International Council on Systems Engineering
*A better world through a systems approach*

# A Knowledge Graph Framework for Failure Analysis and Prevention

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# Today's Agenda

- Global & Problem Context
- How Can It Be Done Better?
- Human-systems Integration
- Knowledge Graphs for Failure Detection and Analysis
- Detection of Emerging Failure
- Future Work

# Global Context

- Space is booming
- Data is becoming more complex
- AI is quickly becoming more powerful
- How can we use this to reduce failures?

# Problem Context

- Failure can get expensive fast
- Pushing your system to the limits characterizes it in a clearer manner
- Rigid parameters will not always catch issues before they arise, and neither will a person

# How can it be done better?

# Knowledge Graphs Support Earlier Failure Detection

- Model the system
- Humans and computers work together to determine failure types and detect failures
- Integrated data visualization, analytics, AI, and machine learning
  - Field data
  - Digital twins
  - Post situation analysis
  - Simulations
- Trend detection
- Communication of key results and findings

# Knowledge Graphs Support Earlier Failure Detection

- Failure location
- Failure type(s)
- Concurrent or related failures
- Root cause
- Cataloging of failure types and causal conditions
- Discover emerging failure patterns and take corrective actions

“Composite AI represents the next phase in AI evolution. It involves combining AI methodologies — such as machine learning, natural language processing and knowledge graphs — to create more adaptable and scalable solutions.”

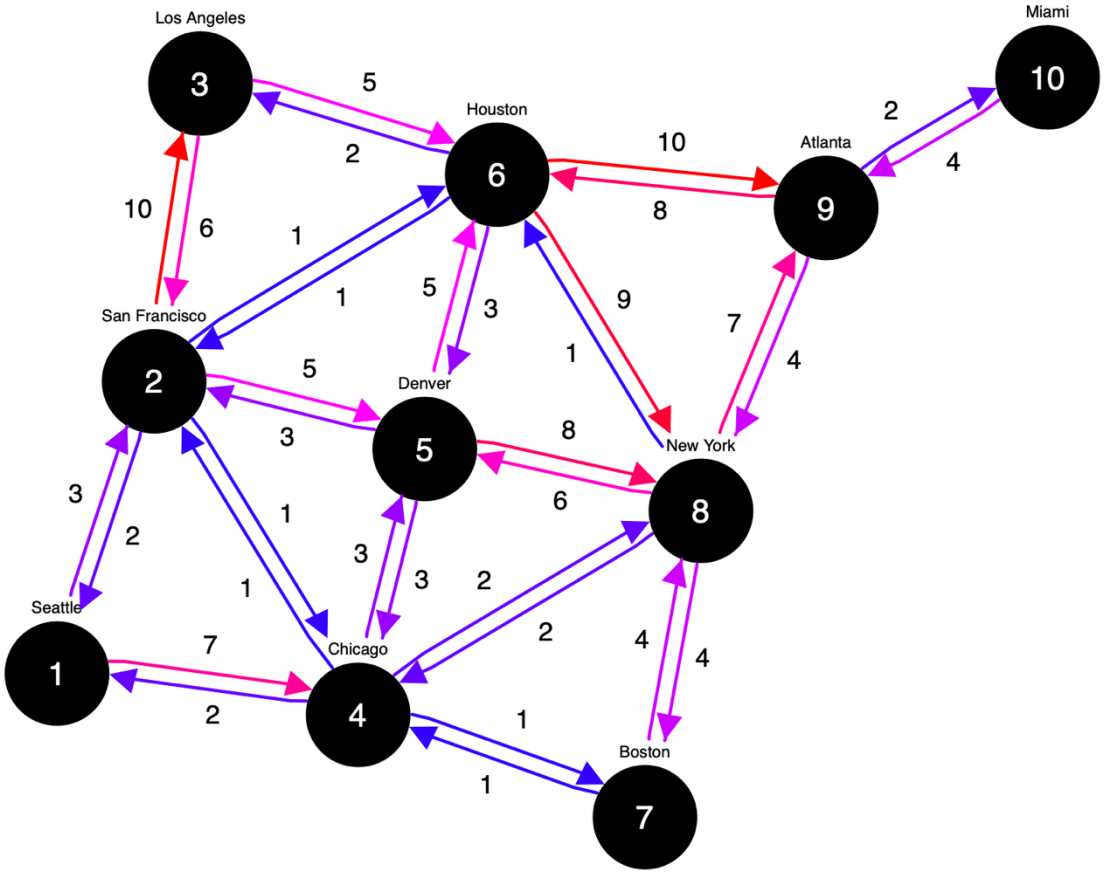
**Gartner**

“Explore Beyond GenAI on the 2024 Hype Cycle for Artificial Intelligence”

# Knowledge Graphs

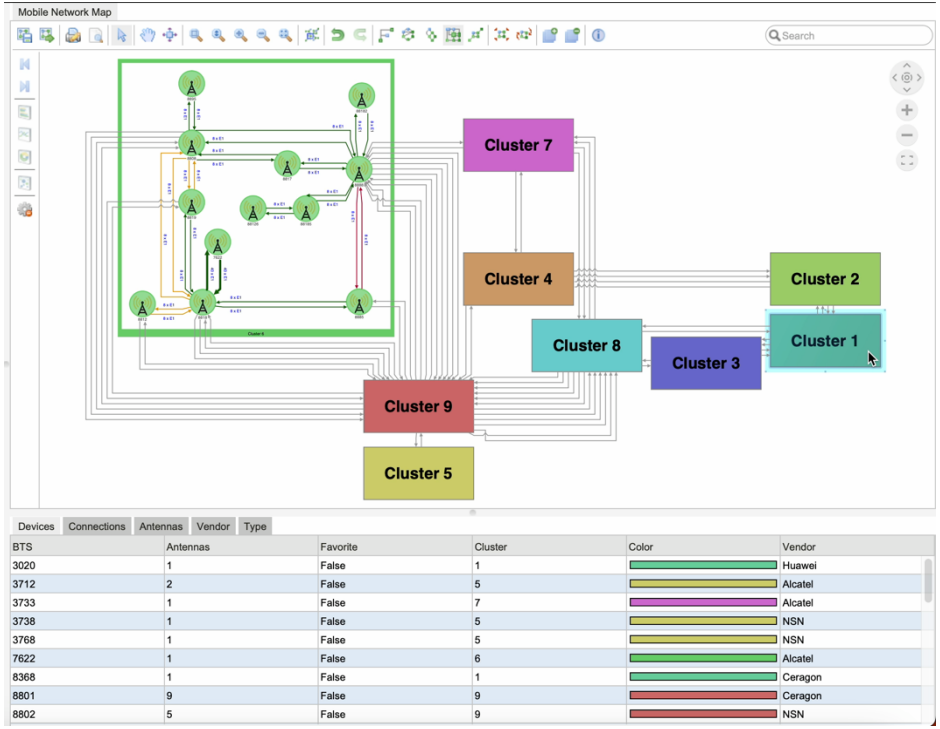
# Graphs

- Nodes (or vertices)
- Relationships (or edges)



# Graphs

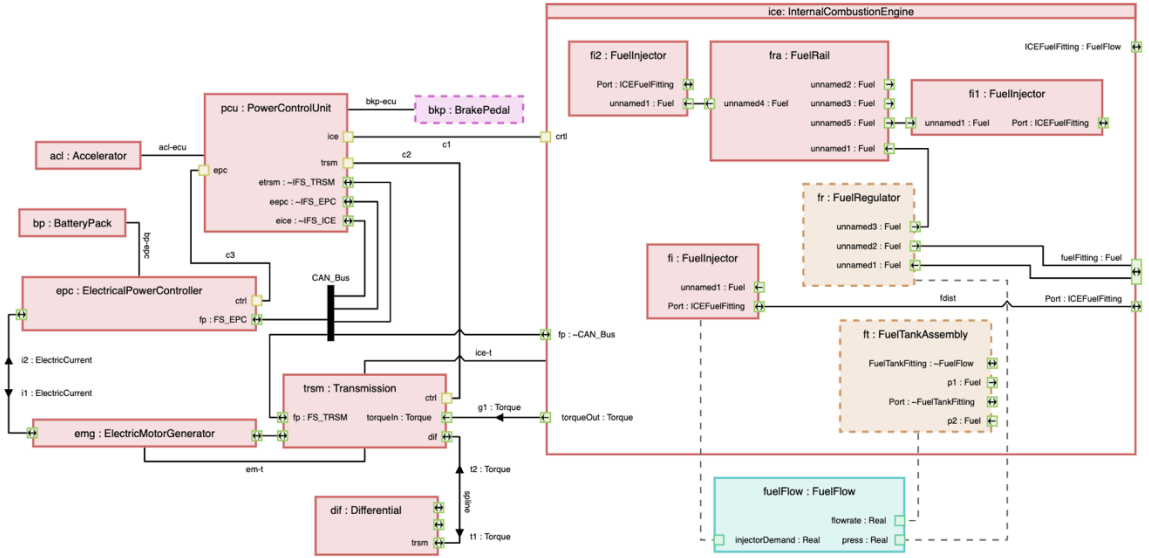
- Nested Drawings
  - Graph inside a node
  - Graph inside an edge
  - Edges to nodes in other nested drawings




