OTD
Operations Technology Development

Assessment of Threats on Cast Iron Pipes

PHMSA R&D Forum Workgroup, 2021

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Operations Technology Development (OTD) Overview

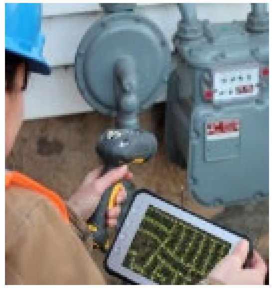
Established 2003

Stand-alone, not-for-profit, member-controlled company where gas utilities work together to develop technology solutions to common issues

- Annual membership dues are calculated based on number of customer meters
- New projects selected by members based on needs
- Each member votes their own dollars to specific projects
- All members have access to all project information

28 Members

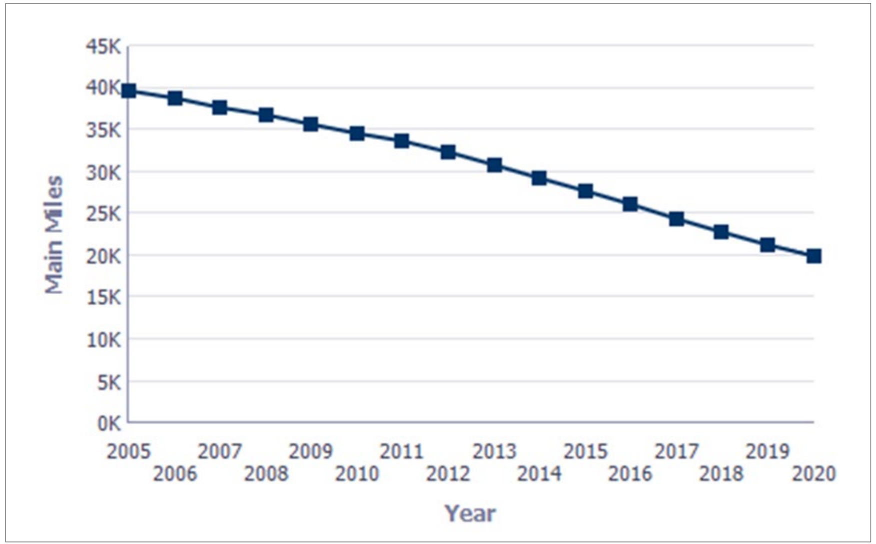
$12M annual dues	**$150-$750k** member/yr	**$0.50** meter/yr



System Characteristics of Cast Iron Pipes

Gas distribution mains incident reports from 2005 to 2020 show:

- 9 percent of the incidents involved cast iron mains. However, only 2 percent of distribution mains are cast iron.
- 36 percent of all fatalities and 16 percent of all injuries involved cast iron pipelines.



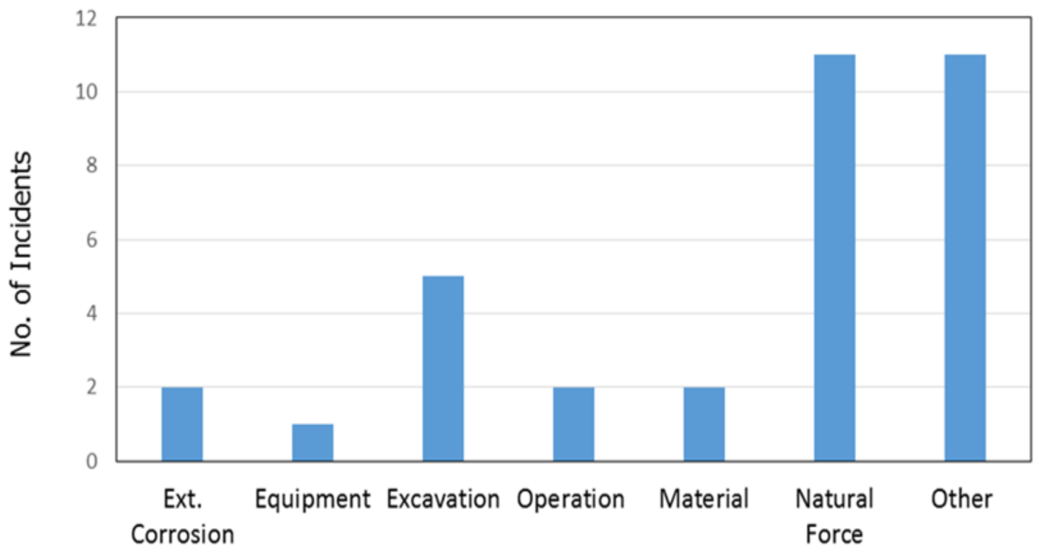
Miles of Cast Iron Distribution Mains [*]

