Risk Analysis and Threat-Mitigation of Natural Gas Transmission Systems

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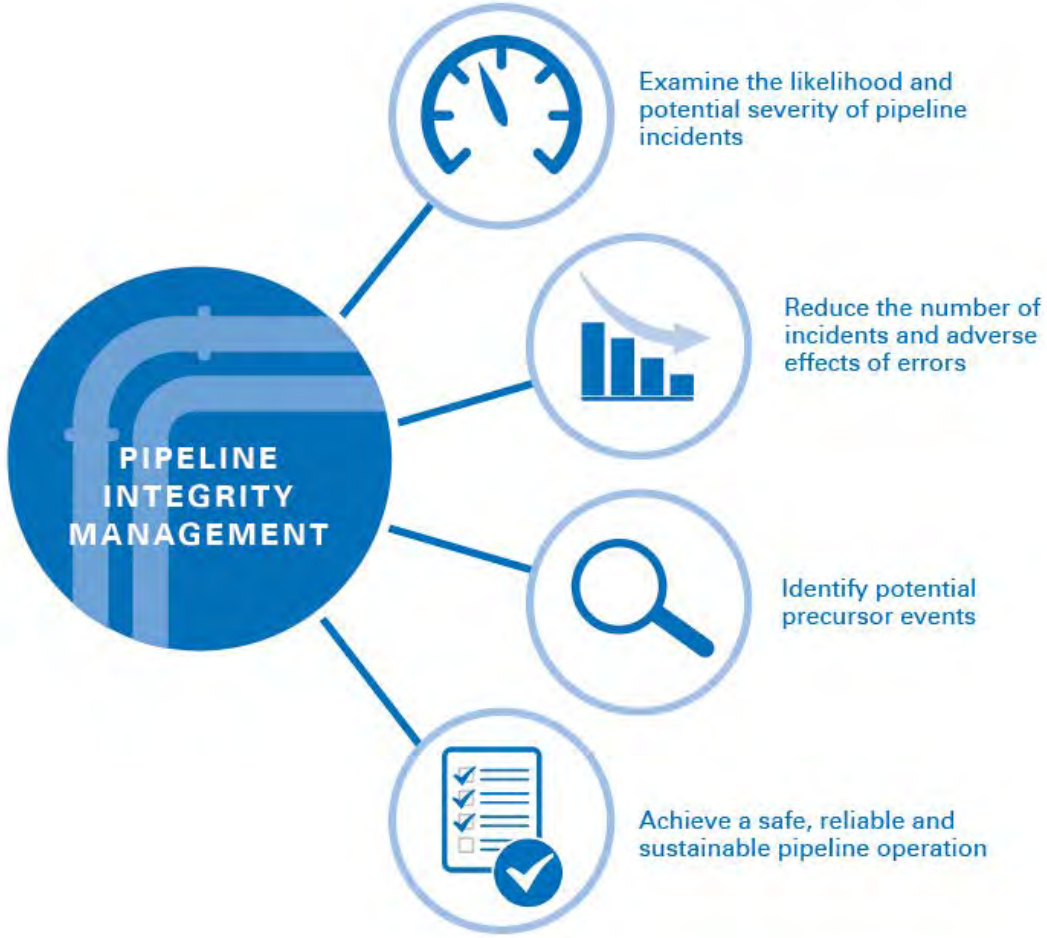
Advancing From Risk Assessment to Risk Management

