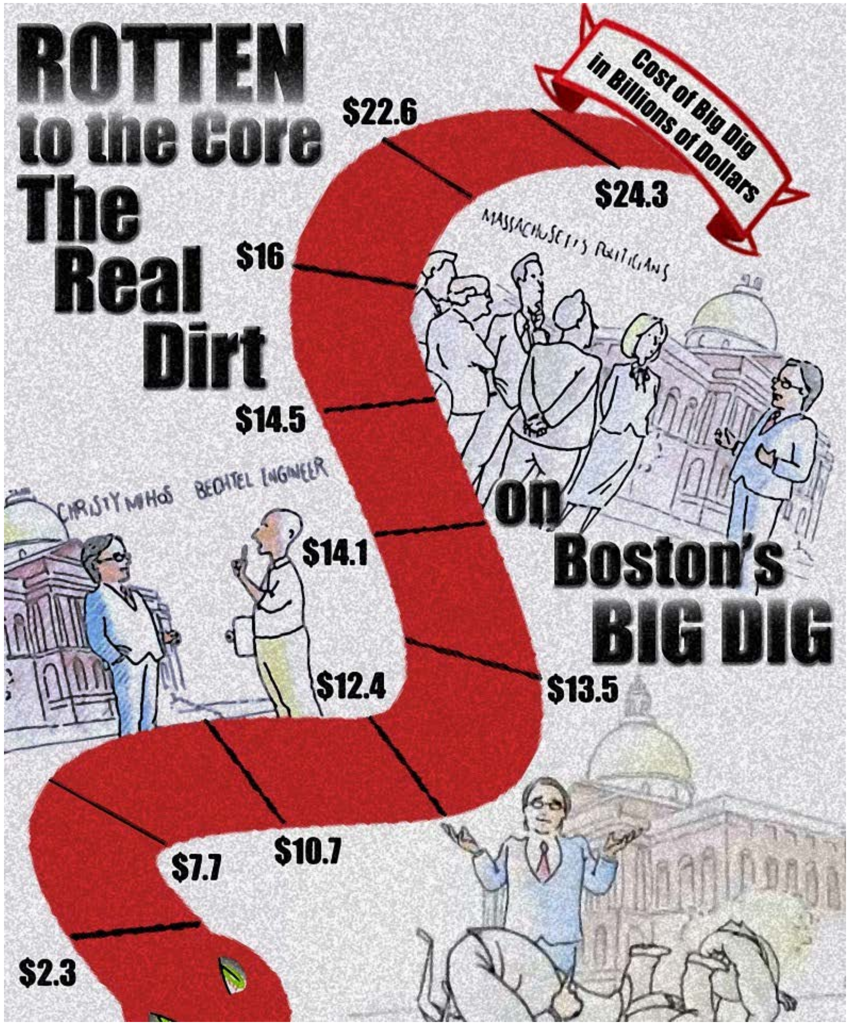
“Big Dig” Central Artery/Tunnel Project

BEFORE

AFTER

“Big Dig” Central Artery/Tunnel Project





1994 Heathrow Airport Tunnel Collapse

- Described by UK Health Safety Executive (HSE) as "the worst civil engineering disaster in the UK in the last quarter century".
- Recovery took nearly two years and cost around £150 million - nearly three times the cost of the original contract.
- "A catalogue of design and management errors, poor workmanship and quality control were at the root of the catastrophic tunnel collapse."

2007 Sao Paulo 100-ft Deep Shaft Collapse

- Seven persons killed.
- "Design shortcomings due to oversimplification of the geomechanical model in terms of overburden load and weaknesses in the sides of the tunnels due rock discontinuities."
- "Failure to consult monitoring data compounded all the errors. There is no evidence of any back analysis of data from monitoring − Data were there but never looked at."

Vision for UTC-UTI

Be a leading Center for the development of technologies for UTIs that are sustainable, less costly and more durable, and that can be efficiently constructed, operated and maintained with minimal problems.

Objectives of UTC-UTI

- **Develop technologies that will improve the durability and extend the life of new and existing UTI** through safe and cost-effective planning, design, construction, operation, maintenance and rehabilitation using advanced intelligent and data-driven systems based on condition monitoring, sensing and performance assessment, as well as in new construction materials and technologies;
- **Educate and train the next generation of engineers from diverse backgrounds with educational, research and entrepreneurial experiences**, and who are attuned to the multifaceted nature and impact of underground transportation projects; and
- **Transfer research results and technology** to industry (consultants, contractors and insurers), professional organizations, governmental institutions, permitting agencies and the academe, and be an incubator of new technologies.