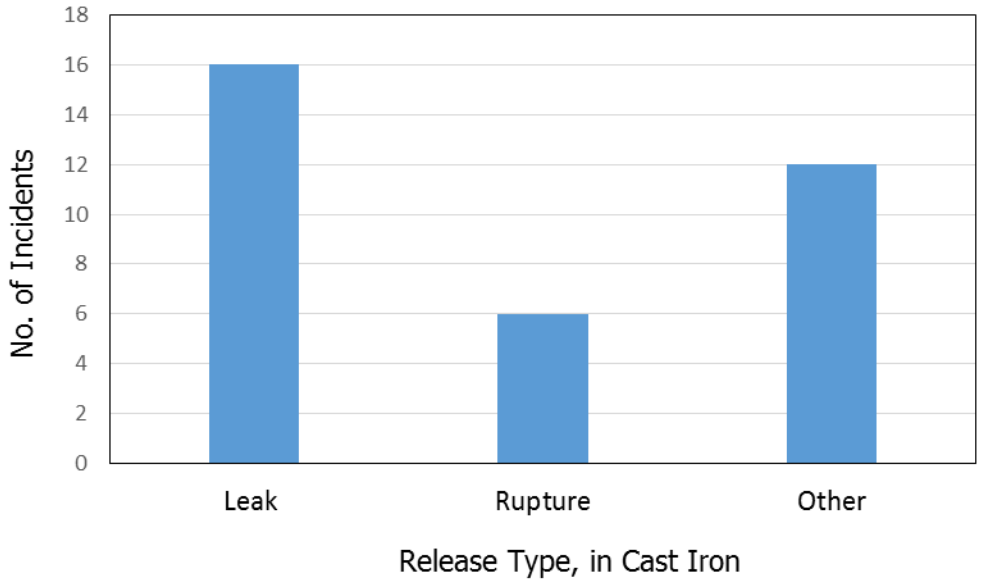
The biggest threat to cast iron pipe is earth movement. These movements are caused by excavations, seasonal frost heave, and ground water uplift.

Pipe graphitization (Cast iron degradation to soft elements) also results in metal loss and susceptibility to cracking.

[*] https://www.phmsa.dot.gov/data-and-statistics/pipeline-replacement/cast-and-wrought-iron-inventory

Failure of Cast Iron Pipes



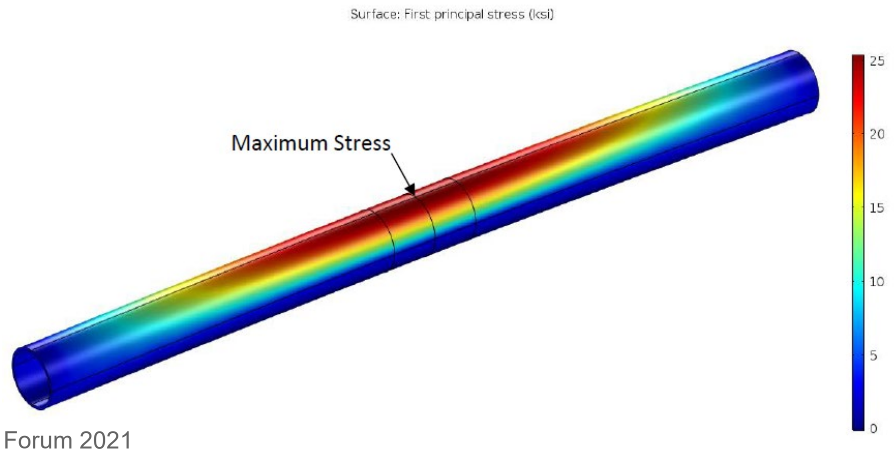


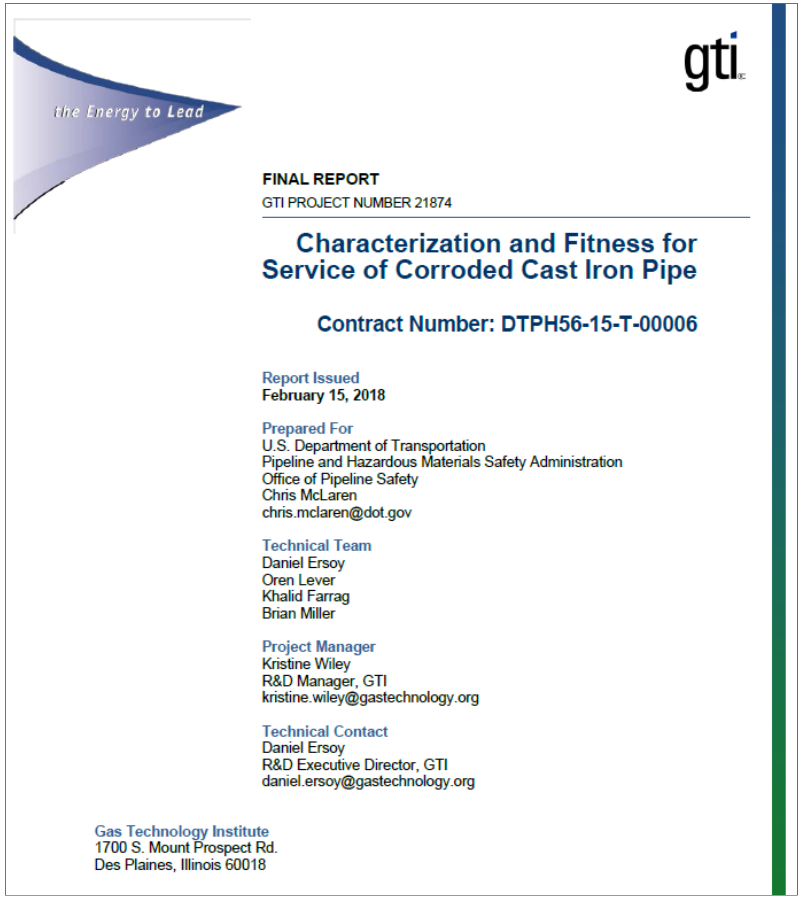
Causes of Incidents in CI Pipes [PHMSA Incident Reports 2010-2016]