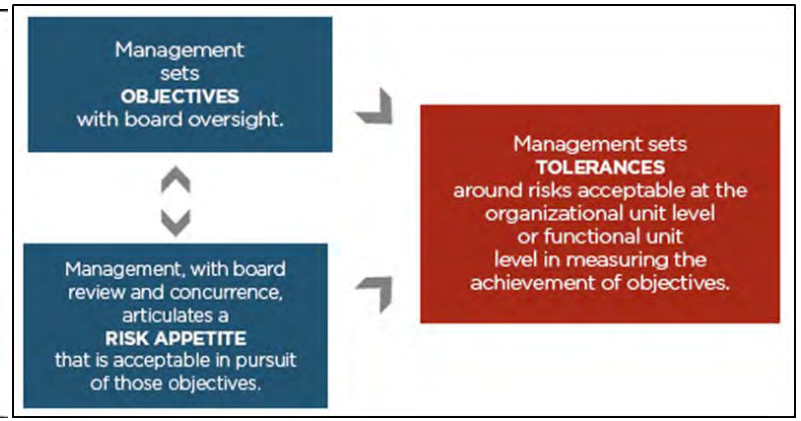


Advancing from Risk Assessment to Risk Management

Risk Assessment	Risk Management
What can go wrong	What can be done and what options are available
What is the likelihood of it going wrong	What are the associated tradeoffs in terms of all benefits, costs and risks
What are the consequences if it goes wrong	***What are the impacts of current management decisions on future options***
In what timeframe	

Adapted from: Haimes, Y.Y. and A.P. Sage, Risk Modeling, Assessment, and Management. 2015: Wiley

Rittenberg, L. and F. Martens, Enterprise Risk Management: Understanding and Communicating Risk Appetite. 2012: Committee of Sponsoring Organizations of the Treadway Commission.



Beasley, M., B. Branson, and B. Hancock, Enterprise Risk Management:Developing Key Risk Indicators to Strengthen Enterprise Risk Management. 2010, Committee of Sponsoring Organizations of the Treadway Commission.

Risk Management dictates development of ***risk acceptance criteria:***

- Meaningful and consistent expression of risk values
- **Key Risk Indicators (KRI)** – risk performance indicators that support a proactive leading indicator approach to managing risks

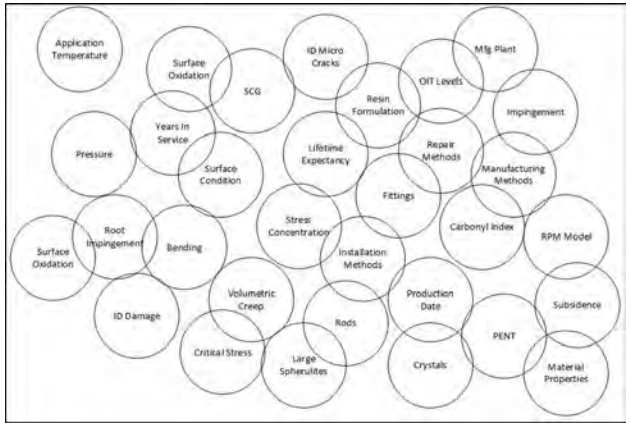
Threat Interactions – Need to be Understood for KRI

> **Background**
  - Many pipeline incidents are the result of multiple, interacting causes, not a single threat.
  - Individual threats can each be at “acceptable” levels but when overlaid result in a significant threat to the pipeline or even a failure.