Challenges in the engineering of underground space:

- Difficulty in predicting complex geologic conditions and material behavior, and long-term geologic material interactions with the built environment.
- Difficulty in managing unexpected ground conditions resulting in project delays and cost escalation.
- Design of underground excavations is still largely empirical due to uncertainties in ground conditions and properties .
- Owners, designers and/or contractors often take large risks or are excessively conservative as a consequence of insufficient geological and geotechnical investigations.
- A fixed design based on limited information is often used, wherein few provisions are made to allow for deviations from perceived initial conditions, even when the original design becomes untenable and continuation leads to large financial losses.

<u>SOLUTION: Real-time and adaptive system</u> for investigating, analysis and design of underground space:

- A unique aspect of underground projects is that they allow for improved understanding of the ground conditions and interactions with the built environment as construction progresses.
- However, current design and construction practices do not allow a project to adapt to new information that can be obtained from the field as the construction is being carried out.
- Even in cases where extensive monitoring is performed, little is done to use new data and information.

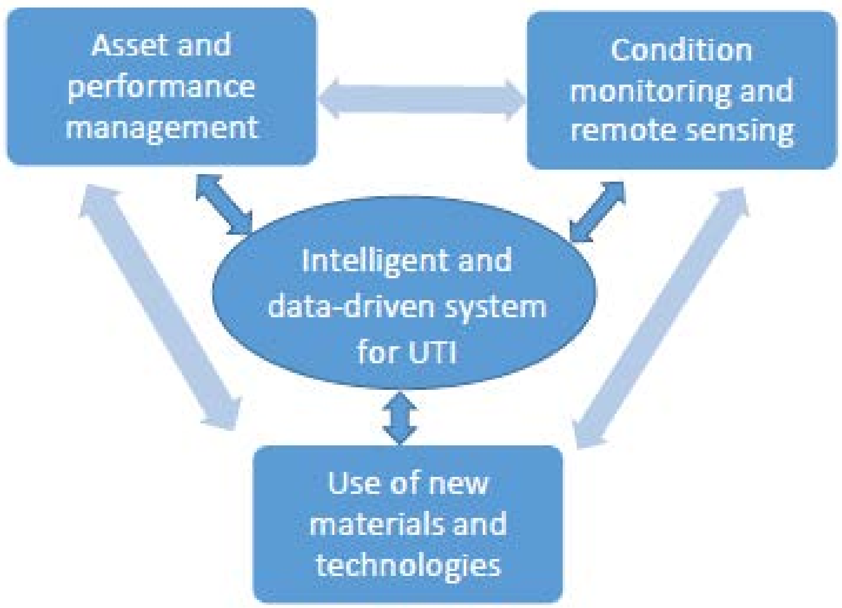
Barriers to implementation and use adaptive real-time systems

- Inflexible contract, potential lawsuit and adversarial relationships between, designer and contractor.
- Underground construction is still too conservative, tradition-bound, and sometimes slow to adopt innovations.
- Outdated regulations and design/construction standards.
- Lack of time, personnel and/or resources to gather field data and monitor response.
- Lack of system to process new data and information, and adaptive models and techniques to adapt design to improve understanding of field behavior.

UTC-UTI Research Topics Under Priority Research Area 4

- Condition monitoring, remote sensing and use of GPS;
- Asset and performance management; and
- Application of new materials and technologies.

The core of UTC-UTI is an ***adaptive, intelligent and data-driven system*** *that turns the results from the asset and performance management system into actionable recommendations, which are implemented through the use of new materials and technologies.*



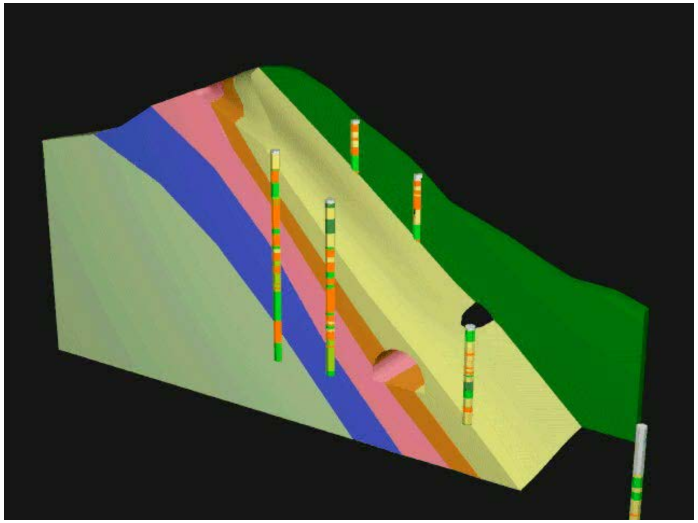
Interplay between the different research topics to be pursued in UTC-UTI.

