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

Model-Based Maintenance Planning and Analytics for Oil & Gas Offshore Systems

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MSc

Principal consultant and chair of the UAF group and has developed complex systems for over 45 years.

Introduction

- Effective planning and data management are crucial in the oil and gas industry and other complex, task-driven sectors.
- As a result, digitalization is becoming increasingly widespread.
- The oil & gas sector requires a holistic, model-based approach to integrated maintenance planning.
- Adapting Model-Based Systems Engineering (MBSE) principles can help meet this need.
- This presentation outlines an MBSE-driven approach to maintenance planning.

Rationale

- Implementing structured planning and scheduling can significantly boost maintenance productivity, from 25–35% to nearly 50%, effectively doubling output (Palmer, 2019).
- Establishing and sustaining planning discipline is challenging; it requires deliberate development and ongoing support (Palmer, 2019).
- Reactive maintenance leads to substantial loss in technician efficiency and overall capacity.
- A model-based approach to planning, scheduling, and coordination is key to enabling cost-effective, proactive maintenance.

Maintenance Planning and Coordination

- Safety-related components are a critical focus in maintenance planning and execution.
- Equipment, such as on-off valves, is part of Safety Instrumented Systems (SIS), which includes sensors, logic solvers, actuators, and final elements.
- Standards require these components to maintain their safety function throughout their operational life.
- Operators must demonstrate compliance during both the design and installation phases, as well as during ongoing operations.
- Effective maintenance depends on planning and scheduling — although time-consuming, these tasks are essential for ensuring safe and reliable performance.

System engineering principles applied to maintenance

- Use systems engineering (SE) principles to create data-driven and automated maintenance plans.
- Apply Model-Based System Engineering (MBSE) to develop system models for maintenance planning.
- MBSE models streamline analysis, updates, and communication of system aspects.
- Reduce or eliminate the reliance on traditional documentation through MBSE.
- Support the creation of integrated and holistic maintenance plans using these approaches.

Maintenance Planning Techniques

Five central maintenance policies have been identified:

- Corrective Maintenance (CM)
- Preventive Maintenance (PM)
- Condition-based Maintenance (CBM)
- Predictive Maintenance (PdM)
- Proactive Maintenance

- The Maintenance and Test Concept (MTC) is a company-specific Generic Maintenance Concept (GMC) that is often captured in a document.
- MTC is developed during the design phase of an asset and updated throughout the asset’s life cycle to meet the asset's and stakeholders' operational and maintenance needs.
- Most oilfield operators on the NCS (Norwegian Continental Shelf) use MTCs in their maintenance management work processes.

Current Oil-field Maintenance Handling Challenges

- Maintenance remains largely corrective and calendar-based. Manual, reactive processes create significant backlogs, particularly for maintaining barrier integrity and managing activities.
- Planning efforts are often fragmented, unstable, and unpredictable.
- Inconsistent or ad hoc risk analysis contributes to planning gaps and operational challenges.
- Without a holistic maintenance plan, stakeholders lack visibility across asset-related activities.
- Overlooked risks can impact workload, resource capacity, and simultaneous operations (SIMOPS) across departments.

Maintenance Management Steps

NORSOK Z-008 outlines key steps in maintenance management:

- Manage resources
- Oversee maintenance work processes
- Analyze results

- Maintenance strategies must be clearly defined for each asset.
- A model-based planning approach should support all of these functions to ensure effective maintenance management.

Maintenance Program

A comprehensive maintenance program must address the following elements:

- Failure causes, modes, and mechanisms impacting safety and production
- Classification of functional consequences and identification of high-risk equipment
- A structured task set: activity types, frequencies, procedures, resources, time, budgeting, and prioritization
- Processes for data reporting, collection, analysis, improvement logging, and management oversight
- Required materials and documentation
- Risk levels, production assurance, and cost projections

All of these must be integrated into a model-based maintenance planning approach.