| BTS | Antennas | Favorite | Cluster | Color | Vendor |
|---|---|---|---|---|---|
| 3020 | 1 | False | 1 | | Huawei |
| 3712 | 2 | False | 5 | | Alcatel |
| 3733 | 1 | False | 7 | | Alcatel |
| 3738 | 1 | False | 5 | | NSN |
| 3768 | 1 | False | 5 | | NSN |
| 7622 | 1 | False | 6 | | Alcatel |
| 8368 | 1 | False | 1 | | Ceragon |
| 8801 | 9 | False | 9 | | Ceragon |
| 8802 | 5 | False | 9 | | NSN |

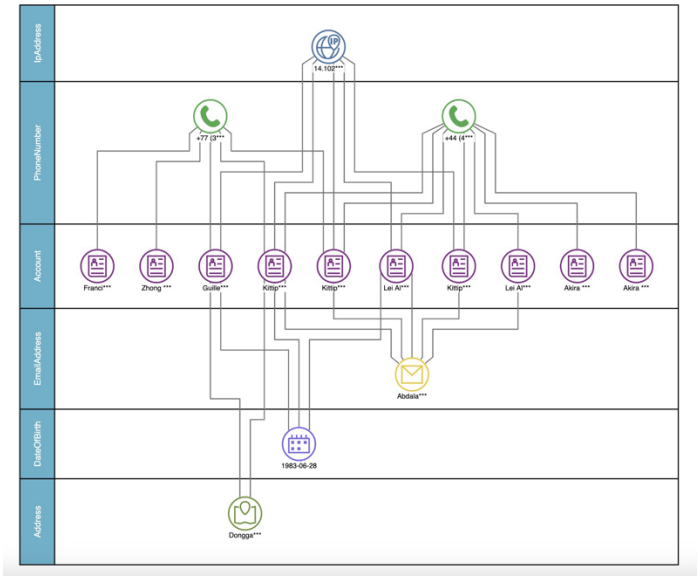
# Graphs

- Labels
  - Node labels
  - Edge labels
  - Connector labels
  - Edge decoration labels



# Graphs

- One-Dimensional Swimlanes

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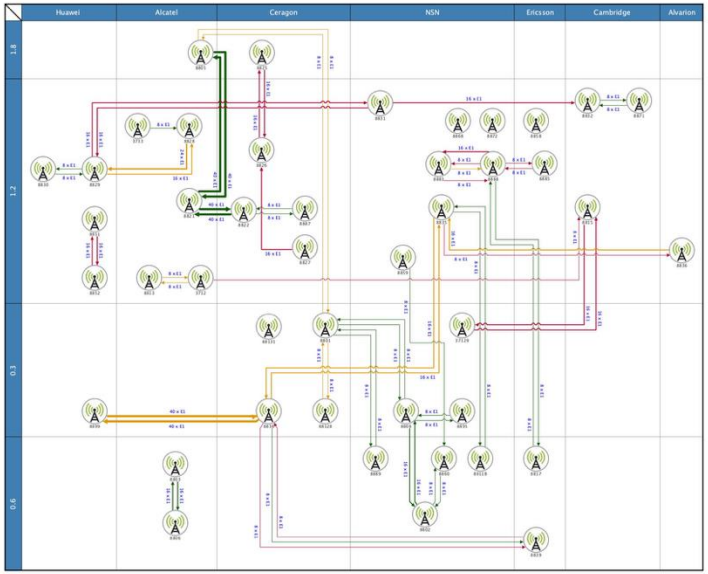
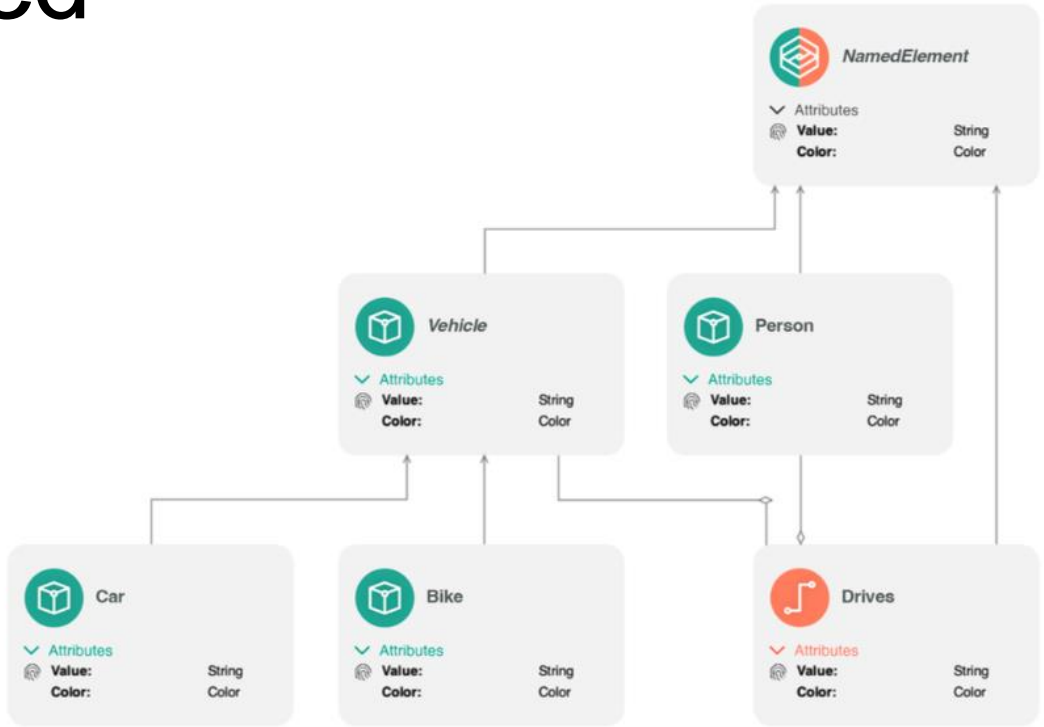


# **Knowledge Graphs** have an expected structure



# Knowledge Graphs for Modeling and Analysis

- Support users in modeling their systems as graphs
- Apply graph visualizations and analyses to discover areas of interest in their data
- Apply graph visualizations and analyses to optimize their systems

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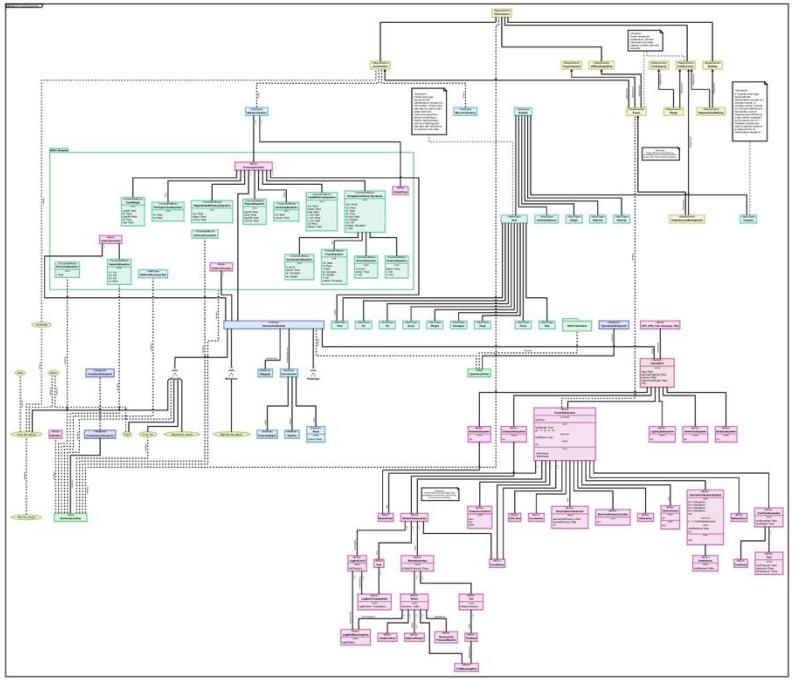

