

# Update on the Applications of Model-Based Systems Engineering for JAXA's Engineering Test Satellite-9 Project

Workshop on Model Based Space Systems and Software  
Engineering (MBSE2022)

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Yuta Nakajima, Tsutomu Fukatsu  
Engineering Test Satellite-9(ETS-9) Project Team  
Space Technology Directorate I,  
Japan Aerospace Exploration Agency





# 1. Introduction

## Engineering Test Satellite-9(ETS-9)

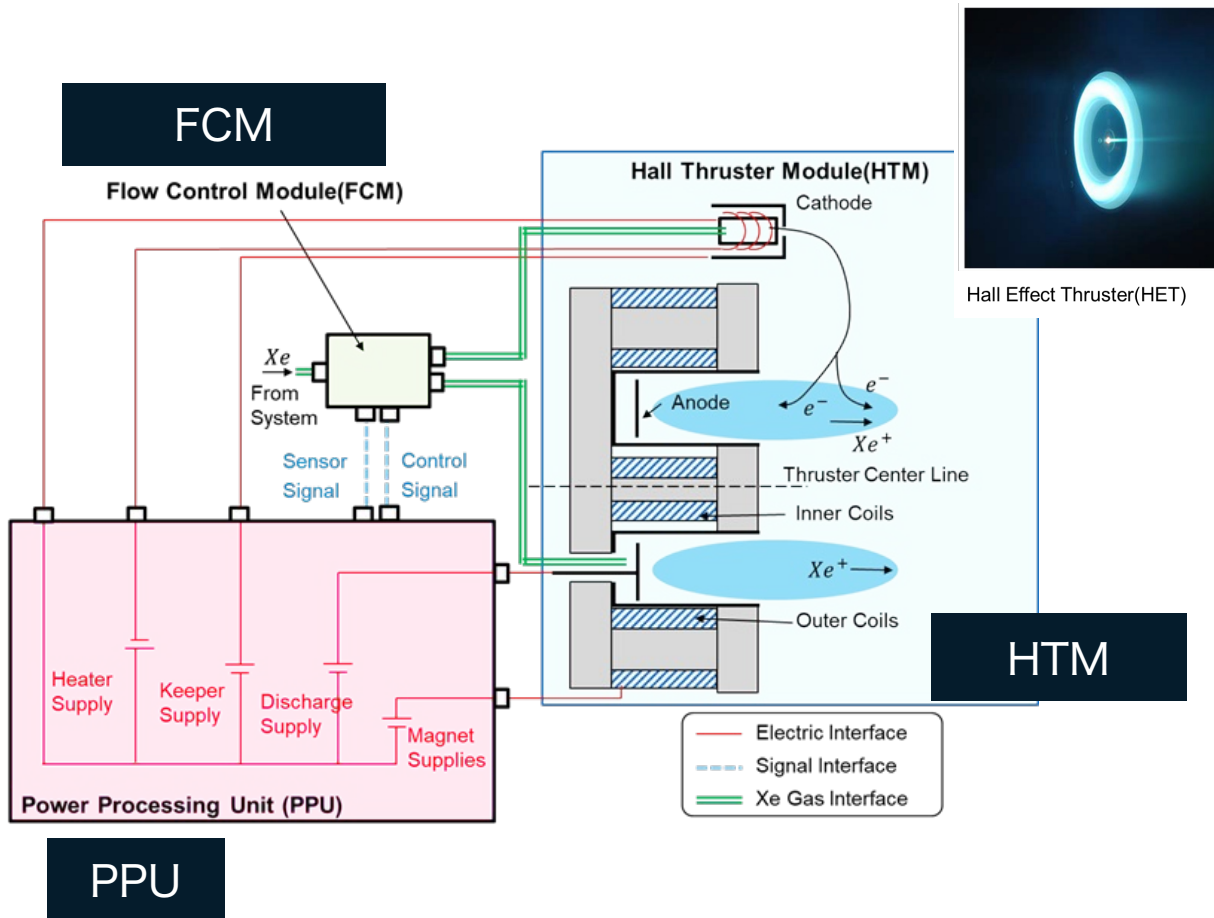
Demonstrate advanced and competitive technologies for  
“Next Generation Geostationary Communication Satellite”

- Fully digital communication payloads
- All-electric satellite bus technologies
- High-power Hall Thruster System



# 2. ETS-9 MBSE Challenge

Applying MBSE to risk management of Complex Hall Thruster System



Hall Thruster System

## System Complexity

- Complex interactions between three components, including power, gas, plasma, and signals.
- The software inside the PPU performs many functions to ensure stable operation.

