



33rd Annual **INCOSE**
international symposium
hybrid event
Honolulu HI USA



Data Visualization to Address Program and Systems Engineering Problems in Large Projects

Modeling Schedule Logic

Outline

- Problem context
- Data visualization with graphs
- Data visualization for modeling and solving problems
- Data visualization for systems engineering
- Case study
- Process to develop the interactive schedule logic modeling capability
- Importance of interactivity
- Ease of process
- Additional material



Problem Context

Problem Context - Working with large schedules

Unique attributes of large projects

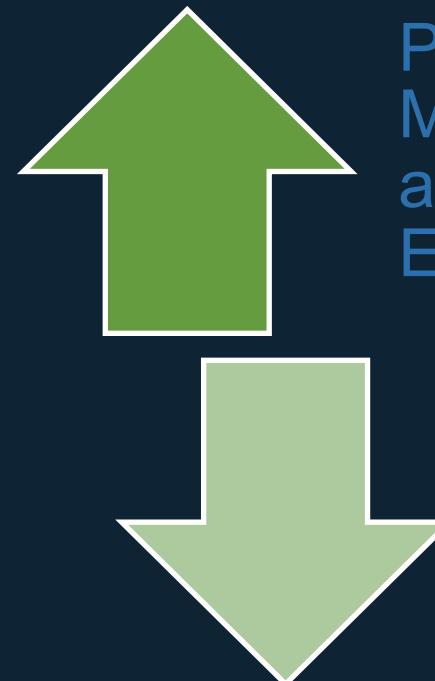
- Extremely large schedules
- Murky picture of work/product relationships
- Changes over time convolute the schedule and understanding of work/product relationships
- Not readily human comprehensible

Types of problems

- Staff/Management/Customer do not have full understanding of schedule
- New staff have difficulty comprehending
- Poor comprehension of risk and impact on other project areas
- Assessment of change is limited – full scope is hard to identify
- Misunderstandings drive unneeded changes – further obscuring schedule structure and resulting in incorrect logic
- Variance Analysis Reports are based on silos of information
- Belief or trust in schedule is deteriorated

Problems impact Program Management and Systems Engineering Efforts

- Earned Value Management
- Management Reserve Allocation
- Risk
- Impact assessments for technical solution feasibility (design, development, integration, verification, validation, production, operation, sustainment)



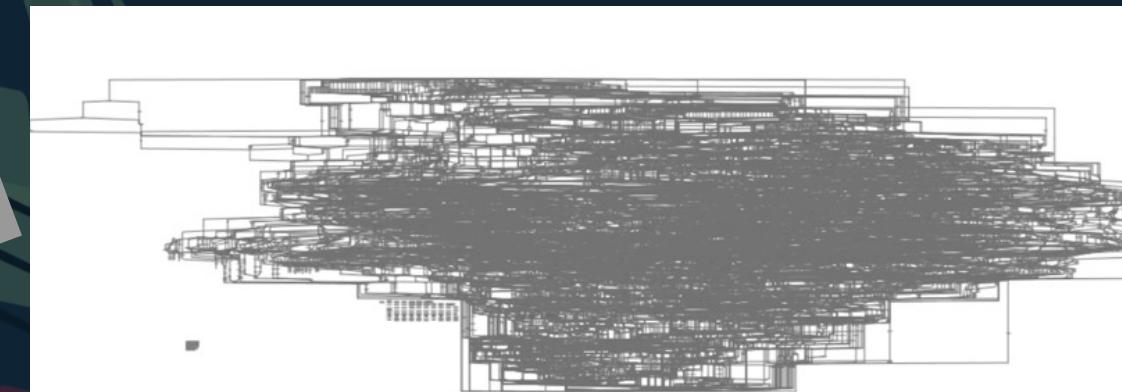
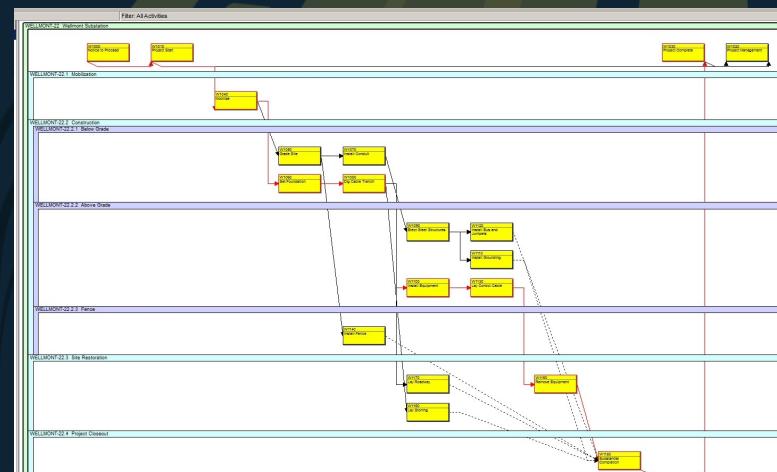
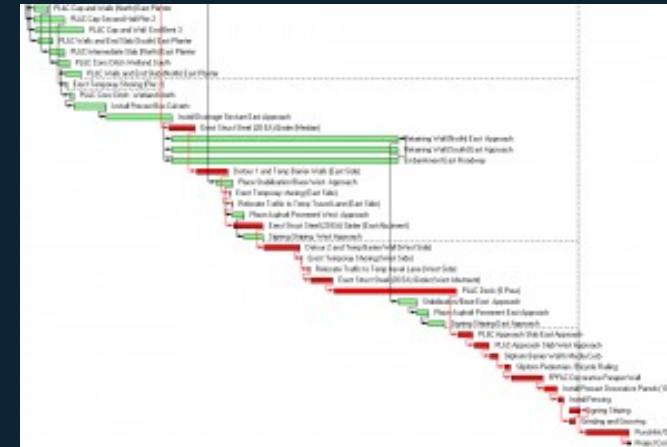
Program
Management
and Systems
Engineering

Poor
Comprehension
of Schedule
Logic

Working with Large Schedules

Current approaches to dealing with large schedules

- Critical path analysis
- Network diagrams (schedule logic diagram) – displays relationships

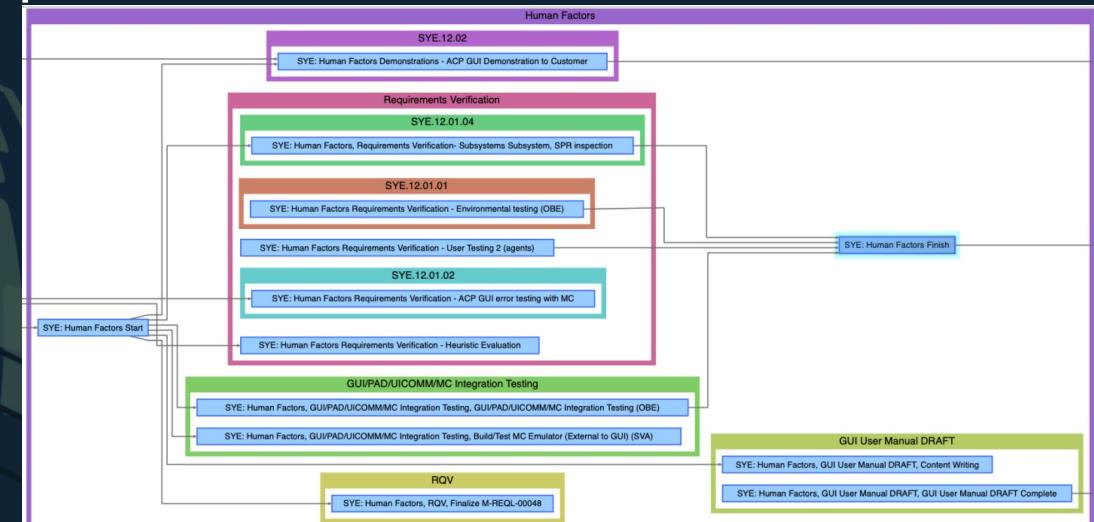
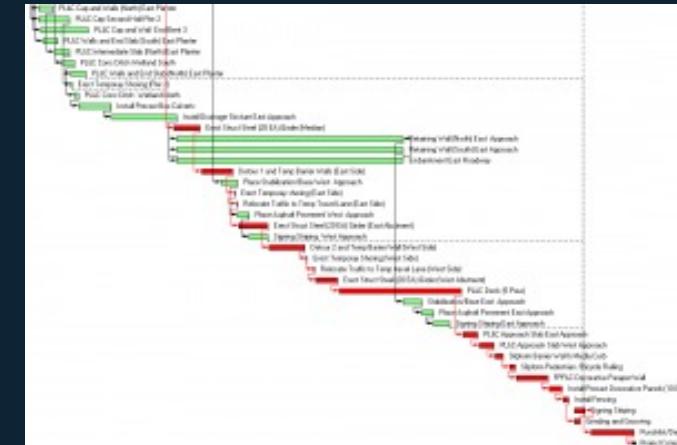
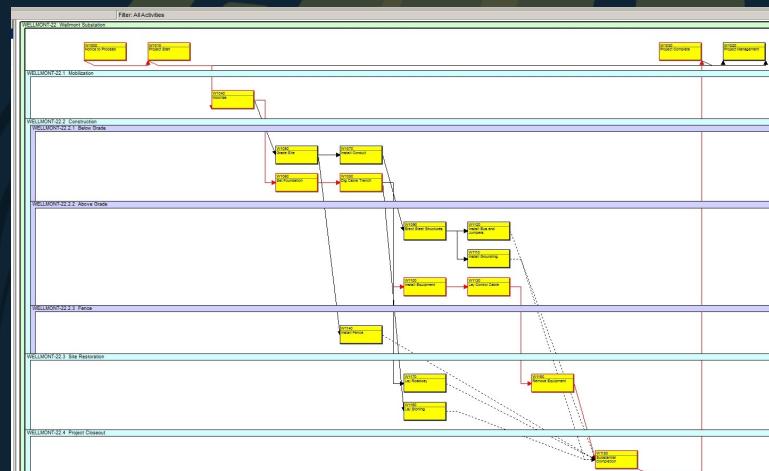


Current State with Large Network Diagrams

Working with Large Schedules

Current approaches to dealing with large schedules

- Critical path analysis
- Network diagrams (schedule logic diagram) – displays relationships

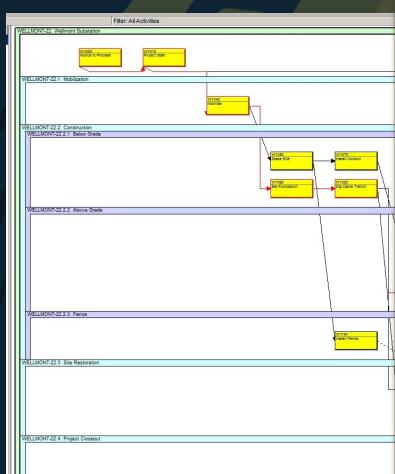


What if we could have this?

Working with Large Schedules

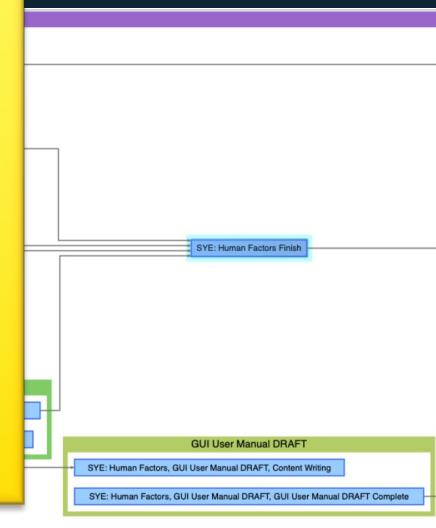
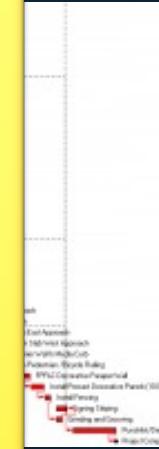
Current approach to large schedules

- Critical path
- Network diagram



What if you could:

- **Vary the levels of abstraction**
- **Visually consider (individually or combined)**
 - completed tasks
 - in-work tasks
 - work not started
 - work by Product Realization Team (PRT)
 - work by major component
 - work by major project milestone
 - work by float duration, critical path or any number of other project specific needs



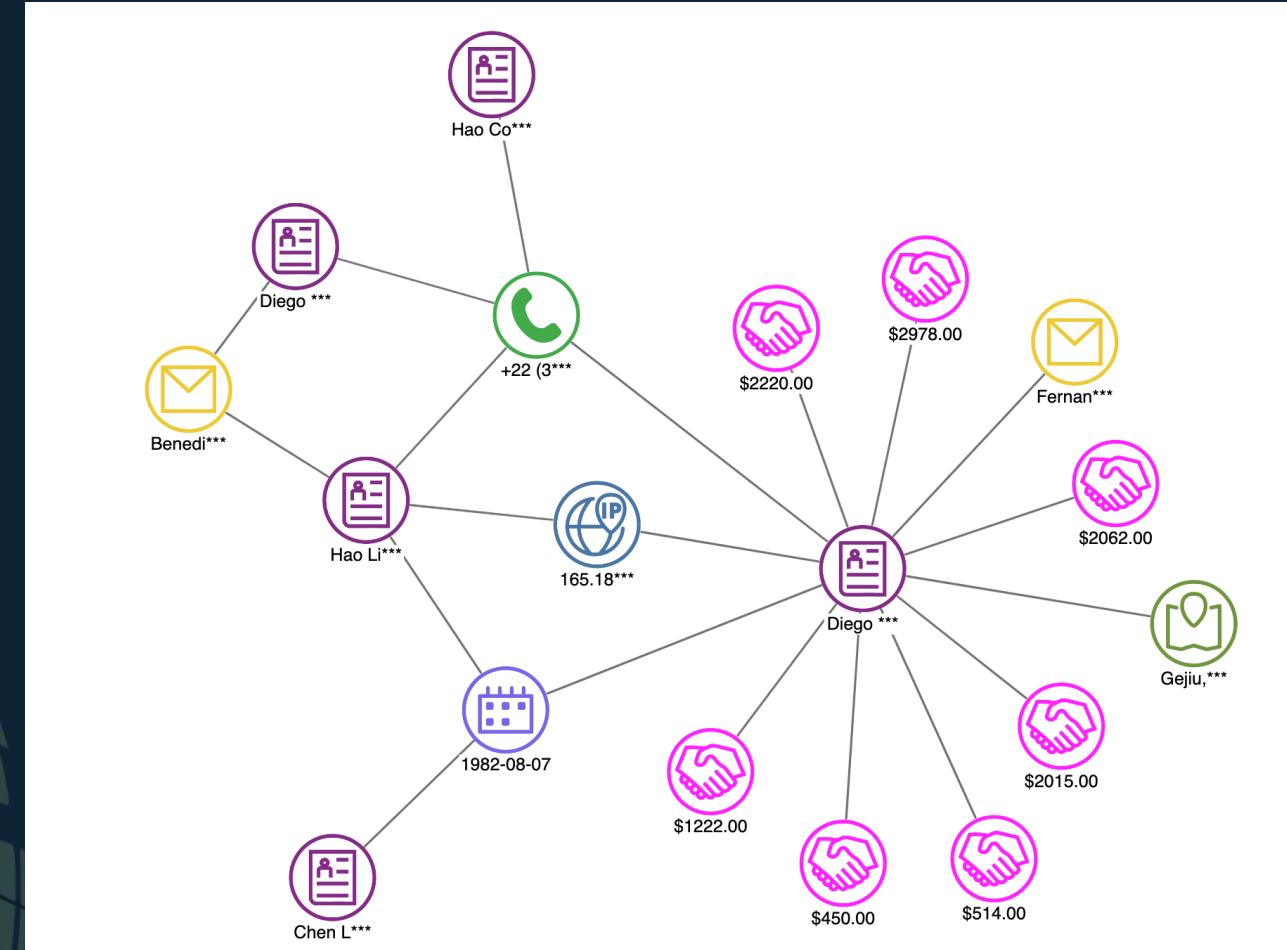
What if we could have this?



