MBSE-Driven Visualization of Requirements Allocation and Traceability

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Agenda

- Introduction
- MBSE on NASA's proposed Europa Mission
- MBSE-driven visualization
- Case studies
- Infrastructure
- Recommendations

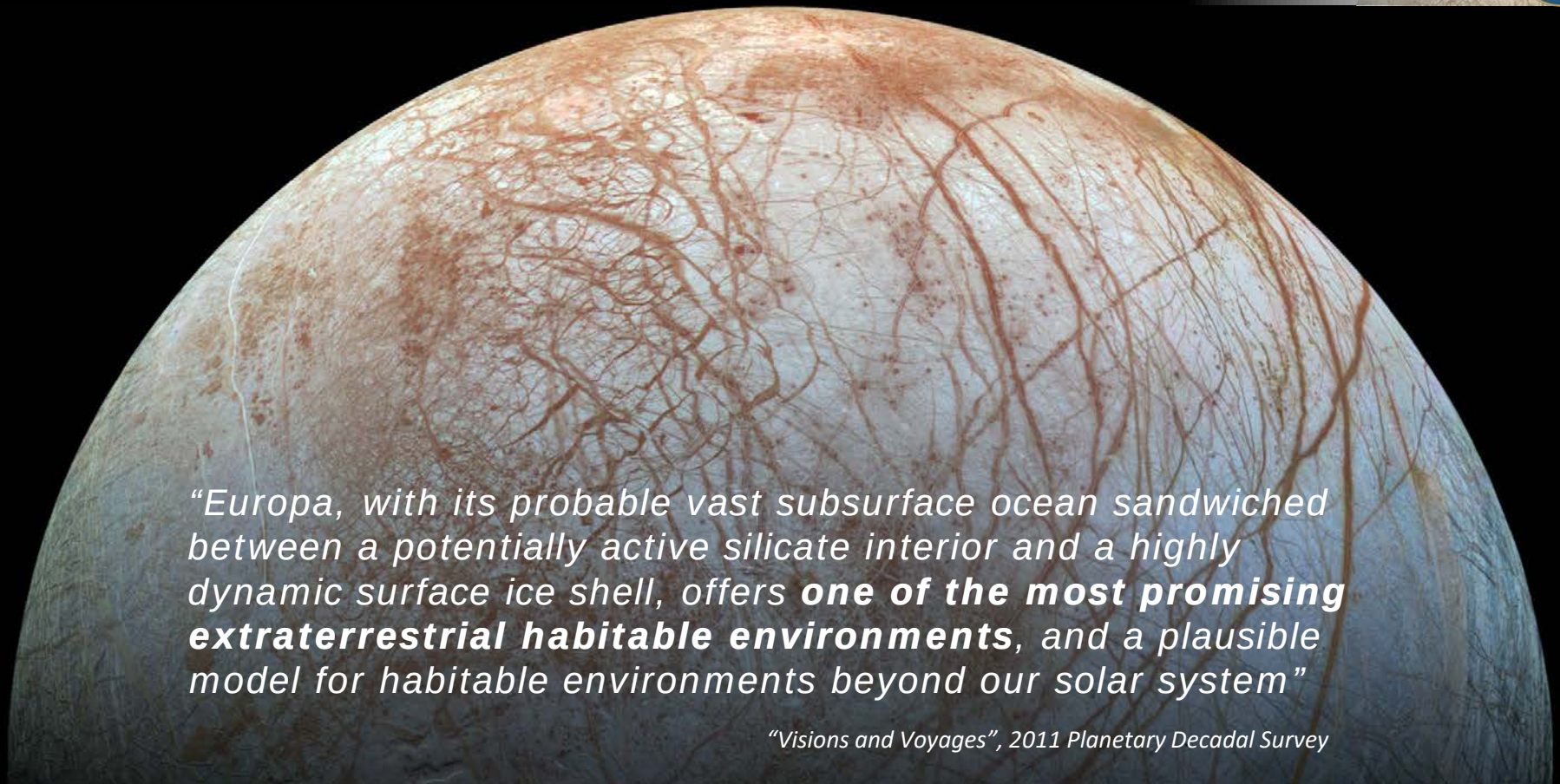
INTRODUCTION

Introduction (who is talking to you?)

- Me: Europa Project for ~2 years
- MBSE for 7
- Roles:
  - Practitioner
  - Systems Engineer on FS requirements team
    - Do requirements engineering, *happen* to use MBSE as tool of choice
    - SW developer for query, automation, tool, visualization, and any other as-need infrastructure
  - Model System Engineer for PSE
    - *One* interface between SEs with more traditional skill sets and system model
    - My particular role is software management (and development)

MBSE ON THE EUROPA PROJECT

Europa



"Europa, with its probable vast subsurface ocean sandwiched between a potentially active silicate interior and a highly dynamic surface ice shell, offers ***one of the most promising extraterrestrial habitable environments****, and a plausible model for habitable environments beyond our solar system"*

"Visions and Voyages", 2011 Planetary Decadal Survey

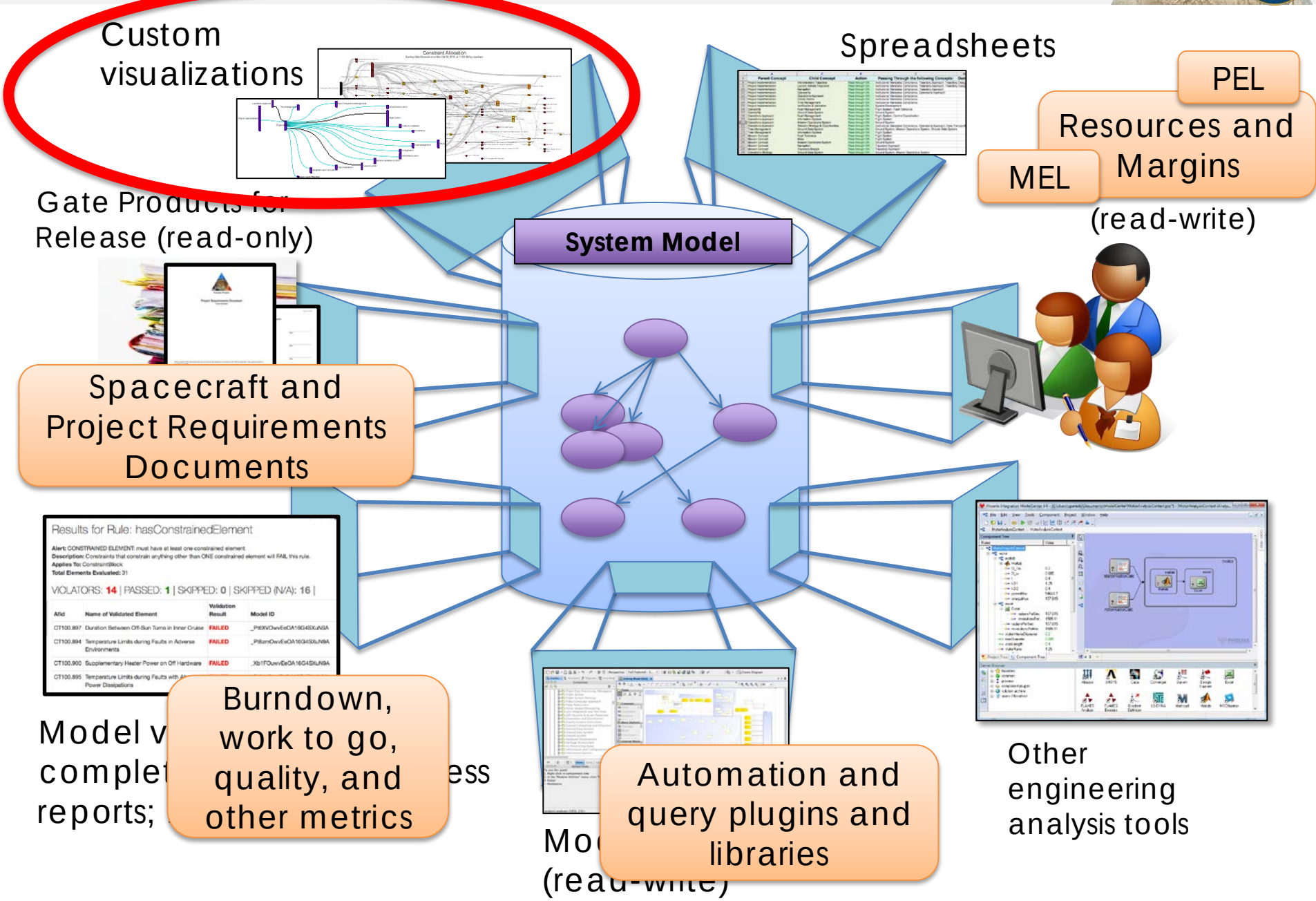
- How do we solve Europa's mysteries? By potentially sending a spacecraft and instruments to collect data for our investigation!
- Europa Project:
  - Early phase
  - Dual focus on system/design architecture and closing big trades *and* requirements derivation, analysis, and flow-down.

MBSE on the Europa Project

- Europa is fully MBSE mission concept (Project and SC level)
  - We *use* MBSE to do our SE
  - MBSE is not the product

- Specifically, for our phase:
  - MELs, PELs, resource allocation and analysis, system decomposition, etc
  - All systems engineering activities
    - Requirements (derivation, justification, traceability, analysis, maturity, history, verification, document generation, metrics, etc.)

What does the Europa Project do with that?



