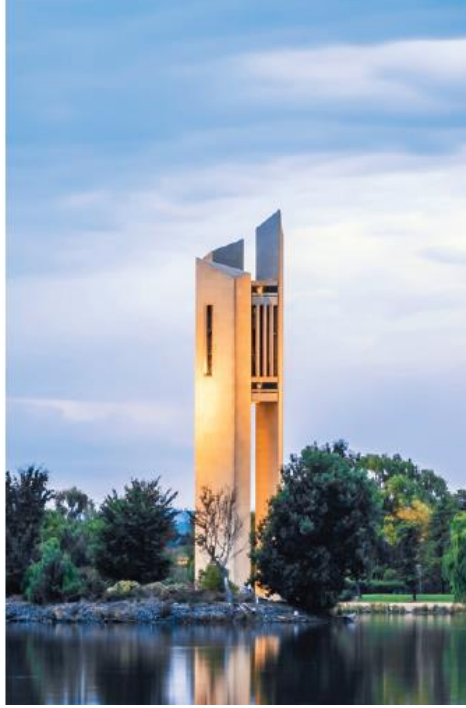
SETE
SYSTEMS ENGINEERING TEST AND EVALUATION CONFERENCE 2019
QT Canberra | Australia
29 April – 1 May 2019



SYSTEMS SCIENCE & ENGINEERING FOR A BETTER AUSTRALIA SETE2019.COM.AU

Development of an Integrity Measure for Heavy Rail Systems

William Scott CSEP

Use of Asset Management Information

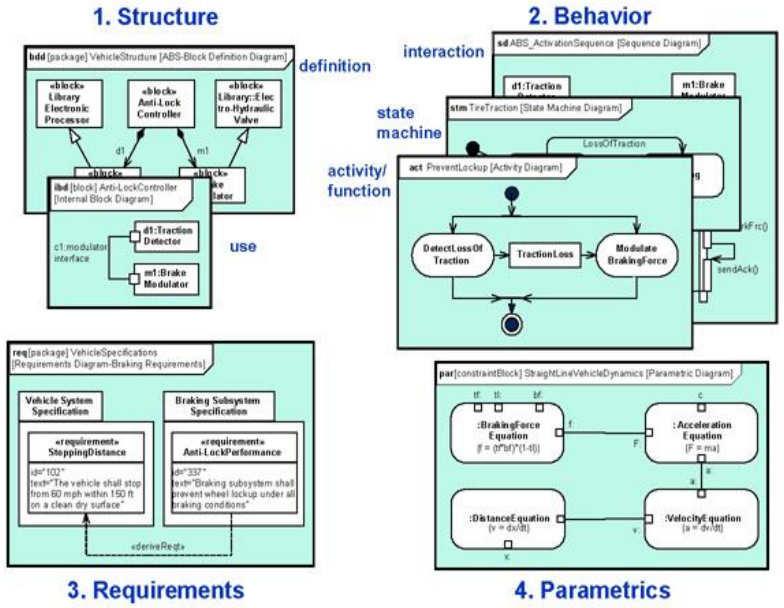
- Asset Management provides a large amount of data related to the health of the individual assets
- It can be difficult to determine the effects of assets on the wider health of the overall system
  - This is even more complex when it's a System of Systems
- The challenge: Measure the overall system integrity based on the health of the individual assets and the interdependencies between them
  - If it can be measured then it can be managed!

System Integrity

- What is System Integrity (SI)?
  - There are numerous definitions and contention about what comprises SI.
- System Integrity here is taken as:
  - The ability of a system to withstand disruption with acceptable levels of disruption and to recover within an acceptable time
- Criteria for an Functional SI measure:
  - Captures the relationship between the threats and consequences
    - Threats may be internal or external
    - Includes the effectiveness of resilience and redundancy
  - Provides a measure over a defined period
    - Not an instantaneous state
  - Considers the impact of a variety of states leading to varying levels of operation
  - Many definitions consider SI as binary (i.e. intact or failed)
    - Large scale systems can have partial failures
      - Failures can reduce functionality
      - Failures can have limited scope (i.e. not effect the entire rail network but only a region)
  - Constrained to the effects of assets (hence the term Functional)
    - Excludes human failures and external influences