Maintenance Plan Work Required

Operational Planning

- Communicate decisions and define installation-specific conditions
- Manage quality assurance and risks impacting activities
- Establish and analyze the operational plan, proposing alternatives
- Prepare and conduct planning meetings, prioritize activities, and distribute the plan

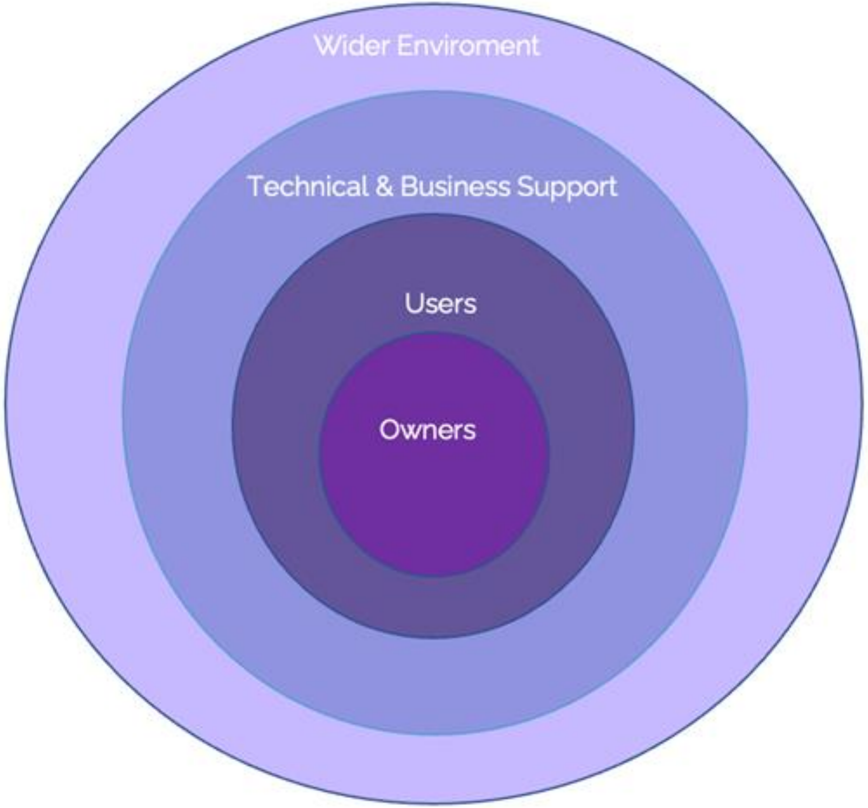
Work Order (WO) Planning

- Identify and review work orders; update status as work progresses
- Coordinate and sequence related work orders
- Define resource needs and schedule accordingly

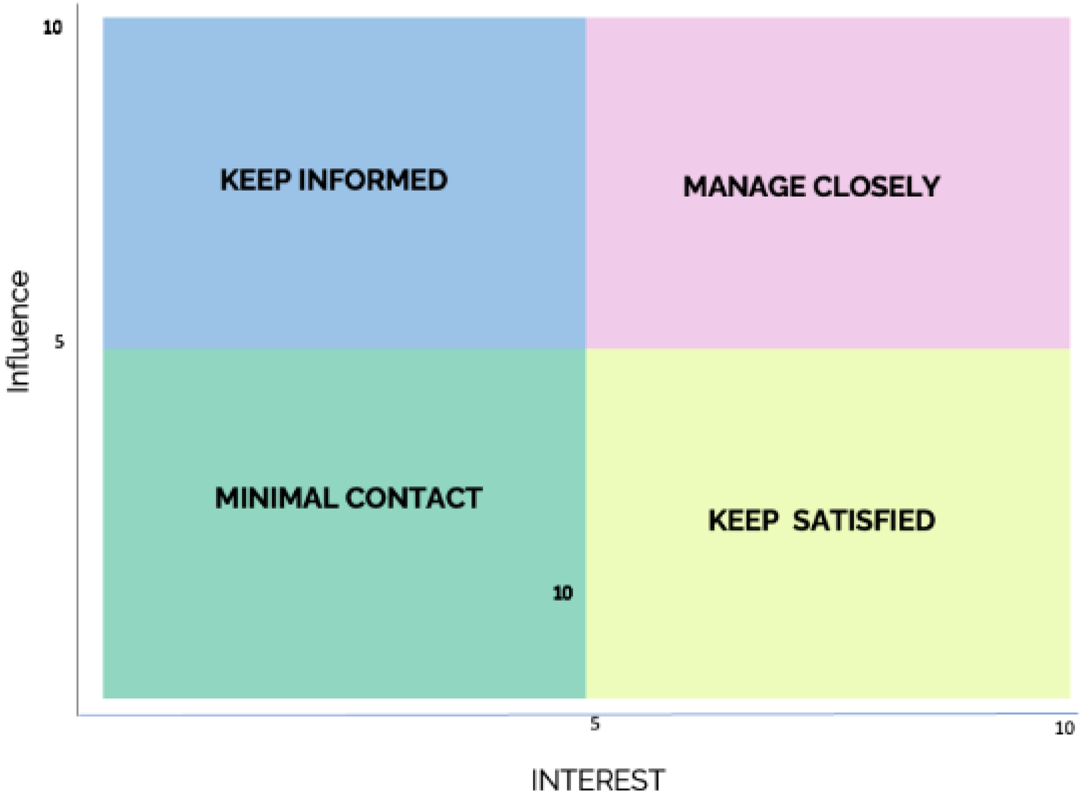
Work Permits (WP)