AMADEUS (Adaptive Real-Time Geologic Mapping, Analysis and Design of Underground Space)

Information Technology Research (ITR)
Funded by the National Science Foundation
2003-2008

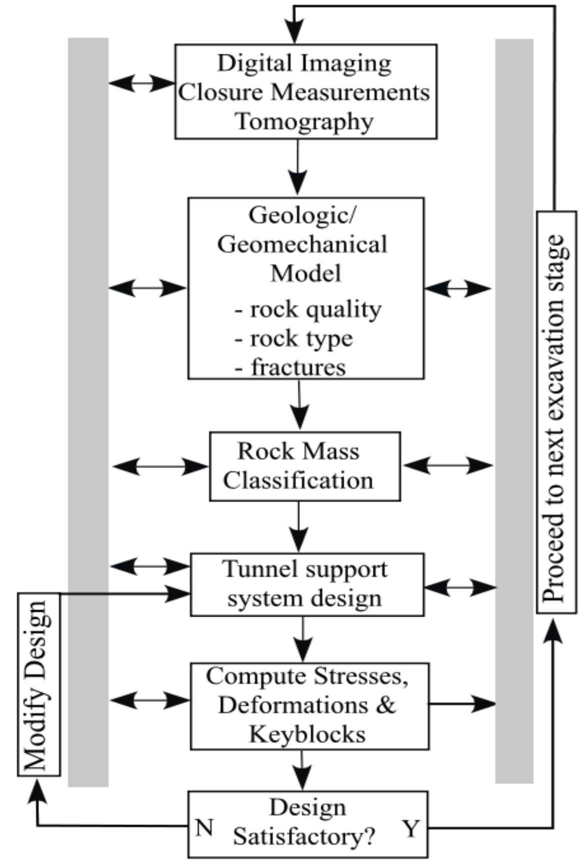
UTC-UTI Initial Suite of Research Projects -
Condition monitoring, remote sensing and use of GPS

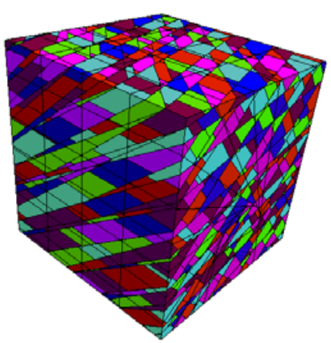
1. Use of sensor networks, LiDAR and Digital Photogrammetry for rapid assessment of underground and infrastructure conditions.
2. Geophysical methods for predicting ground conditions ahead of underground excavations.
3. 3D subsurface mapping and geologic modeling.

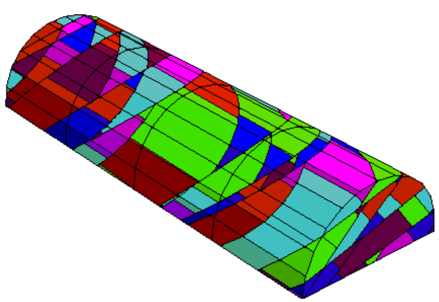


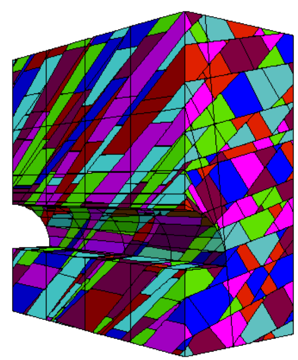
UTC-UTI Initial Suite of Research Projects - Asset and performance management

1. Real-time performance assessment of underground transportation infrastructures.
2. Resilience and sustainability of underground transportation infrastructures.
3. Data-driven risk mitigation.
4. Data assimilation and adaptive computational modeling.
5. Uncertainty modeling and risk assessment.
6. Impact of underground excavation on above-ground infrastructure.
7. Blast and fire hazard mitigation assessment for highway and rail tunnels.