## Project Concerns

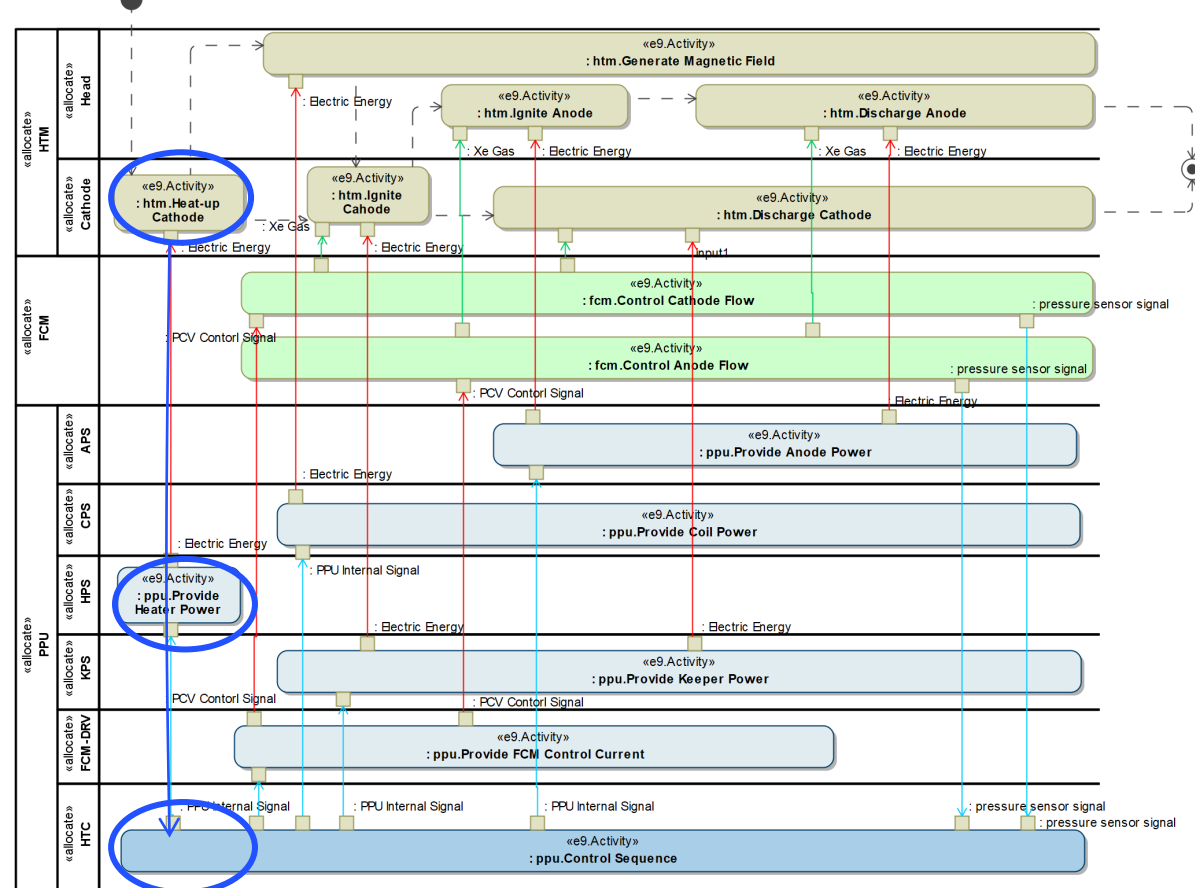
- A comprehensive understanding of the system-level failure modes and the failure propagation effects of complex Hall Thruster system
- From experience to data-driven and reproducible analysis approach