Support from Model-based System Engineering

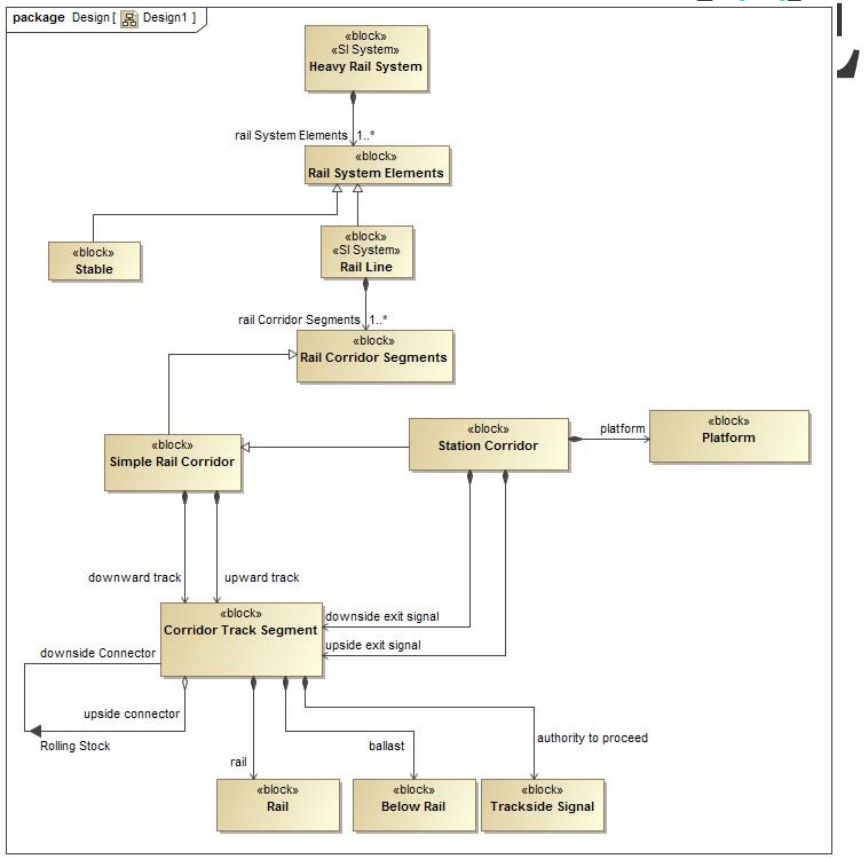
- Systems Engineering tools can be used to understand the systems environment
  - Tools are often built upon SysML
    - An international standard from the Object Management Group
- SysML tools can be used to:
  - Capture interfaces and interactions
  - Model the effects of failures on the state of assets
    - Both direct and indirect effects



Note that the Package and Use Case diagrams are not shown in this example, but are respectively part of the structure and behavior pillars

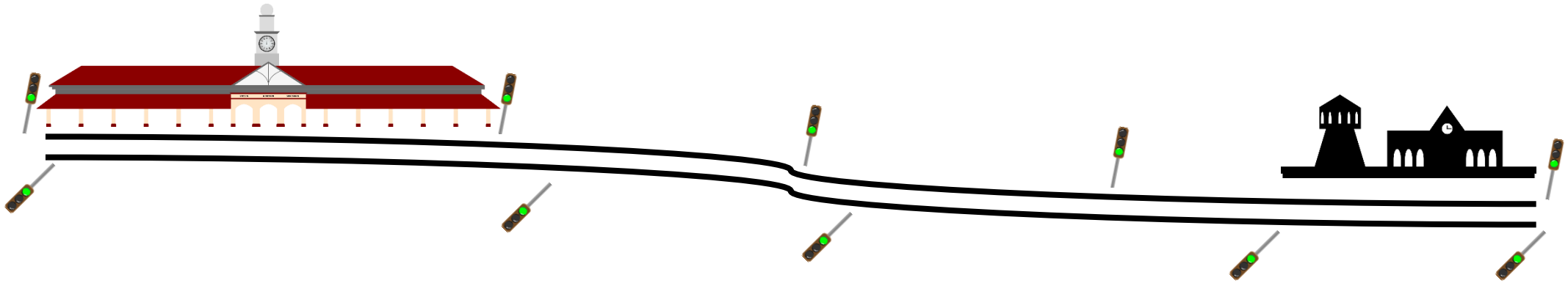
MBSE Model – Generic Structures

- Modelling was done in two stages.
- First was identification of the various types of assets and the common combinations

