Threat Prevention

Geohazards Management

Yong-Yi Wang, Ph.D.
ywang@cres-Americas.com
614-419-2366

Center for Reliable Energy Systems
5858 Innovation Dr.
Dublin, OH 43016
614-376-0765

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Delhi CO2 Pipeline Failure at Satartia, MS, 02/22/2020

- The rupture followed heavy rains that resulted in a landslide, creating excessive axial strain on a pipeline weld.

- **Delhi Pipeline**
  - Installed in 2009
  - 24” OD X80 ERW pipes
  - 77 miles
  - CO2 is used for enhanced oil recovery (EOR)

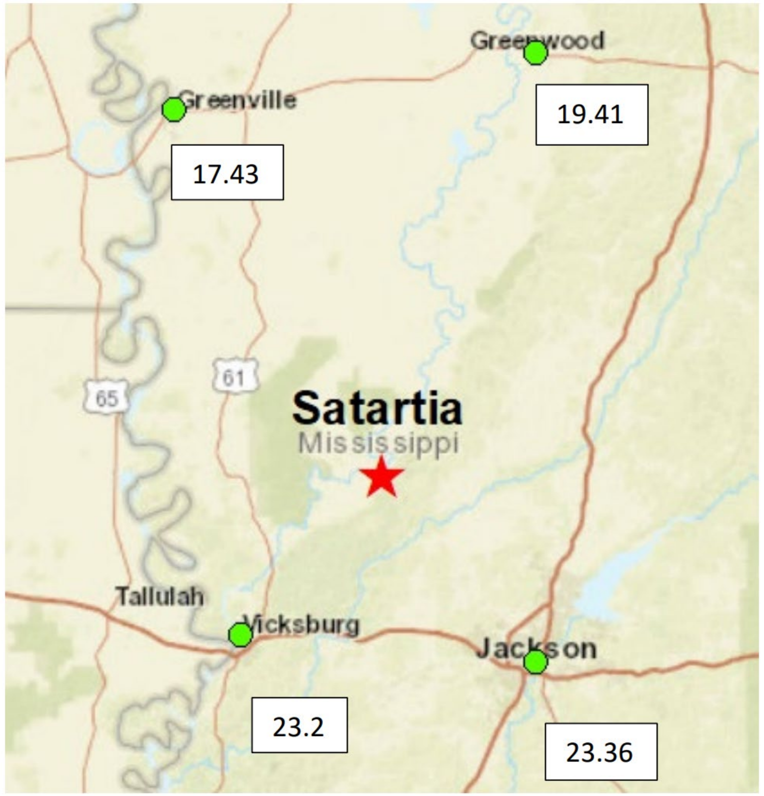
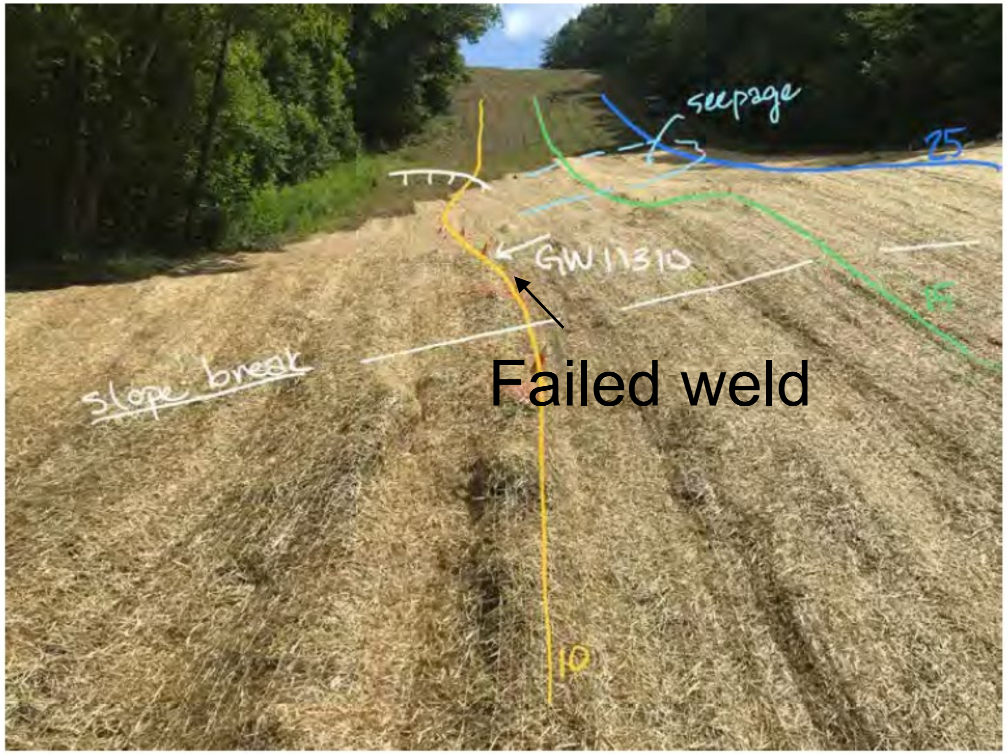