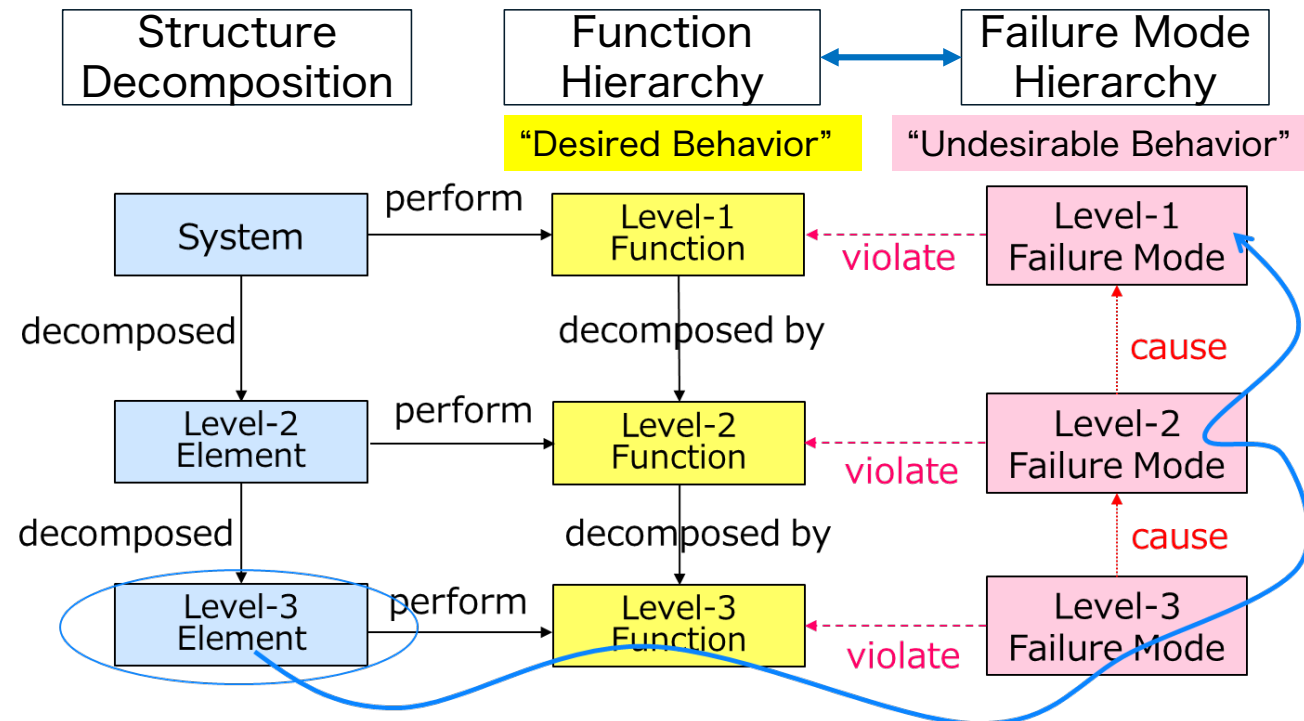
# 3. Model Guided Failure Mode Analysis

System Model helps understand complex interactions

Failure propagation analysis focusing on the chain of functions

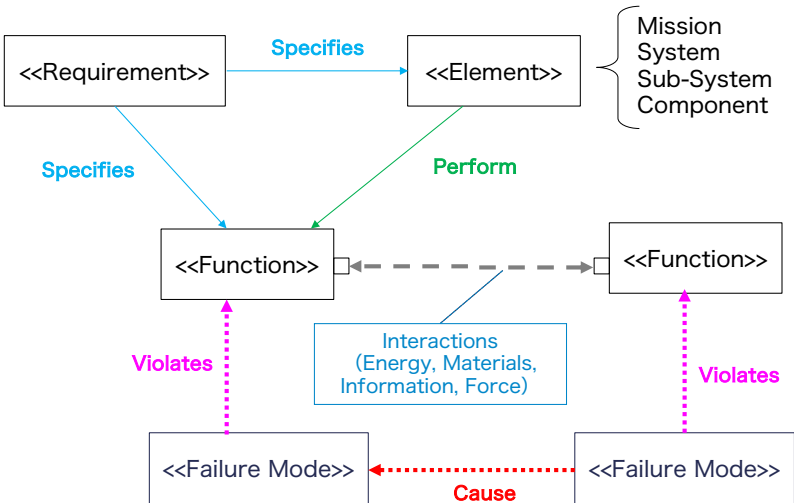


chain of functions



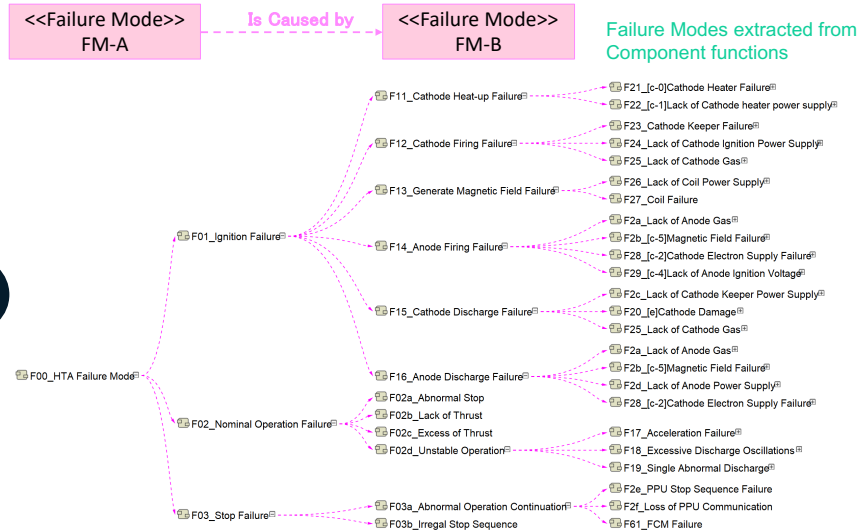
# 4. Current Limitations of MBSE practices