Data Visualization with Graphs

Graphs

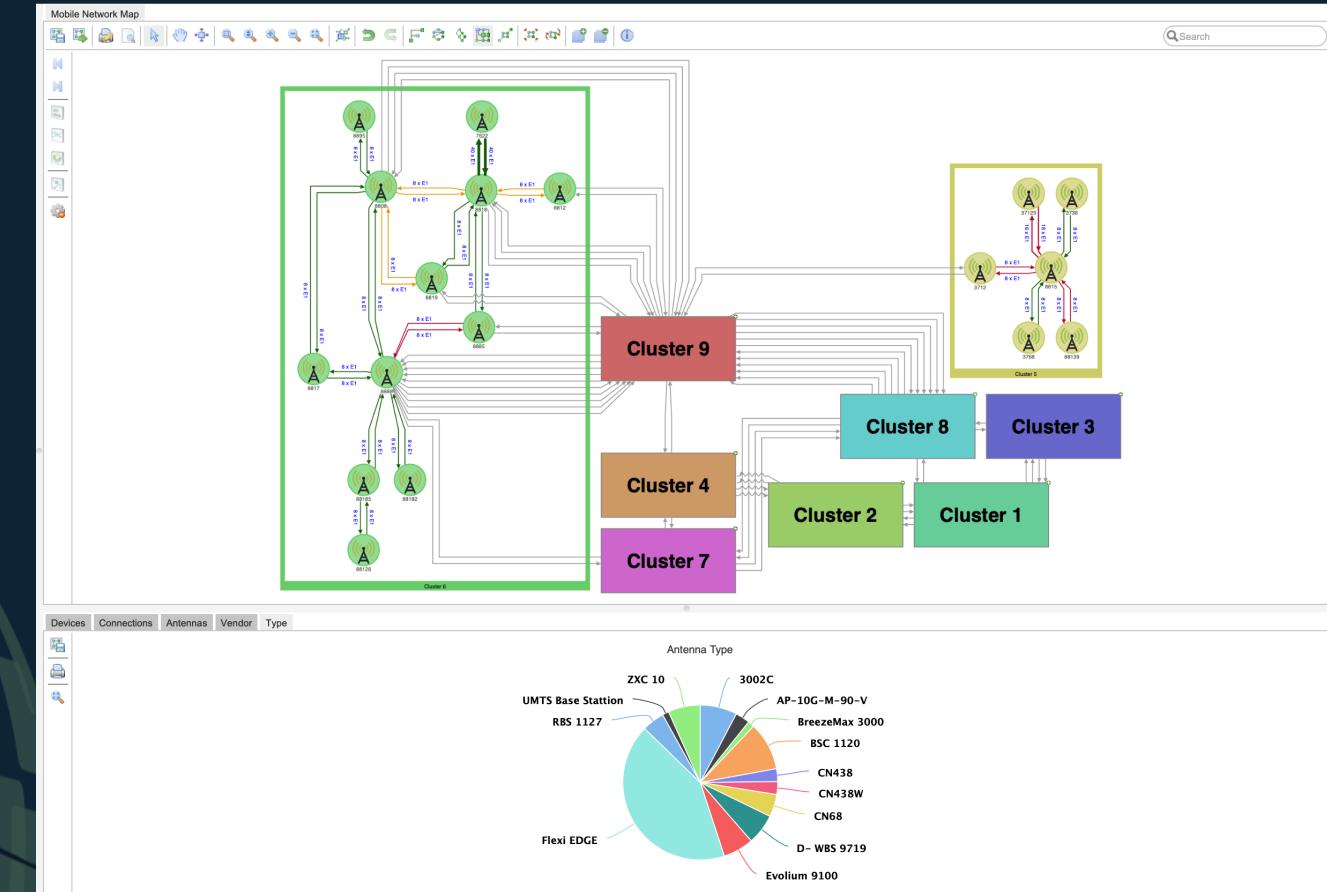
- Nodes (or vertices)
- Relationships (or edges)



Graphs

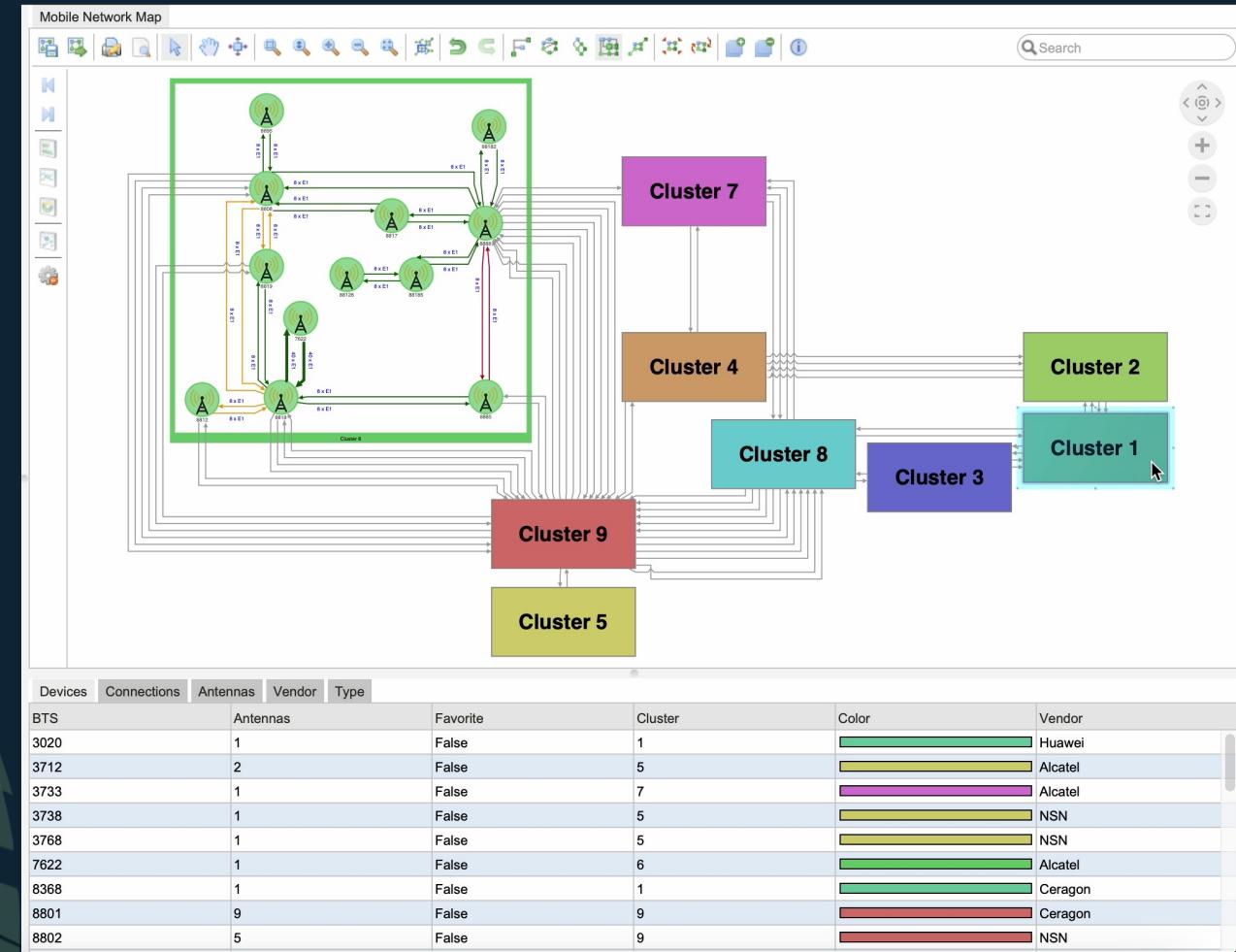
- Nested Drawings

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



Graphs

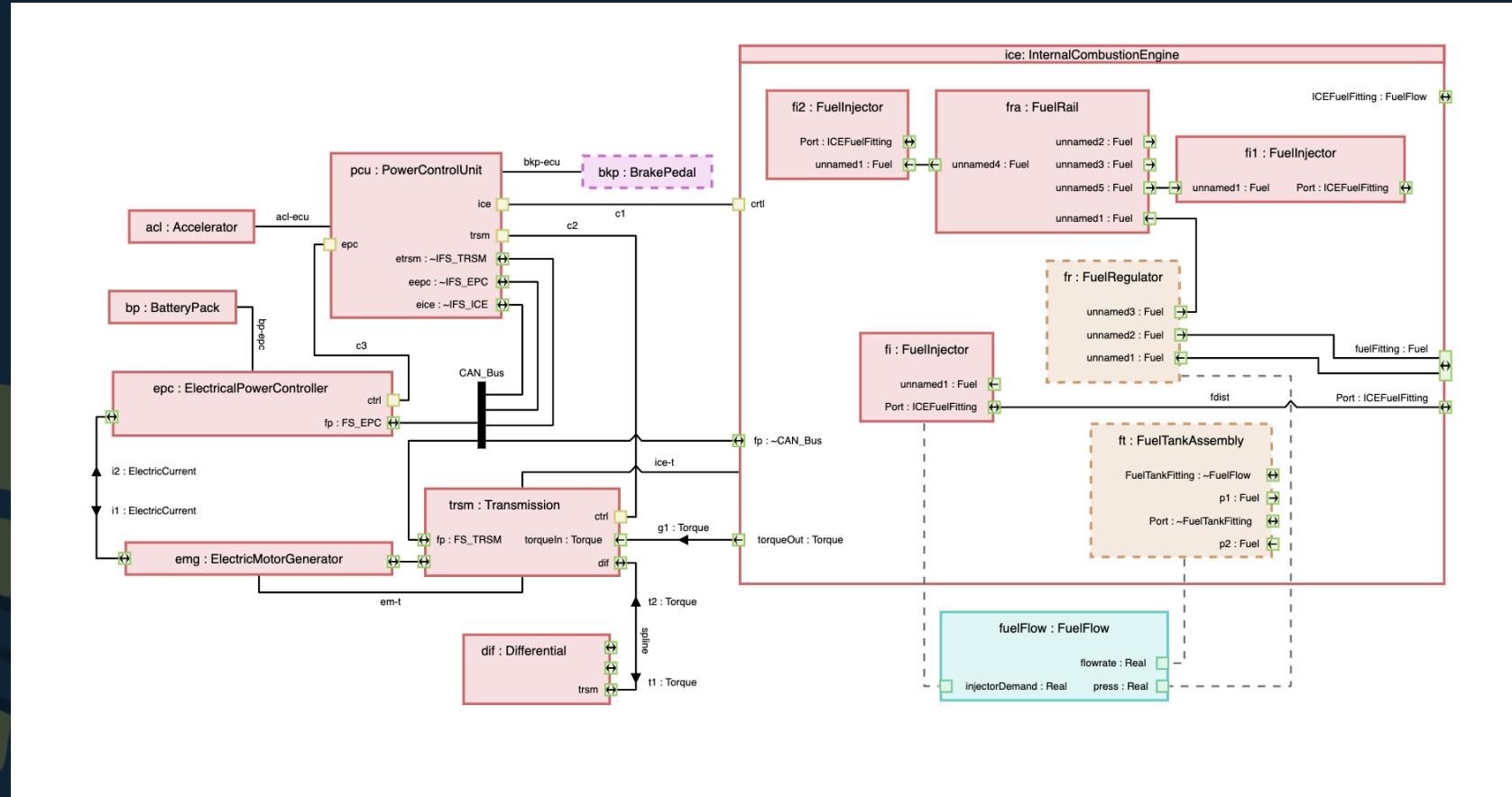
- Nested Drawings
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 - Graph inside an edge
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Graphs

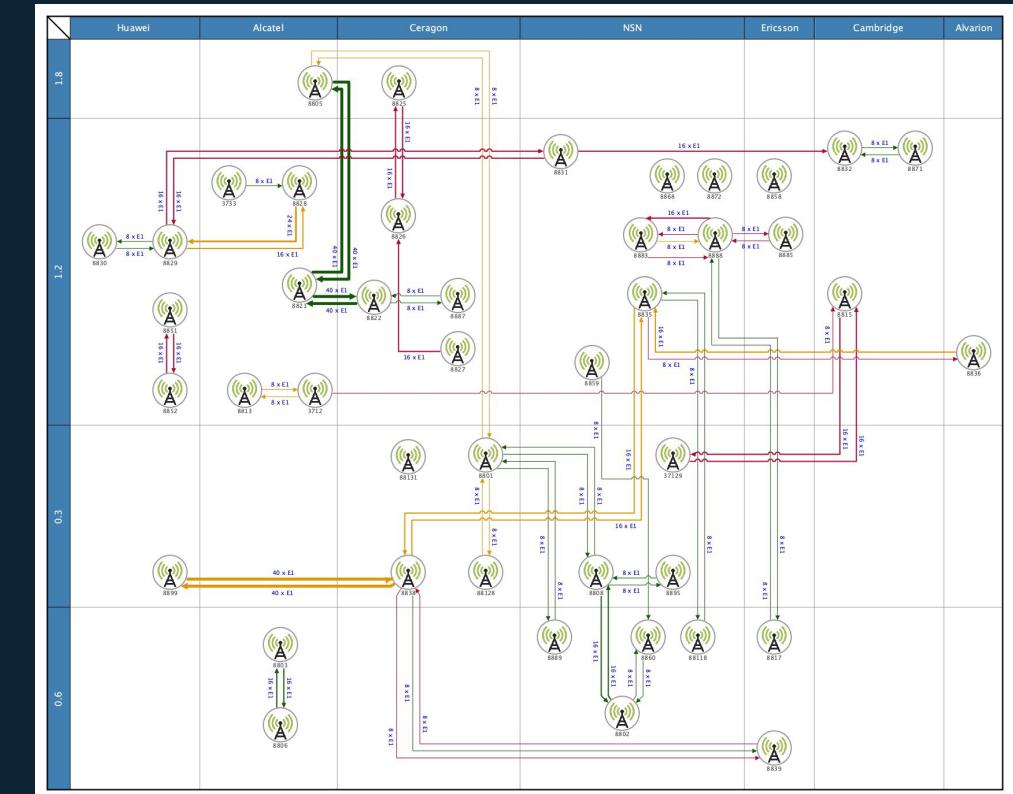
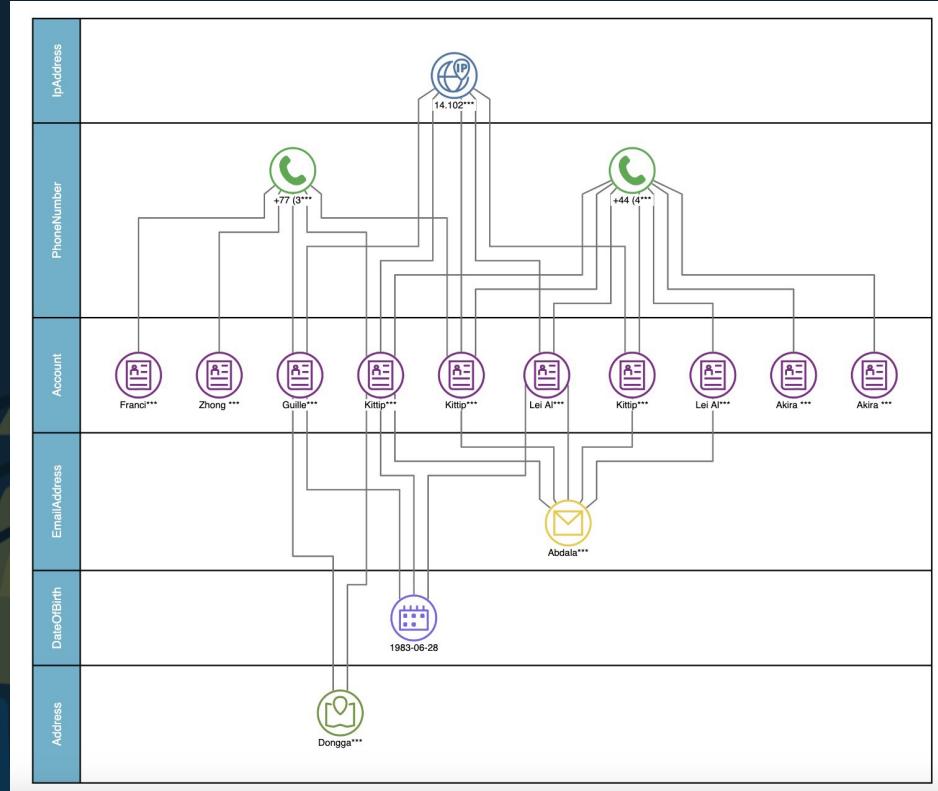
Labels