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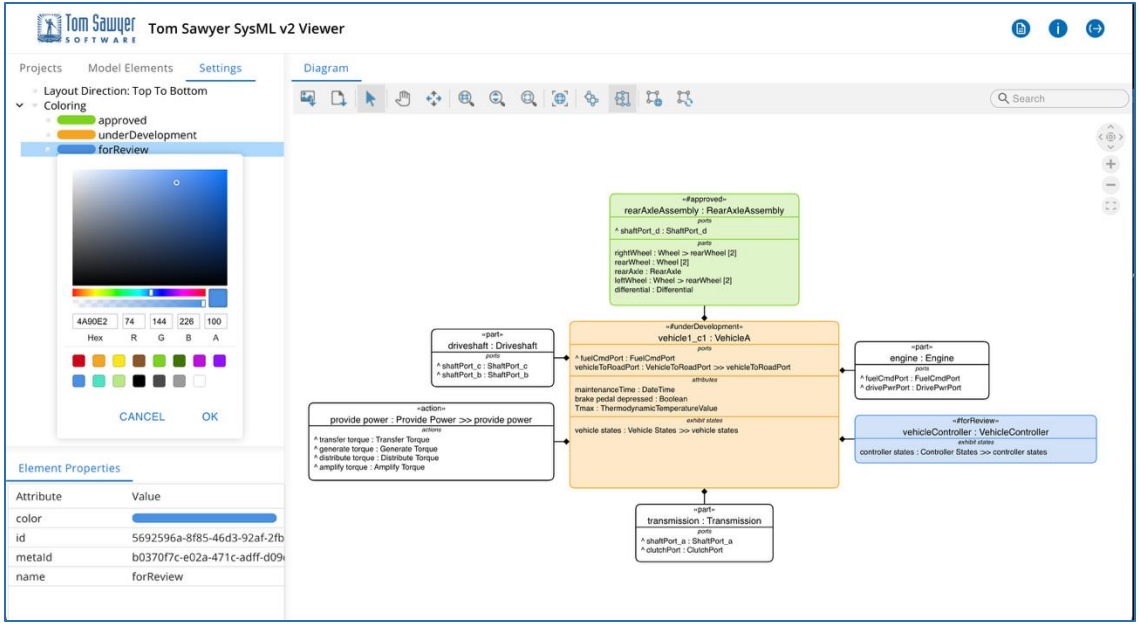

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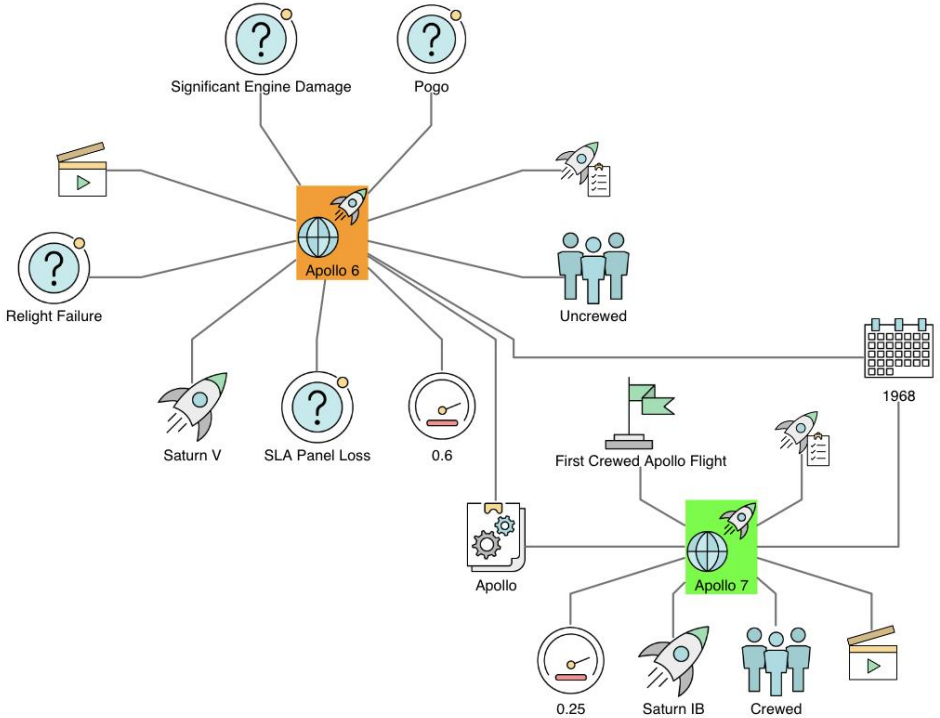

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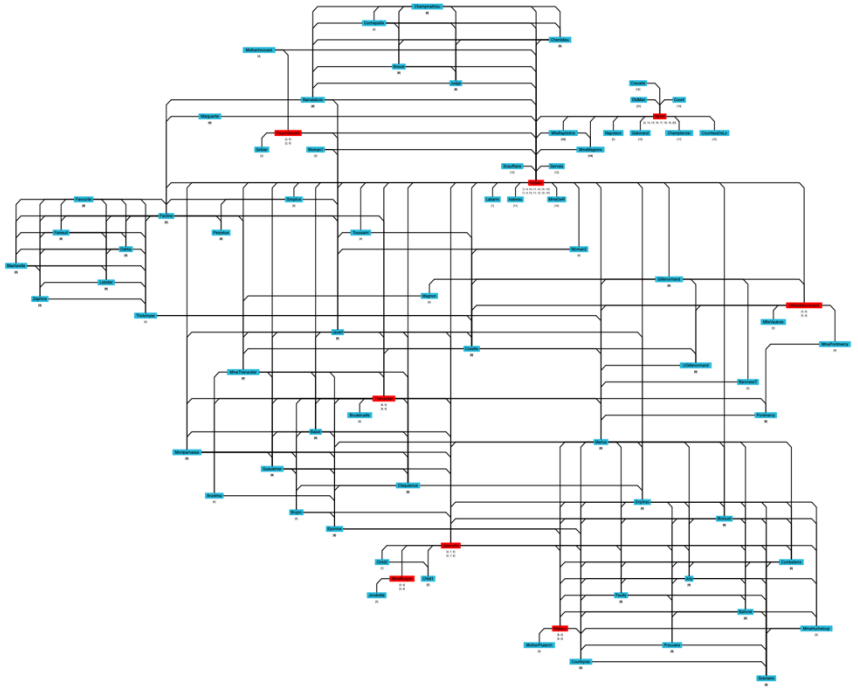

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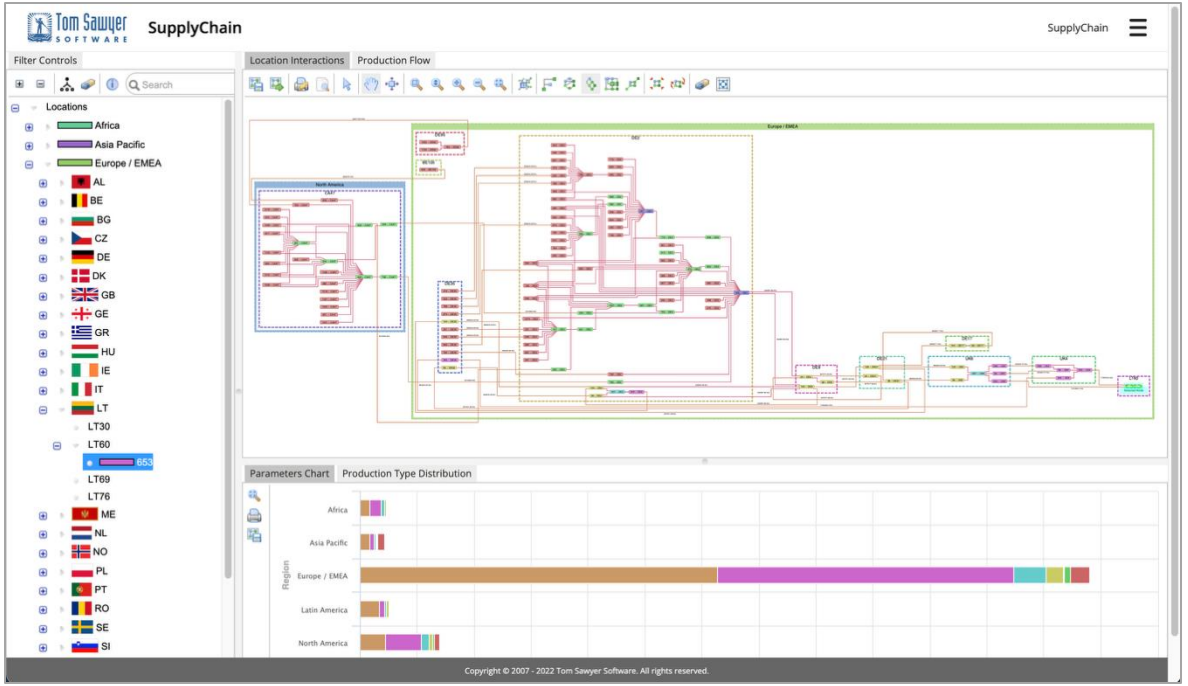