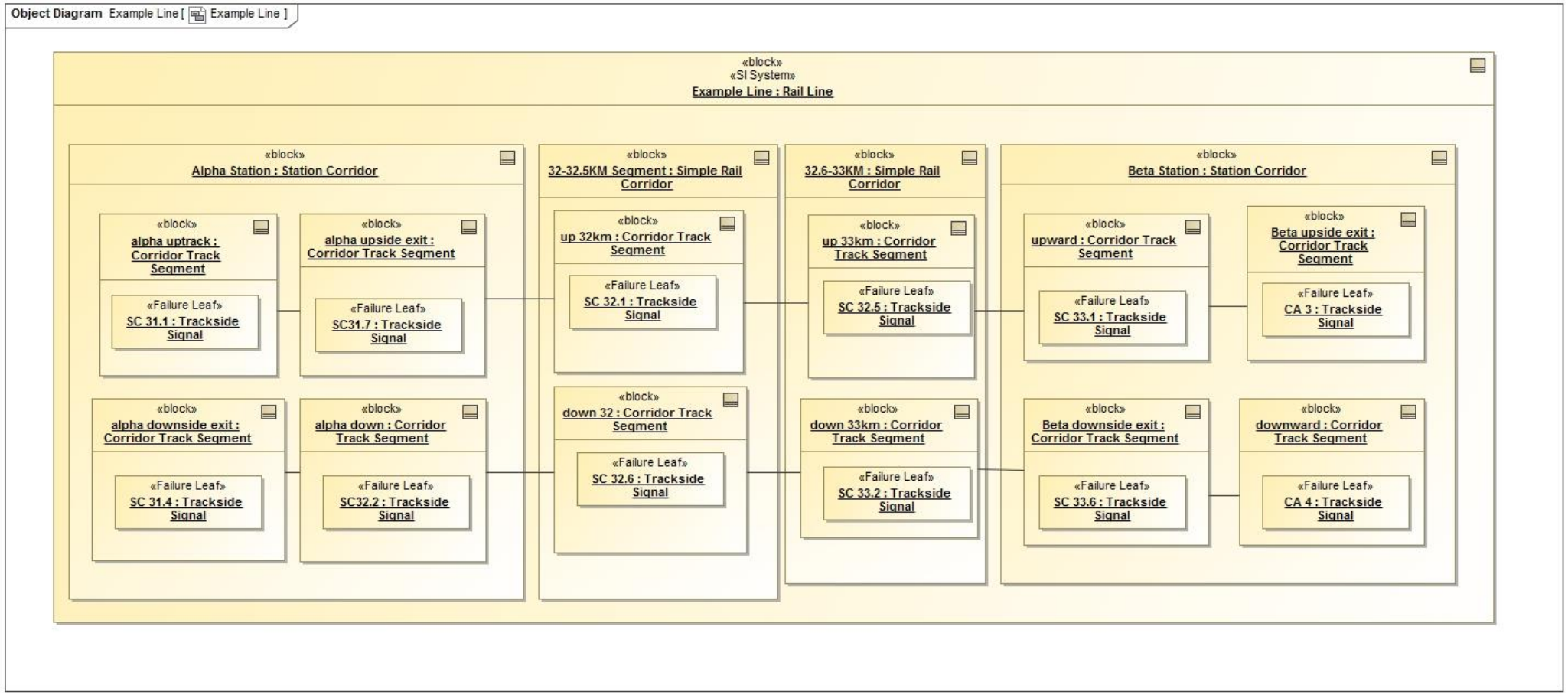


MBSE Model – Asset Allocations

- Actual assets were then allocated and placed in the configurations that most accurately reflected the circumstances
- An example presented here is a simple example with two stations and the connecting section of track.
  - Two lines running between the stations: uptrack and downtrack