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



Graphs

- One-Dimensional Swimlanes
- Two-Dimensional Swimlanes





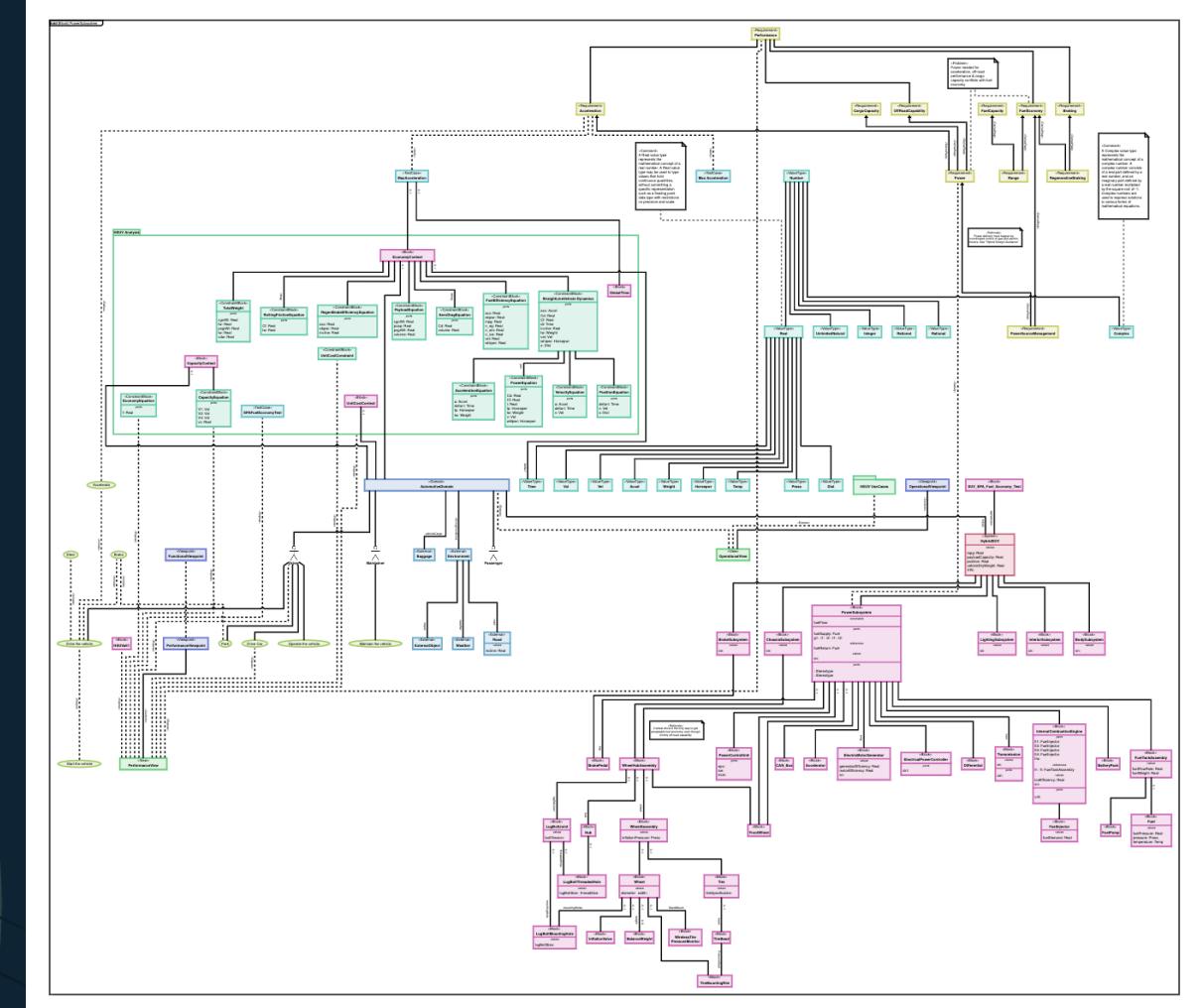
Data Visualization for Modeling and Solving Problems

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

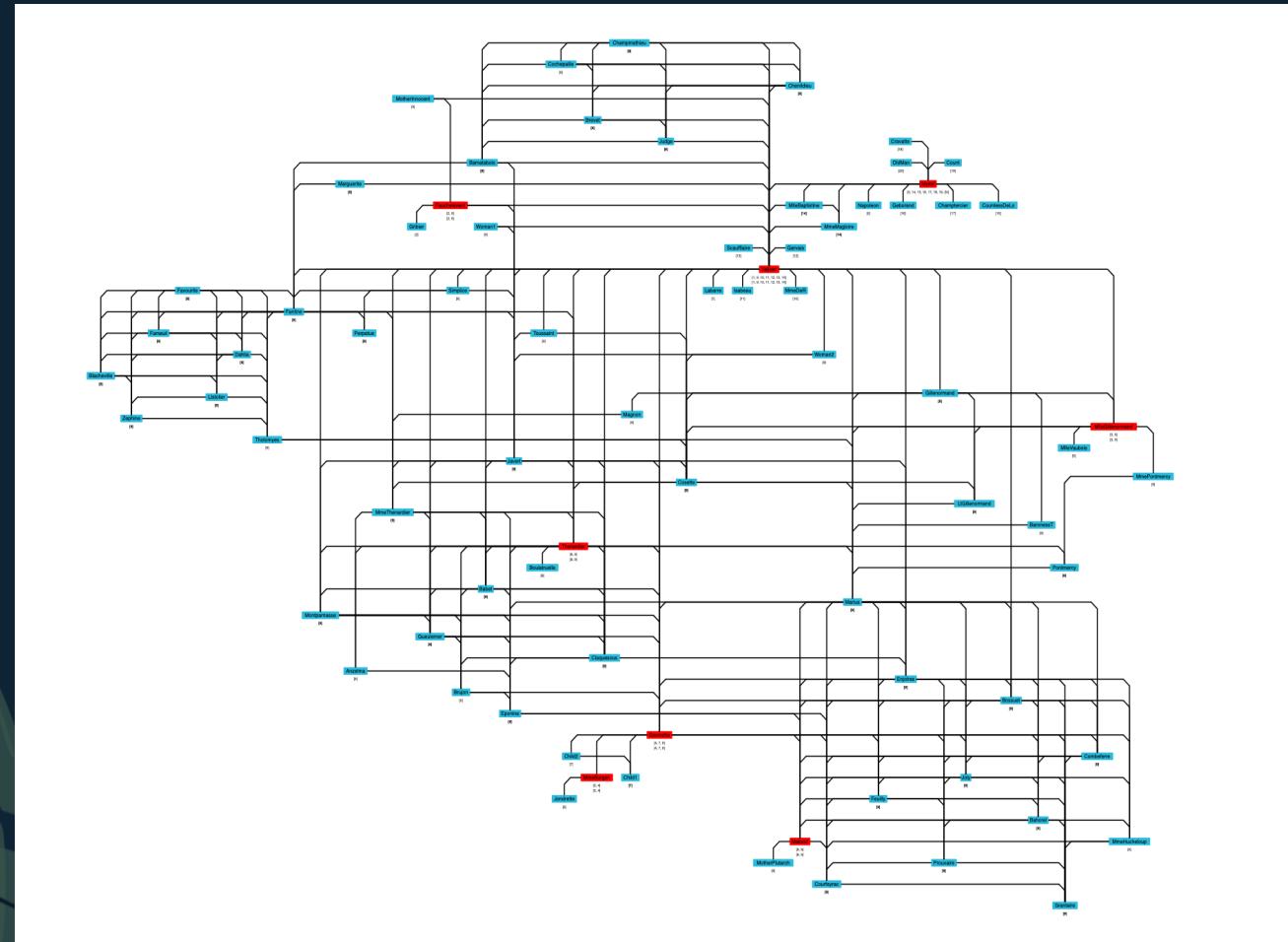
Graphs for Modeling and Analysis

- Support users in modeling their systems as graphs



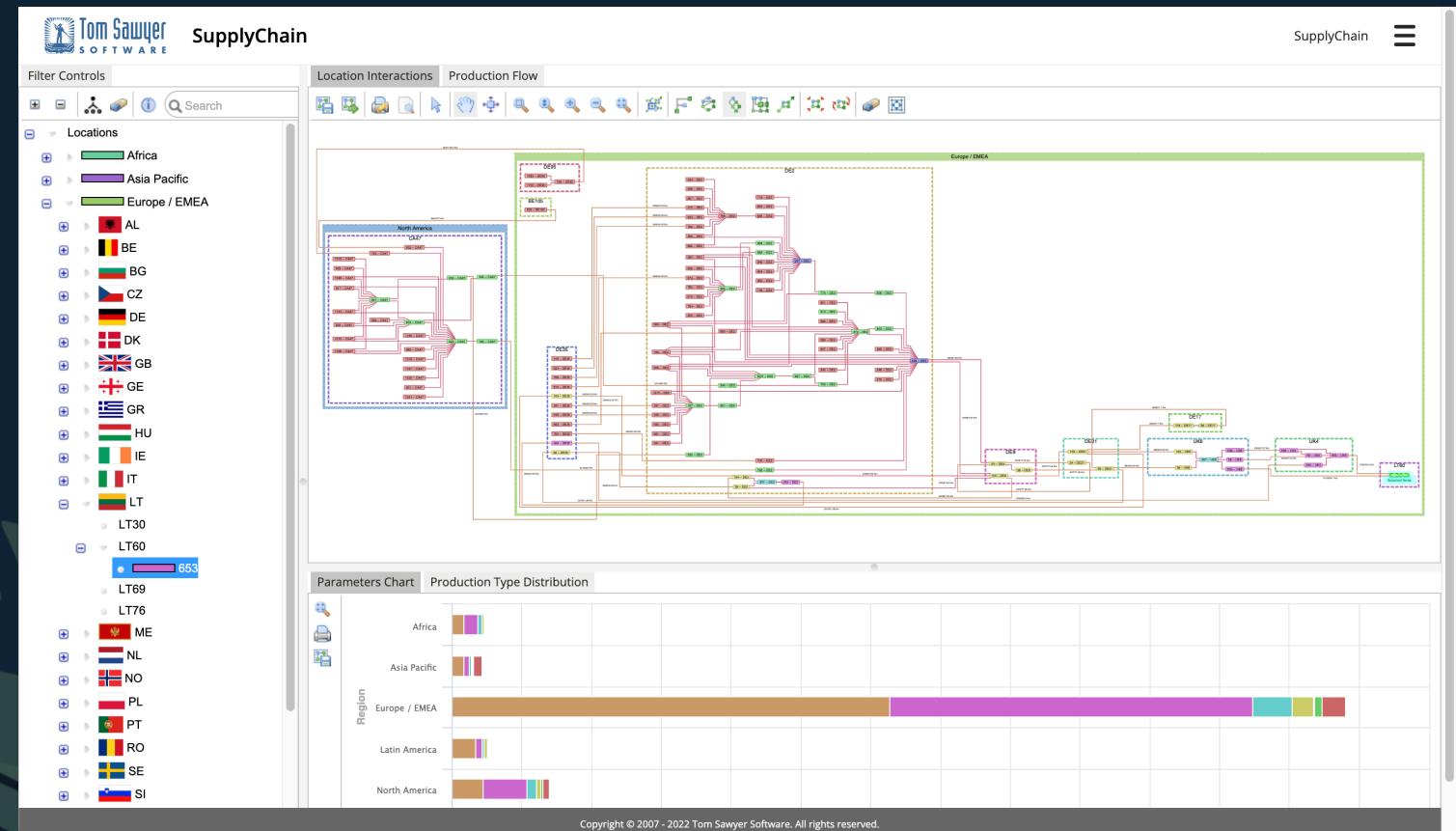
Graphs for Modeling and Analysis

- Apply graph visualizations and analyses to discover areas of interest in their data