MBSE-DRIVEN VISUALIZATION

Visualization + Systems Engineering

- When I say visualization, **what do I mean?**
  - Visual representations of data to reinforce human cognition
  - See, explore, and understand large amounts of information at once

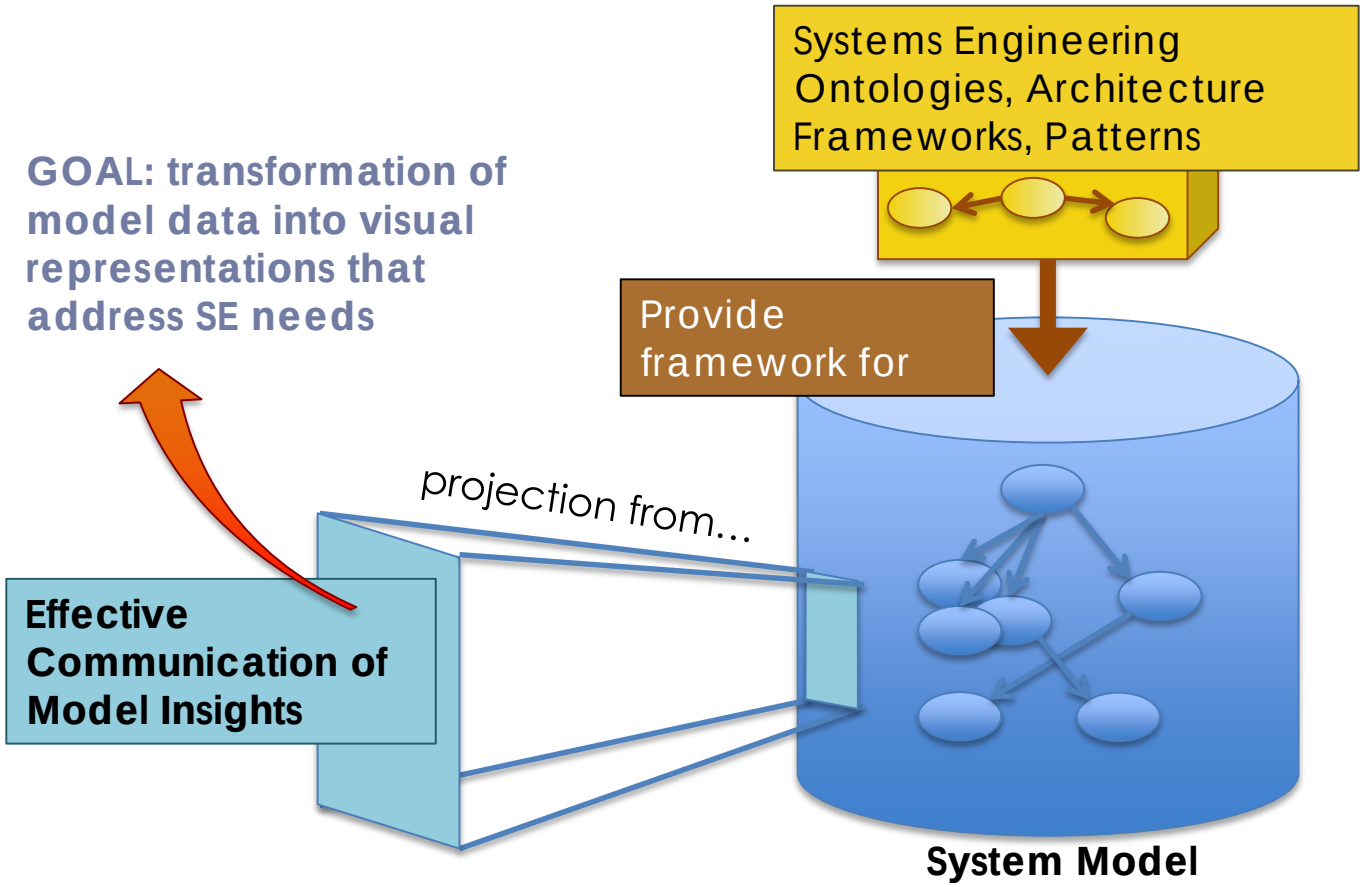
- Visualization ←→ SE?
  - SE: Creative, cross-cutting, innovative, skeptical, broad, detailed, exploratory

- How do we currently interact with data?
  - SE's build individual ways to manage and manipulate data
  - Spreadsheets, filtering, tagging, diagrams, writing, questions…

- What things would SEs care about in a visualization tool?
  - Exploration, filtering, sorting, grouping, tracing, prioritizing, categorizing
  - Interactivity, flexibility, creativity
  - Situational awareness

Why visualization?

- Assertion: MBSE-driven visualization can be enabling technology
  - Can provide value beyond traditional SE

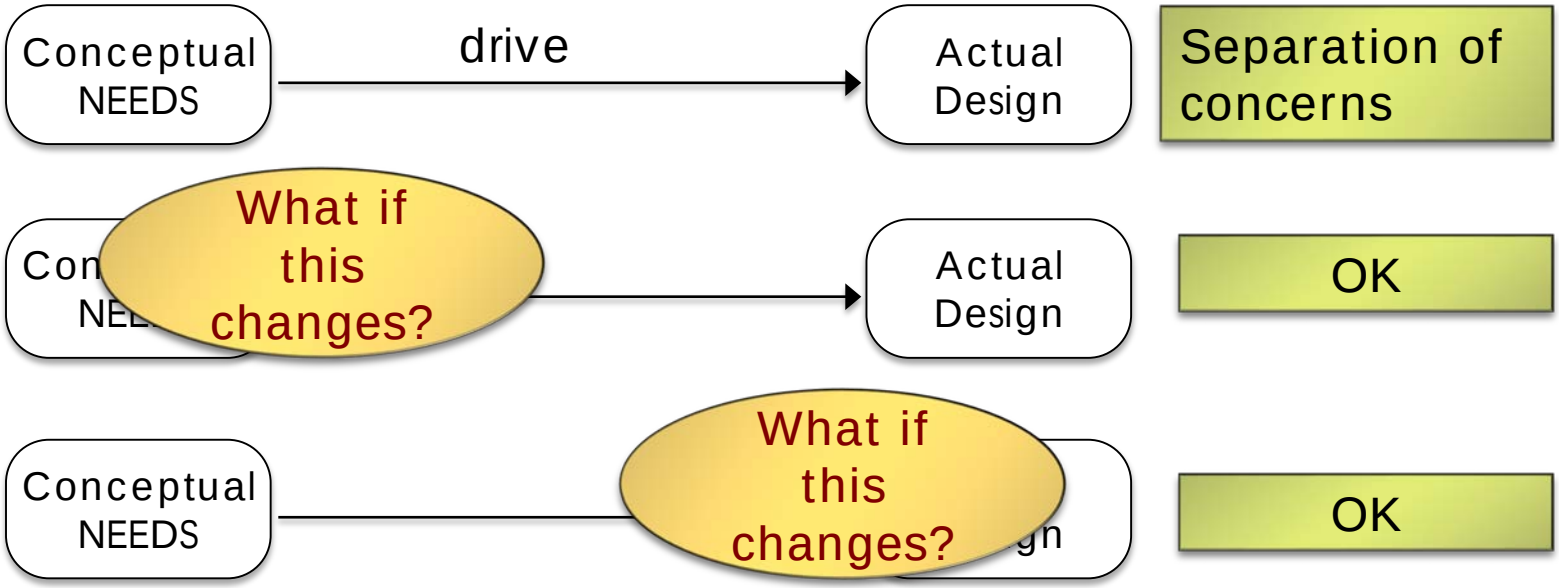


CASE STUDY 1: CONCEPT HIERARCHY

Case study 1: Introduction

A little background…

- Europa Project uses Architecture Framework:
  - Separation of concerns
  - Guides requirements derivation
  - Guides design process/evolution



Case Study 1: Concepts

How do this with MBSE? Divide concern areas into "Concepts"

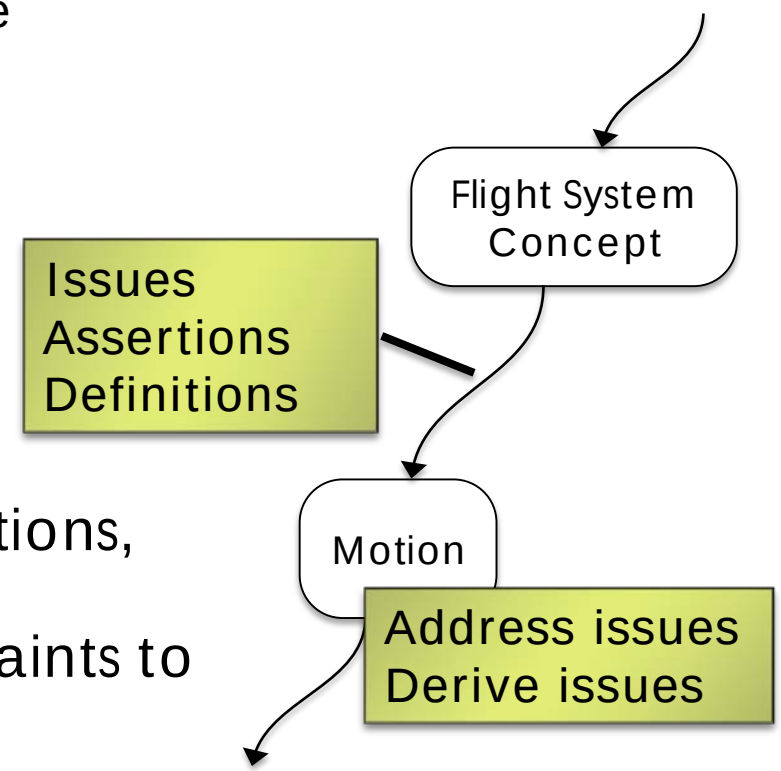
- Concept Lead/Author, Modeler, SE
- Job: EXPLAIN (narrative text)
  - Conceptual approach
  - to issues identified at a higher level…
  - and given to that topic area to solve (requirements);

And DERIVE

  - new issues (requirements) in response
  - allocate to other concepts…
  - or to implementing organizations.