- Stresses resulting from pipe internal pressure are negligible in cast iron pipes carrying pressures up to 30 psig.
- Pipe stresses are mainly caused by soil and traffic loads and other external forces.

Fitness for Service of Corroded Cast Iron Pipes

- A nonlinear, 3D finite element (FE) model, simulating a single pipe span was utilized as the basis for the Fitness-For-Service (FFS) model.
- A Design of Experiment (DoE) method was used to produce response surfaces from the FE simulation results that can predict the maximum stresses in pipes with and without wall loss.





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FINAL REPORT

GTI PROJECT NUMBER 21874

Characterization and Fitness for Service of Corroded Cast Iron Pipe

Contract Number: DTPH56-15-T-00006

Report Issued
February 15, 2018

Prepared For
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Fitness for Service Cast Iron Threats

Example model output of the Finite Element (F.E.) program

Inputs:

Pipe Dimensions

Parameter	Units	Description	Value	Minimum	Maximum
class	ksi	Material class (tensile strength)	40	10	60
D	in	Pipe outer diameter	6	4.8	13.2
span	ft	Pipe span	12	12	18
t	in	Pipe wall thickness (if known)		*<-- If a value is entered h*	
t.pred	in	Pipe wall thickness predicted by OD	**0.413**		

Corrosion Flaw Dimensions

Parameter	Units	Description	Value	Minimum	Maximum
flaw.d	in	Maximum corrosion flaw depth	0.33	0.021	0.330
flaw.l	in	Maximum corrosion flaw length (along pipe axis)	4	0.157	4.723
flaw.w	in	Maximum corrosion flaw width (around circumference)	4	0.942	9.236

Operating Conditions

Parameter	Units	Description	Value	Minimum
P	psig	Pressure	5	0
T.max	°F	Maximum buried operating temperature	75	
T.min	°F	Minimum buried operating temperature	55	

Soil and Traffic Loads

Parameter	Units	Description	Value	
soil.type		Soil type	Gravel/Base	
soil.weight	pcf	Soil wet weight per cubic foot	**153**	
soil.weight.user	pcf	Soil weight per cubic foot, user defined		*<-- If a value is entered h*
soil.depth	ft	Soil depth	4.5	
traffic.type		Traffic type (road,rail,none)	None	

Outputs:

Pipe stresses with corrosion defect

Parameter	Units	Description	Value
UTS	ksi	Material class (tensile strength)	**40**
P1.max	ksi	Maximum resolved tensile stress	**56.9**
SF.corroded	ratio	Tensile strength safety factor	**0.70**

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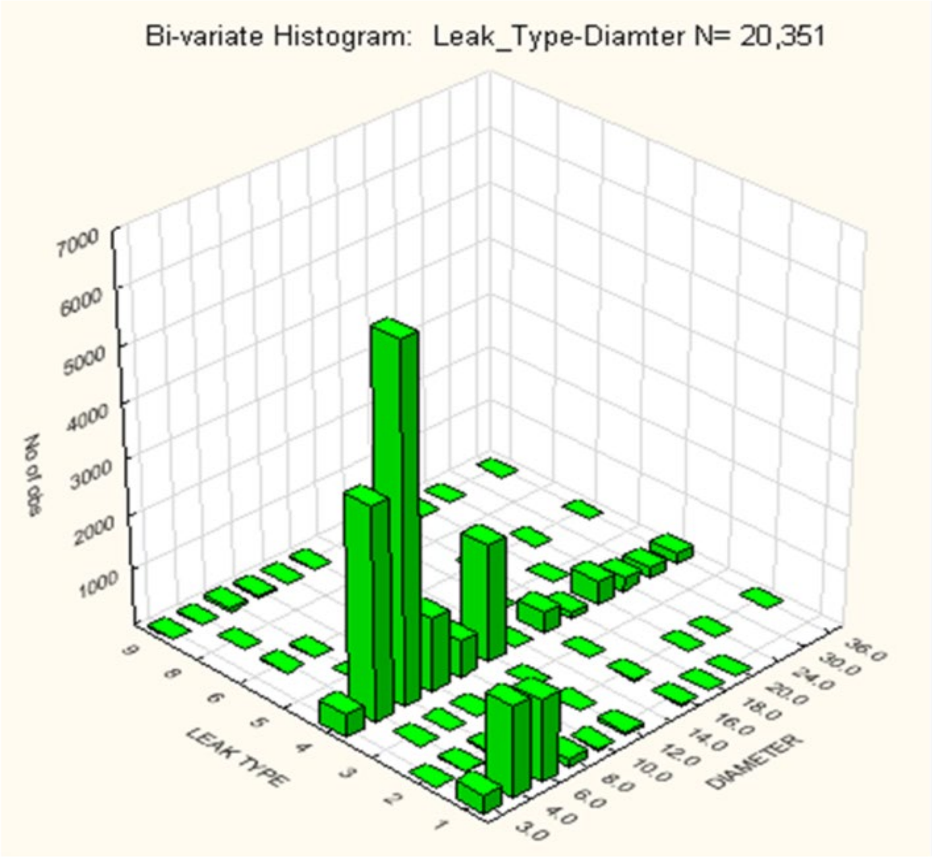
Risk of CI Damage due to Ground Movement