Graphs for Modeling and Analysis

- Apply graph visualizations and analyses to optimize their systems



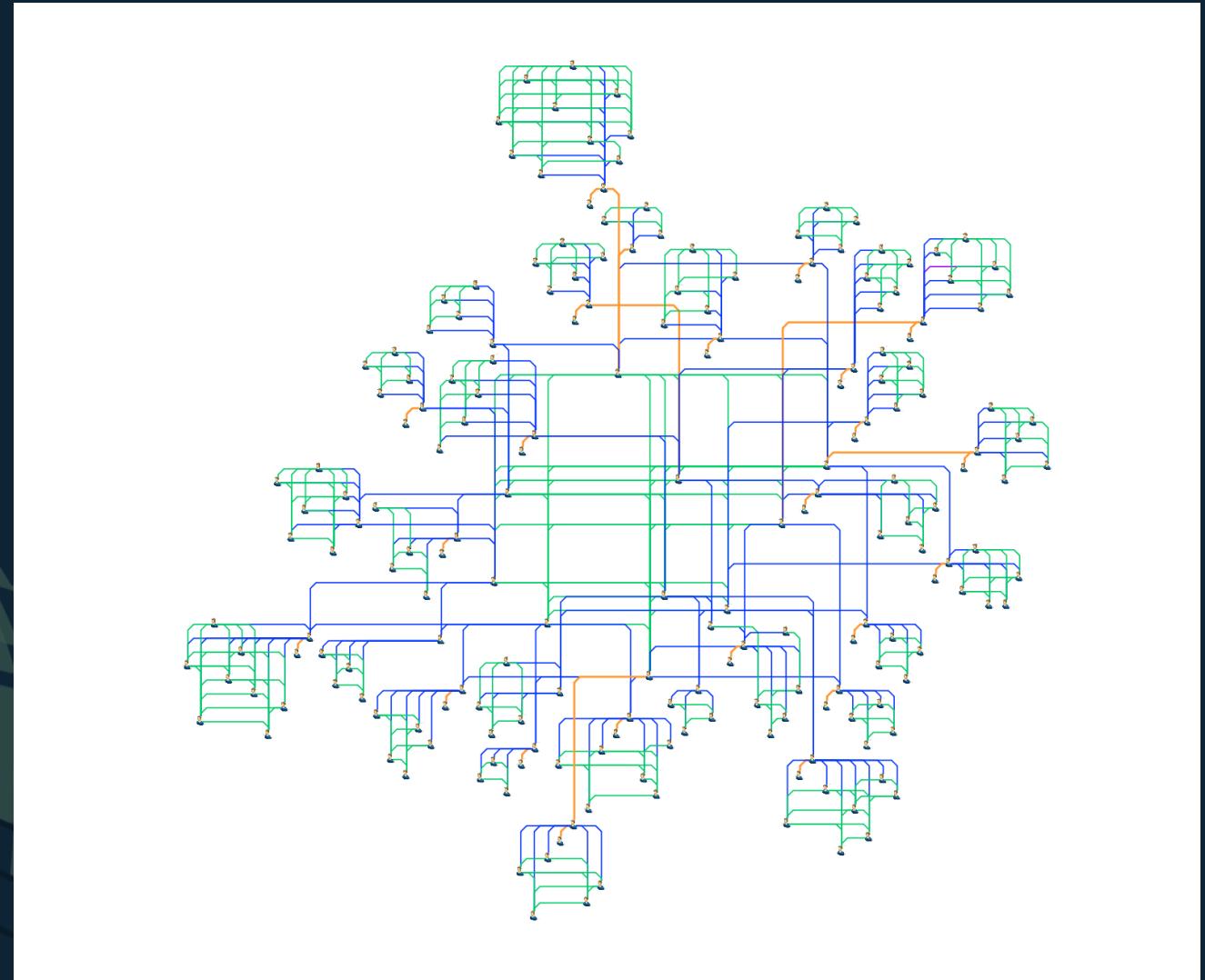
Graphs for Communication

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



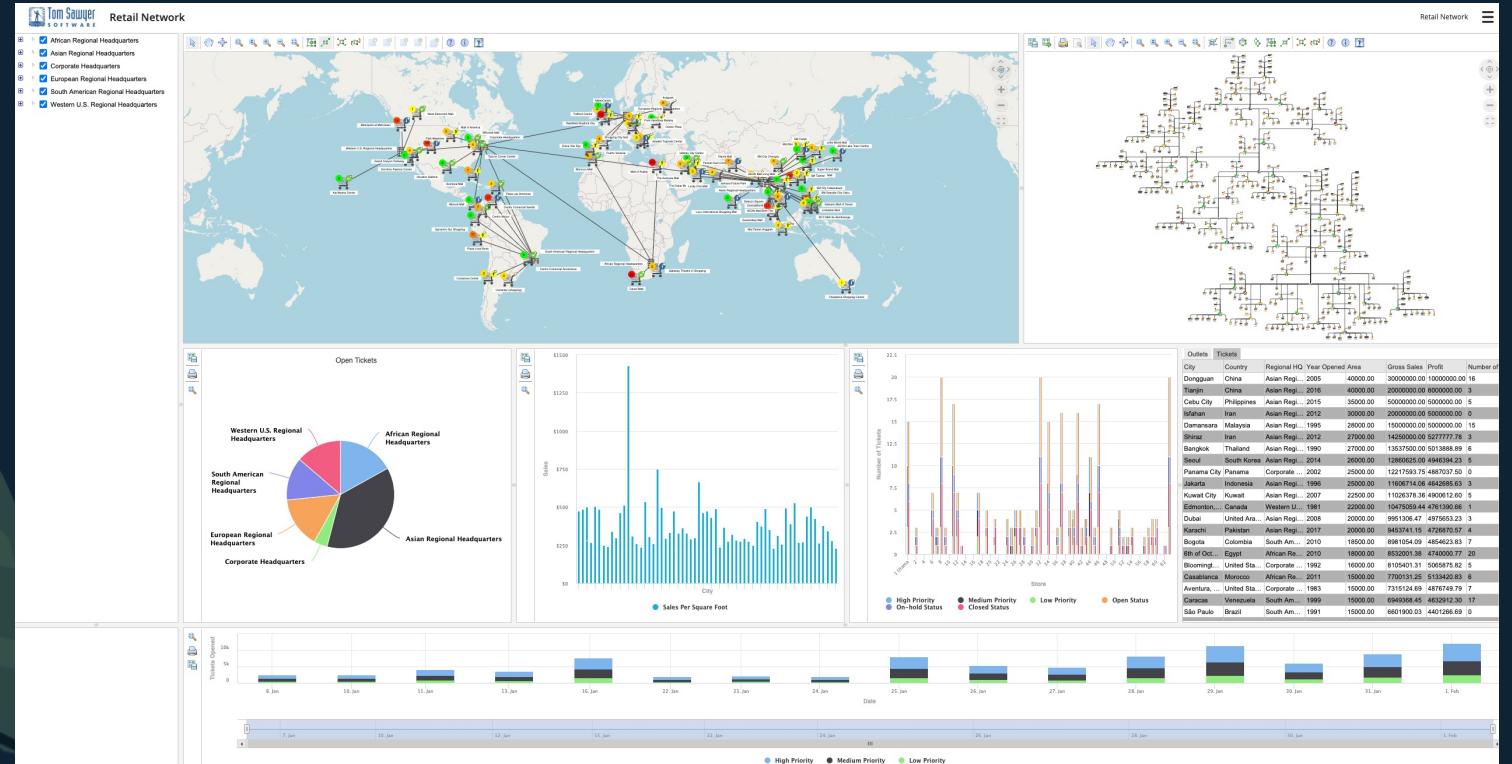
Graphs for Communication

- Deliver pertinent information to decision makers



Graphs for Communication

- Communicate key results to stakeholders





Data Visualization for Systems Engineering

Graphs for Modeling, Analysis, Communication

Bring human experts back into the equation

Graphs for Modeling, Analysis, Communication

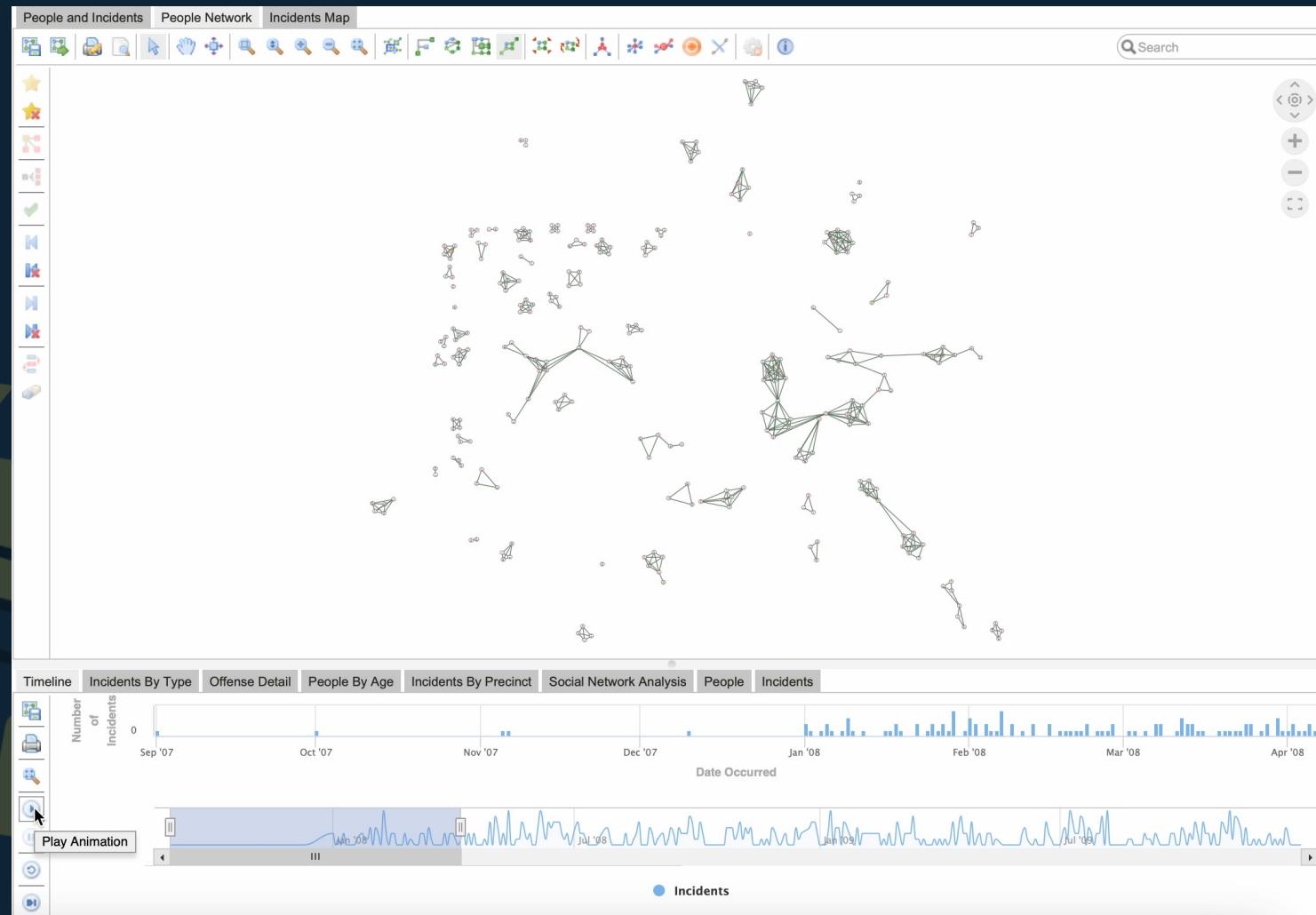
- Bring human experts back into the equation
 - “There is something interesting here, let’s look further”
 - “I have seen this pattern in another situation, a similar solution may be helpful here as well”
 - “There is an almost-pattern right there!” (almost vulnerability in a communications network, 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

Models Changing Over Time

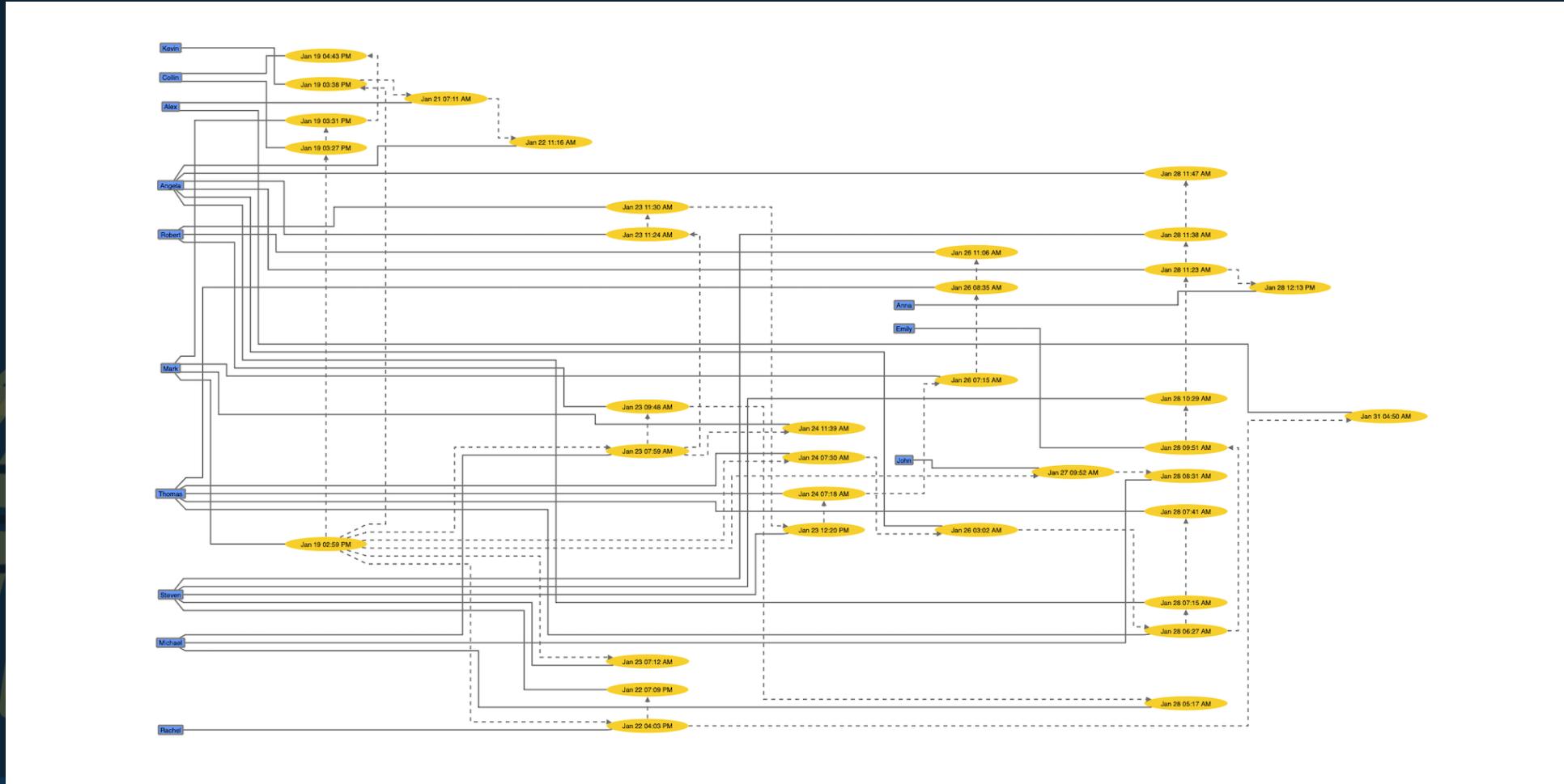
- Implications of dynamic change for visualization and analysis
 - Formation of new graph topology
 - Updates that need to be highlighted
 - Trends to be discovered