- Develop a day plan from WOs and prepare WP schedules for the upcoming days
- Issue work permits after conducting a Safe Job Analysis (SJA)
- Approve WPs and day plans to ensure safe and efficient execution

The Onion Model



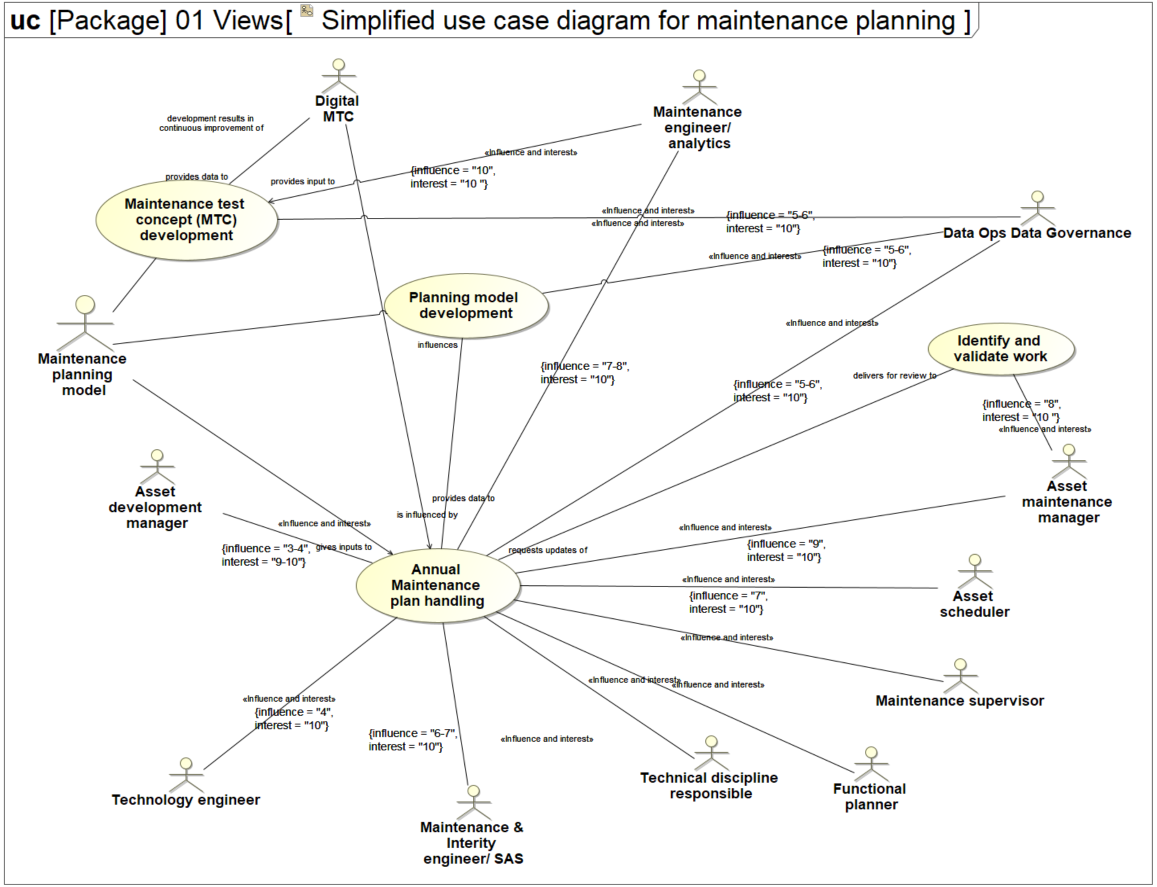
Interest Versus Influence