- December 19, 2019 – A 6" cast iron gas main had circumferential break where a large underground cavity caused ground movement and resulted in the rupture of the main installed in 1928.
- January 20, 2018 – A 6” cast iron main, installed in 1927, was operating at 0.3 psig. Apparent cause of incident was reported as frost heave.
- March 5, 2015 - A circumferential crack in the 6-inch cast iron main. The frost depth was 48”, causing the main to break. The cast iron main was installed in 1923 was operating at 2 psig.
- January 27, 2015 – Earth movement near the cast iron main caused the pipe to crack. The cast iron main was installed in 1952 and was operating at 22 psig.
- January 9, 2012 – A leak originated at a break in a 4” cast iron gas main installed in 1950. The break occurred after rainfall that followed extended drought conditions.
- January 18, 2011 – A circumferential break due to soil movement on a 12” cast iron main installed in 1942 and was operating at 17 psig.

Risk of CI Damage due to Ground Movement



CI Leak and Breakage, Northeast Data from 2002 to 2012

LEAK TYPE

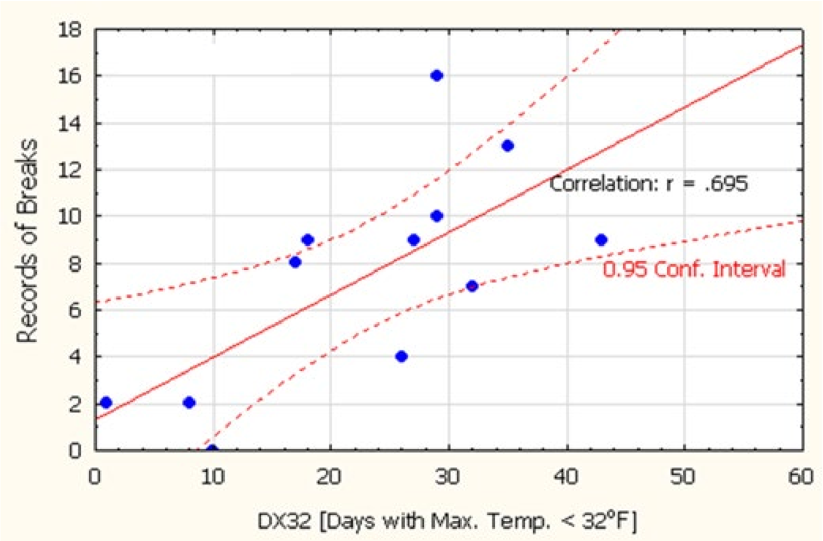
Code	Description
1	Broken Main
2	Leaking Pipe
3	Gate/Valve
4	Joint
5	Fitting
6	Drip
7	Regulator
8	Tap Connect
9	Other

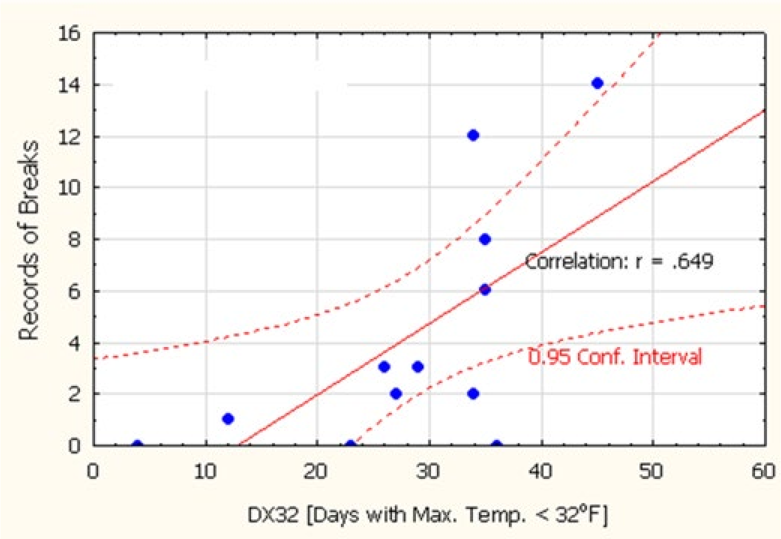
Frost Heave at Pavement Surface

- Earth movement damage to cast iron pipes includes landslide, flooding, thermal, and seismic loads.
- These forces can cause joint displacement, leakage, and pipe breakage.