New Insights to be Discovered and Communicated

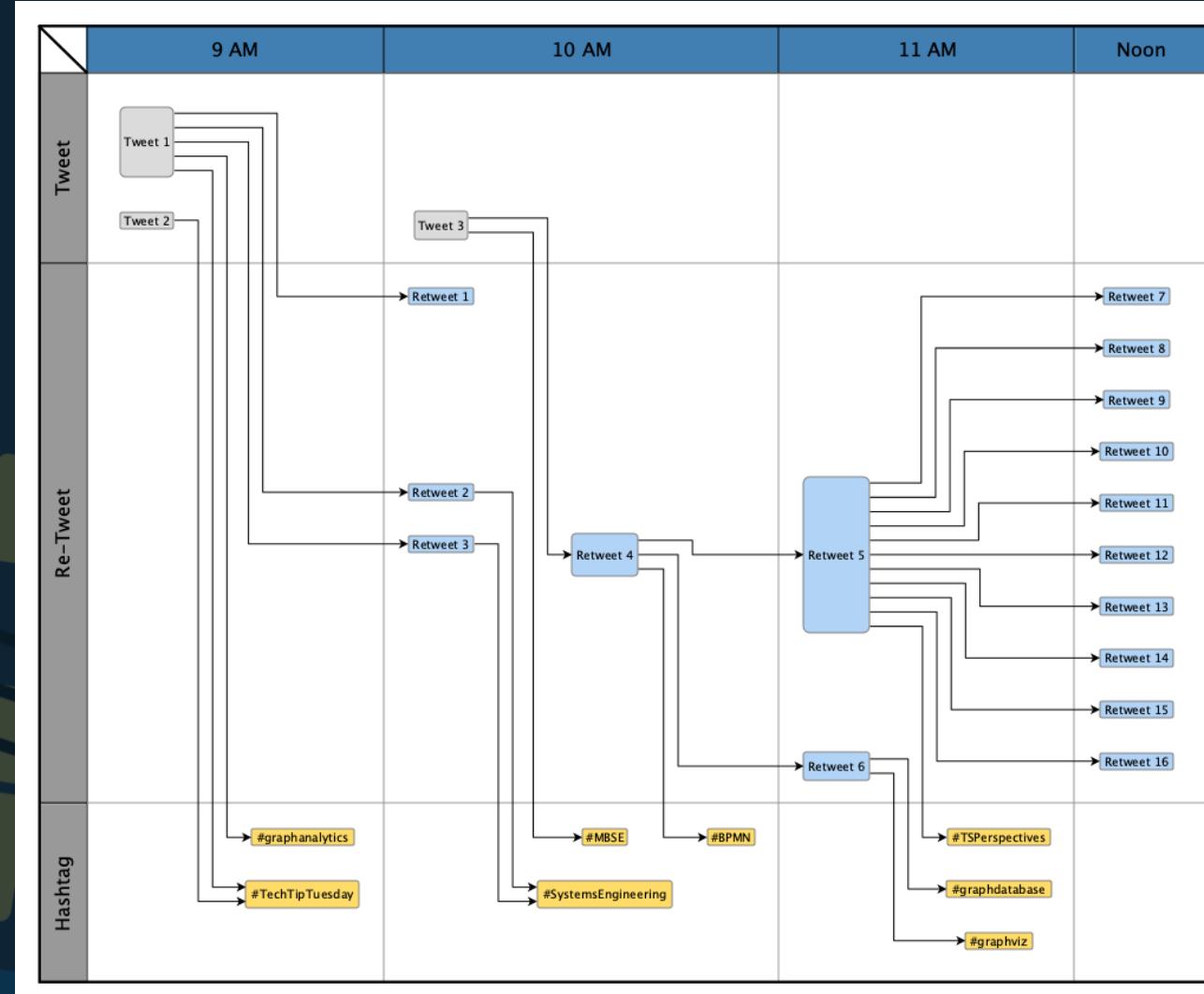
Models Changing Over Time



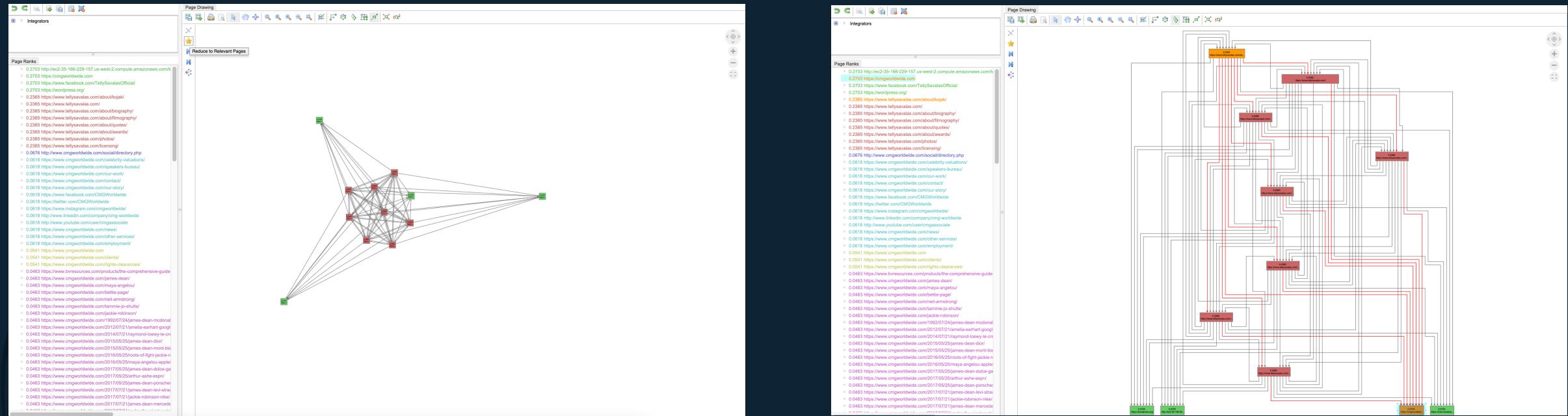
Models Changing Over Time



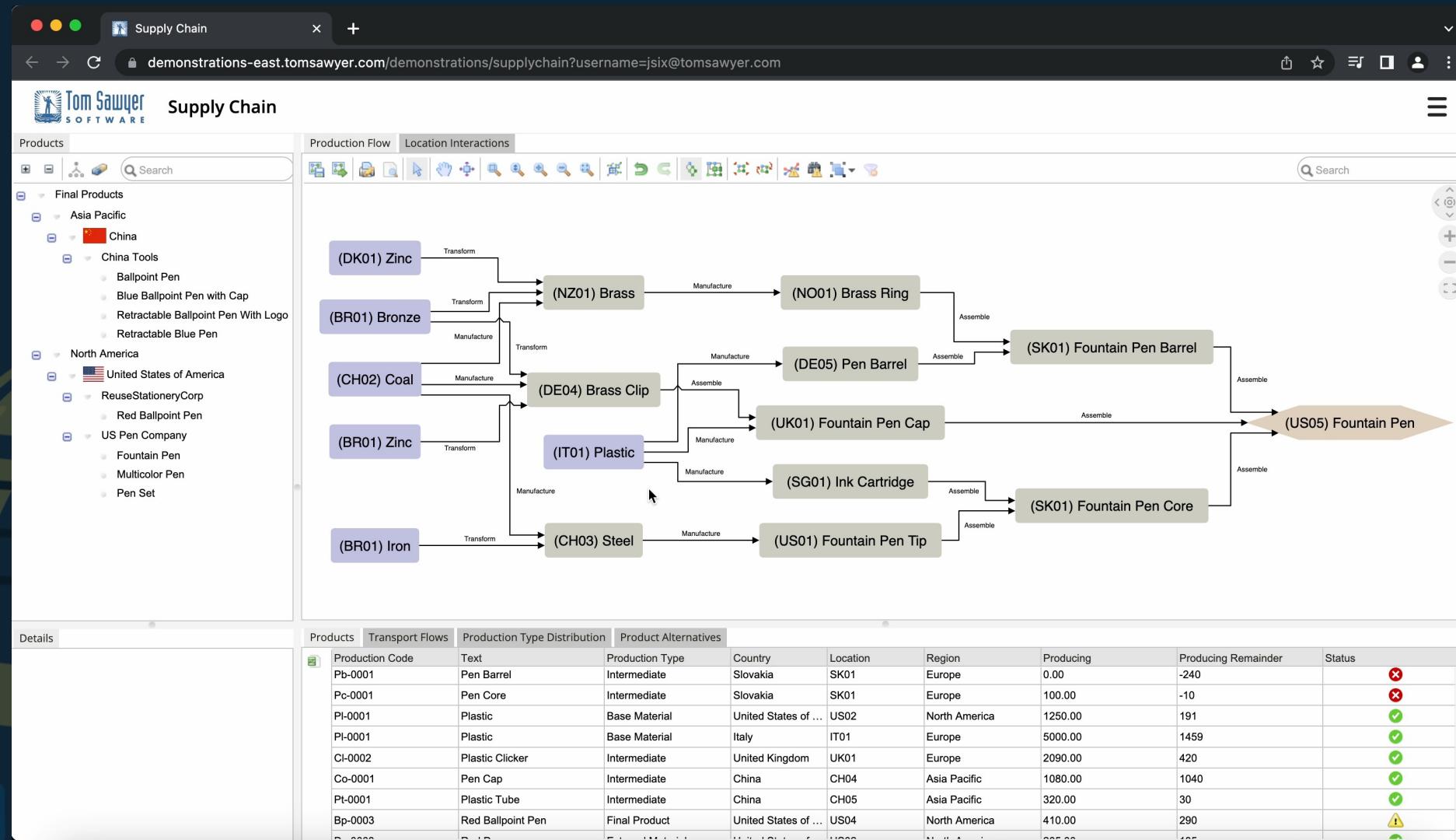
Models Changing Over Time



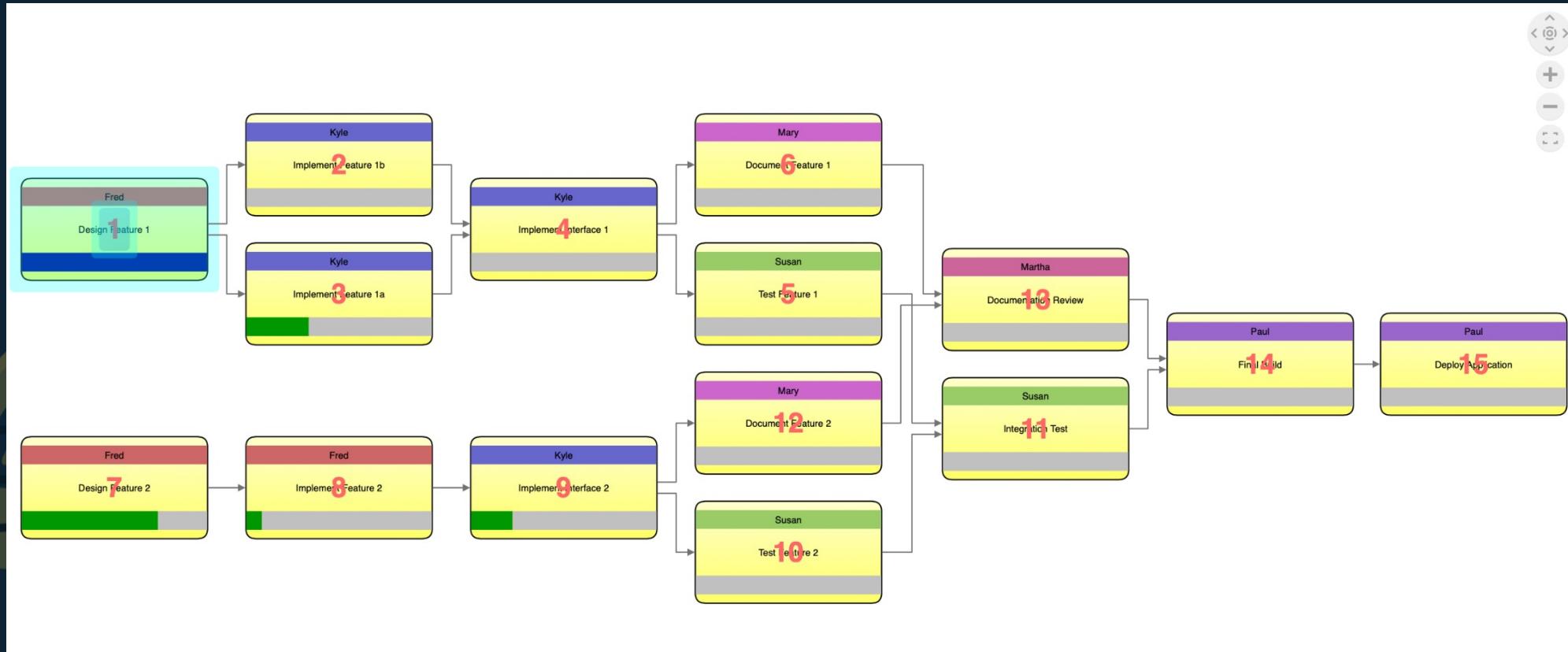
Post Situation Analysis



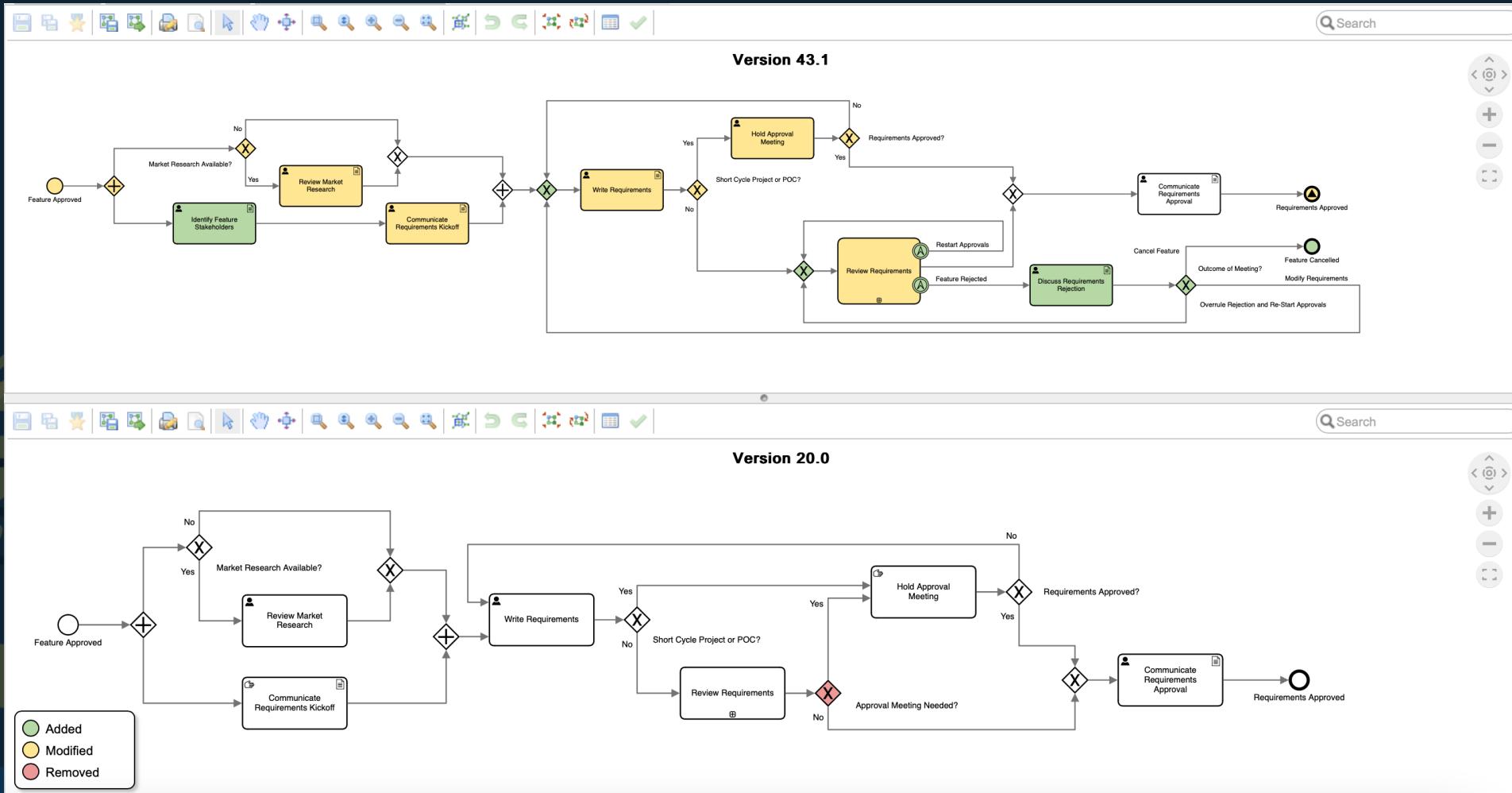
Simulate Future Scenarios



Simulate Future Scenarios



Discover Trends

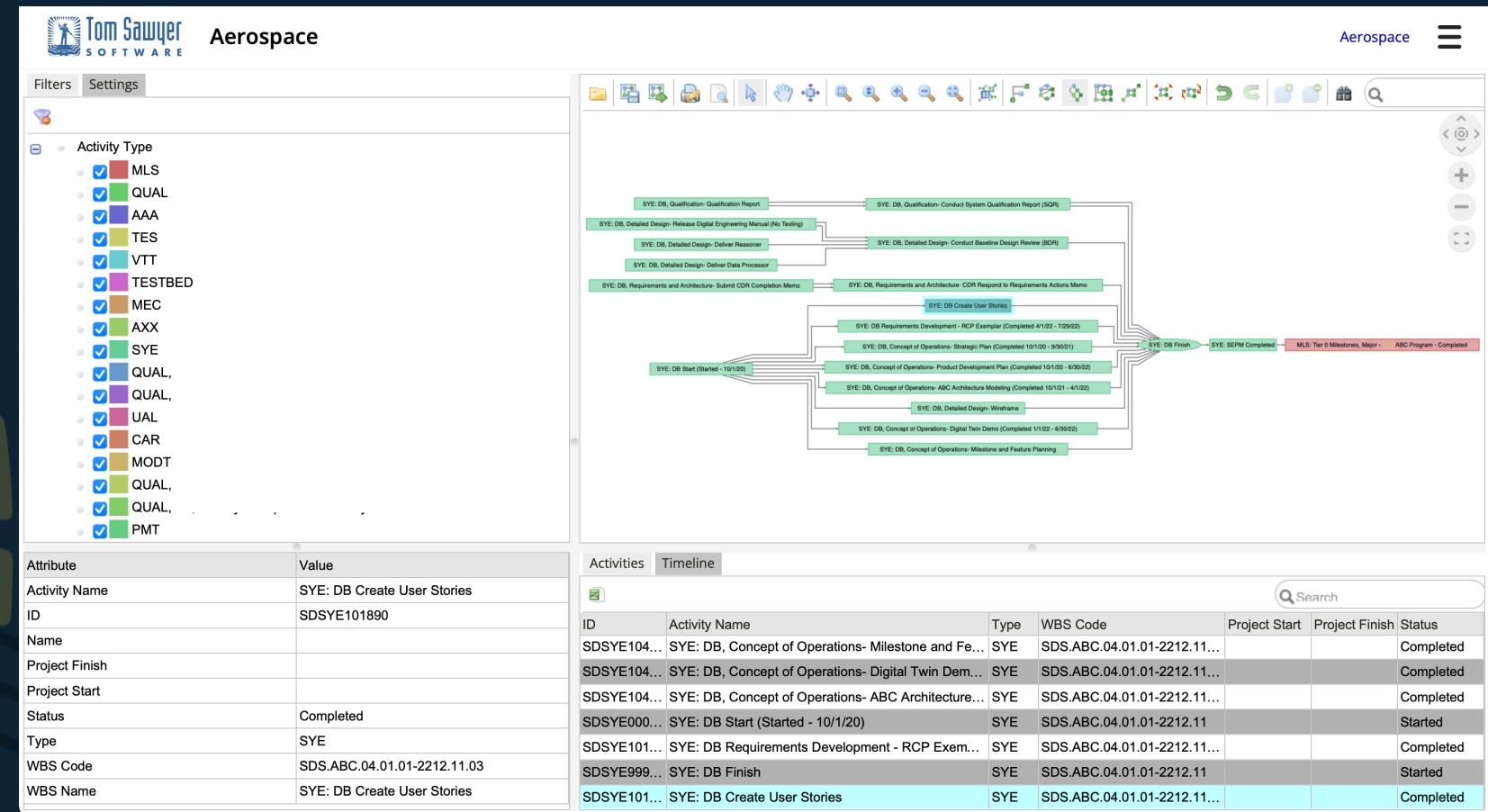


Creating the Data Model

A	B	C	D	E	F	G	H	I
Activity ID	Activity Name	WBS	Start	Finish	BL Project Start	BL Project Finish	Predecessors	Successors
SDTES123010	TES: ENV Tester, Certification - Record Test Results (TD)	SDS.ABC.04.01.08-2212.11.04	-Nov-2020 A	12-Nov-2020 A	6-Nov-20	6-Nov-20	SDTES123000	SDTES123020
SDTES123030	TES: ENV Tester, Certification - Release Tester for Operation	SDS.ABC.04.01.08-2212.11.04	-Nov-2020 A	25-Nov-2020 A	18-Nov-20	24-Nov-20	SDTES122030, SDTES122020, SDTES120150, SDTES120180, SDTES083170	SDTES123000
SDTES122020	TES: ENV Tester, Software - Release Calibration Program (AP)	SDS.ABC.04.01.08-2212.11.03	-Feb-2020 A	30-Apr-2020 A	3-Feb-20	30-Apr-20	SDTES122010	SDTES123030
SDTES122030	TES: ENV Tester, Software - Release Control Program (AM)	SDS.ABC.04.01.08-2212.11.03	-Mar-2020 A	17-Jul-2020 A	23-Mar-20	15-Jul-20	SDTES122000	SDTES123030
SDTES123000	TES: ENV Tester, Certification - Certification Test	SDS.ABC.04.01.08-2212.11.04	1-Jul-2020 A	10-Nov-2020 A	1-Jul-20	30-Sep-20	SDTES121330, SDTES120120, SDTES120020	SDTES123010
SDTES121330	TES: ENV Tester, Hardware, Build - #2 Assemble	SDS.ABC.04.01.08-2212.11.02.03	1-Oct-2019 A	31-Oct-2019 A	1-Oct-19	31-Oct-19	SDTES121320, SDTES121110	SDTES123000
SDTES121320	TES: ENV Tester, Hardware, Build - #2 Fabricate	SDS.ABC.04.01.08-2212.11.02.03	-Sep-2019 A	30-Sep-2019 A	3-Sep-19	30-Sep-19	SDTES121300, SDTES121310	SDTES121330
SDTES121240	TES: ENV Tester, Hardware, Procure - Inventory	SDS.ABC.04.01.08-2212.11.02.02	-Aug-2019 A	30-Aug-2019 A	19-Aug-19	30-Aug-19	SDTES121200, SDTES121100, SDTES121210, SDTES121220, SDTES123030	SDTES123030
SDTES121060	TES: ENV Tester, Hardware, Design Drawing Definition - Release Drawing	SDS.ABC.04.01.08-2212.11.02.01.01	-Feb-2020 A	20-Mar-2020 A	3-Feb-20	20-Mar-20	SDTES121050	SDTES123030
SDTES121050	TES: ENV Tester, Hardware, Design Drawing Definition - Peer Review	SDS.ABC.04.01.08-2212.11.02.01.01	-Nov-2019 A	3-Dec-2019 A	1-Nov-19	29-Nov-19	SDTES121040, SDTES121000, SDTES121010, SDTES121020, SDTES121060	SDTES121060
SDTES120240	TES: ENV Tester, Requirements, Documentation, Software Requirement	SDS.ABC.04.01.08-2212.11.01.02.05	-Feb-2020 A	20-Mar-2020 A	3-Feb-20	20-Mar-20	SDTES120230	SDTES123030
SDTES120230	TES: ENV Tester, Requirements, Documentation, Software Requirement	SDS.ABC.04.01.08-2212.11.01.02.05	-Dec-2019 A	6-Jan-2020 A	23-Dec-19	27-Dec-19	SDTES120220	SDTES120240
SDTES120210	TES: ENV Tester, Requirements, Documentation, Software Documentation	SDS.ABC.04.01.08-2212.11.01.02.04	-Feb-2020 A	20-Mar-2020 A	3-Feb-20	20-Mar-20	SDTES120200	SDTES123030
SDTES120200	TES: ENV Tester, Requirements, Documentation, Software Documentation	SDS.ABC.04.01.08-2212.11.01.02.04	-Dec-2019 A	6-Jan-2020 A	23-Dec-19	27-Dec-19	SDTES120190	SDTES120210
SDTES120180	TES: ENV Tester, Requirements, Documentation, Operating Procedure (1)	SDS.ABC.04.01.08-2212.11.01.02.03	-Feb-2020 A	20-Mar-2020 A	3-Feb-20	20-Mar-20	SDTES120170	SDTES123030
SDTES120170	TES: ENV Tester, Requirements, Documentation, Operating Procedure (1)	SDS.ABC.04.01.08-2212.11.01.02.03	-Dec-2019 A	13-Dec-2019 A	2-Dec-19	13-Dec-19	SDTES120160	SDTES120180