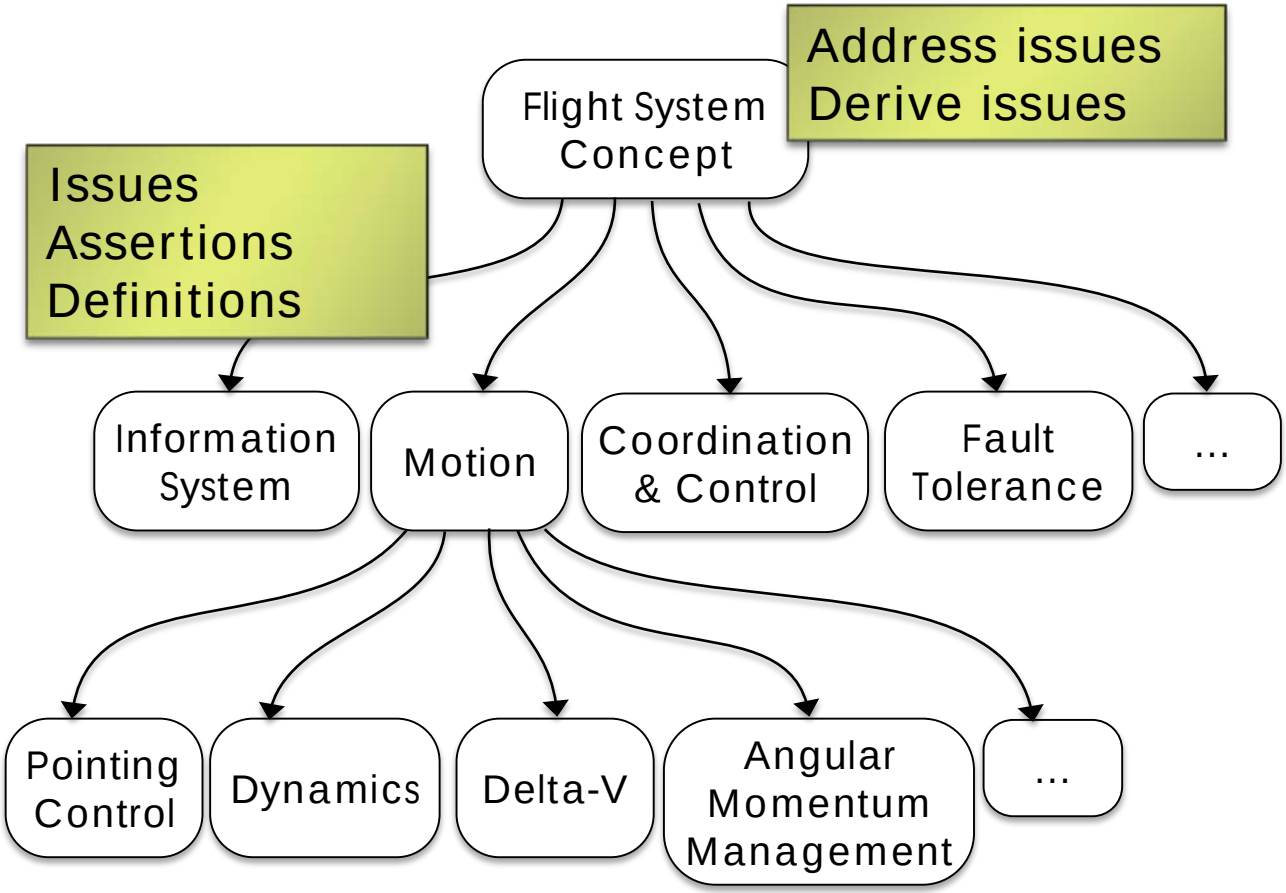
In practice:

- Hierarchy of concepts
- Parents and children
- Provide scope (assertions, definitions, elements)
- Pass issues (requirements, constraints to be addressed)



Concept Hierarchy

What does this look like?



Case Study: Concept Hierarchy

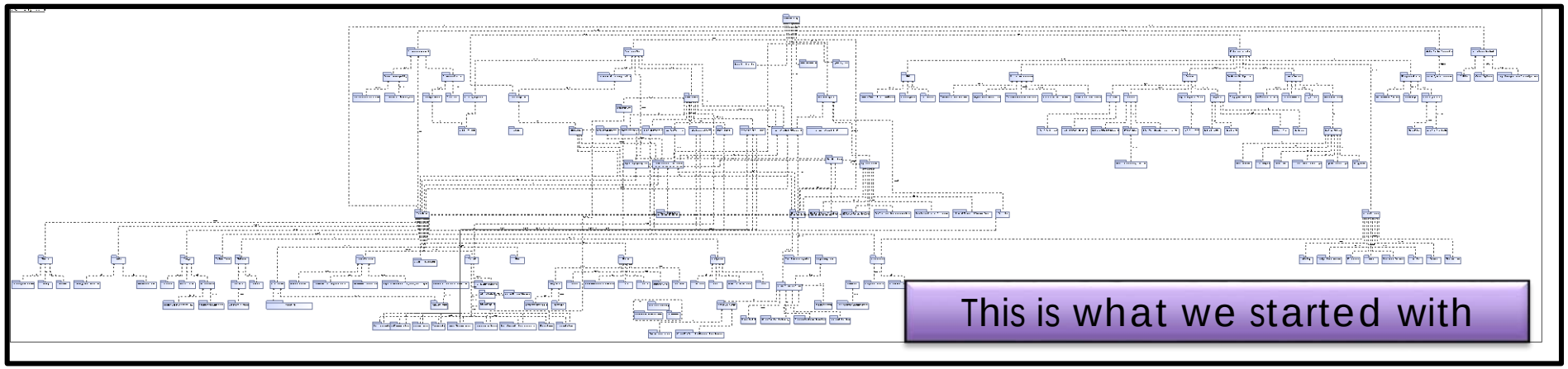
Problem:

- ~150 Concepts
- What IS the hierarchy?

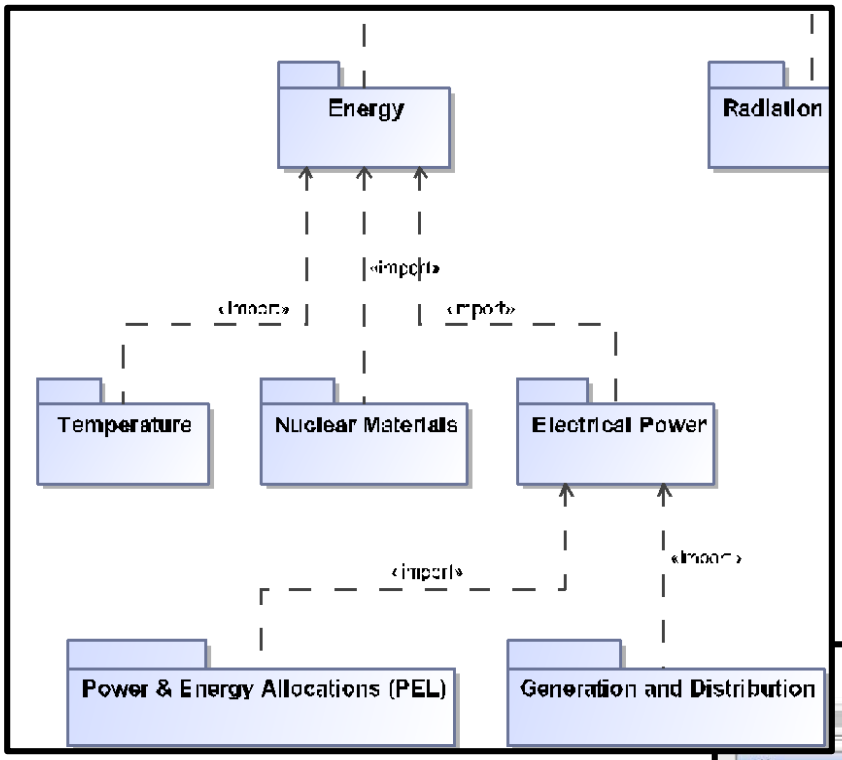
Questions:

- Concept lead: who are my parent concepts? Child concepts? What information is at my disposal?
- SE: What concepts influence each other? Is the hierarchy complete? Correct?

Maybe some sort of …picture…?



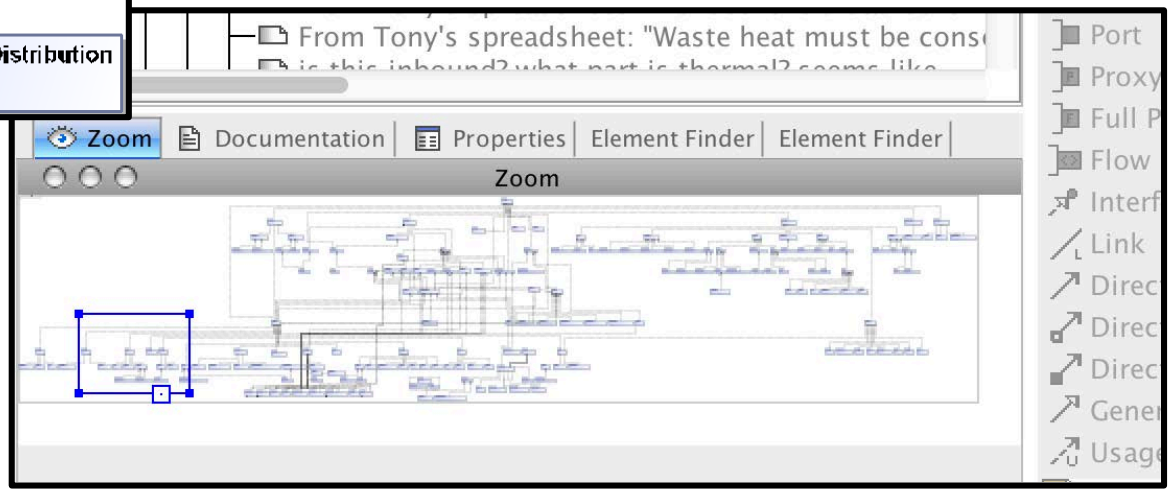
Case Study: Concept Hierarchy



- The "scroll" is not TOO bad when you zoom in…
- If you you know where to zoom…
- If you have the scroll.
- If magicdraw is open.
- If you know the link.