Figure 2: Vehicle is Parked on HWY 433 - The White is Ice Generated by the Release of CO_2 - The Blue Arrow Points North (Aerial Drone Photograph Courtesy of the Mississippi Emergency Management Agency)

Wesley Mathews, “Failure investigation report – Denbury Gulf Coast Pipelines, LLC – Pipeline Rupture / Natural Force Damage,” US DOT PHMSA OPS, May 26, 2022.

Texas Eastern Line 10 Rupture

- Fleming County, Kentucky, May 4, 2020
- Rupture, fire, no injuries or fatalities



Standing on ROW, looking upslope (NE) at deflected Lines 10 and 15.

Figure 1. Ruptured pipeline.
(Source: BGC Engineering USA, Inc.)

NTSB Investigation Number: PLD20LR001

PNG LNG Pipeline Survived in 7.5 Magnitude Earthquake

- No rupture or leak was found after a 7.5 magnitude earthquake on February 25, 2018.
- Designs
  - Strain-based design for segments crossing faults, expected to be able to survive strain up to 3%
  - Robust allowable stress design for the majority of the PNG LNG pipeline segments
- Linepipe selection
  - Lower grade, thicker wall, good strain hardening
- Welding
  - Weld strength overmatching, good toughness
  - Tight flaw tolerance