## System Model



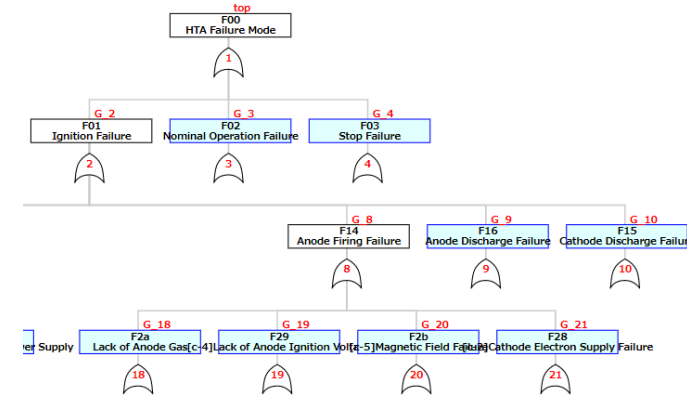
Rigor Description of Complex Interactions

## Model Guided Analysis



Failure Mode Analysis based on chains of functions

## SE Artifacts

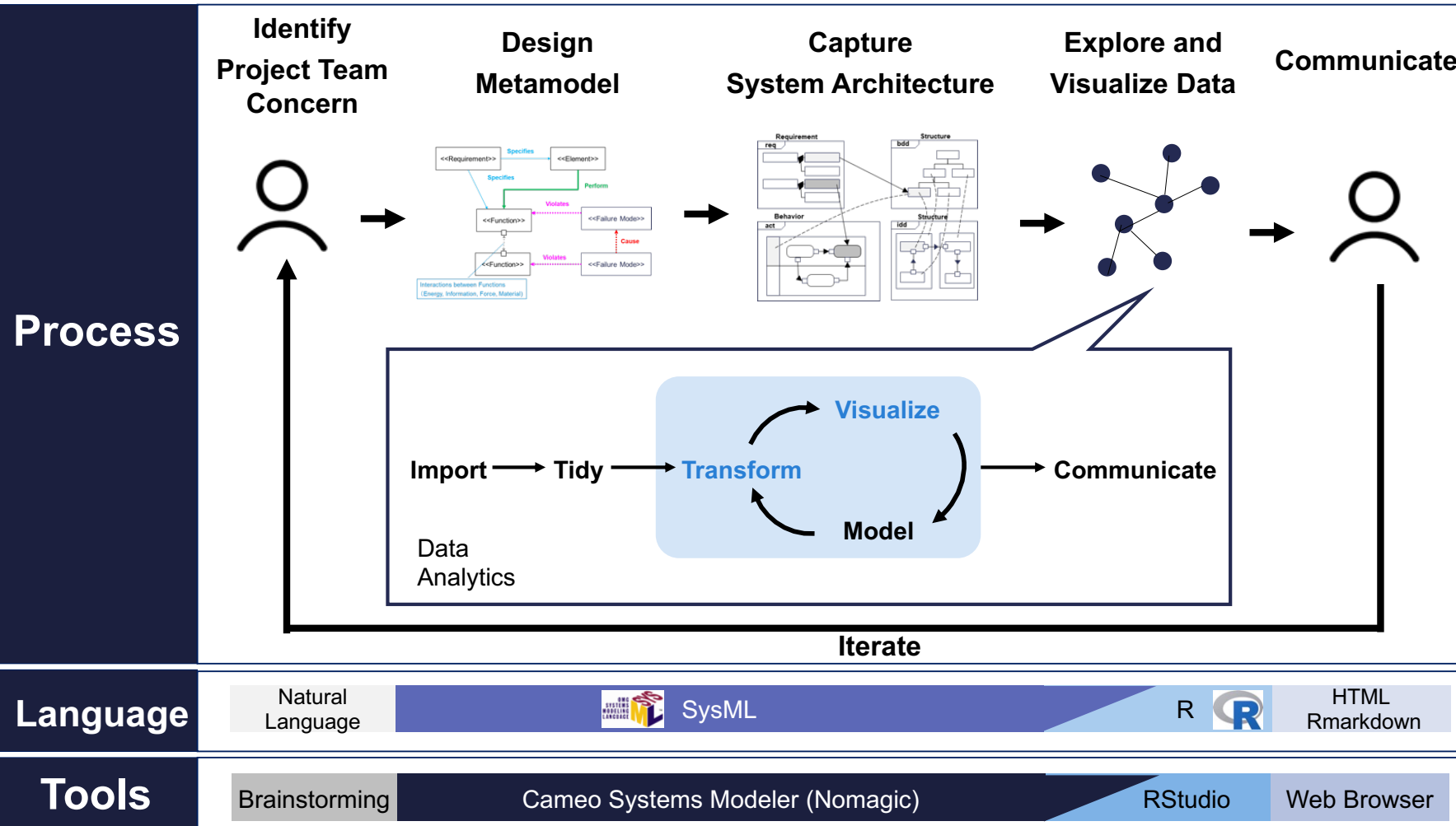


FTA as a standard RAMS product

## Limitations

- Manually explore the chain of functions
- Automation

# 5. Exploratory System Architecture Analysis Framework

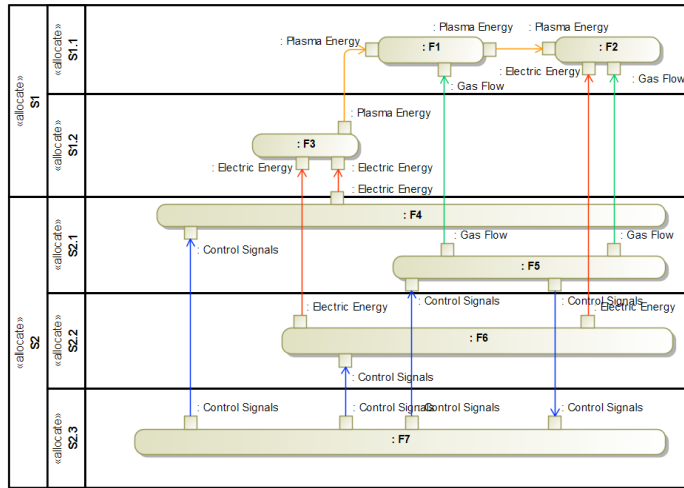