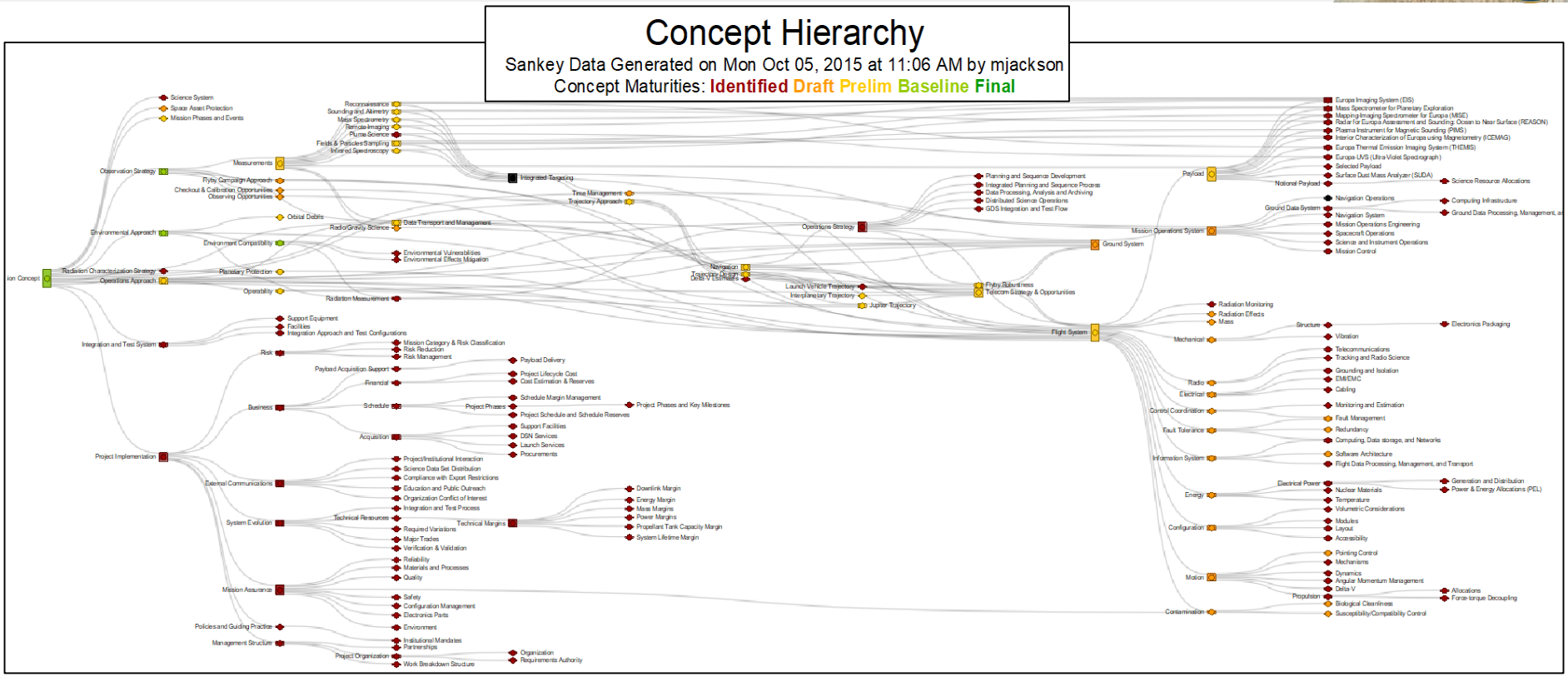
Bonus: overview in MagicDraw →

Extra bonus: it took me several minutes to make the above graphic because I couldn't find the energy concept



Couldn't we have something better?

Address with visualization



Interactive visualization of concept hierarchy (read left-to-right)

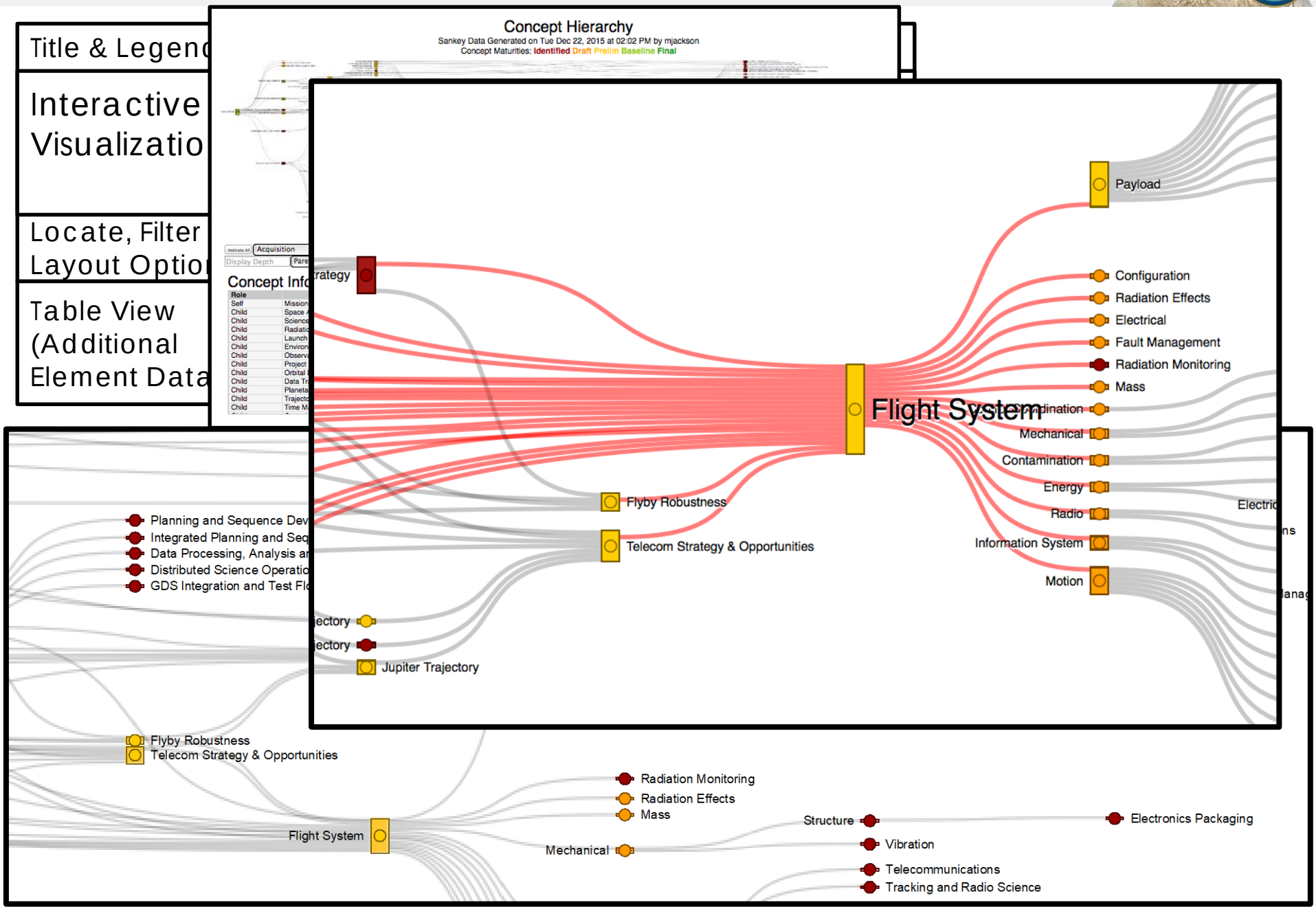
Features

Title & Legend

Interactive Visualization

Locate, Filter Layout Option

Table View (Additional Element Data

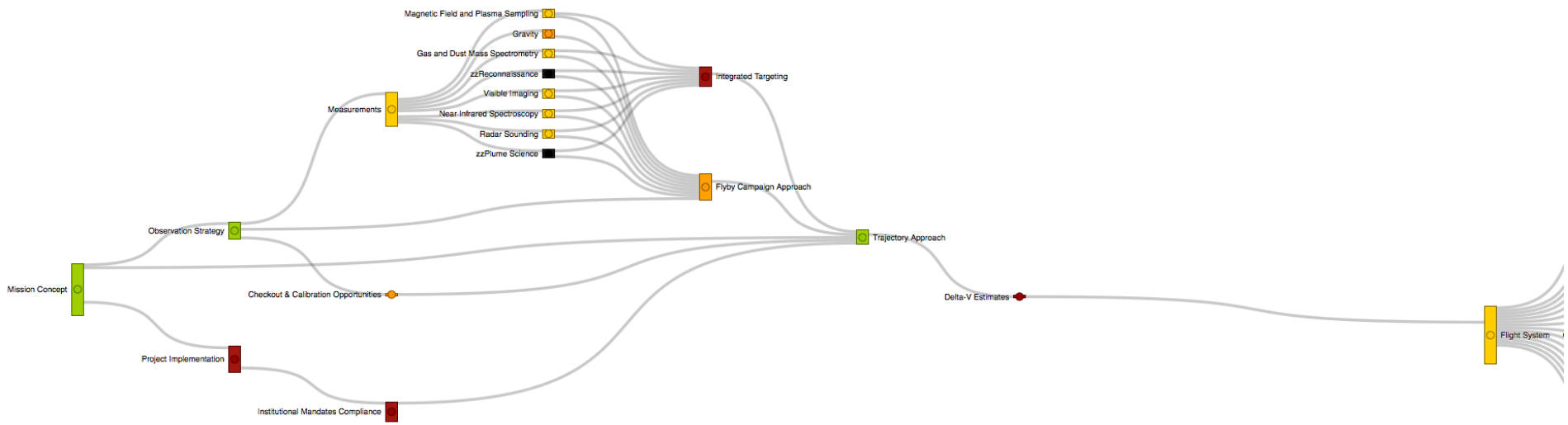


Demo

Is this useful?

Yes! Examples of use:

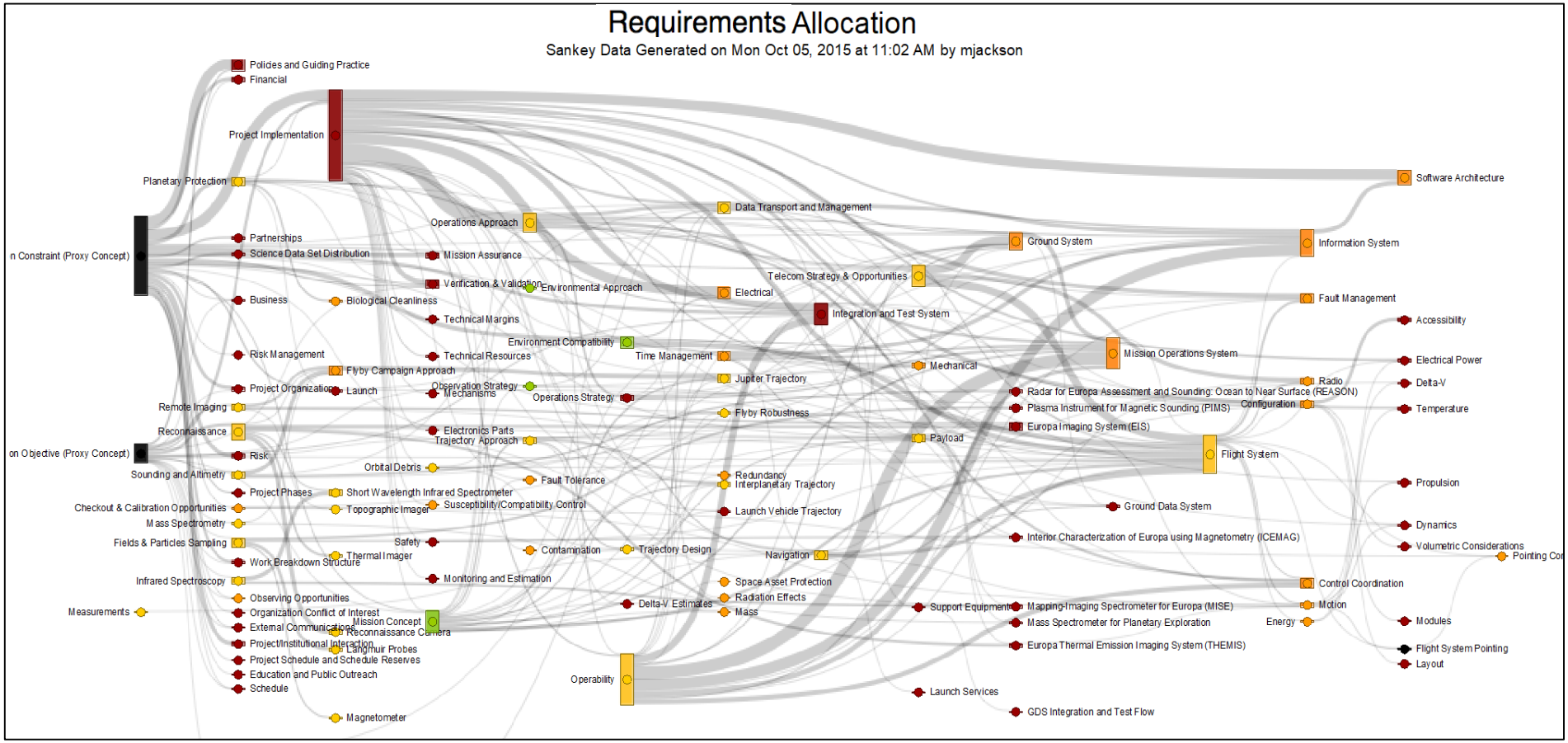
- Reviews (orient the audience; explain neighbors)
- Working meetings
- Personal work (who do I talk to)
- Model integrity checks
- Maturity progress