# Knowledge Graphs for Communication

- Deliver pertinent information to decision makers
- Communicate key results to stakeholders

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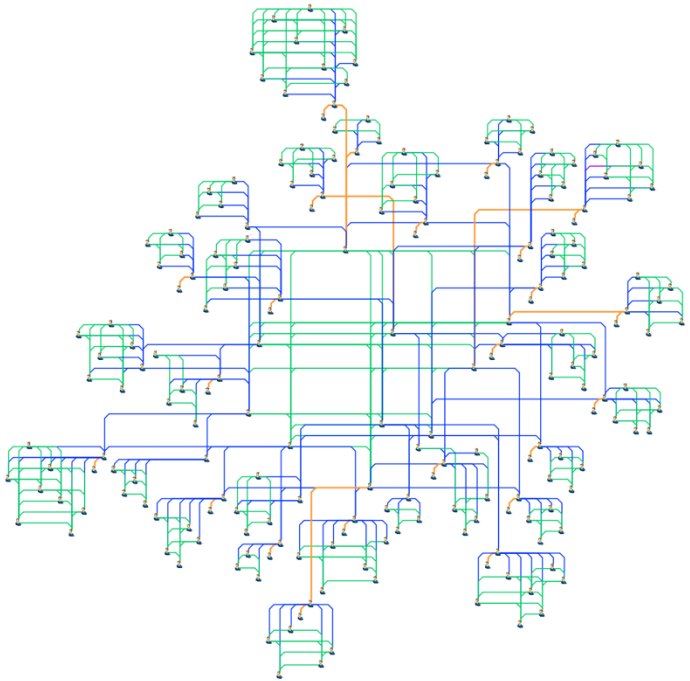

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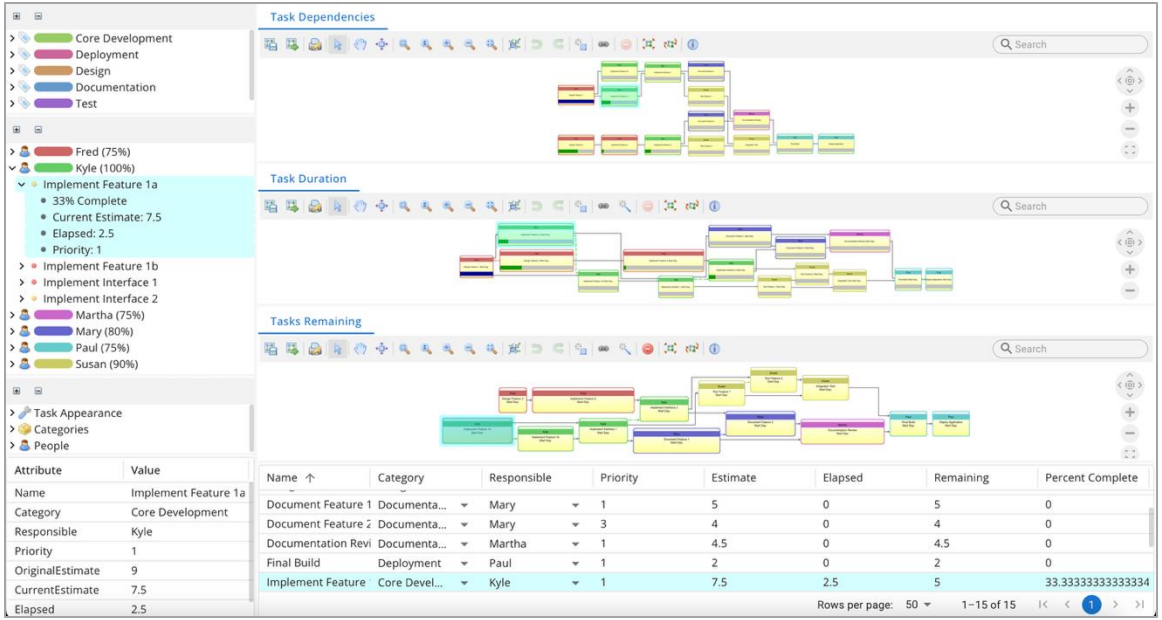
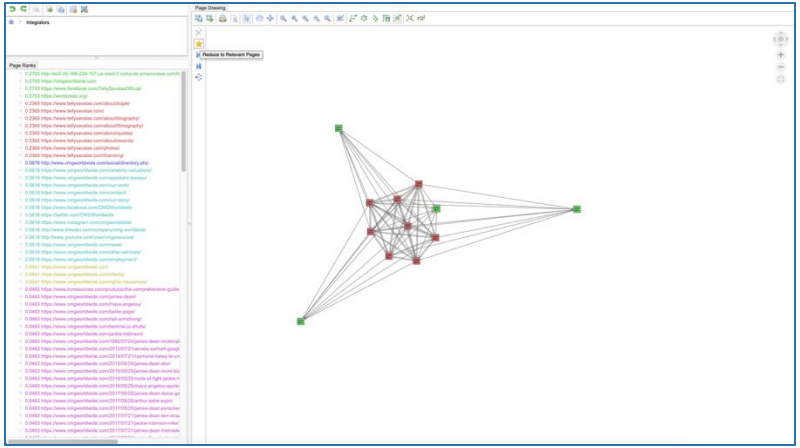
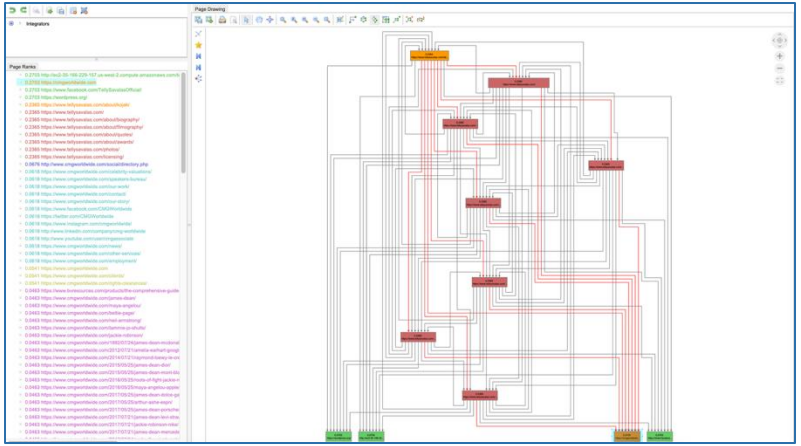