Risk of CI Damage due to Ground Movement

- Analysis should be site specific to incorporate local soil, pipe, and site characteristics.
- Correlate the influencing parameters (weather, soil types, pipe size, etc.) with leakage and breakage records.
- Short number of freeze days is not as significant as long freeze periods (#days with max temp. < 32°F)





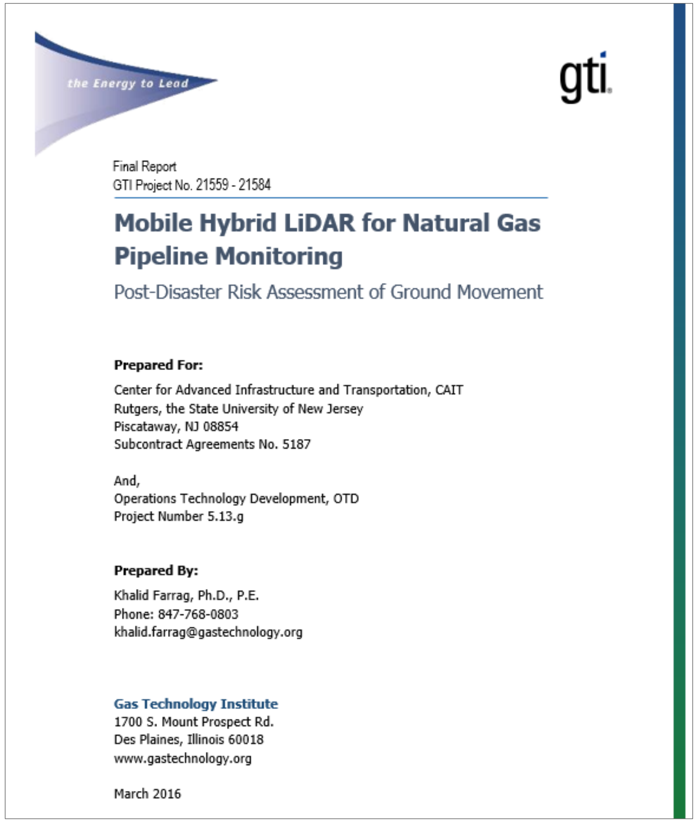
Increase in CI breaks with # of freeze days

Risk of CI Damage due to Ground Movement

Cast Iron pipes (and joints) have very small tolerance to deformations (joint rotation and pullout).

Recommended Joint Deformation Values

Loading Type	Cornell Study [1]	LC-12 [2]
Traffic Thermal	0.5 to 1.0 degree Pullout to 0.1 inch	0.1 degree Pullout to 0.04 inch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Final Report
GTI Project No. 21559 - 21584

Mobile Hybrid LiDAR for Natural Gas Pipeline Monitoring

Post-Disaster Risk Assessment of Ground Movement

Prepared For:

Center for Advanced Infrastructure and Transportation, CAIT
Rutgers, the State University of New Jersey
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Subcontract Agreements No. 5187