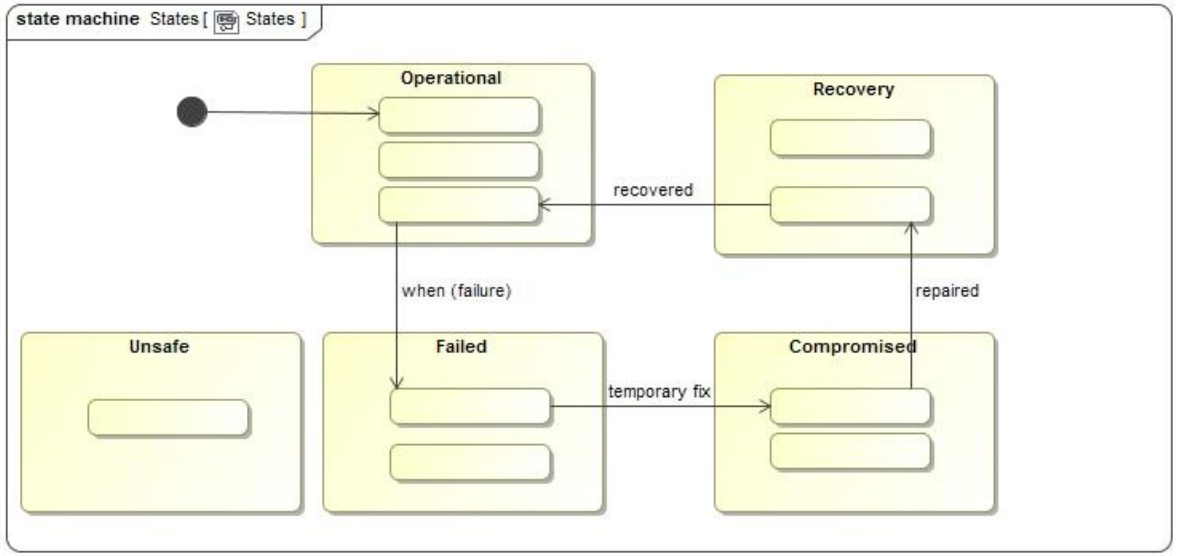


Resulting Model Example



Effect of Failures

- Assets and Systems have states that are categorised
- Failures and recovery actions are captured as transitions between these states
- States are weighted to reflect their impact on operations
  - Weights are used as a penalty so
    - Unsafe and Failed states have a weight of 1.0
    - Operational states have a weight of 0.0
    - Compromised and Recovery states weights depend on how close they are to operational or failed



Determining an Asset's FSI

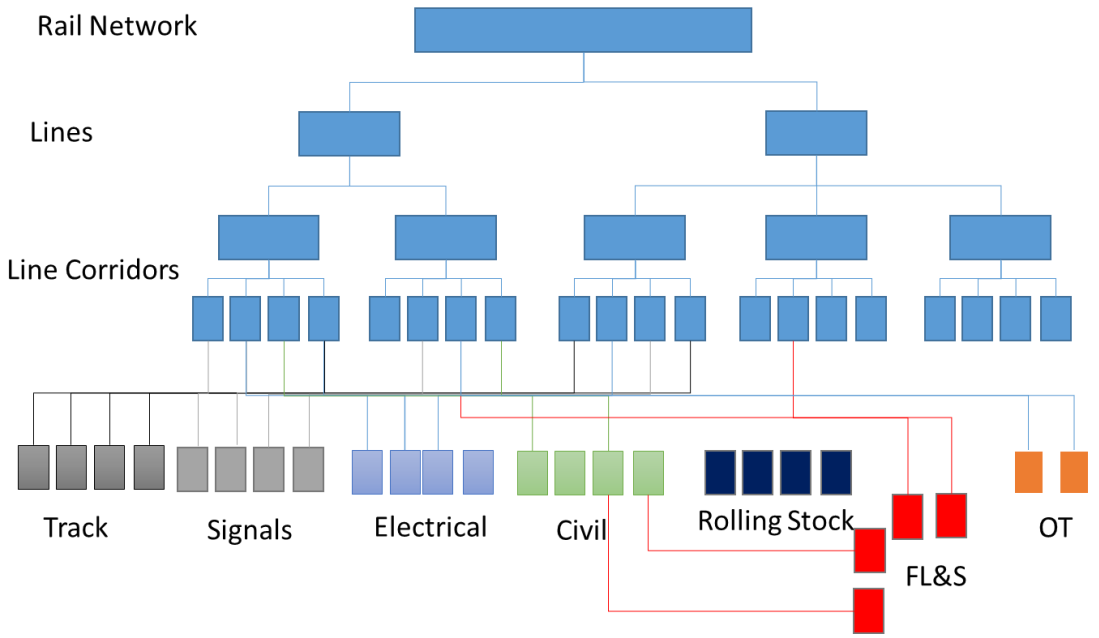
1. Failure reports are examined to gather the observed failures
2. For each failure
   - Determine the resulting states
   - Duration in each state
3. Calculate Penalty to FSI