# Data Visualization for Systems Engineering

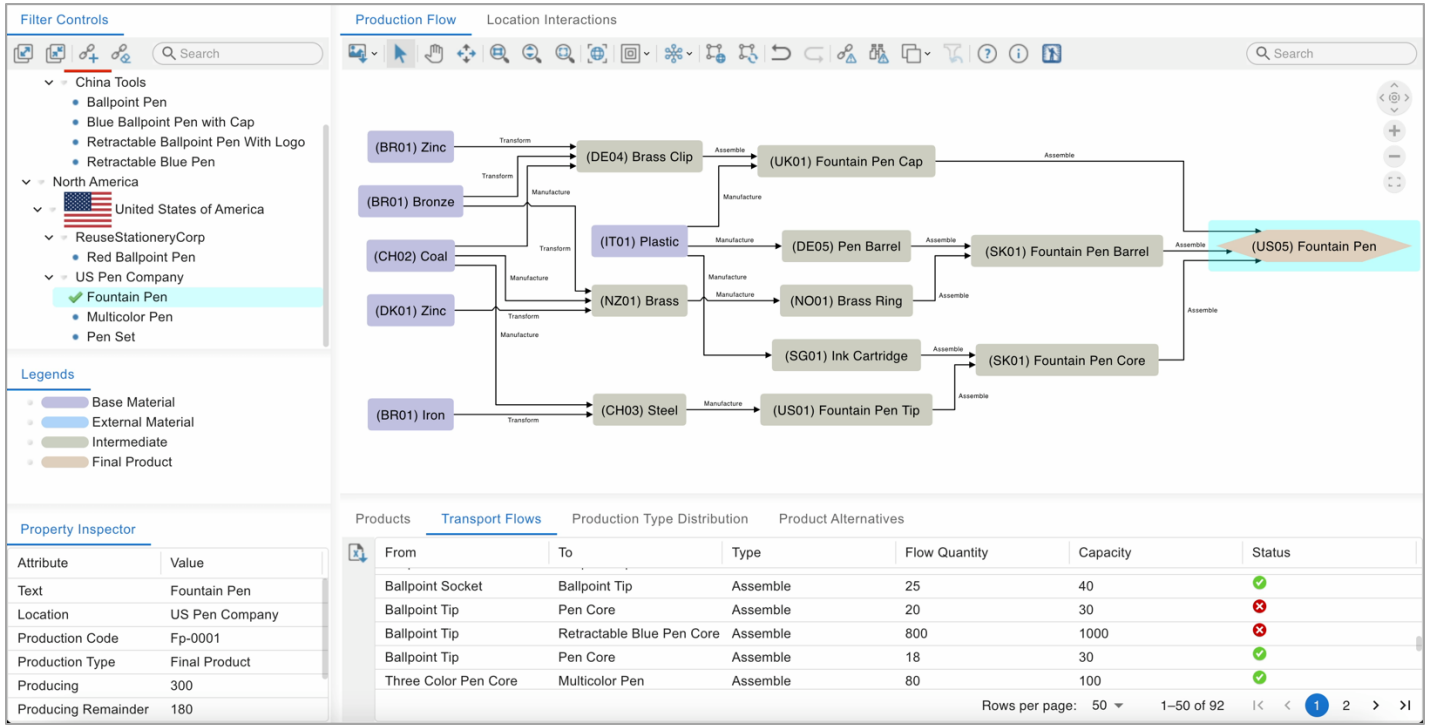
- Bring human experts back into the equation
  - “There is something interesting here, let’s look further”
  - “I have seen this pattern in another situation, a similar solution may be helpful here as well”
  - “There is an almost-pattern right there!” (almost vulnerability in a communications network, almost viable alternative for supply chain component, etc.)
  - “We can optimize the system here”
  - Multiple views into the same data provide a basis for the solution

# Post Situation Analysis





# Simulate Future Scenarios



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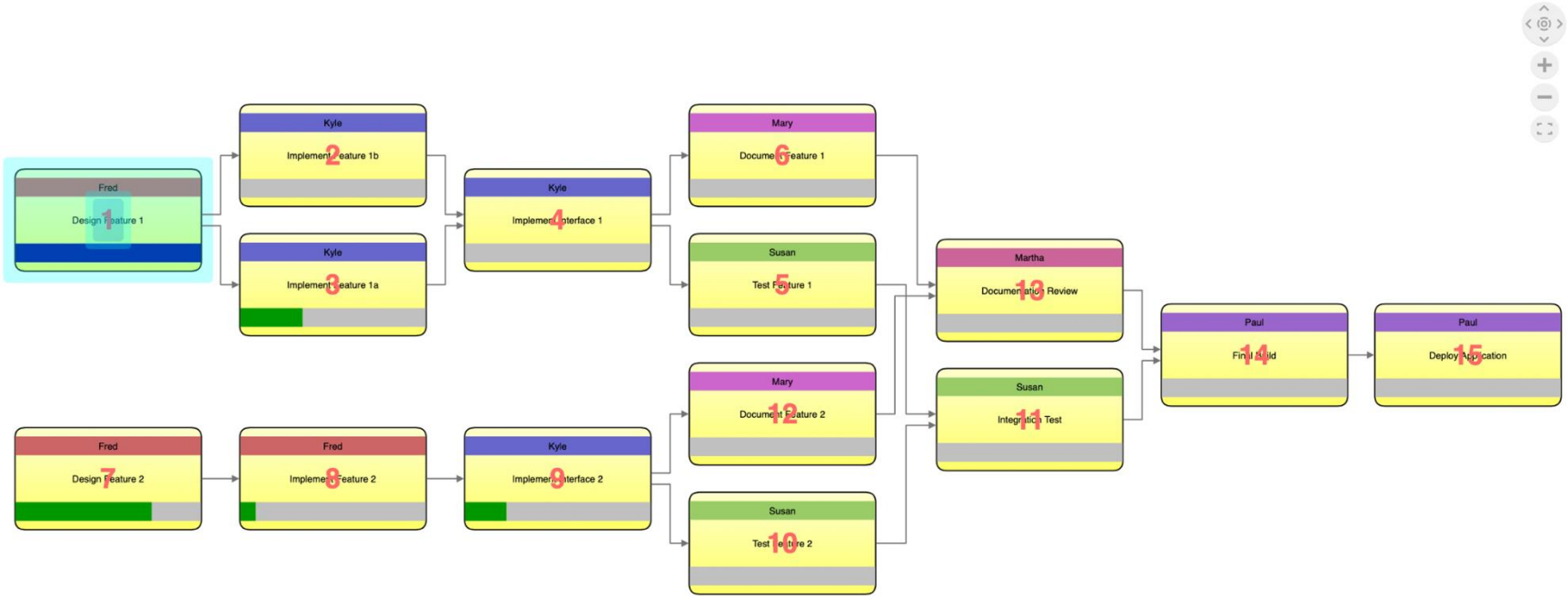
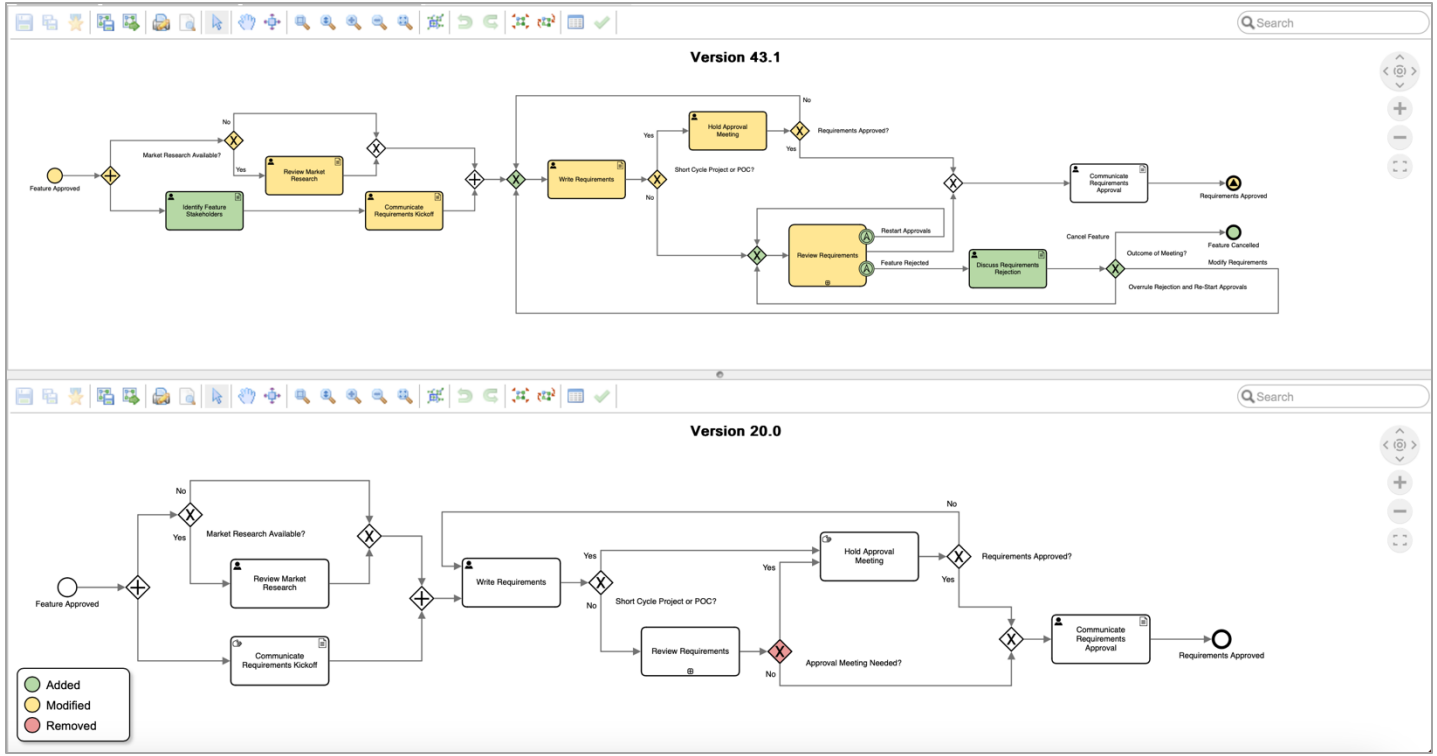


# Discover Trends



# Knowledge Graphs for Failure Analysis

# Finding the Hidden Insights in Spaceflight Data

- Extremely complex, heterogeneous data
- Legacy data
- Difficult to find deeper insights
- Systematic approach required for accuracy and breadth of findings
- Adaptability of approach supports additional data sources and new failure types

# Human System Interaction

## The System

- Analyzes patterns in historical data.
- Notices common sequences that precede failure and the amount of times it results in an unfavorable outcome.
- Depending on the system configuration, it would either notify an operator and/or automatically implement mitigation measures.