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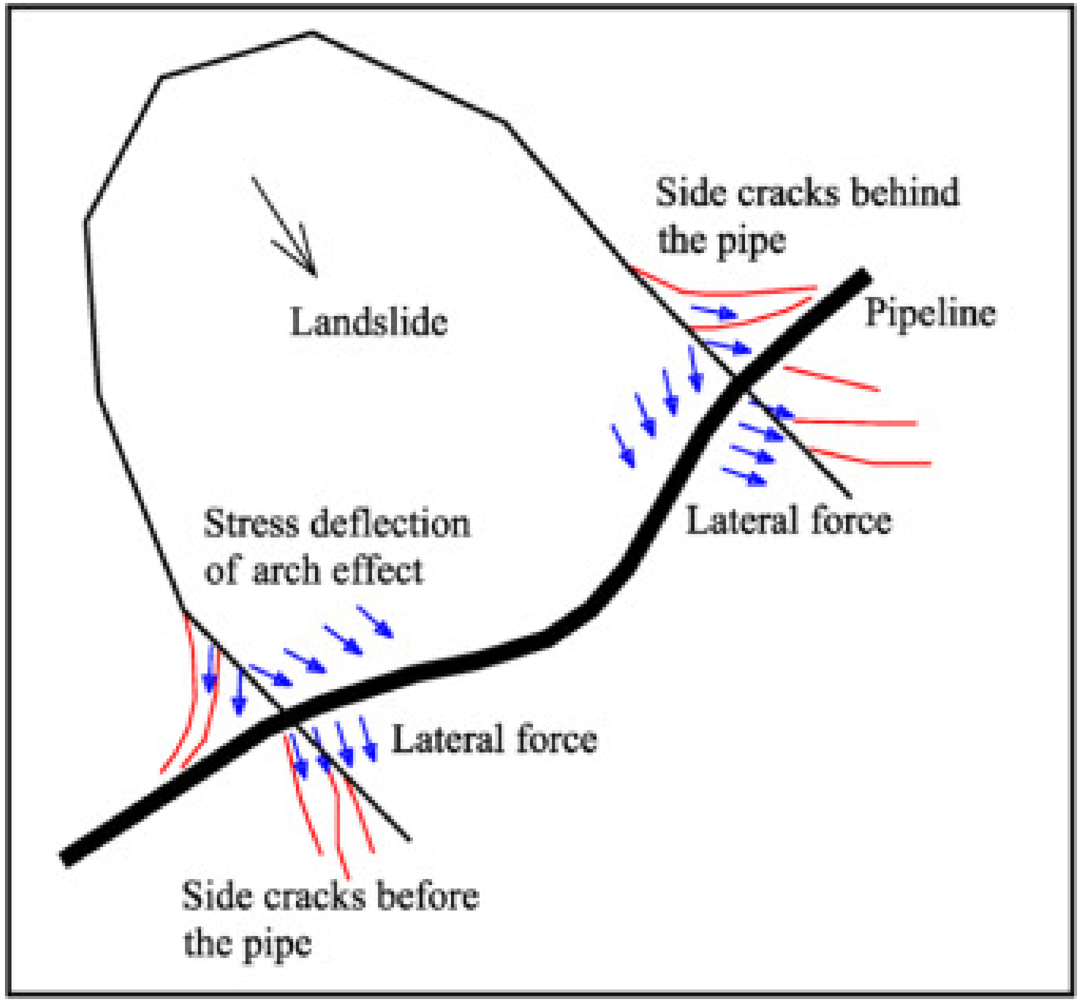
Mario L. Macia, Justin Crapps, Fredrick F. Noecker II, Nathan E. Nissley, Michael F. Cook, “PAPUA NEW GUINEA EARTHQUAKE PROVES THE VALUE OF ROBUST PIPELINE MATERIALS SELECTION AND CONSTRUCTION, IPC2020-9376

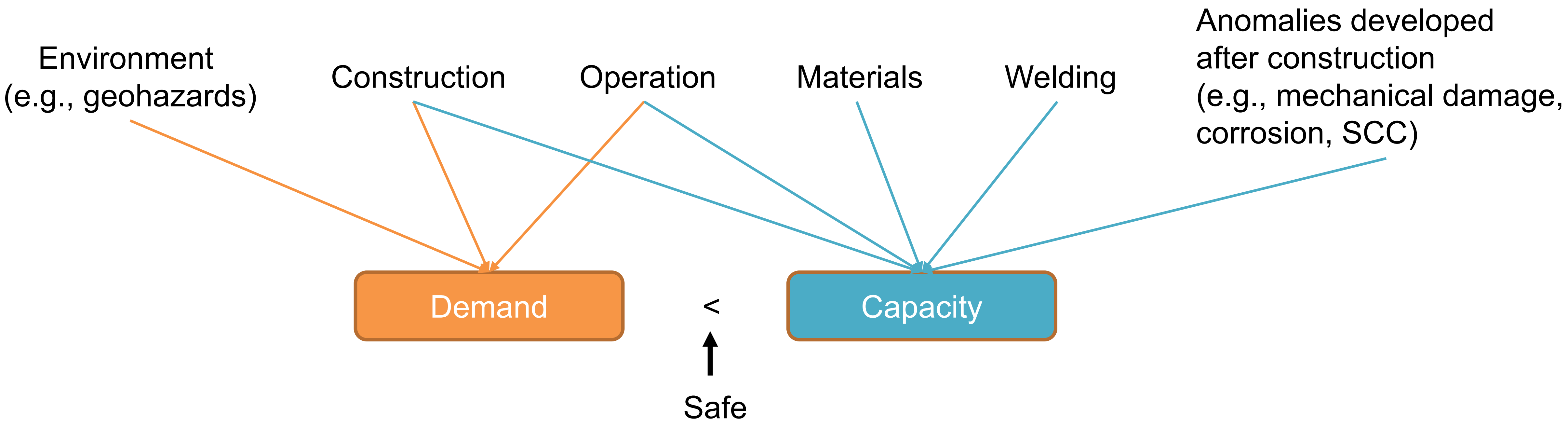
Pipeline Being Impacted by a Landslide, Generating Demand