## Solution : Integration of MBSE and data science

- ✓ A new framework that combines traditional MBSE efforts with exploratory data analysis techniques
- ✓ Data and analytics-based problem solving of Systems Engineering

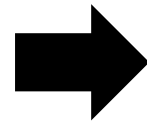
# 6. The main idea

## SysML System Model

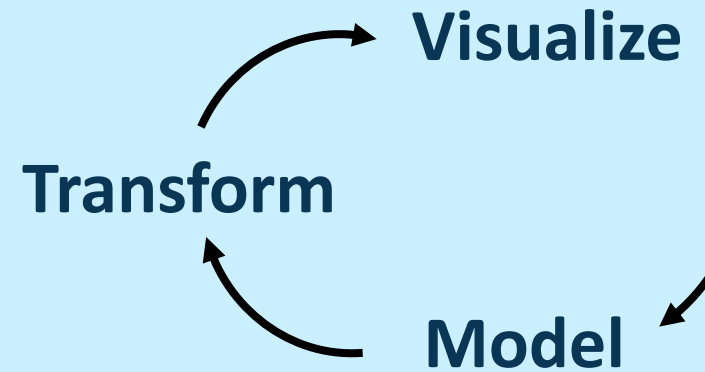
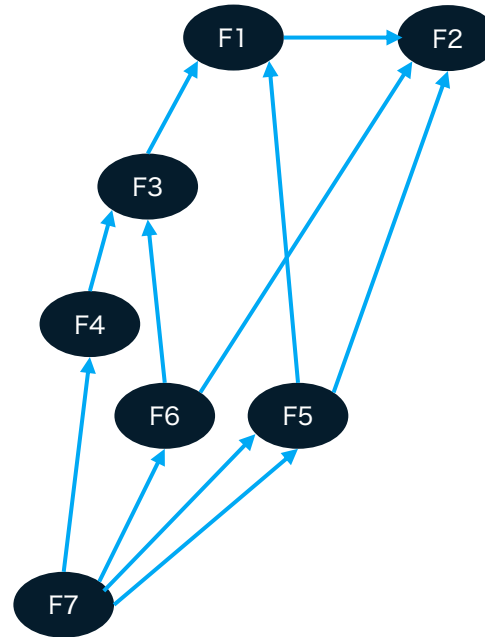