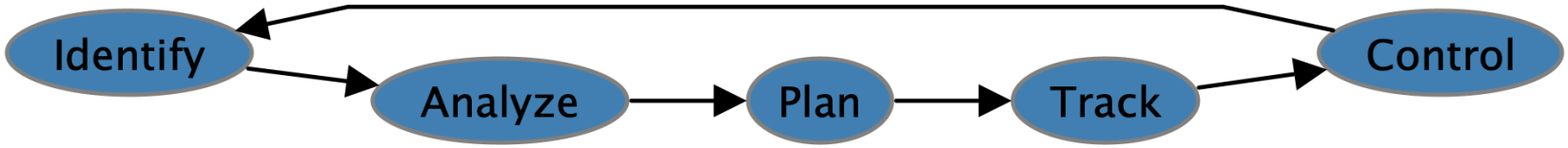
## The Human Interaction

- The system will create a visible alert that showcases need-to-know information and the suggested mitigation measures.
- The level of input the human has depends on the configuration of the system.

## Added Benefits

- Helps increase accuracy of fixed limitations to minimize the amount of failures and the amount of aborted tests that later are found to have been safe to proceed.
- Saves money and time throughout the testing phase.

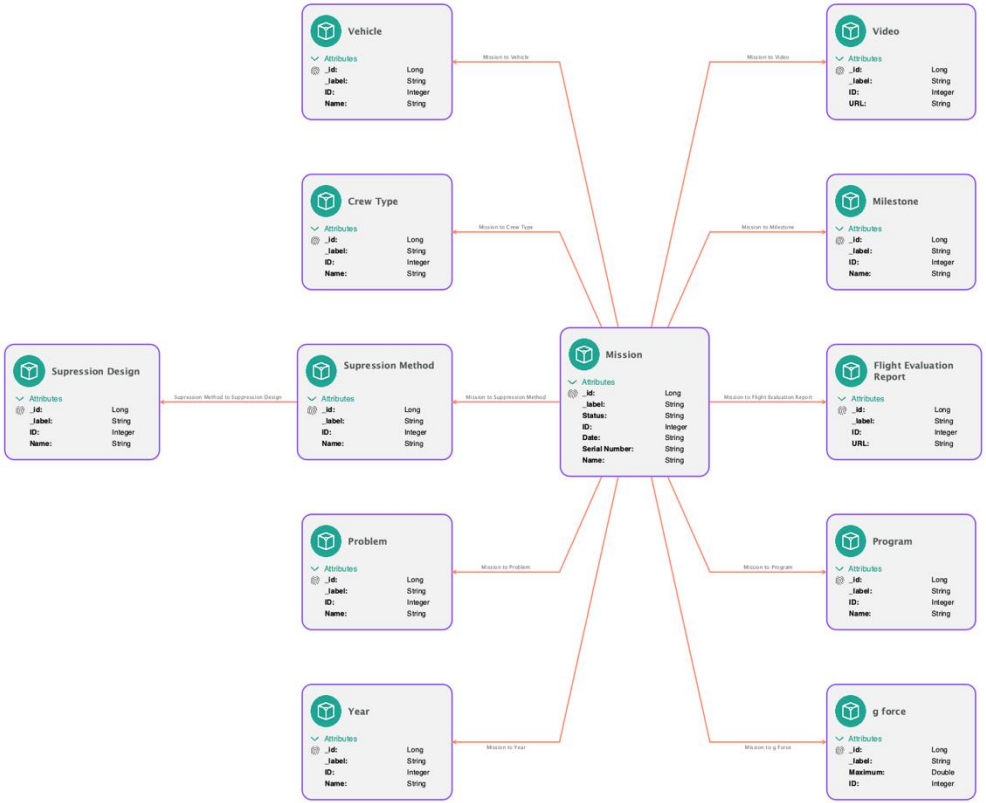
# Continuous Risk Management (CRM)



“The CRM process manages risk by identifying specific issues that are of concern to one or more stakeholders, and which are perceived as presenting a risk to the achievement of one or more performance requirements.”