Feng, W., et al., Large-Scale Field Trial to Explore Landslide and Pipeline Interaction," The Japanese Geotechnical Society *Soils and Foundations*, Volume 55, Issue 6, December 2015, Pages 1466-1473, Elsevier ScienceDirect

Why Some Pipelines Failed, Others Did Not?

- What drives integrity with geohazards loading?



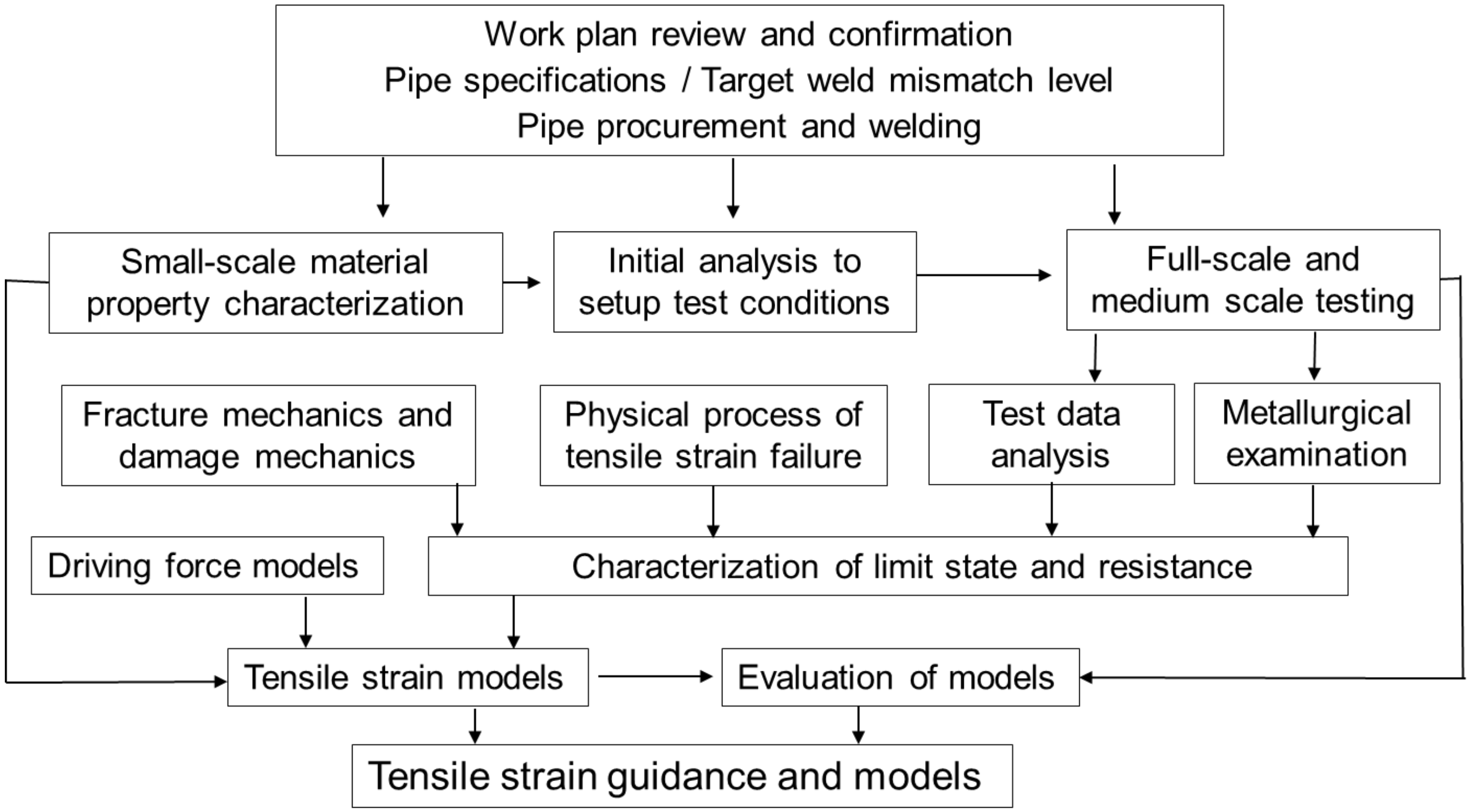
Proposed RD #1

- An adaptive framework for ranking integrity and safety of pipelines subjected to geohazards
  - Goal: ability to rank risk of failure for pipelines subjected to geohazards
  - Deliverables: an adaptive multi-tier system that can work with pipelines of different vintages and varying levels of available data
  - Data integration
    - Strain demand
      - Hazards characteristics
      - ILI IMU
      - Simulation models
    - Strain capacity
      - Vintage – construction practice
      - Anomalies/flaw from ILI, in-ditch NDE
      - Strain capacity models
    - Existing database

Proposed RD #2

- Targeted tests to support and further refine strain capacity models
  - Goal: have well designed and executed tests for the determination of strain capacity, along with material and flaw characterization
  - Approach
    - ►Similar to the successful joint efforts by PHMSA and PRCI for the development of strain-based design technology for new pipeline construction

Development process of strain-based design technology



Wang, Y.-Y., Liu, M., Zhang, F., Horsley, D., and Nanney, S., "Multi-Tier Tensile Strain Models for Strain-Based Design Part 1 – Fundamental Basis," Proceedings of the 9th International Pipeline Conference, Paper No. IPC2012-90690, September 24-28, 2012, Calgary, Alberta, Canada.