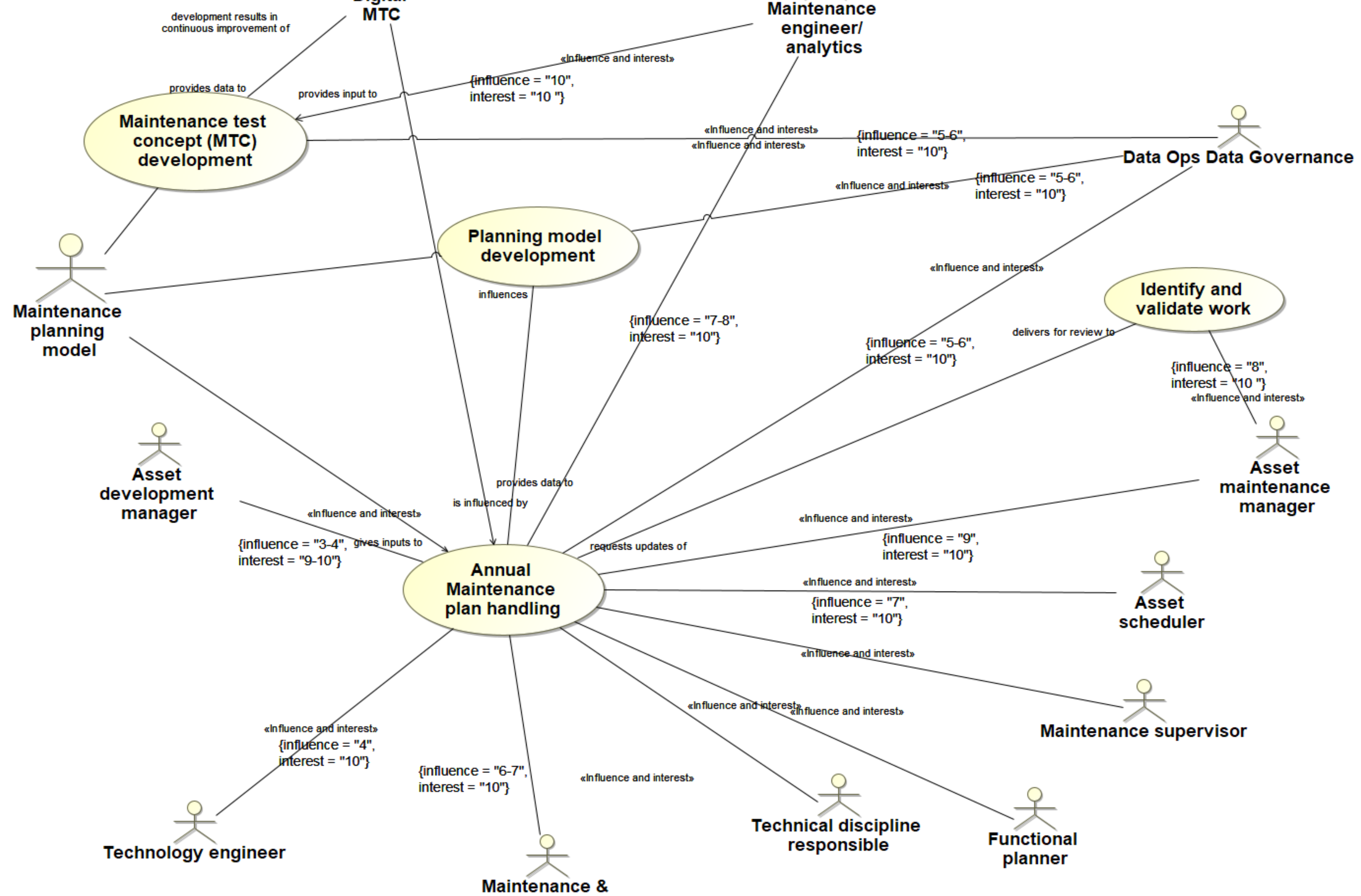


Key Stakeholders with Mapping Example

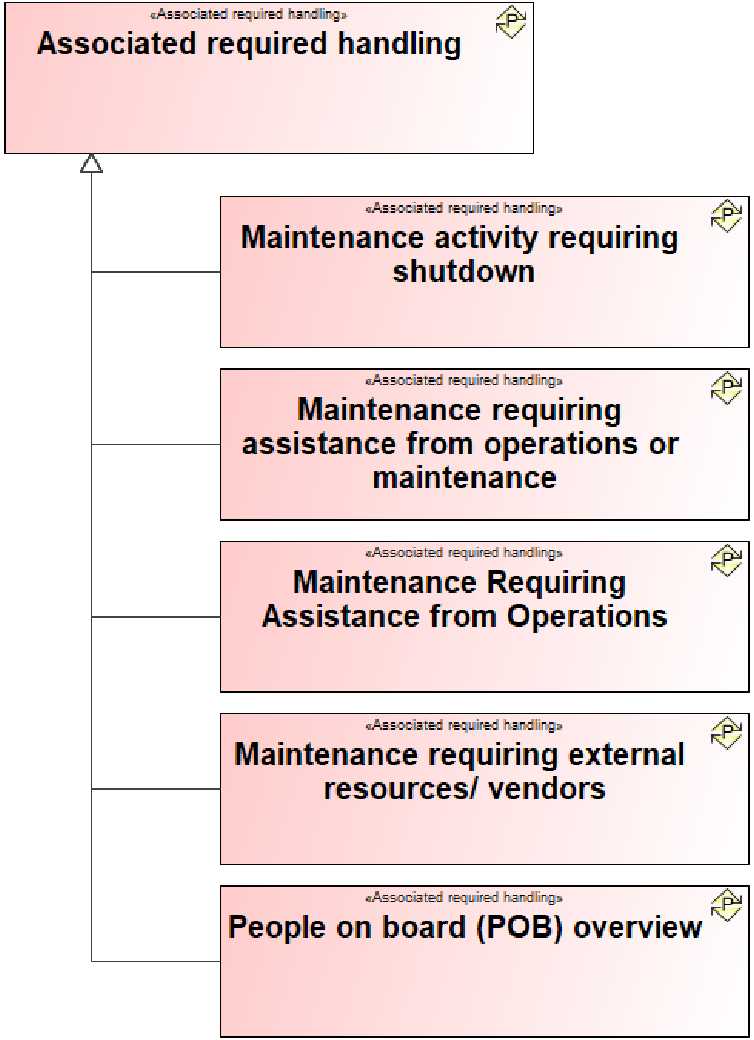
Stakeholder	Influence	Interest	Owners	Users	Technical & business support	Wider environment
Asset Integration Manager	8	10				
Asset Scheduler	7	10				
Maintenance Engineer/ analytics	7 - 8	10				
Asset Maintenance Manager	9	10				
Data Management & Governance Specialist	5 - 6	10				
Technology Engineer	4	10				
Maintenance & Integrity Engineer /SAS	6 -7	10				
Asset Operation Manager	10	10				
Asset Engineering Manager	4	10				
Asset Development Manager	3 - 4	9 - 10				