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Project Number 5.13.g

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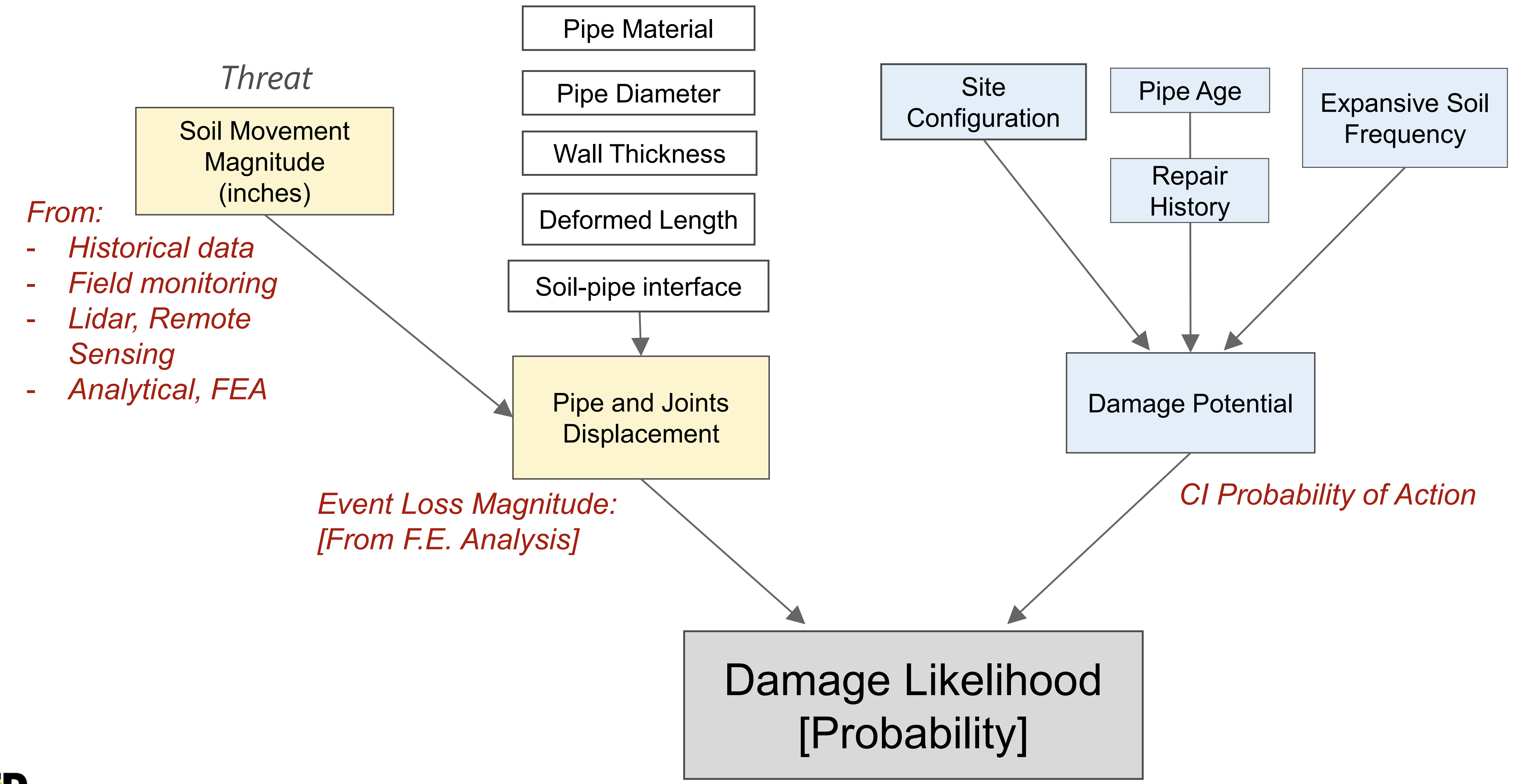
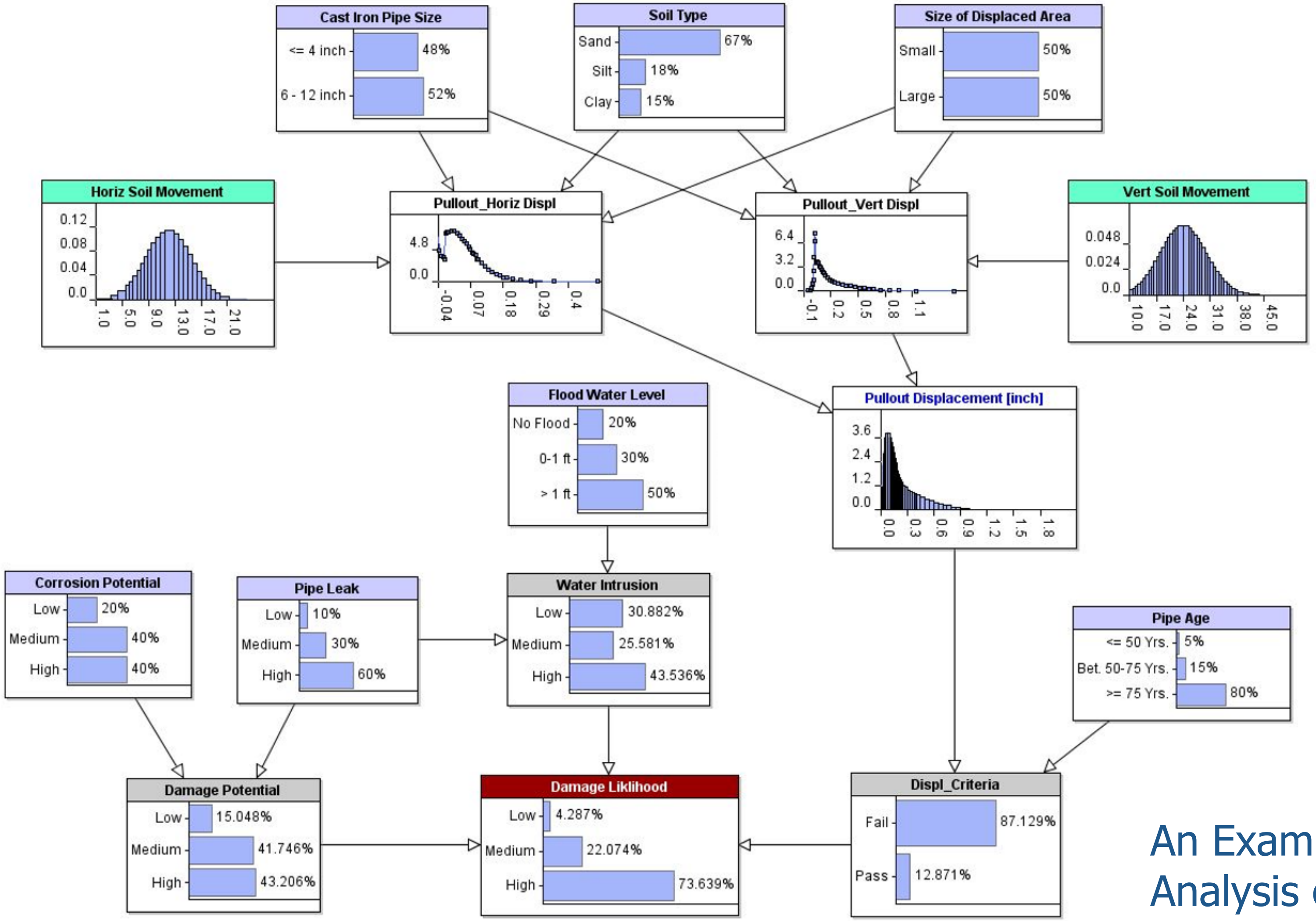
March 2016