**NASA Risk Management Handbook**

# Create Knowledge Graph



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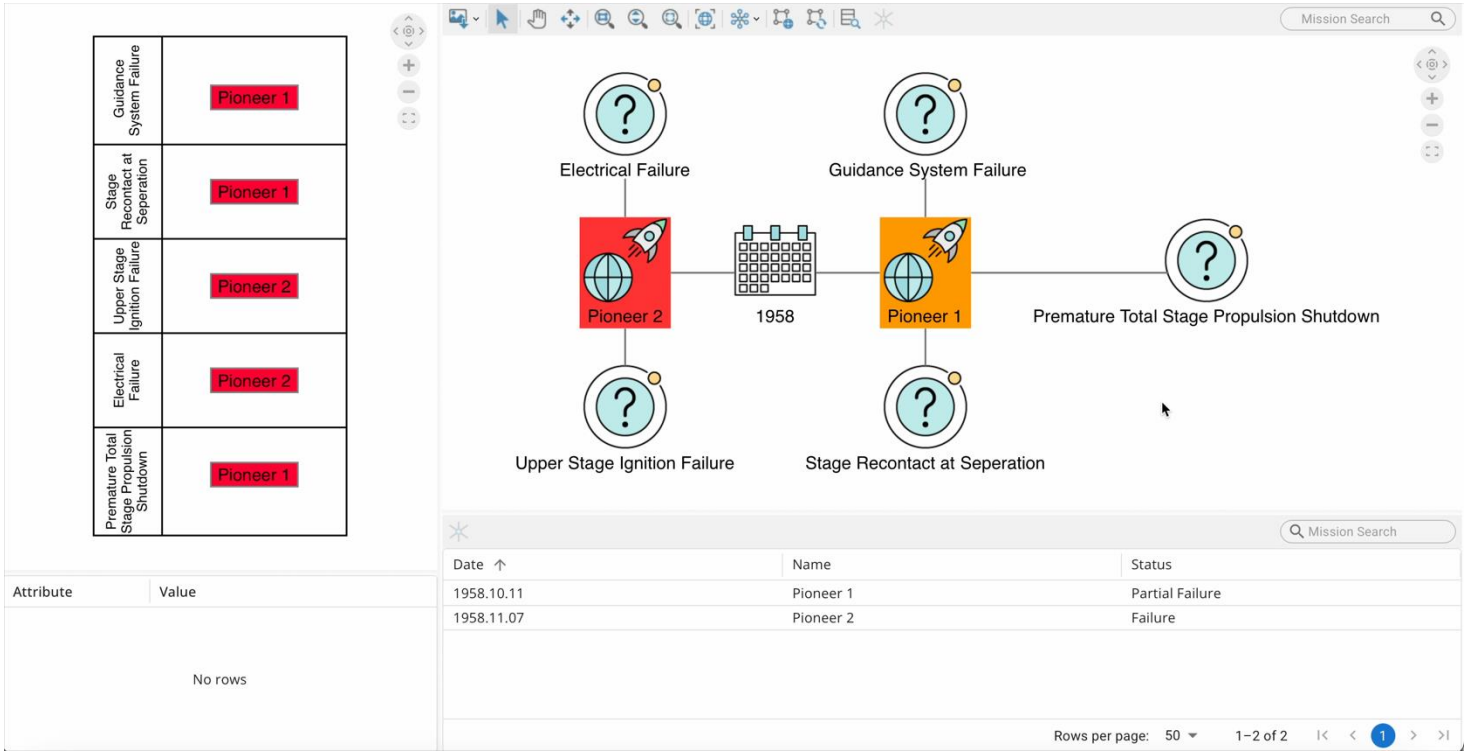
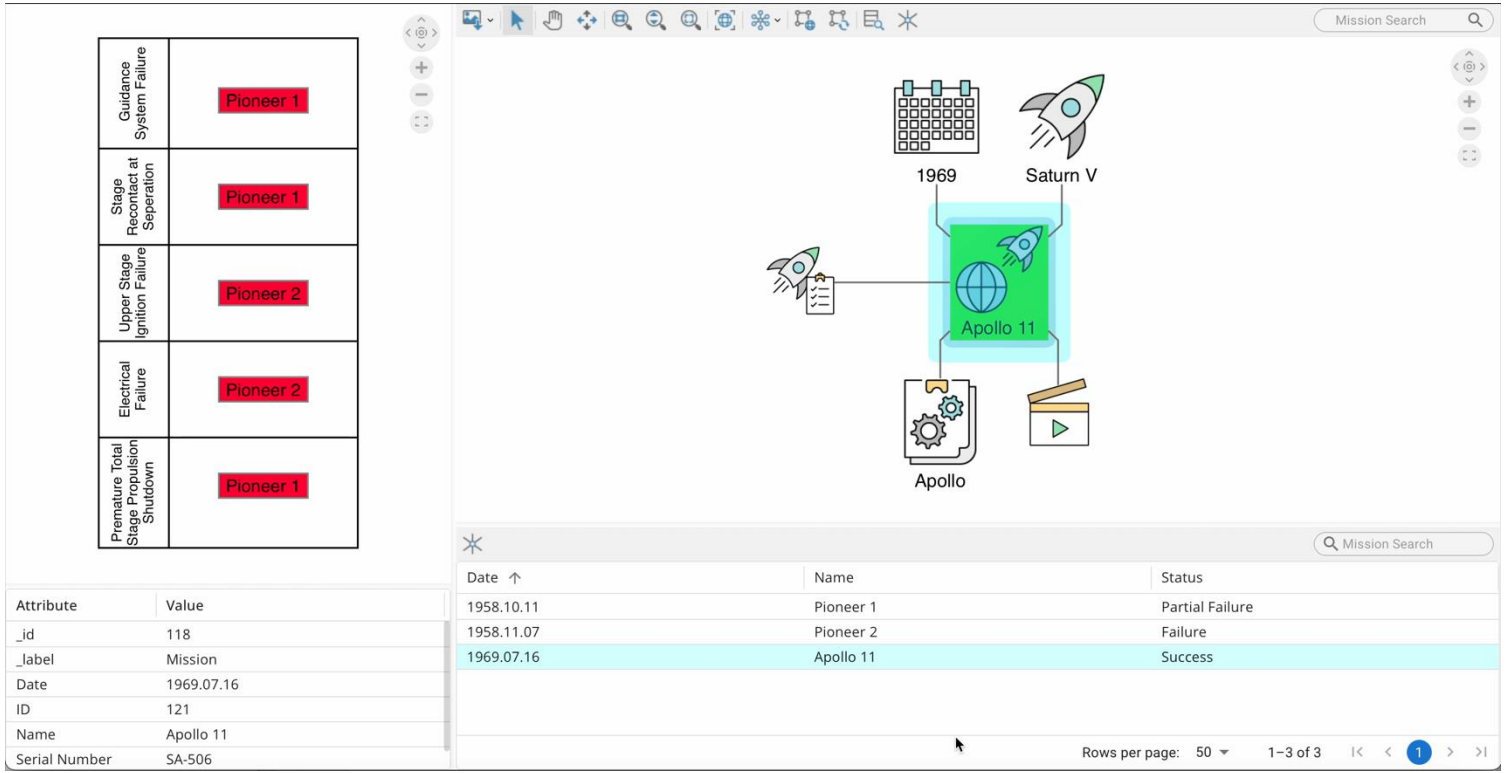
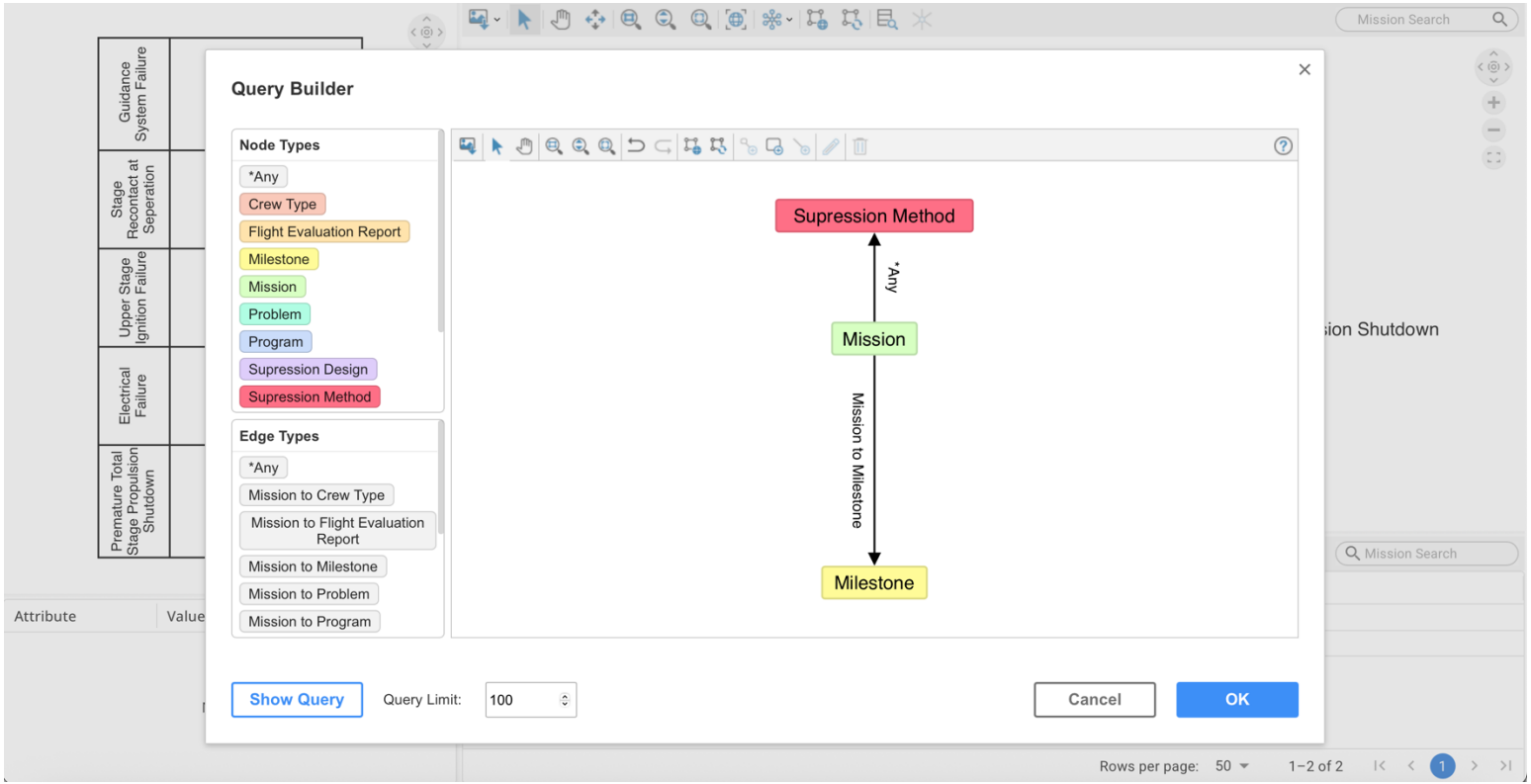