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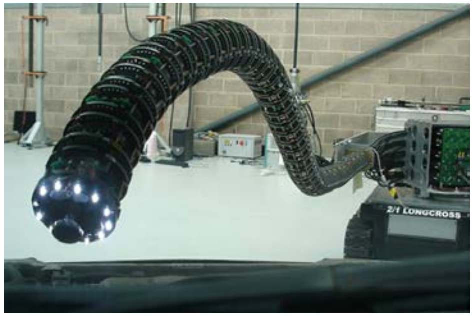
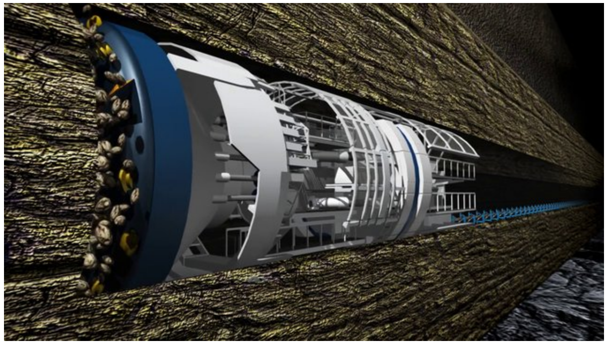
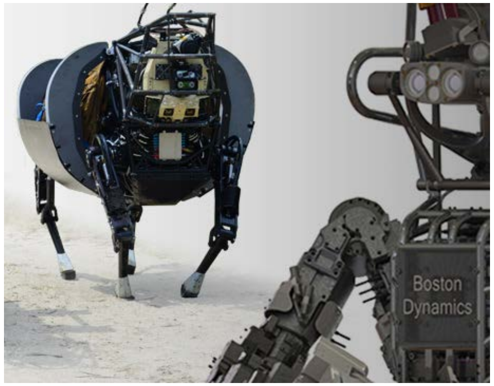
UTC-UTI Initial Suite of Research Projects - Application of new materials and technologies.

1. Sustainable and high-performance materials for underground construction
2. Performance-based design methodology for underground construction using new materials
3. New excavation technologies for underground construction
4. Development of a blast and fire resistant structural tunnel liner







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Faculty Participants

Marte Gutierrez
Paden Chair and Professor, Civil Eng.

Reza Hedayat
Assistant Professor, Civil Eng.

Panos Kiousis
Assoc. Professor, Civil Eng.

Mike Mooney
Grewcock Chair Center Director Professor, Civil Eng.

Shilling Pei
Assistant Professor, Civil Eng.

Gabe Walton
Assistant Professor, Geological Eng.

Wendy Zhou
Associate Professor, Geological Eng.

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Andrei Swidinsky
Assistant Professor, Geophysics

Richard Brune
Research Professor, Mining Eng.

Rennie Kaunda
Assistant Professor, Mining Eng.

Eunhye Kim
Assistant Professor, Mining Eng.

Hugh Miller
Assoc. Professor, Mining Eng.

Priscilla Nelson
Professor and Dept Head, Mining Eng.

UTC-UTI Education and Workforce Development Activities:

- Courses Related to Urban Transportation Infrastructure
- Center Level Course on Urban Transportation Infrastructure
- Undergraduate Minor or Area of Special Interest in Urban Transportation Infrastructure
- Graduate Degrees Focused on Urban Transportation Infrastructure
- Short Courses
- Seminar Series
- Field Trips to Construction Sites
- Research Experiences for Undergraduate (REU) Students
- Pre-College K-12 Education

UTC-UTI Technology Transfer

- Industrial/Practitioner Partnership
- Continuing Education Short Courses
- Other means of dissemination of results (worldwide web, print media, conference presentations, demonstrations to contractors and engineers, and archival journals)
- All products will be available to the public through RiP, NTL, TRID and Research Hub

Careers in Underground Transportation Infrastructure

- High demand which will continue to grow (in California, one in six construction workers has fallen into the "underground economy").
- Job stability – many underground projects last for years and even decades.
- Challenging – everything is new and different – and requires a high degree of innovation.
- Opportunity to travel the world.
- Diverse work force. Women are joining the underground construction industry in increasing number.
- Diverse types of work – from office to field.
- Opportunity to grow.
- Opportunity to work in landmark projects that will have major impact to society.

Undergraduate and Graduate Student Opportunities at UTC-UTI

- REU – Research Experiences for Undergraduates during spring and gall semesters and summer
- Research assistant-ships from graduate students in CEE, MN, UCTE and GGE. Research topics cover field work, laboratory testing, analysis and design, and analytical and computational modeling.

Please consult UTC-UTI Faculty Participants in your Department or:

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Director, University Transportation Center for Underground Transportation Infrastructure (UTC-UTI)
James R. Paden Distinguished Professor
Civil and Environmental Engineering
Colorado School of Mines
Coolbaugh 308, 1012 14th St., Golden, CO 80401
E-mail: mgutierr@mines.edu