Documenting the Planning with Use Cases

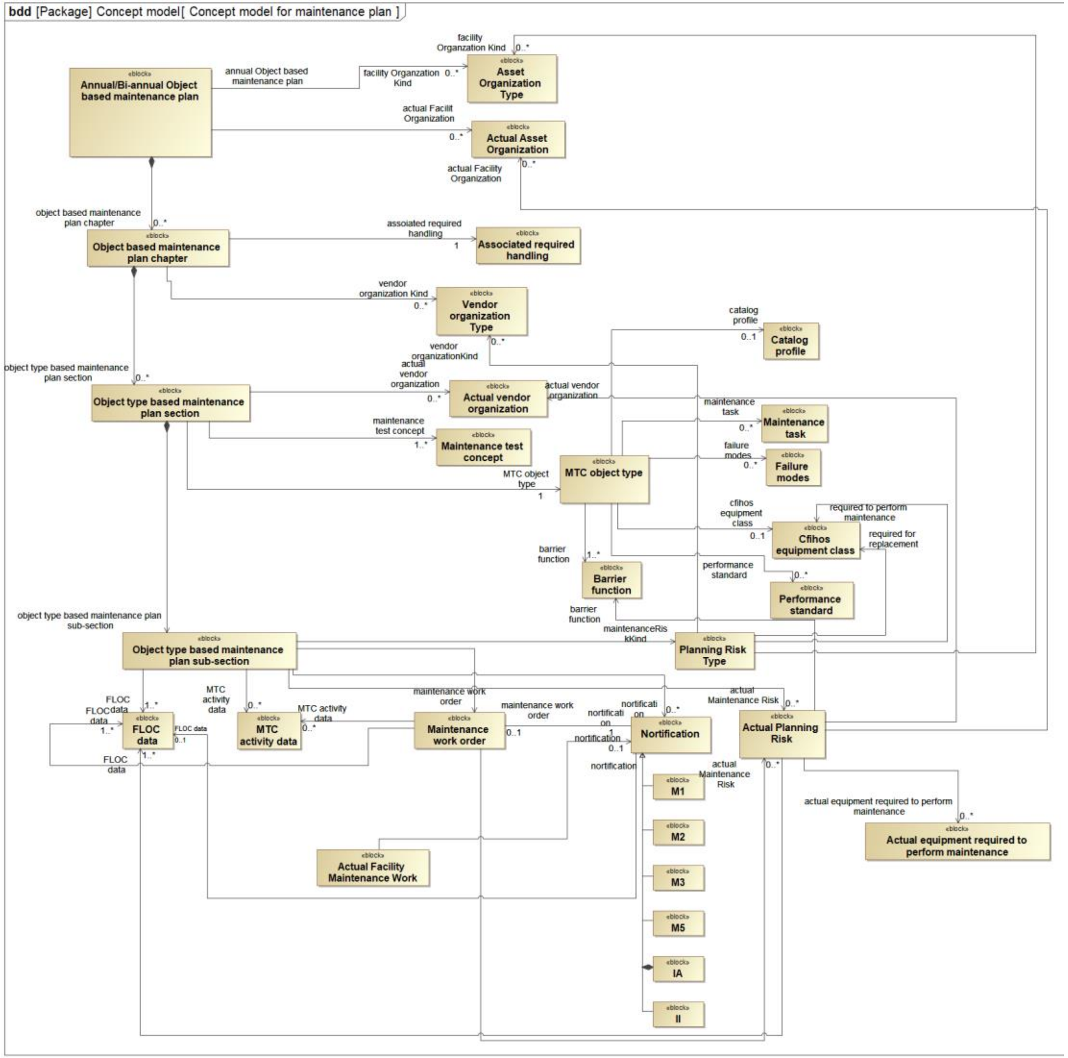



MTC
development results in continuous improvement of
Maintenance engineer/ analytics
«Influence and interest»
{influence = "10", interest = "10 "}
provides data to
provides input to
Maintenance test concept (MTC) development
«Influence and interest»
«Influence and interest»
{influence = "5-6", interest = "10"}
Data Ops Data Governance
«Influence and interest»
{influence = "5-6", interest = "10"}
Planning model development
influences
Maintenance planning model
«Influence and interest»
Identify and validate work
{influence = "7-8", interest = "10"}
{influence = "5-6", interest = "10"}
delivers for review to
{influence = "8", interest = "10 "}
«Influence and interest»
Asset maintenance manager
Asset development manager
provides data to
is influenced by
«Influence and interest»
{influence = "3-4", interest = "9-10"}
gives inputs to
requests updates of
«Influence and interest»
{influence = "9", interest = "10"}
Annual Maintenance plan handling
«Influence and interest»
{influence = "7", interest = "10"}
Asset scheduler
«Influence and interest»
Maintenance supervisor
«Influence and interest»
«Influence and interest»
«Influence and interest»
{influence = "4", interest = "10"}
{influence = "6-7", interest = "10"}
«Influence and interest»
Technology engineer
Maintenance &
Technical discipline responsible
Functional planner