$$s = 1 - \sum_{i=1}^{N} \sum_{j=1}^{M} w_i t_{ij}$$

Heavy Rail System Hierarchy for Aggregation

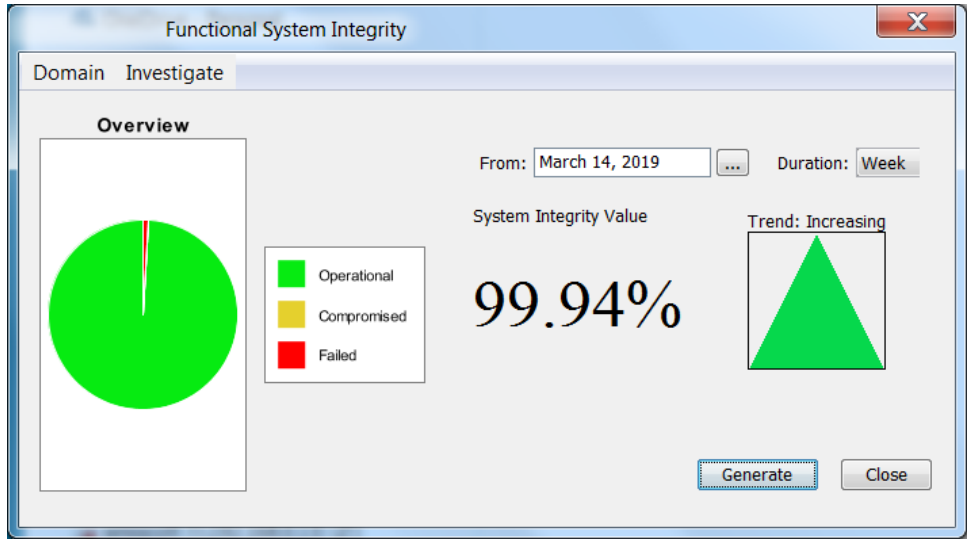
- System hierarchy created to capture which assets interact with other assets
- Importance of assets in each level of the hierarchy captured in weighting
- Generation of composite system's integrity can be obtained as a weighted sum:

$$s = \sum_{i=1}^{N} w_i s_i$$

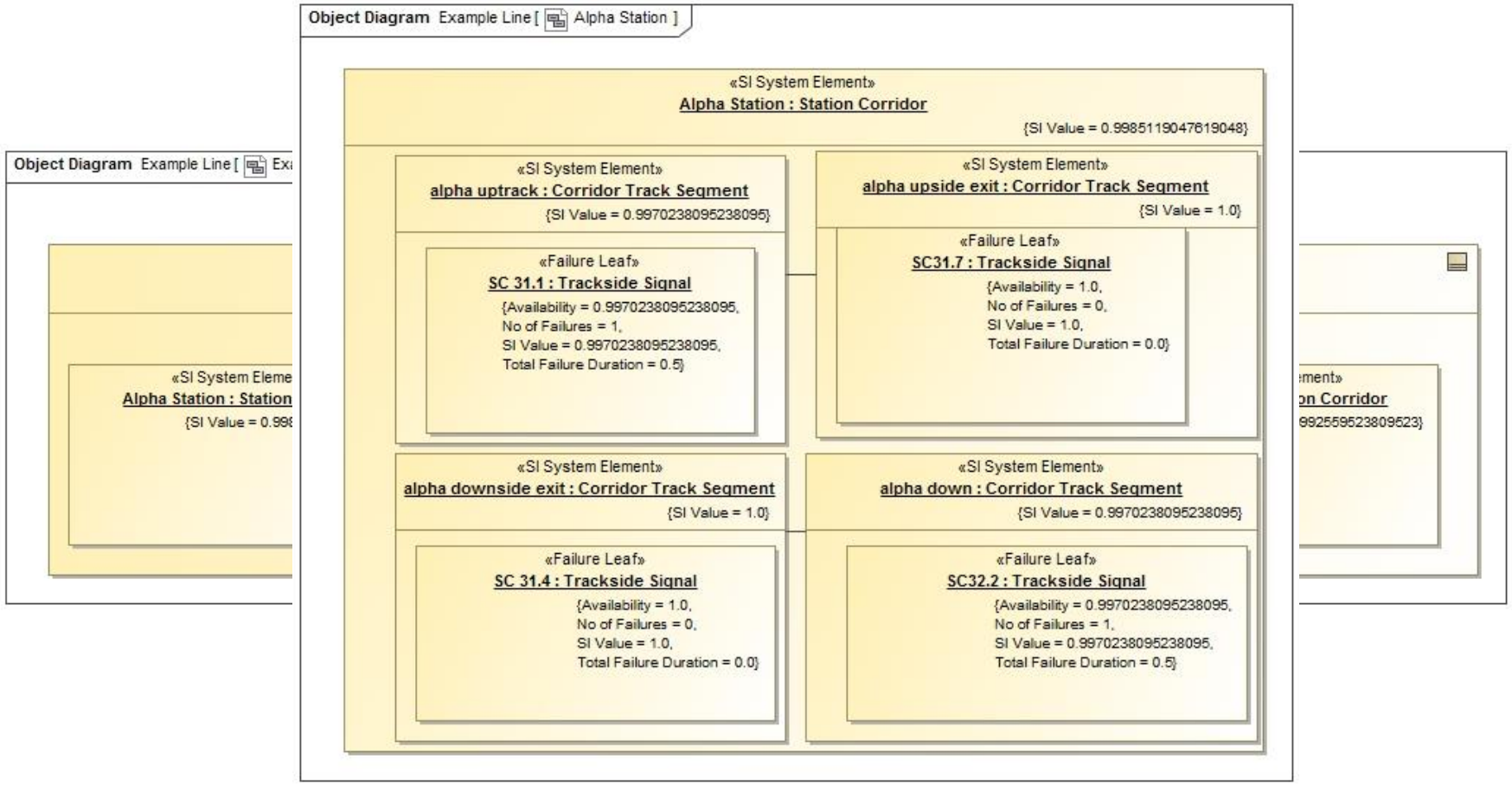


Presentation of Results

- Results are presented in three levels of detail
  1. General Overview
     - Presents the FSI value from the analysis
  2. High Level Investigations
     - Presents comparisons and overview of associated information
  3. Detailed Breakdown
     - Enables user to navigate through derived values
       - Determine elements to be addressed
       - Validate the derived outcomes
       - Understand changes from previous periods



Detailed Breakdown Example



Next Stage Enhancements

- Transitory System Elements
  - Trains and other forms of rolling stock transition through the system
  - Compromised trains will limp through the system causing backlogs
  - Place where trains may fail cannot be predetermined
- Interdependencies within systems
  - Corridor segments are not entirely independent
    - Blocked tracks in one segments will stop trains being fed to connected lines

Questions!

SETE

QT CANBERRA | AUSTRALIA

29 APRIL – 1 MAY 2019

ENGINEERS AUSTRALIA

SESA

INCOSE

SOUTHERN CROSS INTERNATIONAL CHAPTER