Rigor description of  
system architecture

MBSE

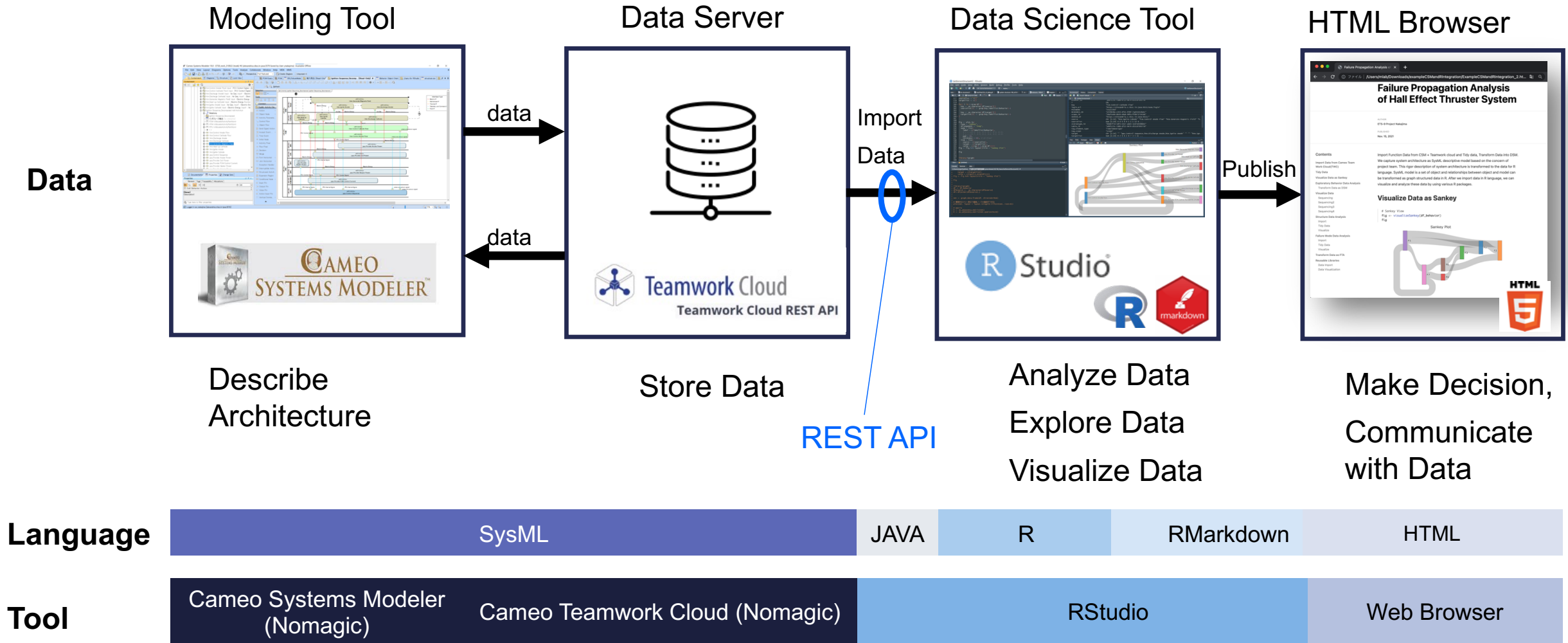


## Graph Data (Set of Nodes and Links)



Data Science

# 7. Seamless Tool Integration of SysML and R language

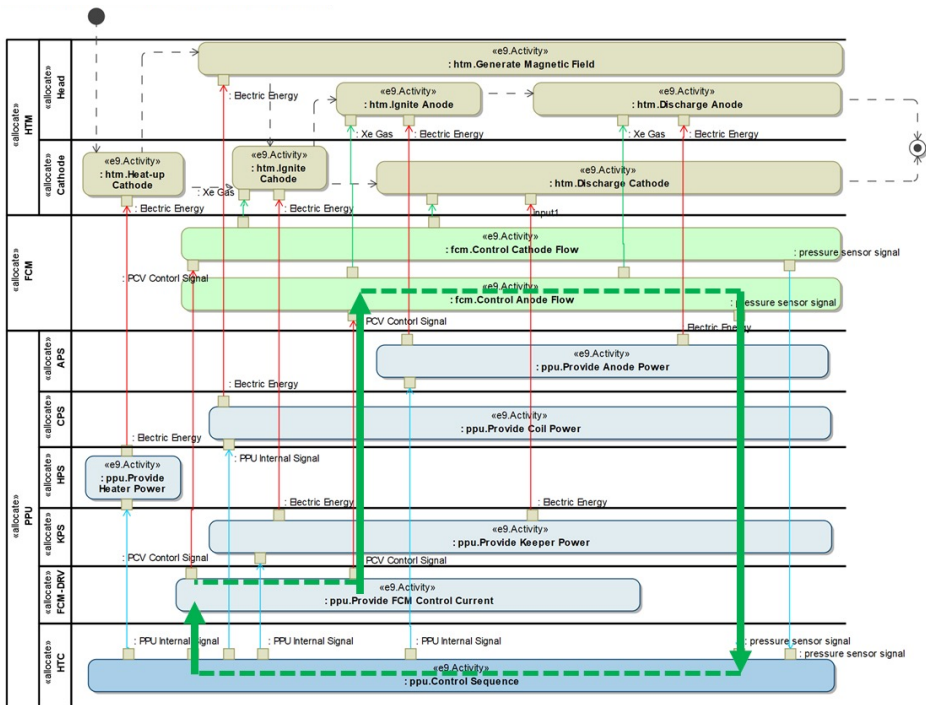