SDTES120150	TES: ENV Tester, Requirements, Documentation, Maintenance Procedure	SDS.ABC.04.01.08-2212.11.01.02.02	-Feb-2020 A	20-Mar-2020 A	3-Feb-20	20-Mar-20	SDTES120140	SDTES123030
SDTES120140	TES: ENV Tester, Requirements, Documentation, Maintenance Procedure	SDS.ABC.04.01.08-2212.11.01.02.02	-Nov-2019 A	11-Dec-2019 A	21-Nov-19	9-Dec-19	SDTES120130	SDTES120150
SDTES120120	TES: ENV Tester, Requirements, Documentation, Test Plan (TK) - Release	SDS.ABC.04.01.08-2212.11.01.02.01	-May-2020 A	30-Jun-2020 A	20-May-20	29-Jun-20	SDTES120110	SDTES123000
SDTES120110	TES: ENV Tester, Requirements, Documentation, Test Plan (TK) - Peer Review	SDS.ABC.04.01.08-2212.11.01.02.01	-May-2020 A	19-May-2020 A	1-May-20	19-May-20	SDTES120100	SDTES120120
SDTES120020	TES: ENV Tester, Requirements, Compatibility (CD) - Release	SDS.ABC.04.01.08-2212.11.01.01	-Sep-2019 A	20-Mar-2020 A	3-Sep-19	10-Mar-20	SDTES120010	SDTES123000
SDTES120010	TES: ENV Tester, Requirements, Compatibility (CD) - Peer Review	SDS.ABC.04.01.08-2212.11.01.01	-May-2019 A	17-May-2019 A	13-May-19	17-May-19	SDTES120000	SDTES120020
SDTES116030	TES: ENV Tester, Certification, BTT, Record Test Results (TD)	SDS.ABC.04.01.08-2212.10.05	20-Feb-23	24-Feb-23	27-Apr-21	3-May-21	SDTES116200	SDTES116050
SDTES116190	TES: ENV Tester, Certification, Build #2, VTT, Release Tester for Operation	SDS.ABC.04.01.08-2212.10.05	23-Mar-23	29-Mar-23	7-Apr-22	13-Apr-22	SDTES116180	SDTES1009770, SDTES1017610
SDTES116180	TES: ENV Tester, Certification, Build #2, VTT, Analyze Test Results	SDS.ABC.04.01.08-2212.10.05	16-Mar-23	22-Mar-23	31-Mar-22	6-Apr-22	SDTES116170	SDTES116190
SDTES116170	TES: ENV Tester, Certification, Build #2, VTT, Record Test Results (TD)	SDS.ABC.04.01.08-2212.10.05	9-Mar-23	15-Mar-23	24-Mar-22	30-Mar-22	SDTES116160	SDTES116180

Creating the Data Model

- Nodes are activities in the schedule
- Relationships are the schedule logic (predecessors and successors)



Creating the Data Model

The screenshot displays the Tom Sawyer Software interface for the Aerospace domain. The top navigation bar includes the Tom Sawyer logo, the title 'Aerospace', and a three-line menu icon. The left sidebar contains 'Filters' and 'Settings' buttons, followed by a list of filters and status categories. The main workspace shows a complex data model diagram with various nodes and connections, primarily in shades of orange, red, and yellow. A large red box highlights a specific section of the diagram. The bottom section features a table of activity details.

Attribute	Value
Activity Name	SYE: SEPM Completed
ID	SDSYE99999
Name	
Project Finish	09-01-2026
Project Start	
Status	Started
Type	SYE
WBS Code	SDS.ABC.04.01.01-2...
WBS Name	SYE: SEPM Completed

Activities		Timeline				
ID	Activity Name	Type	WBS Code			
Project Start	Project Finish	Status	Search			
SDSYE99999	SYE: SEPM Completed	SYE	SDS.ABC.04.01.01-2212	09-01-2026	Started	
SDSYE104520	SYE: Safety	SYE	SDS.ABC.04.01.01-2212.13.02		Started	
SDSYE1000770	SYE: Risk Ranking of Subsystem Hazards complete	SYE	SDS.ABC.04.01.01-2212.13.01		Completed	
SDSYE104850	SYE: RE	SYE	SDS.ABC.04.01.01-2212.15.04.01		Not Started	
SDSYE104860	SYE: RE	SYE	SDS.ABC.04.01.01-2212.15.04.01		Not Started	
SDSYE101020	SYE: Requirements, PM, FY23, (TA) - Release initial draft of DB s...	SYE	SDS.ABC.04.01.01-2212.01.01.06.01		Started	
SDSYE100990	SYE: Requirements, PM, FY23, (TA) - Release Final	SYE	SDS.ABC.04.01.01-2212.01.01.06.01		Started	

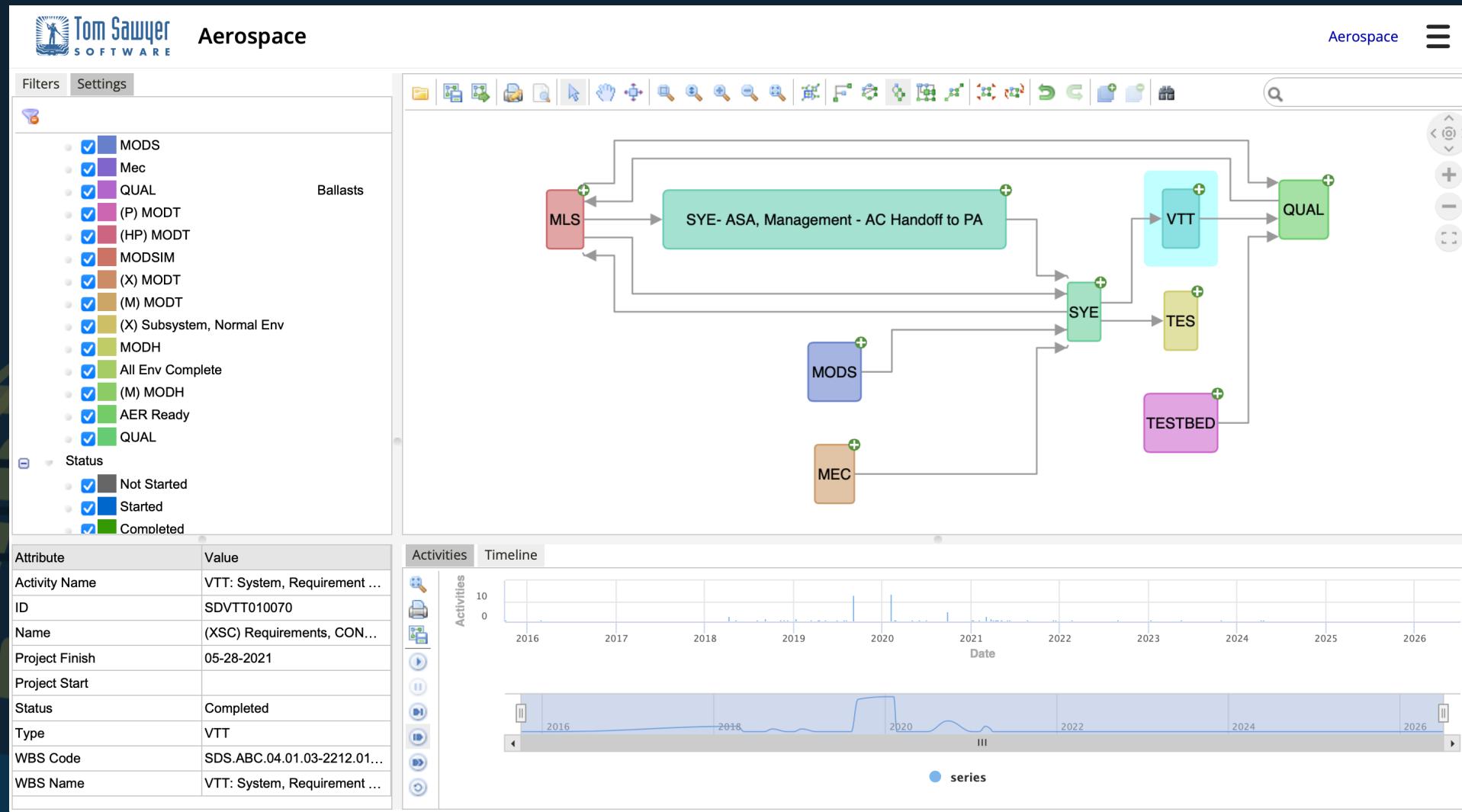
Creating the Data Model

The screenshot displays the Tom Sawyer Software interface for Aerospace, specifically for the SYE- ASA, Management - AC Handoff to PA project. The interface is divided into several sections:

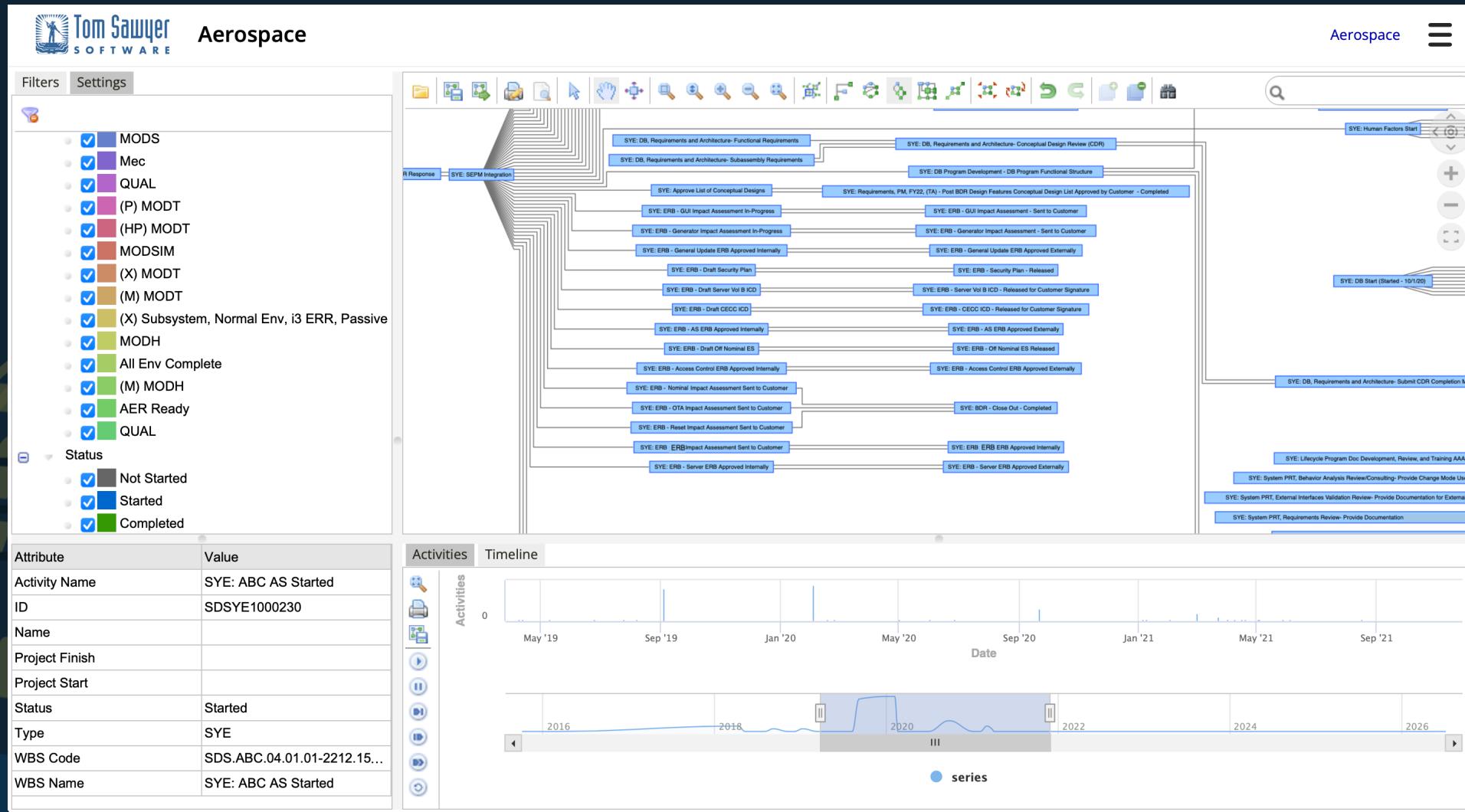
- Top Left:** A sidebar with a "Filters" tab and a "Settings" tab. The "Filters" tab is active, showing a list of selected items: MODS, Mec, QUAL, (P) MODT, (HP) MODT, MODSIM, (X) MODT, (M) MODT, (X) Subsystem, Normal Env, i3 ERR, Passive, MODH, All Env Complete, (M) MODH, AER Ready, and QUAL. The "Status" section is also visible, with "Not Started" checked.
- Top Right:** A toolbar with various icons for file operations, search, and navigation.
- Main Area:** A diagram showing the project structure. It includes a green rounded rectangle labeled "SYE- ASA, Management - AC Handoff to PA", a red rectangle labeled "MLS", a blue rectangle labeled "MODS", and a green rectangle labeled "SYE". Arrows indicate relationships between these entities. A "+" sign is located in the top right corner of the green box.
- Bottom Left:** A table titled "Attribute" and "Value" showing details for the selected activity. The activity name is "SYE: Risk Ranking of Subsy...", ID is "SDSYE1000770", Name is blank, Project Finish is blank, Project Start is blank, Status is "Completed", Type is "SYE", WBS Code is "SDS.ABC.04.01.01-2212.13...", and WBS Name is "SYE: Risk Ranking of Subsy...".
- Bottom Right:** A table titled "Activities" and "Timeline" showing a list of activities. The table includes columns for ID, Activity Name, Type, WBS Code, Project Start, Project Finish, and Status. The activities listed are:

ID	Activity Name	Type	WBS Code	Project Start	Project Finish	Status
SDSYE999999	SYE: SEPM Completed	SYE	SDS.ABC.04.01.01-2212		09-01-2026	Started
SDSYE104520	SYE: Safety	SYE	SDS.ABC.04.01.01-2212.13.02			Started
SDSYE1000770	SYE: Risk Ranking of Subsystem Hazards complete	SYE	SDS.ABC.04.01.01-2212.13.01			Completed
SDSYE104850	SYE: RE	SYE	SDS.ABC.04.01.01-2212.15.04.01			Not Started
SDSYE104860	SYE: RE	SYE	SDS.ABC.04.01.01-2212.15.04.01			Not Started
SDSYE101020	SYE: Requirements, PM, FY23, (TA) - Release initial draft of ...	SYE	SDS.ABC.04.01.01-2212.01.01.0...			Started
SDSYE100990	SYE: Requirements, PM, FY23, (TA) - Release Final	SYE	SDS.ABC.04.01.01-2212.01.01.0...			Started

Creating the Data Model



Creating the Data Model



Creating the Data Model

The screenshot displays the Tom Sawyer Software interface for Aerospace. The top navigation bar includes the Tom Sawyer logo, the word "Aerospace", and a menu icon. The left sidebar contains a "Filters" section with checkboxes for various project categories like PMT, SYE-ASA, Management, MODS, Mec, QUAL, and MODT, and a "Status" section. Below this is a table with activity details:

Attribute	Value
Activity Name	VTT: VTT - Started
ID	SDVTT000000
Name	Started
Project Finish	
Project Start	01-04-2017
Status	Started
Type	VTT
WBS Code	SDS.ABC.04.01.03-2212
WBS Name	VTT: VTTronics - Started

The main workspace features a large, complex network graph with many nodes and connections, representing a system architecture or data model. Below the graph is an "Activities" table:

ID	Activity Name	Type	WBS Code	Project Start	Project Finish	Status
SDVTT000000	VTT: VTT - Started	VTT	SDS.ABC.04.01.03-2212	01-04-2017		Started
SDVTT000001	VTT: VTT - Integration	VTT	SDS.ABC.04.01.03-2212		06-01-2019	Completed
SDVTT999999	VTT: VTT - Completed	VTT	SDS.ABC.04.01.03-2212		02-24-2025	Started
SDVTT140200	VTT: Tracking, Update, Rigidflex HW, Test - PWA	VTT	SDS.ABC.04.01.03-2212.14.01.03	08-07-2019	01-21-2020	Completed
SDVTT140070	VTT: Tracking, Update, Rigidflex HW, Design - Schematic - F...	VTT	SDS.ABC.04.01.03-2212.14.01.01		07-11-2018	Completed
SDVTT140050	VTT: Tracking, Update, Rigidflex HW, Design - Review Sche...	VTT	SDS.ABC.04.01.03-2212.14.01.01	07-05-2018	07-10-2018	Completed
SDVTT140020	VTT: Tracking, Update, Rigidflex HW, Design - Review Design	VTT	SDS.ABC.04.01.03-2212.14.01.01	07-02-2018	07-02-2018	Completed



Case Study

Case Study

- Active project
- Schedule implemented in Oracle Primavera P6
 - 3 years old – rebaselined 3 times
 - Design Agency and Production Agency schedules
 - Over 13,000 activities in each schedule
 - Manual handoffs between schedules
 - In the middle of rebaselining again
 - Trying to plan verification and production activities
 - Trying to assess impact of changes
 - Cannot meet schedule
- This research developed a process to model schedule logic and analyze the results
 - Problem framing – questions that needed to be answered and how the answer can be understood
 - Work within limitations of existing resources
 - Modeling the schedule logic (workflow or predecessors/successors)
 - Tom Sawyer Perspectives data visualization software
 - Interactive meetings





Process to Develop the Interactive Schedule Logic Modeling Capability

Developing the interactive schedule logic modeling capability



Process – Identify Key Factors

Five data elements pulled from schedule

Derived additional elements from Activity text for filtering/grouping

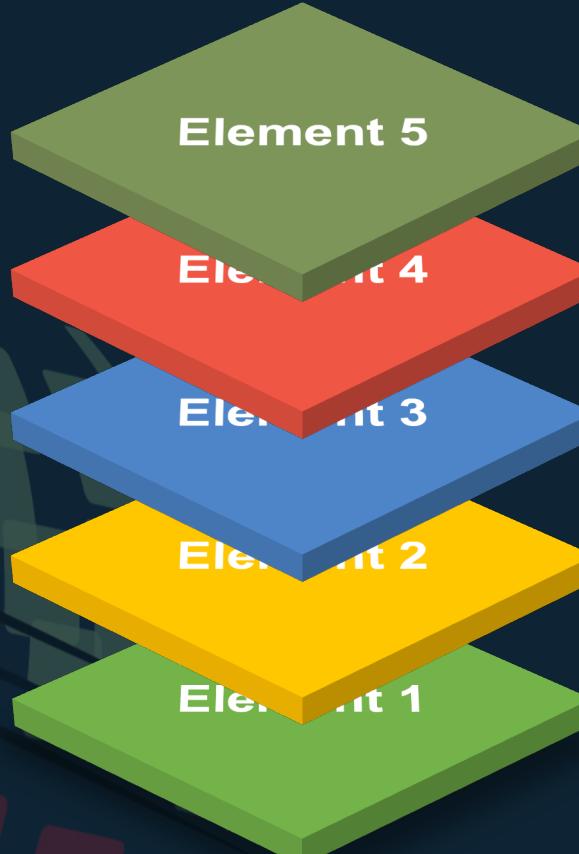
Work Breakdown
Structure (WBS)



Relationship
(Predecessors/
Successors)



Activity ID



Start/Finish



Activity
Name/Description

Process – Set Filtering/Nesting

Searchable Activity Table

- Activity ID
- Activity Name/Description
- Relationship (predecessors/successors)
- Start/Finish (baseline, current)
- WBS for hierarchy/structure

Timeline

- Activities by date



Filters for Diagram

- Status (Complete, In work, Not started)
- Project Realization Team (PRT)
- Project Phase
- Process Area

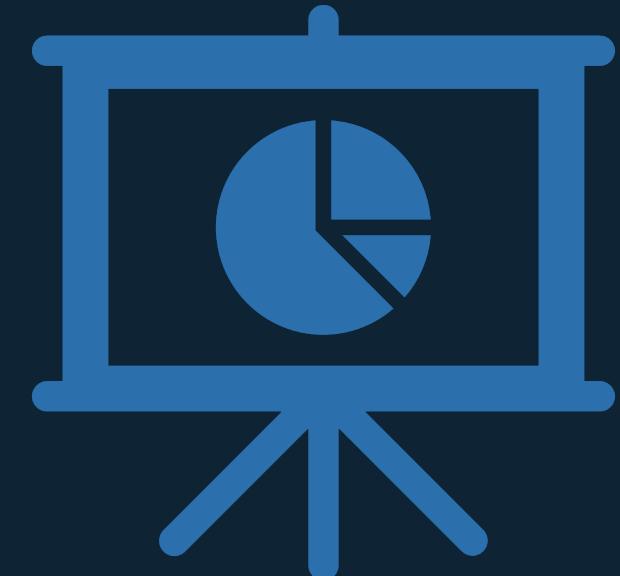
Nesting/Grouping for Diagram

- PRT
- WBS
- Relationship
- Multiple 'depths' of schedule path

Results

Addressed specific schedule and program problems

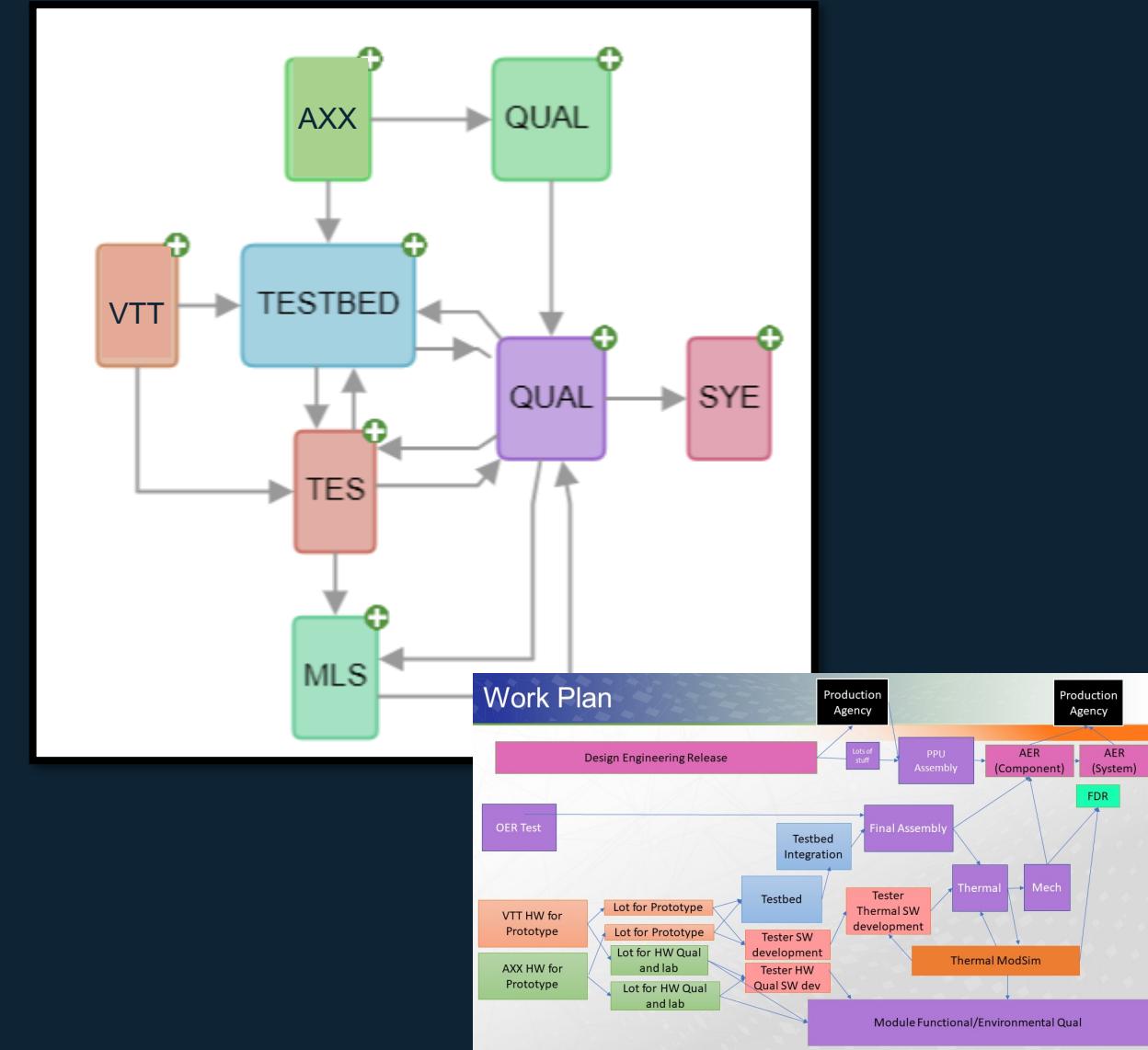
1. Program schedule flowchart generated for basis of replanning - compared to implementation in schedule (Correctness)
2. Testers supporting environmental and functional testing. All activities are occurring at the same time and there are not enough testers to support this. Does this need to be reworked? (Identification of Risk)
3. Overlap of planned functional, environmental and acceptance testing for electronics modules. (Identification of Risk and Verification planning)
4. Acceptance testing durations for electronics modules – too long and all on top of each other (Identification of Risk)
5. Test Equipment hardware deliveries to production agency – new scope (Impact Assessment)
6. Path from Advanced Engineer Release (AER) to First Production Unit (Correctness and Identification of Risk)