1. Evaluating Service Life of Anaerobic Joint Sealing Products and Techniques, Cornell University, for Gas Research Institute, Report GRI-96/0318, 1996.
2. British Gas Corporation, "Anaerobic Type Joint Penetrating Systems for Joint Repair on Ferrous Distribution Systems Operating Up to 2 Bar", BGC/PS/LC12, November 1988.

Risk of CI Damage due to Ground Movement



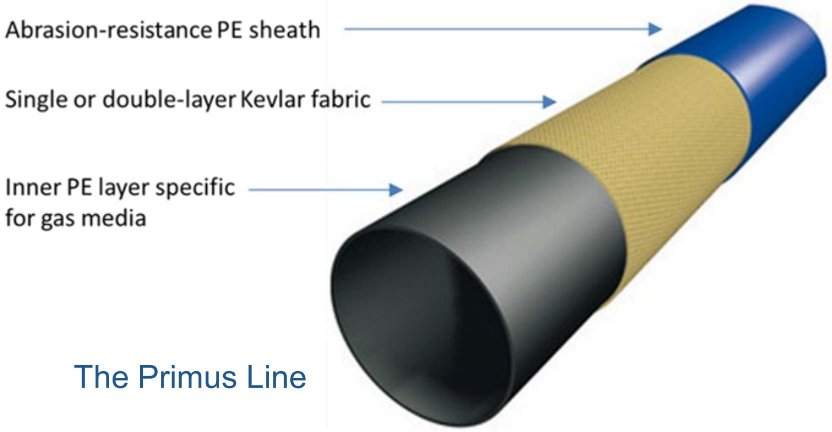
Risk of CI Damage due to Ground Movement



An Example of a ‘simplified’ Bayesian Analysis of Ground Movement

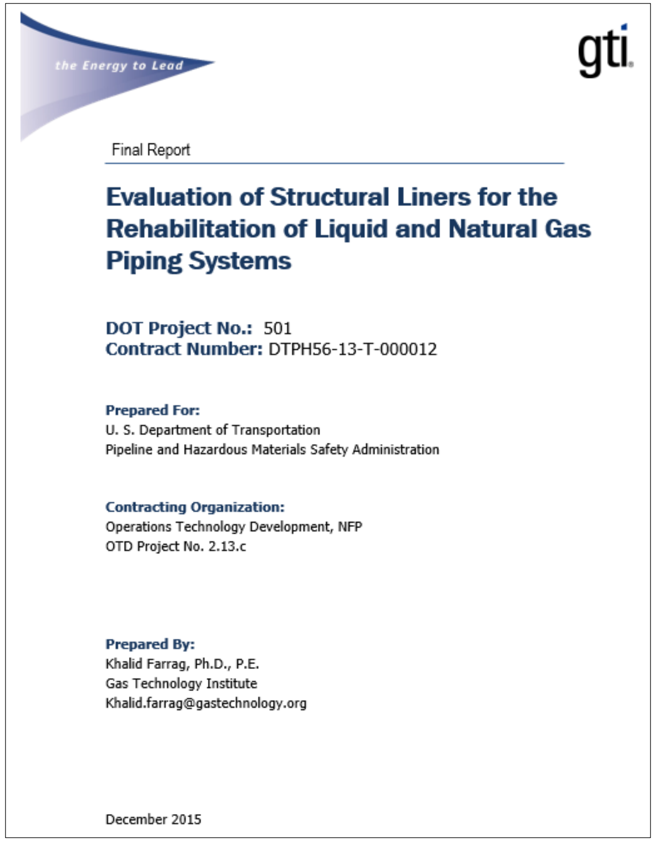
Rehabilitation of Cast Iron Pipes

- Various types of composite pipes and Cured-in-Place liners exist in the market for CI rehabilitation.
- Several types of reinforcement fibers are used, including glass fiber, aramid, and carbon fibers.
- A following NGA presentation will discuss CI rehabilitation with Starline systems.