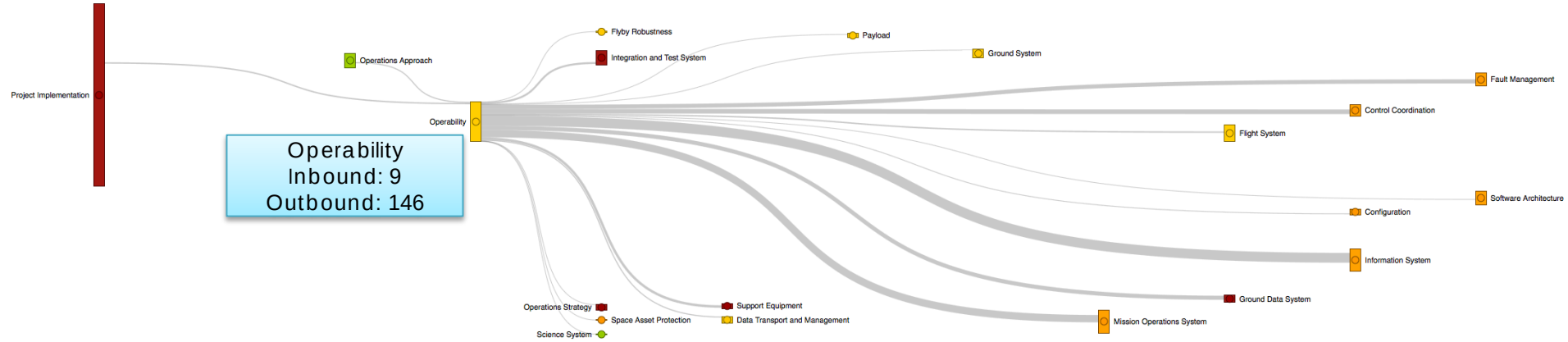
CASE STUDY 2: ALLOCATION

Allocation

- The Concept Hierarchy is supposed to guide requirements allocation.
- Tools don't enforce hierarchy; allow any allocation
- What have we **actually** allocated?



Features



Display Controls

Operability | Ping Concept!

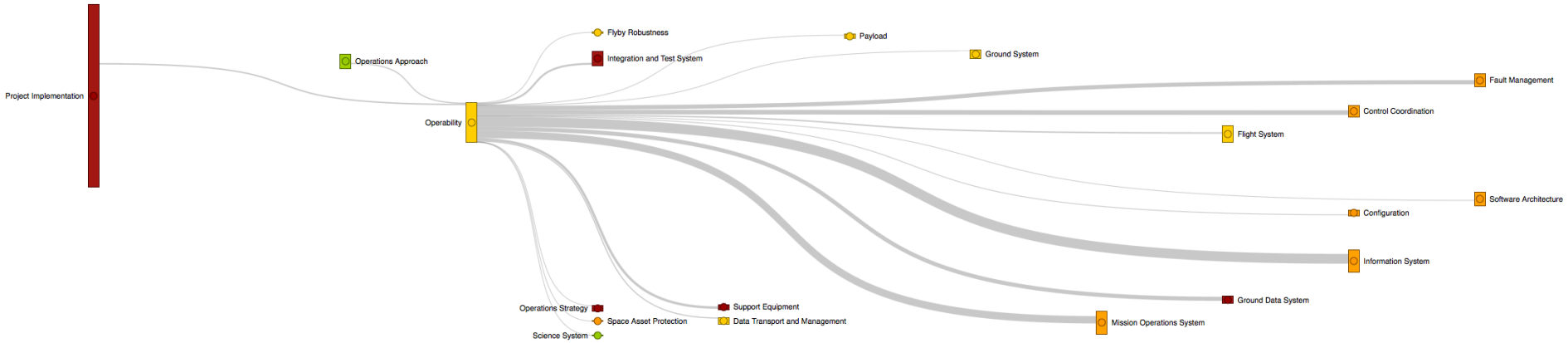
1 | Parents & Children | Focus On Concept | Reset Focus | LinkScaleFactor – | LinkScaleFactor + | PassThrough – | PassThrough + | Toggle Path Mode

Constraint Info: Science System

Direction	AFID	Constraint ID	Constraint Name	Constraint Text	Allocation Status	Constraint Status
Outbound (Ground System)	CT102.162	OBS.06	Availability of Data Products	[text from attached requirement (RQ103.921)] Collaborative data products shall be available within 3 days of ground receipt of the data.	Both Accepted Provisionally - Needs Discussion between Sub and Parent	Baseline
Outbound (Ground System)	CT102.164	OBS.08	Public Availability of Data Products	[text from attached requirement (RQ103.926)] Public data products shall be available within one week of data receipt and production.	Both Accepted Provisionally - Needs Discussion between Sub and Parent	Baseline
Outbound (Ground System)	CT102.163	OBS.07	Delivery of Data Products	[text from attached requirement (RQ103.919)] Archival data products shall be delivered to the PDS within six months of data receipt.	Allocation Final - Parent and Subview Fully Agree on Allocation	Baseline

Usage

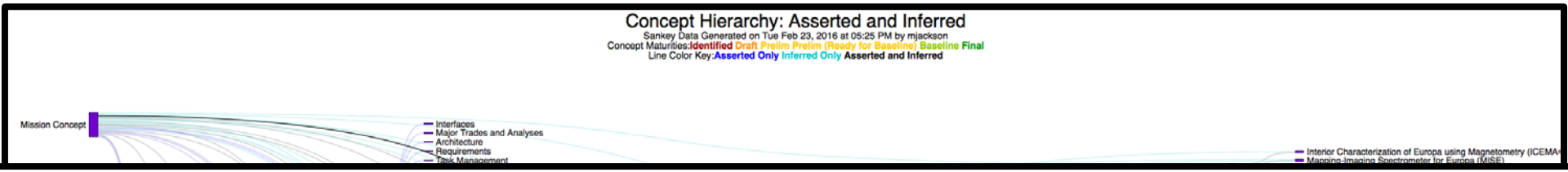
- What is actually flowing between concepts
- Work to go (maturity, quantity)
- Magnitude of influence
- Specific requirements

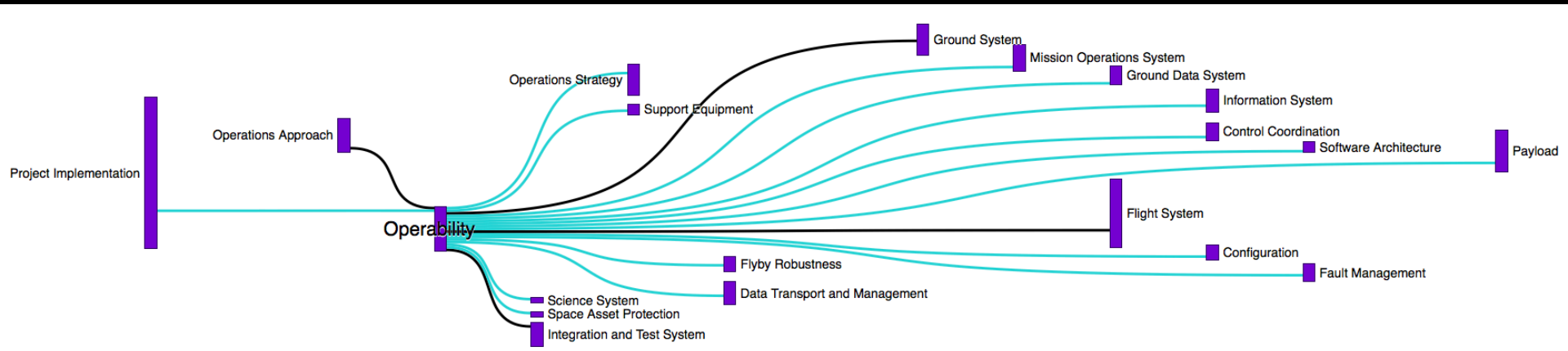


CASE STUDY 3: COMPARING THE HIERARCHIES

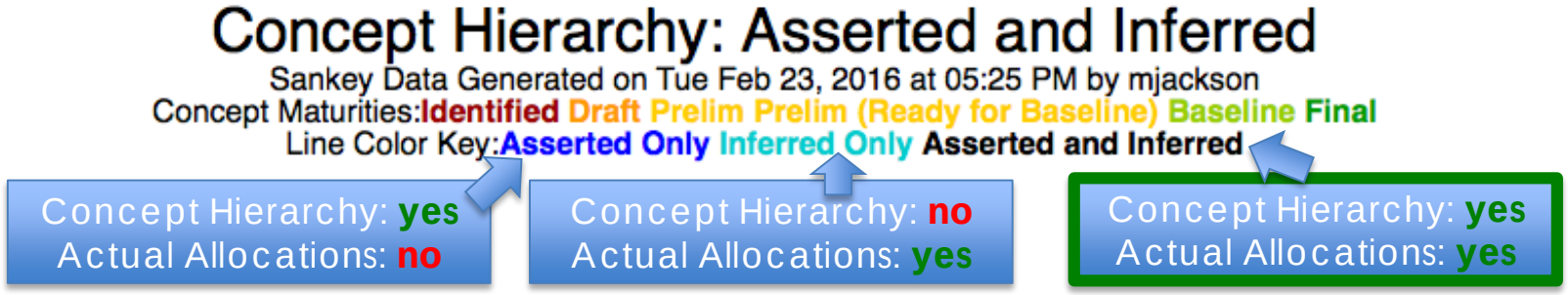
Comparing the Hierarchies

- How do we understand the hierarchy mismatch?