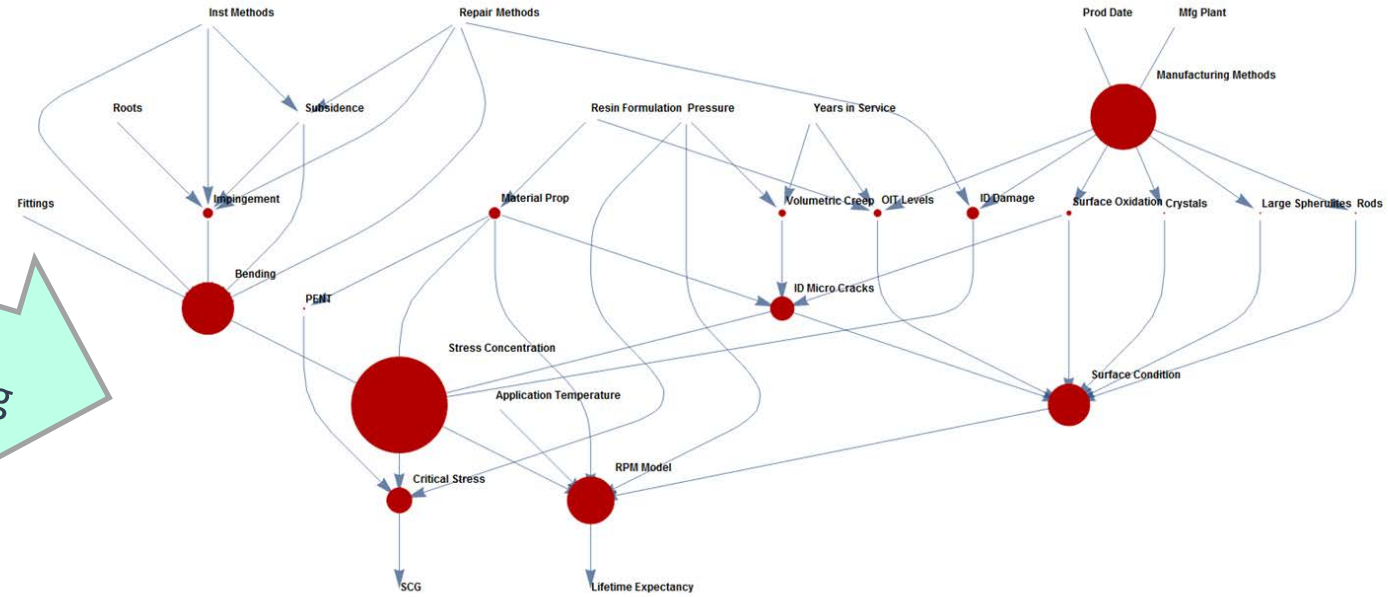
> **Approach**
  - Identify threat combinations to address and control,
  - Develop a method to calculate threat interaction levels and severity, and
  - Provide a method to continuously monitor threat interactions and flag concerns at trigger points.

> **Benefits**
  - Operators will be able to adequately identify combinations of threats and their associated risk.
  - Reduction of an operator’s risk and enhancement of compliance with regulations.

Reducing the Scale of the Interaction Problem



SME Driven Causal Modeling



n=32

2^32 = **4,294,967,296**

Theoretically possible combinatorial interactions

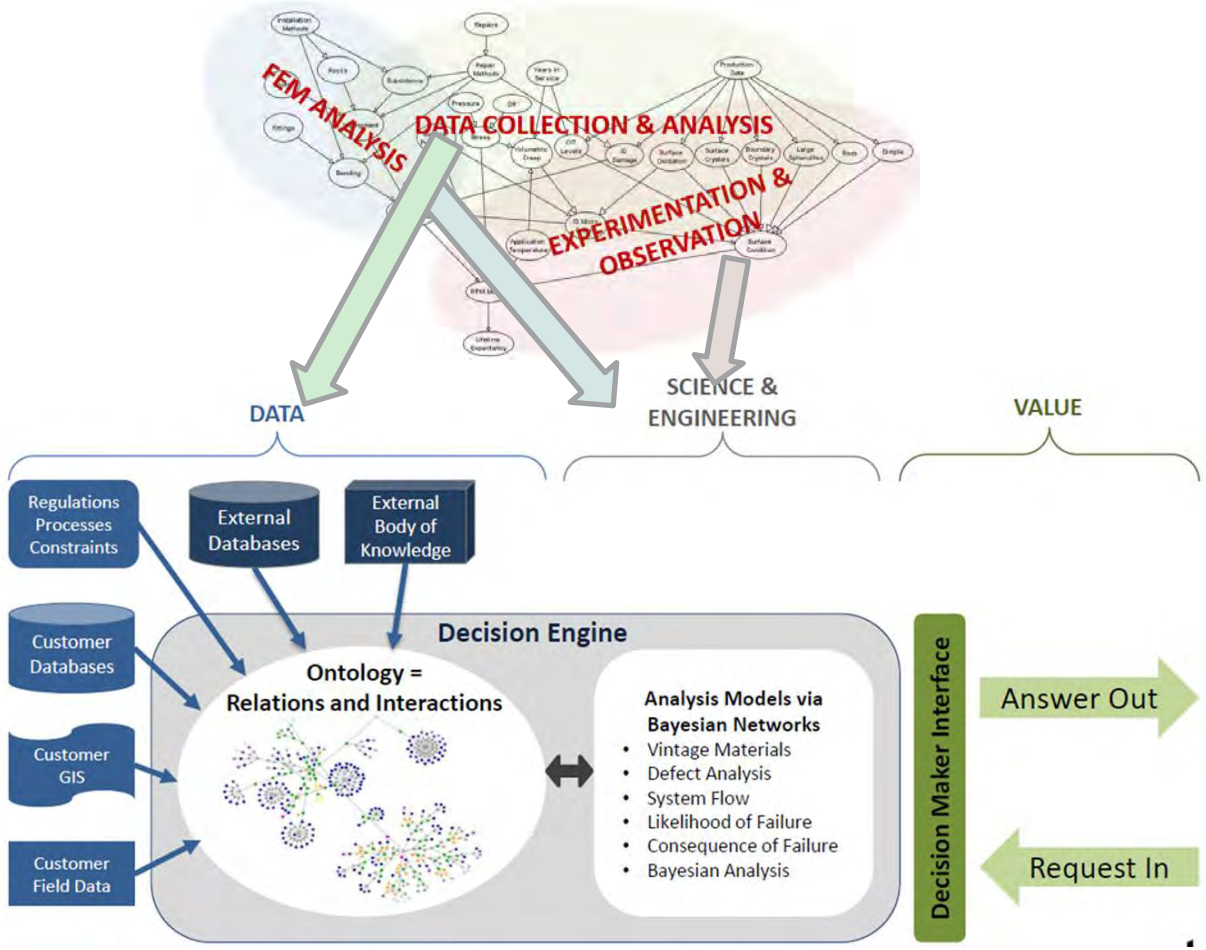
Reduced to **49** physics based interactions that can actually occur