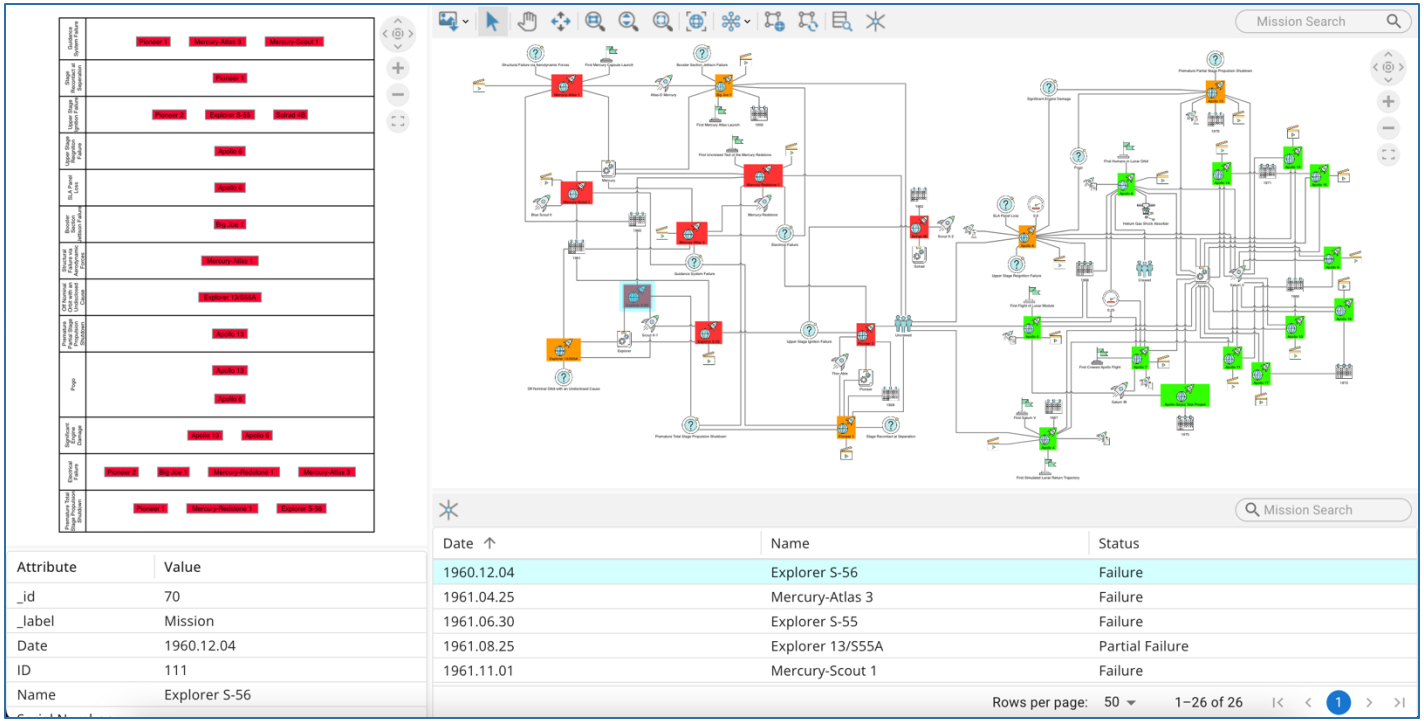
# Support Graph RAG



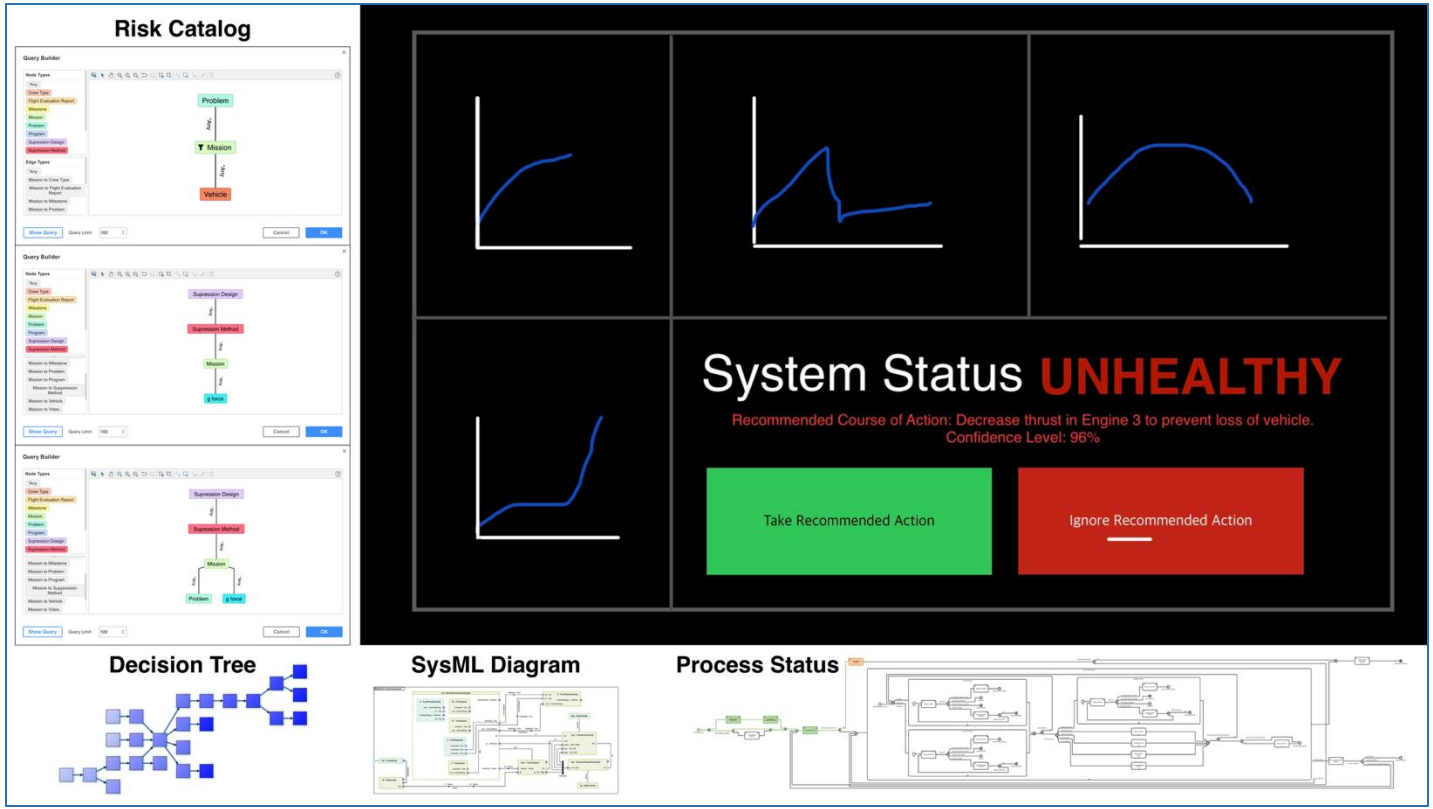
# Define Advanced Graph Patterns



# Communicate Key Findings to Stakeholders and Decision Makers



# Emerging Failure Detection



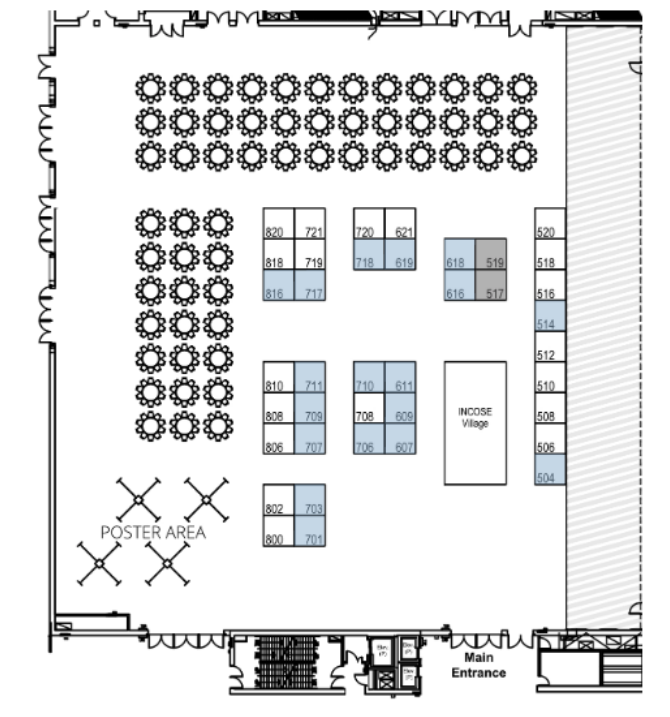
# Supporting Systems Engineering Vision 2035

- Adaptability to evolving technology and requirements
- Increased interoperability with simulation and multi-disciplinary analysis
- Analytic framework to understand, define, and sustain increasingly complex systems
- Provide reliable and timely knowledge for decision management
- Management of complexity and risk

# Future Work

- Apply this approach to other industries including manufacturing and automotive
- Increase integration with SysML v2 modeling
- Provide insights for Risk-Informed Decision Making (RIDM)

# Let's connect





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