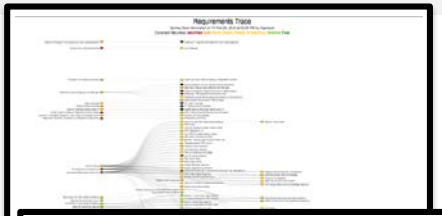


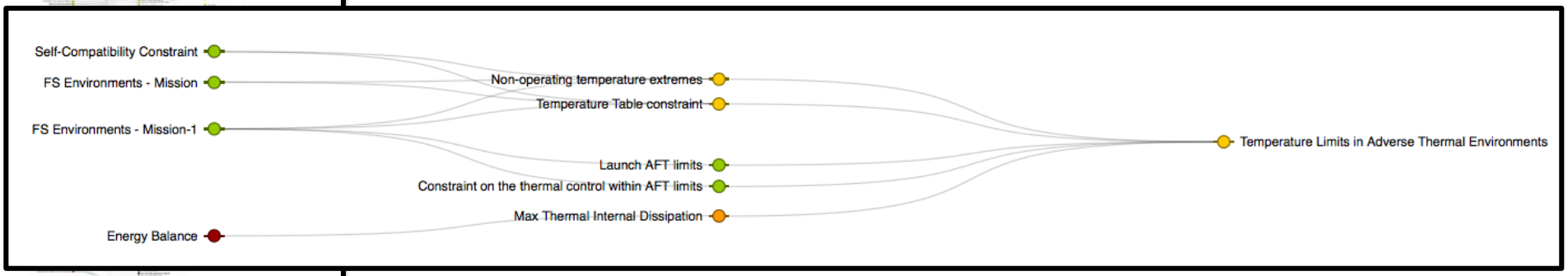
Role	Concept Name	Concept Author	Concept Link	Concept Maturity
Self	Flight System	TBD	Flight System	Prelim
Child	Radio	Peter Iiott	Radio	Draft
Child	Radiation Effects	David Brinza	Radiation Effects	Draft
Child	Radiation Monitoring	Rich Meitzler	Radiation Monitoring	Identified
Child	Energy	Marcus Wilkerson	Energy	Draft