EdgeCount[scgMap]=49

Causal Modelling, Intelligent Data Collection/Analytics

GTI has developed Bayesian network methods that are ideally suited to:

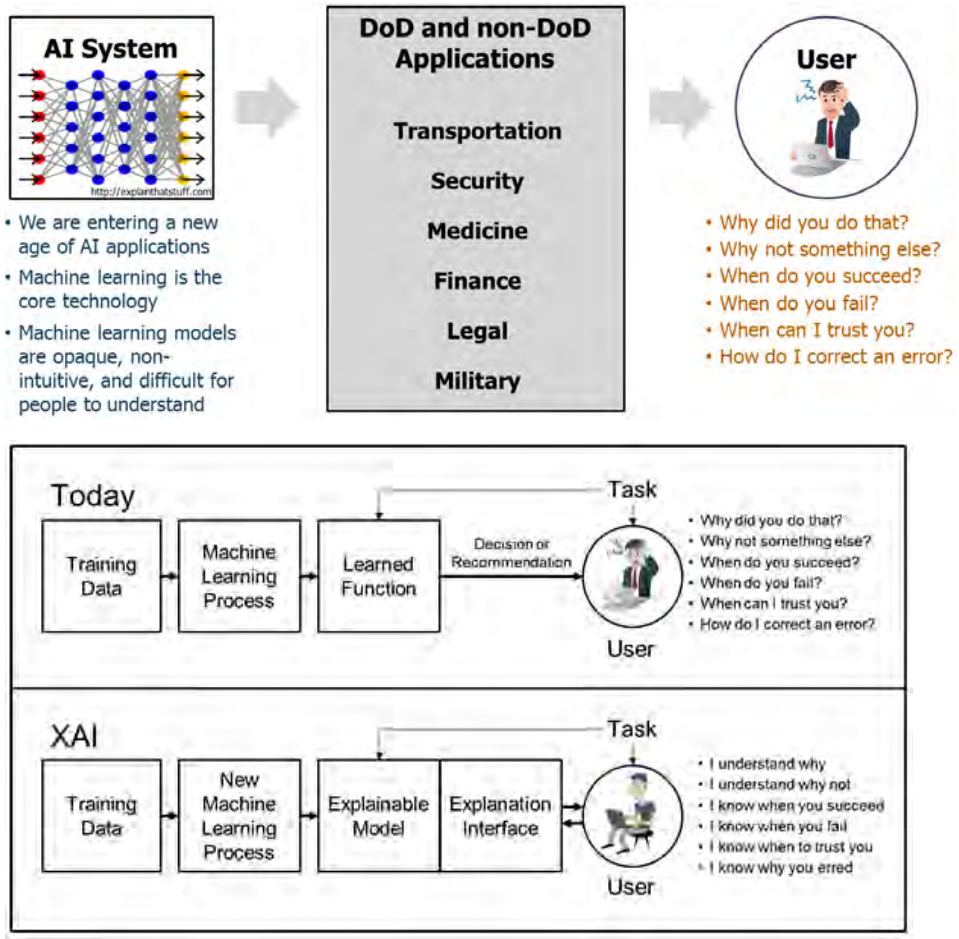
- Addressing interactions
- Dealing with sparse data
- Providing forensic reasoning to identify root causes
- Providing probabilistic prediction of future states