# 8. Results: Advanced Data Analytics

## Model Elements as Diagram View

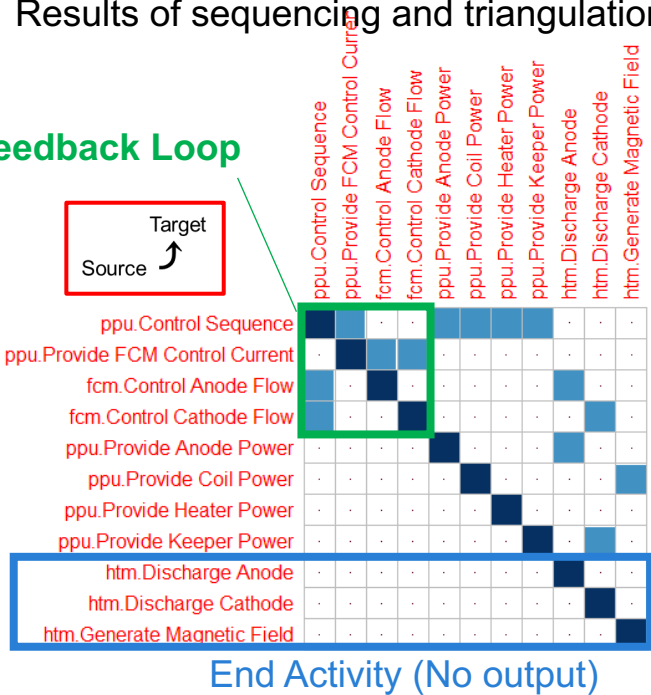
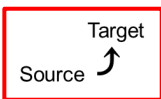
### SysML Activity Diagram



### Design Structure Matrix

Results of sequencing and triangulations

### Feedback Loop



Transform  
and  
"Explore"