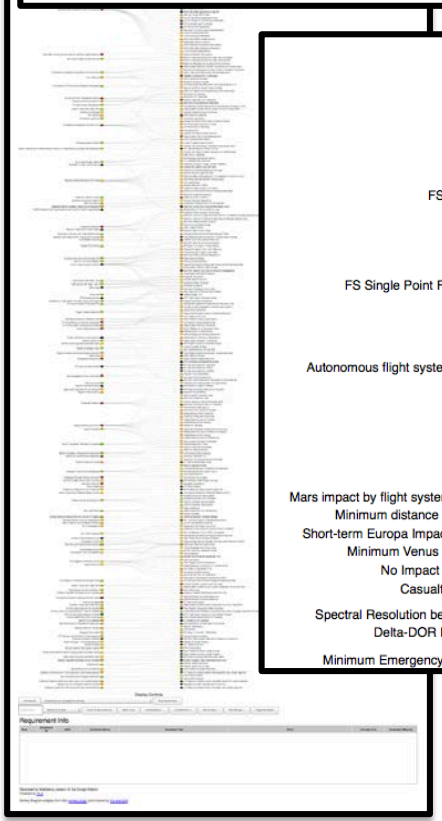


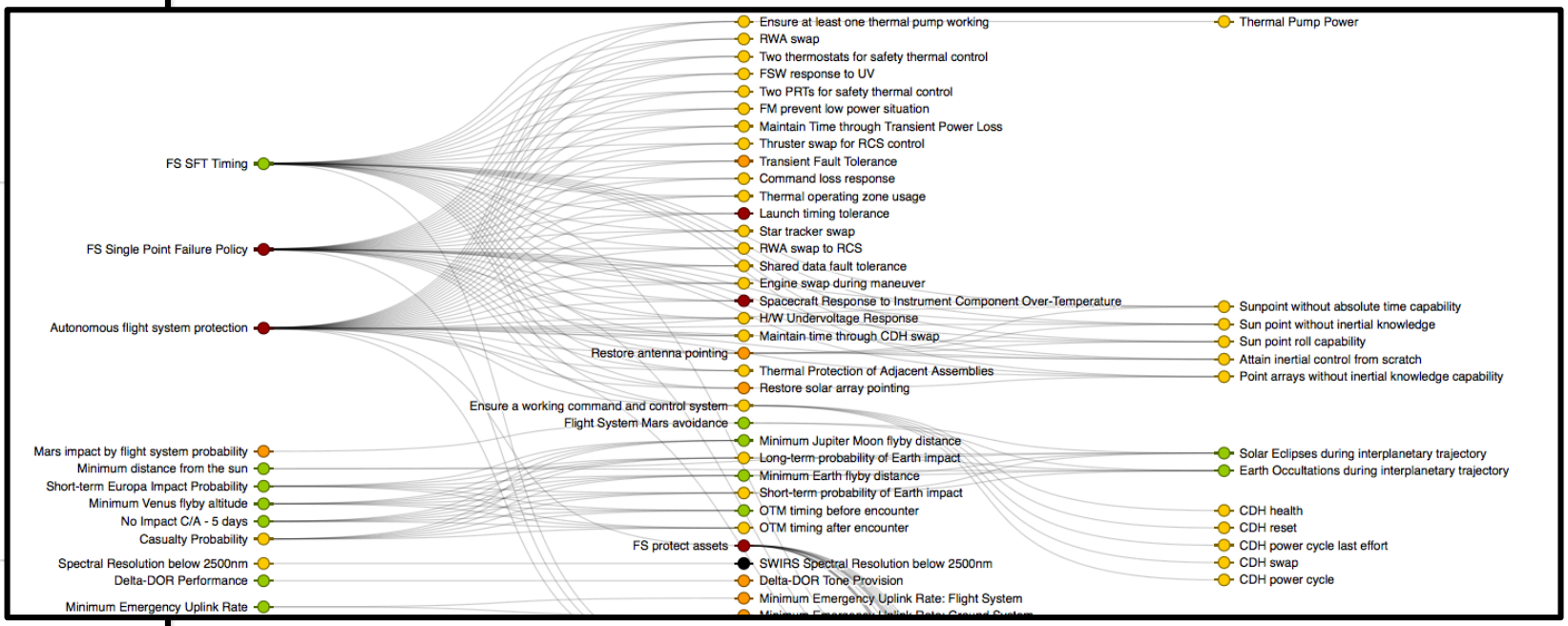
CASE STUDY 4: REQUIREMENTS TRACEABILITY

Requirements Traceability

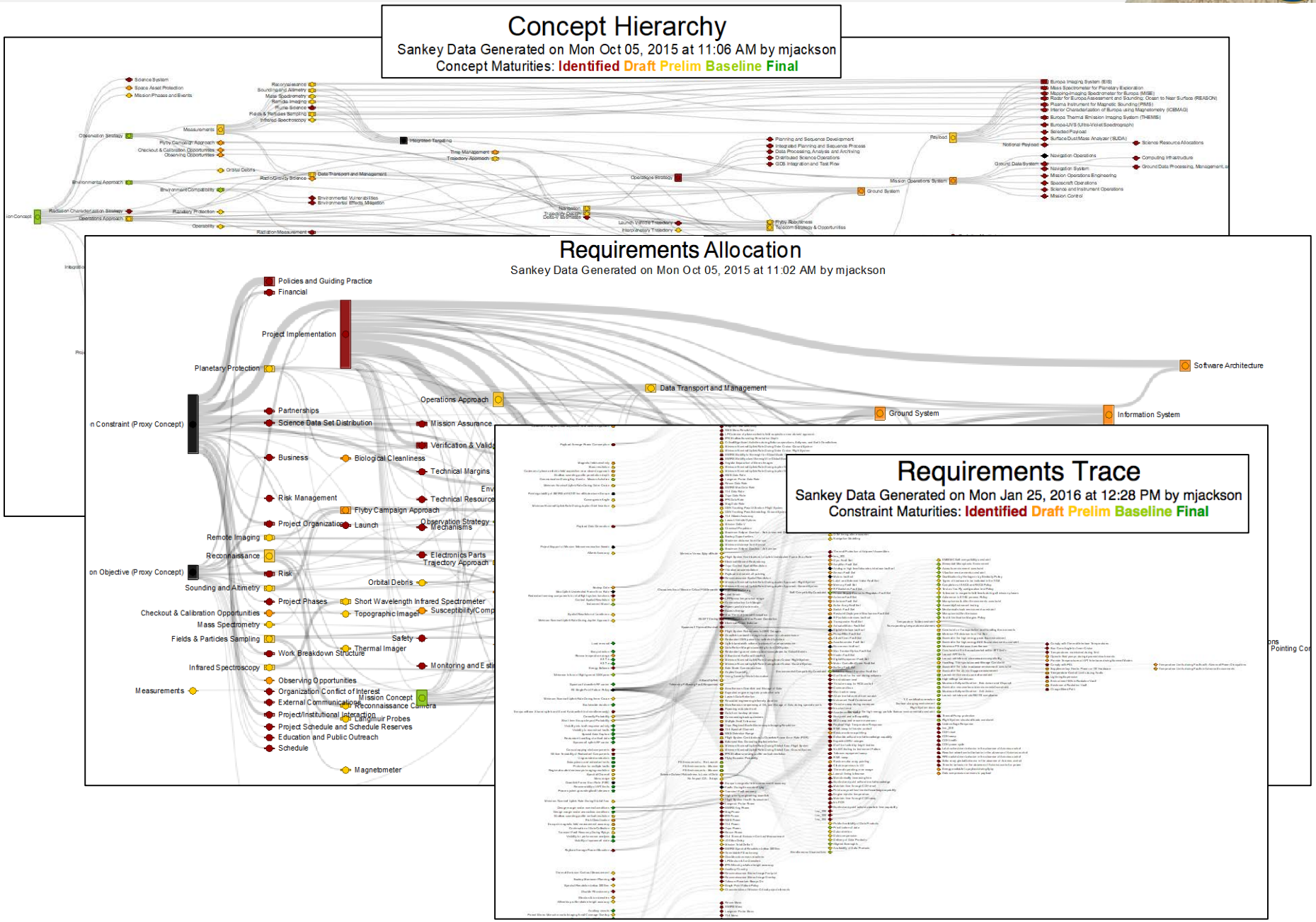






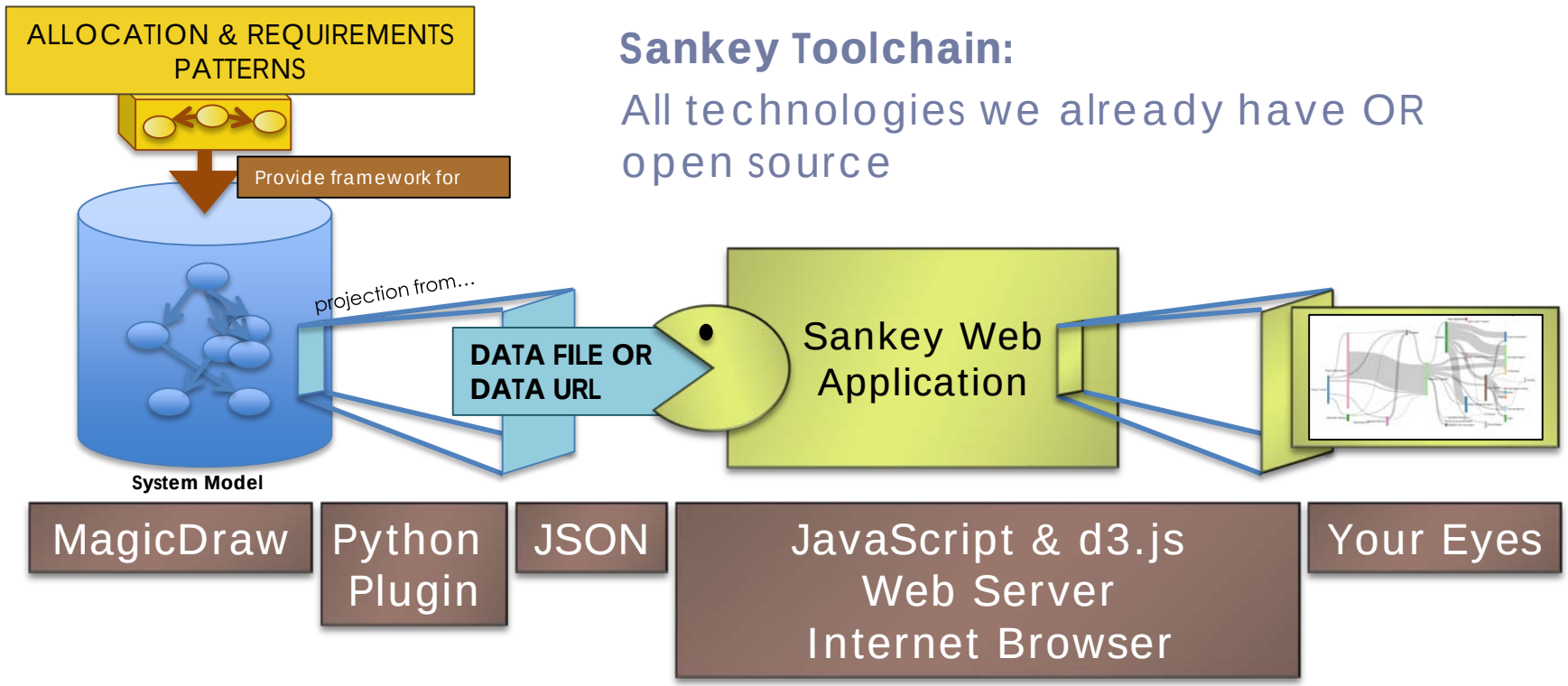


What have we done with MBSE?



TECHNICAL DETAILS

Technologies



Sankey Toolchain:

All technologies we already have OR open source

Already "standard" with MBSE: MagicDraw, Web Servers, Your Eyes
Standard customizations: Python data generator plugin for MD

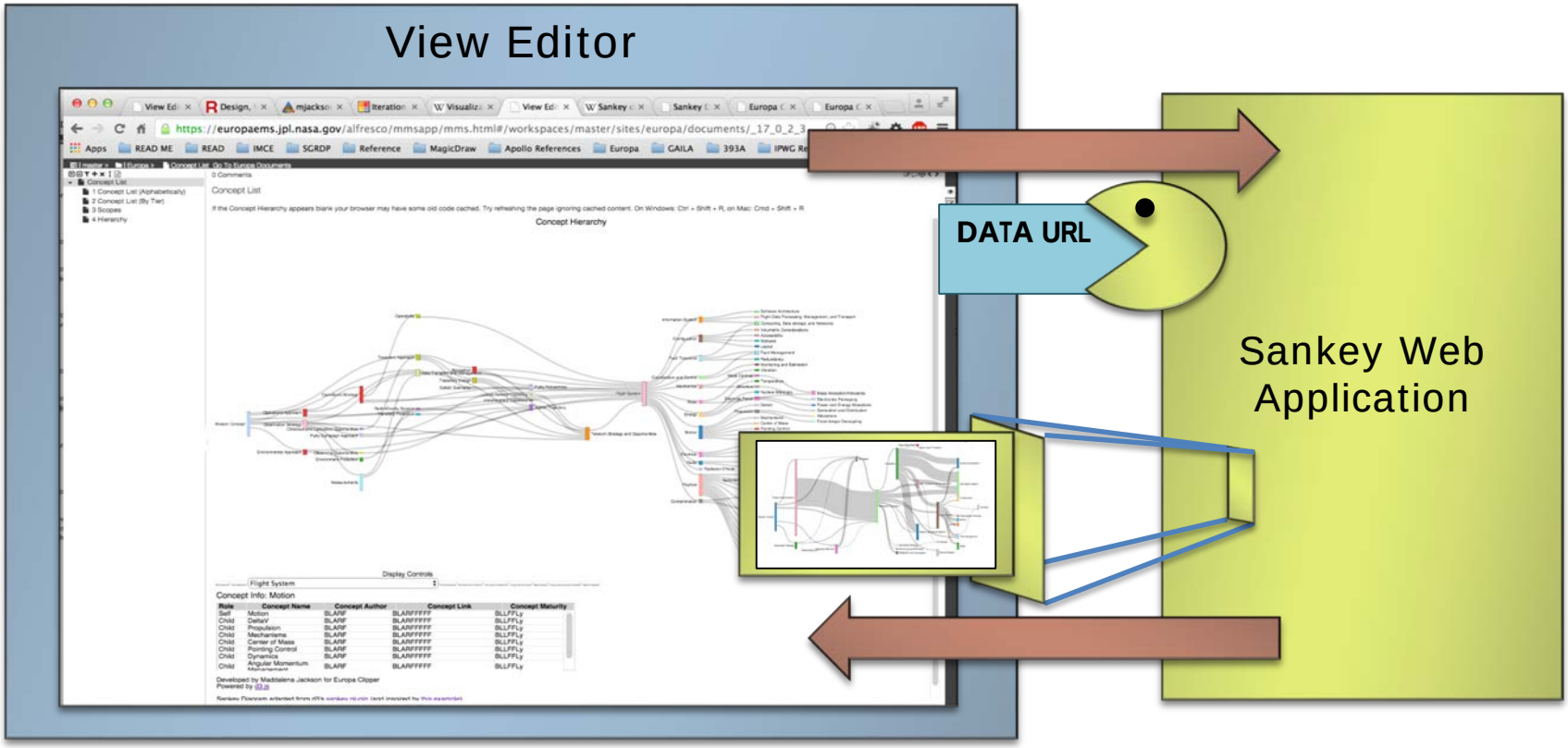
New:

- d3.js (library for JavaScript) & sankey.js – **open source**
- web app built with JavaScript and d3, customized sankey.js

Integration

Integration is easy:

- Can be easily rendered in other web applications
  - JPL Web front-end (View Editor) renders visualization web app
- Code can be easily re-used for other embedding



CONCLUSIONS

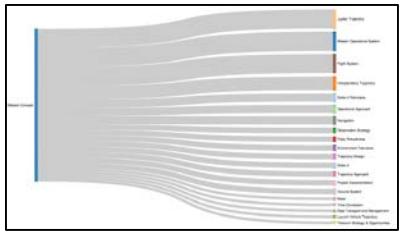
Summary: goals and opportunities

Goal: *facilitate interaction with model data for SE in an organized effective needs-based way.*

- Efforts contribute to state of practice.
- Don't reinvent the wheel.
- Lower overhead while enhancing creativity.
- Successful mission based on MBSE.

Good environment for study and development:

- Framework to host these data representations. (View Editor)
- Gaining traction: standardization of in-model data representation (via patterns)
- Collaboration, community of practice, strategic reuse
- Europa (among others) encourages creativity, enables development of effective prototypes and apps.
- Skilled, interested people



Tensions

Tension: SE skills

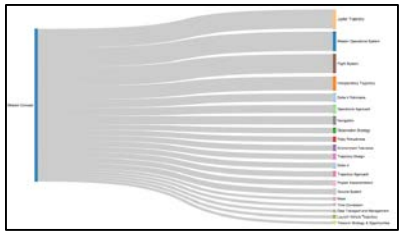
- *Should SE's be modelers?*
- *Should SE's be software developers?*
- Cross-training, cost

Tension: View Standardization

- *Standardization is good:* reduce overhead with reuse, lower barrier to entry, reduce time, don't have to pay developers, common visual taxonomy and patterns, templates…
- *Standardization is bad:** reduces creativity, narrows scope, prevents innovation, entrenched routines, removes human factor (mistakes?)