Explainable AI (DARPA Program)

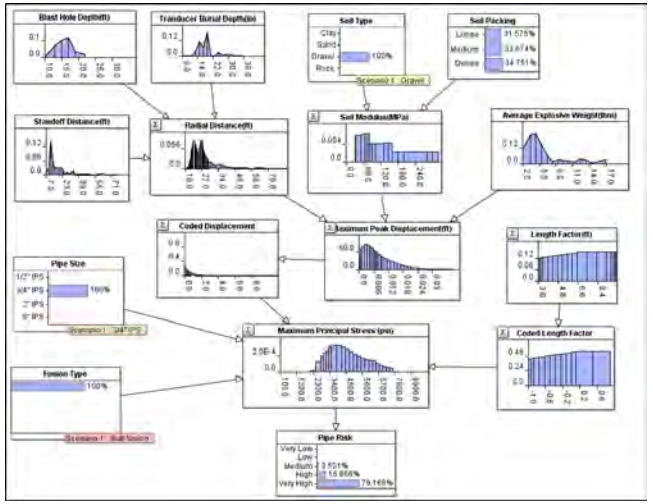
The Explainable AI (XAI) program aims to create a suite of machine learning techniques that:

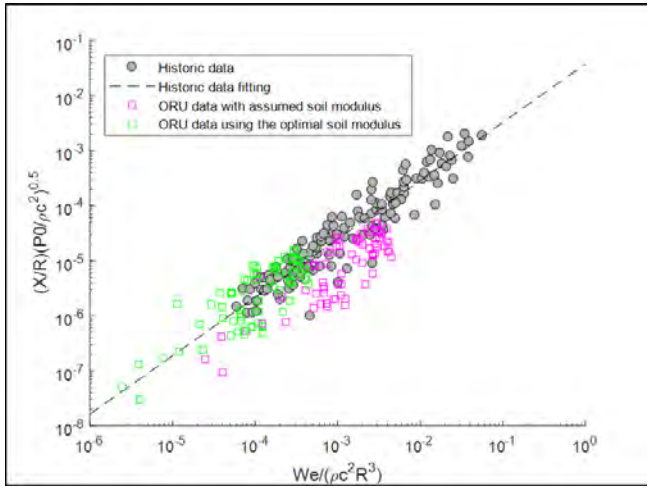
- Produce more explainable models, while maintaining a high level of learning performance (prediction accuracy); and
- Enable human users to understand, appropriately trust, and effectively manage the emerging generation of artificially intelligent partners.



Bayesian Network Analytics in Asset Management

- GTI has applied the Bayesian network analytics approach to gas distribution systems
- The models are not black-box, they are very explainable – **fits in well with XAI**
- The models have used historic data sets for learning
- First applications were for plastic piping systems
  - Sensitivity analysis
  - Predicting future performance
- Validated by utilities
- Being integrated into GIS and AI applications





Advantages of Bayesian Network Analytics in Asset Management

Bayesian network methods are ideally suited to:

- Addressing interactions
- Dealing with sparse data
- Incorporating big data
- Learning with each iteration
- Providing forensic reasoning to identify root causes
- Providing probabilistic prediction of future states

Incorporating remote sensing data streams is a natural extension that will:

- Address resiliency in the face of natural forces: floods, frost heave, wild fires etc.
- Assist in better modeling of peak day demands:
  - local climate conditions vs regional climate conditions
  - Reconcile top down and bottom up approaches

Questions