The Primus Line

HPL-G Starline



Final Report

Evaluation of Structural Liners for the Rehabilitation of Liquid and Natural Gas Piping Systems

DOT Project No.: 501
Contract Number: DTPH56-13-T-000012

Prepared For:
U. S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration

Contracting Organization:
Operations Technology Development, NFP
OTD Project No. 2.13.c

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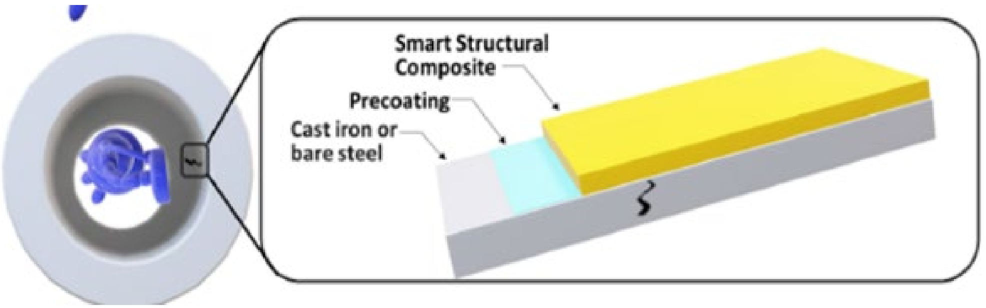
December 2015

Rehabilitation of Cast Iron Pipes

arpa-e
CHANGING WHAT'S POSSIBLE

REPAIR—**R**apid **E**ncapsulation of **P**ipelines **A**voiding **I**ntensive **R**eplacement



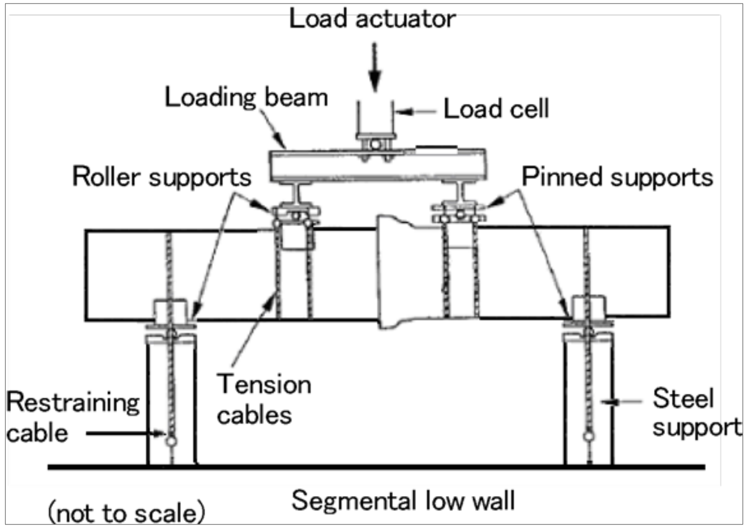
An Example of a Sprayed-in Technology of the REPAIR Program

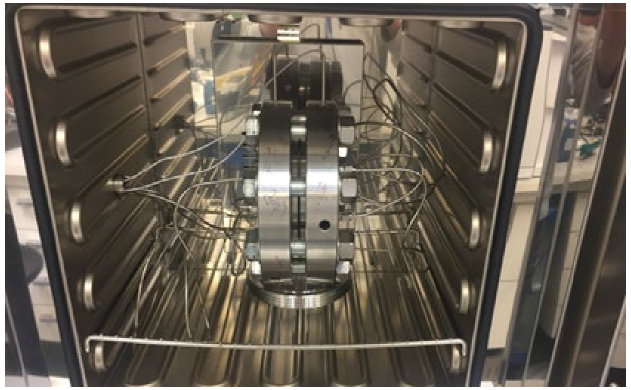
- The REPAIR program seeks to reduce natural gas leaks from cast iron pipes by developing a suite of technologies to enable automated construction of a new pipe inside an existing pipe.
- The previous ARPA-E presentation presented details of this program.

Rehabilitation of Cast Iron Pipes

REPAIR – Technologies Evaluation:

- Define performance metrics (e.g., pressure capacity, deformations, bending strength) required to support implementation of REPAIR technologies.
- Establish a framework to evaluate & validate design life for Pipe-In-Pipe (PIP) solutions.





Bending, Pressure, and Permeability Testing of Liners

Research Needs

- Accelerated replacement programs: Develop GIS risk-based decision-making web-based tool including cost analysis and risk tolerances.
- Quantifying gas emissions in CI pipes and potential reduction in rehabilitated systems.
- Risk Assessment of CI failure due to frost-heave and other ground movement threats.

Questions

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