Tension: Technologies

- Why are we considering d3.js AND Tom Sawyer? What's wrong with MagicDraw's diagrams? What about excel?
- Technologies can be *complementary*
- Too many technologies is problematic (overhead, interchange…)



*imagine an extreme situation; hyperbole

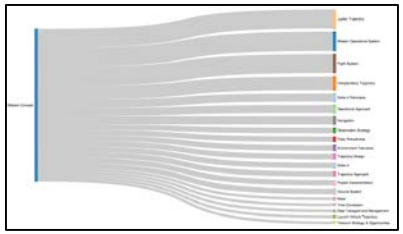
Conclusion

- Remember this goal?
- "GOAL: transformation of model data into visual representations that address SE needs"
  - The technology is not a problem
  - Should be studying visualizations for SE by asking *what are the Systems Engineering needs?*
  - Core assertion: these visualizations were low-hanging fruit and proved very useful. Imagine what we can do with real study!

BACKUP

Summary: Challenges and Opportunities

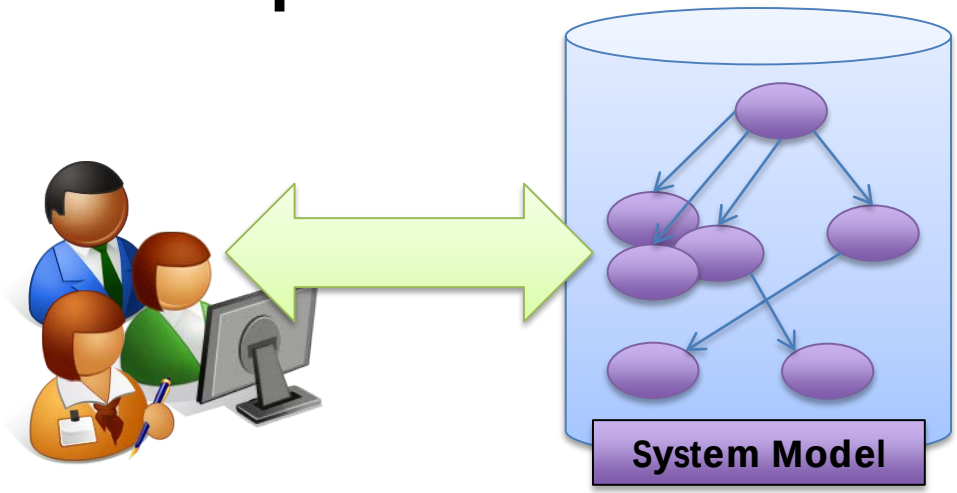
- **Challenges:**
- Allow products to spring up, demonstrate value …while not losing control or oversight of broader direction.
- Enable SE interaction with data, continue existing workflows
  - …in a model-driven way
  - …without requiring them to learn too many tools in impractical depth.
- Select and support technologies …that complement each other.
- Core challenges:
  - If we can't explore the model's data, can't do job.
  - If we can't communicate model data intuitively, effectively, creatively to stakeholders, MBSE infusion is difficult or unsuccessful.
- **Opportunities:**
- Europa: early phase, lots of use cases, people with broad skill sets.
- Collaboration with visualization and human interface experts (as seen in the IMCE MBSE Visualization Working Group)
- Tom Sawyer, d3.js, GoJS, etc. available on lab
- Have a strategic body (IMCE/Line) to coordinate
  - Development efforts
  - Lessons learned



Recommendations

- Choosing your team
  - Do you want your SEs to be modelers?
    - Do you want to train them?
    - Do they want to learn?
    - SE ←→ modeler:
      - Good: cross-training, exposure, target skills
      - Bad: bottlenecks, lag
  - SE/Software combination is very effective
    - Do you need something beyond your MBSE tool? **Then you will need developers**
    - Personal bias: SEs who code ☺
      - I've seen what people do with excel…
    - Get everyone talking algorithms

Visualization can help with the Model Accessibility problem



- Model Accessibility
  - Supposed to be easy
  - Getting data in
    - Tools, training, process
    - Ontologies, patterns
    - Time
  - Getting data out
  - Doing our work (using the data)
    - Supposed to be improving how we do business
    - Reviews
    - Individual assessment
    - Meetings/discussions
    - Providing feedback
    - Analysis

Looking Forward

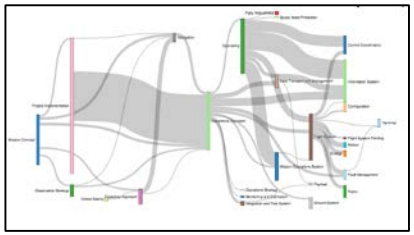
Examine: what did it take to get this capability?

Skills/favorable circumstances:

- Aware of need.
  - Not directed work. I needed it and knew there were people who might find it useful.
- Had a certain skill set:
  - Getting the data out of MagicDraw: MagicDraw super-user (SysML, MagicDraw's software API, Jython, JSON, Java)
  - Building the Sankey web application
    - Javascript and d3.js
    - Geometry ☺
    - Minimal web server configuration
  - Practical knowledge of SE needs (embedded / part of team)
  - Patience and enthusiasm (I love doing this stuff!)

But…

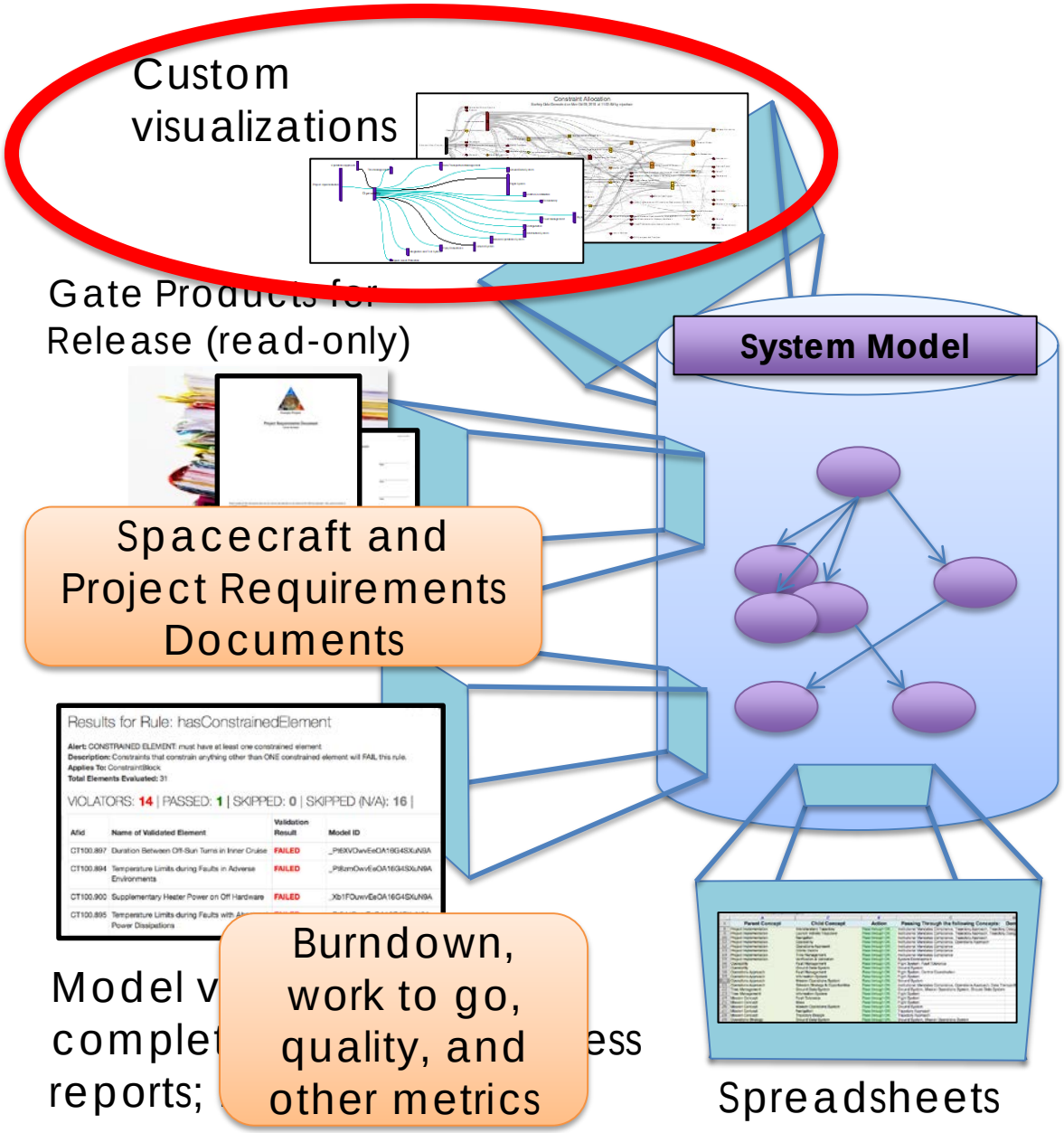
Is this a practical way to apply visualization to MBSE?



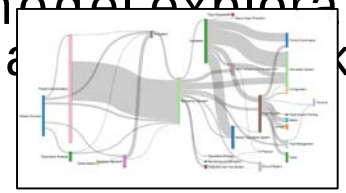
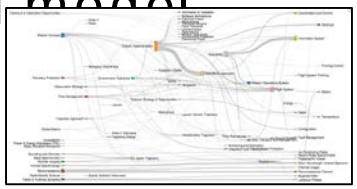
Biggest problems with MBSE infusion

- This is supposed to help me get my work done but it's taking longer
  - I can't grok it
- Logistics
  - Model Accessibility (working with the model, input/output)
  - How do people get their work done
  - How do we meet existing "interface requirements" (documents, standards, CM, etc)
  - IT issues (licenses, latency, tool config, etc)
- Knowledge representation
  - "what's a function"
- Scoping and Managing MBSE

Visualizations are more than just graphics



Recommendations

- Develop visualizations according to the three roles
- Learn from the Patterns Working Group
- Consider formalizing views – see 393 work
- Strategic study of MBSE-driven visualization
  - Institutional Infrastructure
  - Explicit goals for study of
    - SE needs
    - SE process
    - SE views
  - Explicit goals for visualization infrastructure development
    - Tools, examples, community of practice, etc.
- Higher level collaboration between line organizations with visualization/SE/software/architecture skills
- Regular visualization showcases/discussion groups

- These recommendations are to everyone (SEs, managers, line, project). I believe in the value of MBSE and in moving forward with MBSE infusion, ontologies, and patterns, but we really need to be strategic about supporting rich and effective model exploration interfaces and communication of model da keholders.