Language



SysML



HTML  
Rmarkdown

Tools

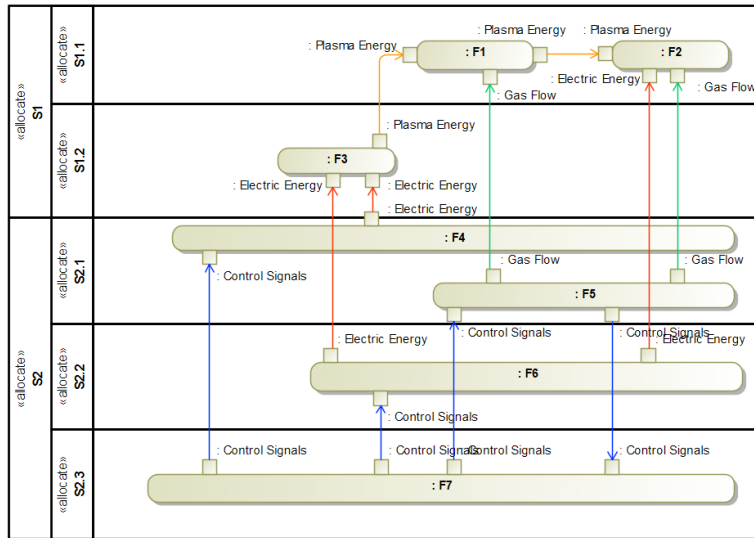
Cameo Systems Modeler

RStudio

Web Browser

# 8. Results: Rich Visualization

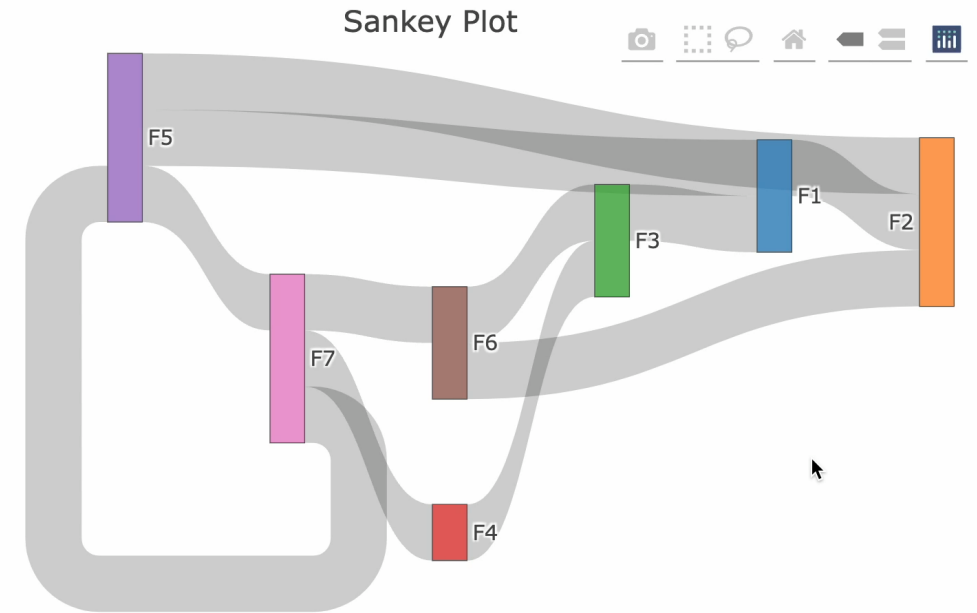
## Model as Activity Diagram Views



## Visualize Data as Sankey Plot

```
# Sankey View  
fig <- visualizeSankey(df_behavior)  
fig
```

Transform  
and  
Publish



Products

Language



SysML

R



HTML  
Rmarkdown

Tools

Cameo Systems Modeler

RStudio

Web Browser

# 8. Results: Automation

Products

Model Elements as Table View

#	△ Name	e9.Risk.Cause_Source
1	FM-01-TOP	FM-10(context S1.2)
2	FM-10	FM-13(context S1.1) FM-11(context S1.1) FM-12(context S1.1)
3	FM-11	FM-17(context S2.3) FM-15(context S2.1) FM-18
4	FM-12	FM-17(context S2.3) FM-16(context S2.2) FM-15(context S2.1) FM-19
5	FM-13	FM-14(context S2.1) FM-16(context S2.2) FM-17(context S2.3)
6		
7		
8		
9		
10		

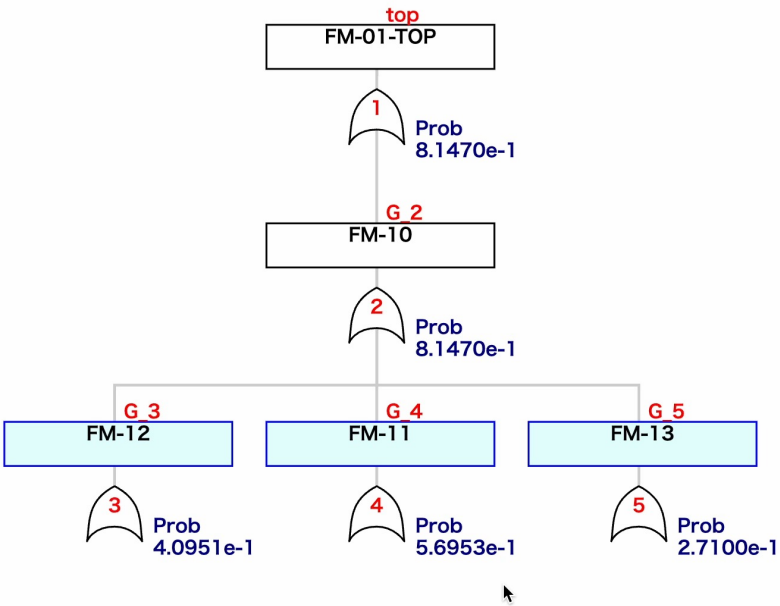


Transform  
and  
Publish

```
1 # r generate fta, echo=TRUE, message=FALSE, warning=FALSE}
2 # Import Failure Mode Data from CSM + Team Workcloud
3 df <- getSysMLData(SERVER_IP, USER_NAME, PASSWORD, RESOURCE_ID, ELEMENT_ID2, R_STRUCTURE)
4
5 # Tidy Data
6 df <- TidyDataOfFailureMode(df)
7
8 #Convert to FTA data by using FaultTree Package
9 fta <- transformDFtoFTA(df)
10
11 #Publish
12 ftree2html(fta, write_file=TRUE)
13 browseURL("fta.html")
14 ...
```

Import  
Tidy  
Transform  
Publish  
R Code

FTA: Standard RAMS



Language



SysML

R



HTML  
Rmarkdown

Tools

Cameo Systems Modeler

RStudio

Web Browser



# 9. Conclusion

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MBSE application to the  
failure mode analysis



Proposed data-driven risk  
analysis approach