Proposed RD #3

- Predictive girth weld flaw characterization in vintage pipelines
  - Goal: Being able to provide a reasonably accurate representation of likely weld flaws in vintage pipelines
  - Data integration using Bayesian network
    - ILI
    - In-ditch
    - Existing database
  - Output
    - Likely flaw distribution for a given vintage of pipelines

Proposed RD #4

- Guidance on selecting the most effective approaches to geohazards management
  - Goal: select the most effective approaches at the earlies time possible

Prevention (New Construction, Pipe Replacement)		Mitigation (Existing Assets)	
Demand - Hazards	**Capacity**	**Demand - Hazards**	**Capacity**
Hazard aoidance	Design requirement	Hazards characterization	Risk ranking
Mitigatiing hazards near ROW	Linepipe specifications	Hazards mitigation	Flaw characterization (ILI, database)
Hazards monitoring	Welding and inspection	Hazards monitoring	Strain capacity models (output: strain limit)
Pipeline centerline	Construction pracitce	Rerouting	Test data to support capacity models
Pipe-soil interaction	Intervention threshold (from strain capacity)	Pipe-soil interfaction	Capacity enhancement

Proposed RD #5

- Guidelines for the assessment of interacting threats
  - Interacting threats: typical threats to pipeline integrity in addition to geohazards, such as corrosion, mechanical damage, cracks, etc.
  - Gaps: most current integrity assessment models for common anomalies such as corrosion and mechanical damage have limited considerations for high axial/longitudinal stress/strain that can be generated by geohazards.

Thanks

- Questions?