Results – Correctness of Schedule

Replan – verify correctness of schedule

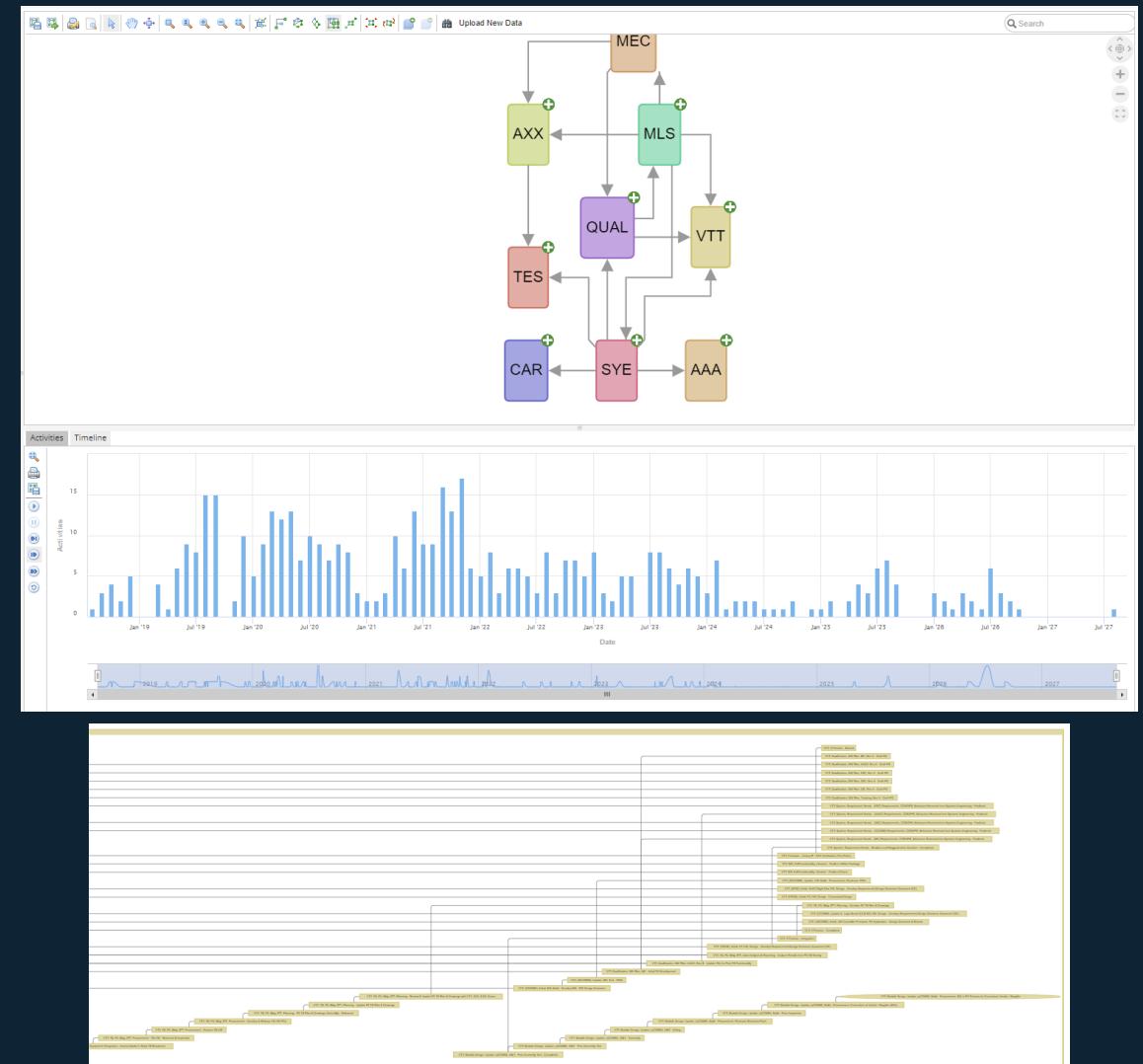
- Matches planned flow of work
- Missing links in schedule
- PRT missing entire interface to another subsystem
- Incorrect coding in schedule (naming convention)
- Missing handoffs from production schedule – no ties into real body of work



Results – Identification of Risk

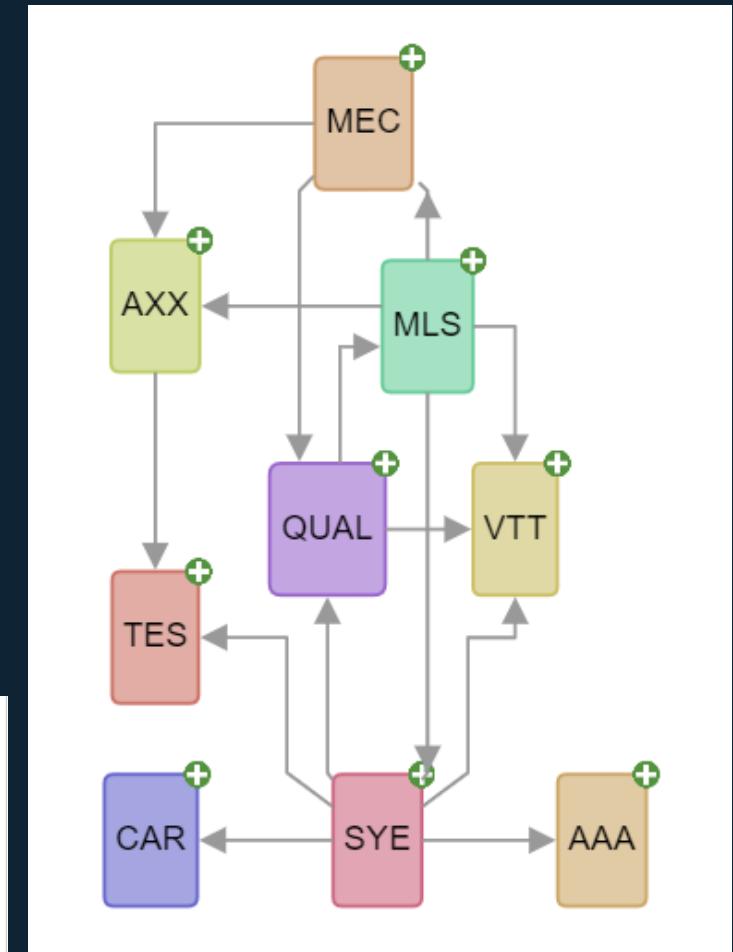
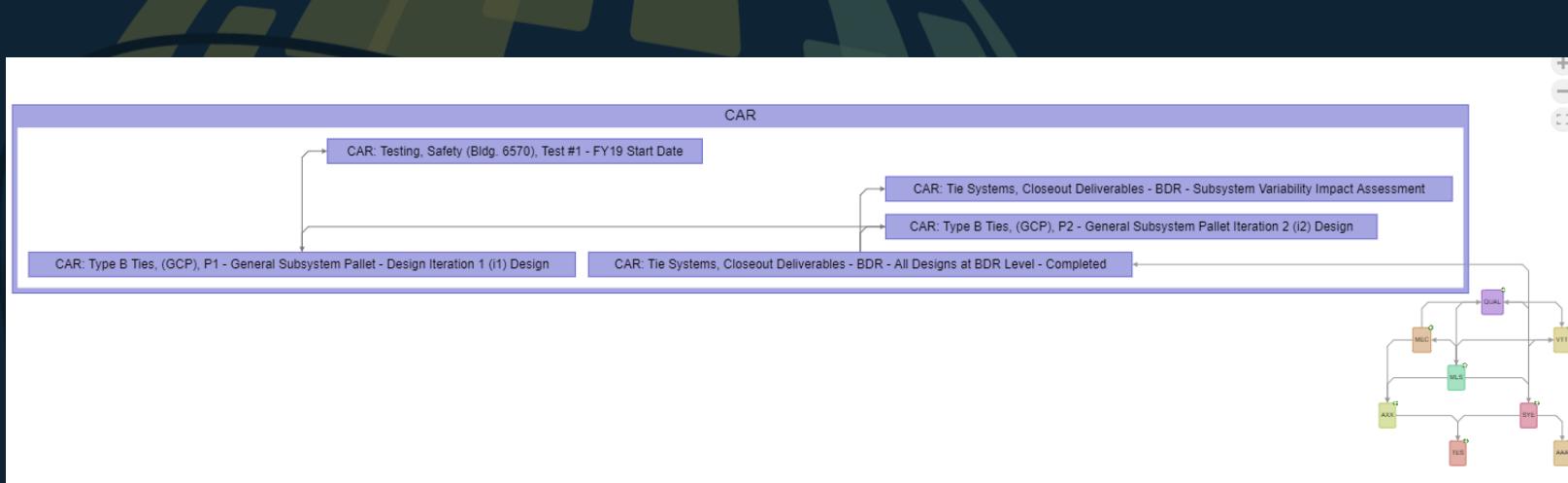
Understand known areas of concern better as well as identify areas of concern not realized before

- Rolling bow wave of activities as schedule pushes (timeline)
- Multiple activities in parallel
- Downstream areas of activities at risk
- Production planning and handoffs – linking of schedules



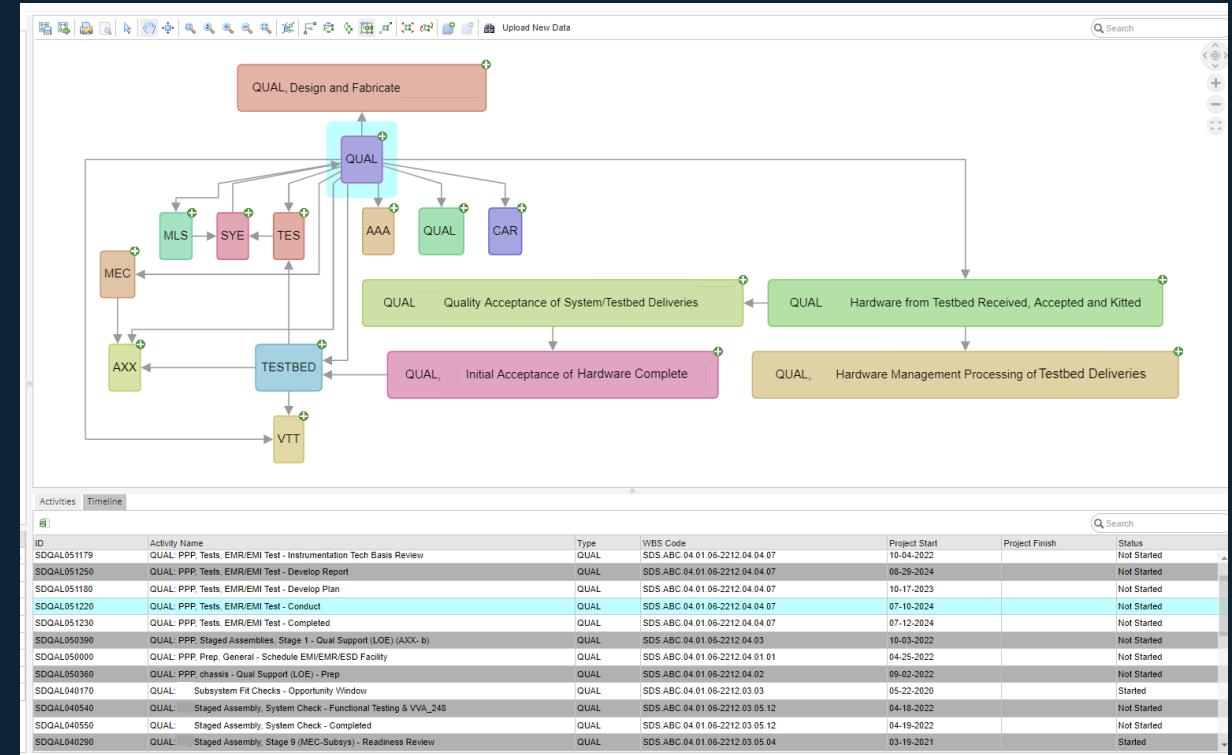
Results – Impact Assessment for Proposed Changes

- Identify each touchpoint for area of change
- See farther downstream



Results – Verification Planning

- Identification of activities and data feeding into a verification activity
- Identification of bottlenecks for shared facilities or resources
- Feasibility of verification approaches based on availability of data and resources





Importance of Interactivity

Results – importance of interactivity

- Comprehension
- Consensus
- Credibility
- Correct
- Comparison
- Change Verification or Impact Assessment
- (Re)Centering during investigation
- Concentration/Focus
- Communication/Awareness



Results – importance of interactivity

- Comprehension
- Consensus
- Credibility
- Correct
- Comparison
- Change Verification or Impact Assessment
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- Communication/Awareness

Common understanding



Results – importance of interactivity

- Comprehension
- Consensus
- Credibility
- Correct
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- Change Verification or Impact Assessment
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- Communication/Awareness

Common understanding

Work with Data to address issues



Results – importance of interactivity

- Comprehension
- Consensus
- Credibility
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- Change Verification or Impact Assessment
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Common understanding

Work with Data to address issues

Tools to facilitate work





Ease of Process

Results - Feasibility



Can this process be performed by a Systems Engineer with no training in the tool set?

Easy

- Export of data from schedule
- Using the interactive diagrams
- Updates with new schedule data
- Repeating process
- Inviting users to use the application

Moderate

- Identification of factors critical for viewing (several iterations)
- Setting up filters in Perspectives
- Determining what to investigate first when addressing a problem
- Setting up nesting/grouping in Perspectives (for someone with training)

Hard

- Setting up nesting/grouping in Perspectives (for someone with no training or experience)
 - Needed training
 - One time effort to establish settings

Future Work

- Highlight changes from updates (comparison)
- Expansion of timeline capability
- Providing guidelines to activity naming structure to maximize capability
- Research performed for projects in the aerospace and defense industry, but application can be more broad
 - Applicable to any industry with large, multi-faceted projects such as education, energy, healthcare, information and technology, large infrastructure projects
 - SysML v 2.0
 - Digital Engineering Environment
 - Digital Thread
 - App Building





Additional Material

Exhibit Map

Want to see more? Ask more questions?

Come by the Tom Sawyer booth (#2)

This case study data is available for demo

Times to come by:

Monday, July 17	09:30 – 19:30
Tuesday, July 18	09:30 – 18:00
Wednesday, July 19	09:30 – 17:00



Questions? Contact Us

Dr. Davinia Rizzo, Aerospace Corporation

- davinia.rizzo@aero.org

Dr. Janet Six, Tom Sawyer Software

- jsix@tomsawyer.com

Joshua Salinas, Aerospace Corporation

- Joshua.Salinas@aero.org





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