Associated required handling



Concept model for maintenance plan



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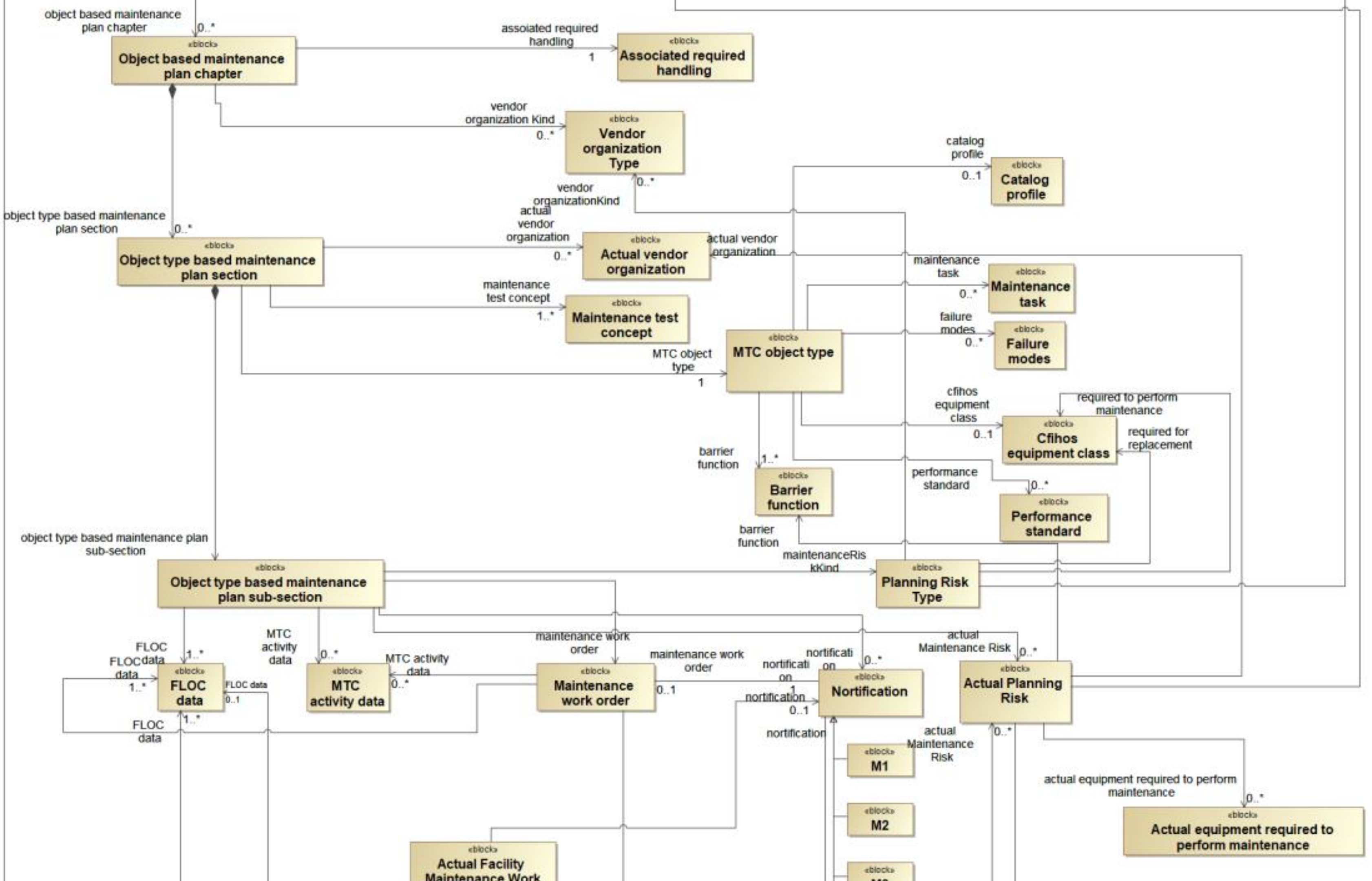
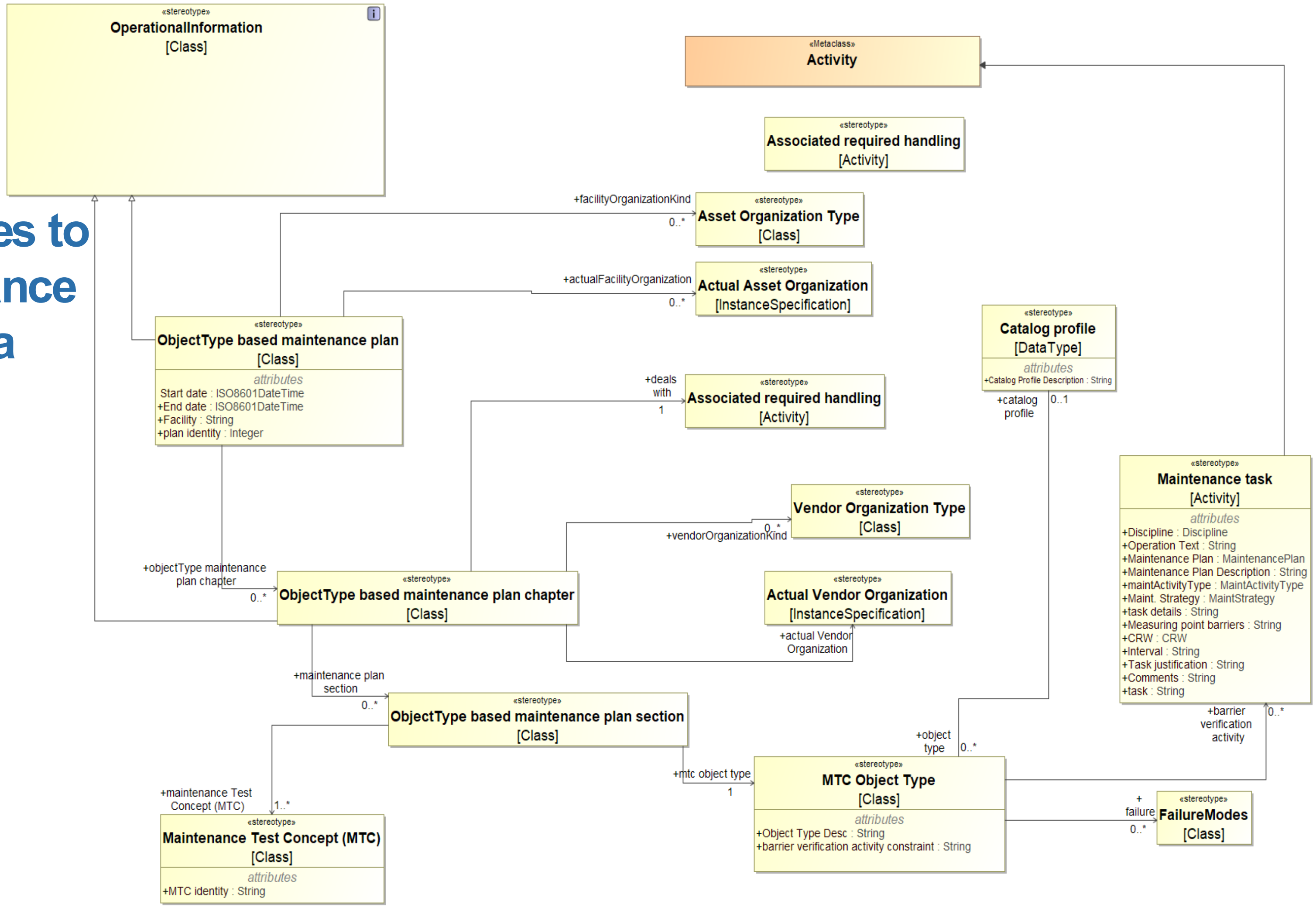


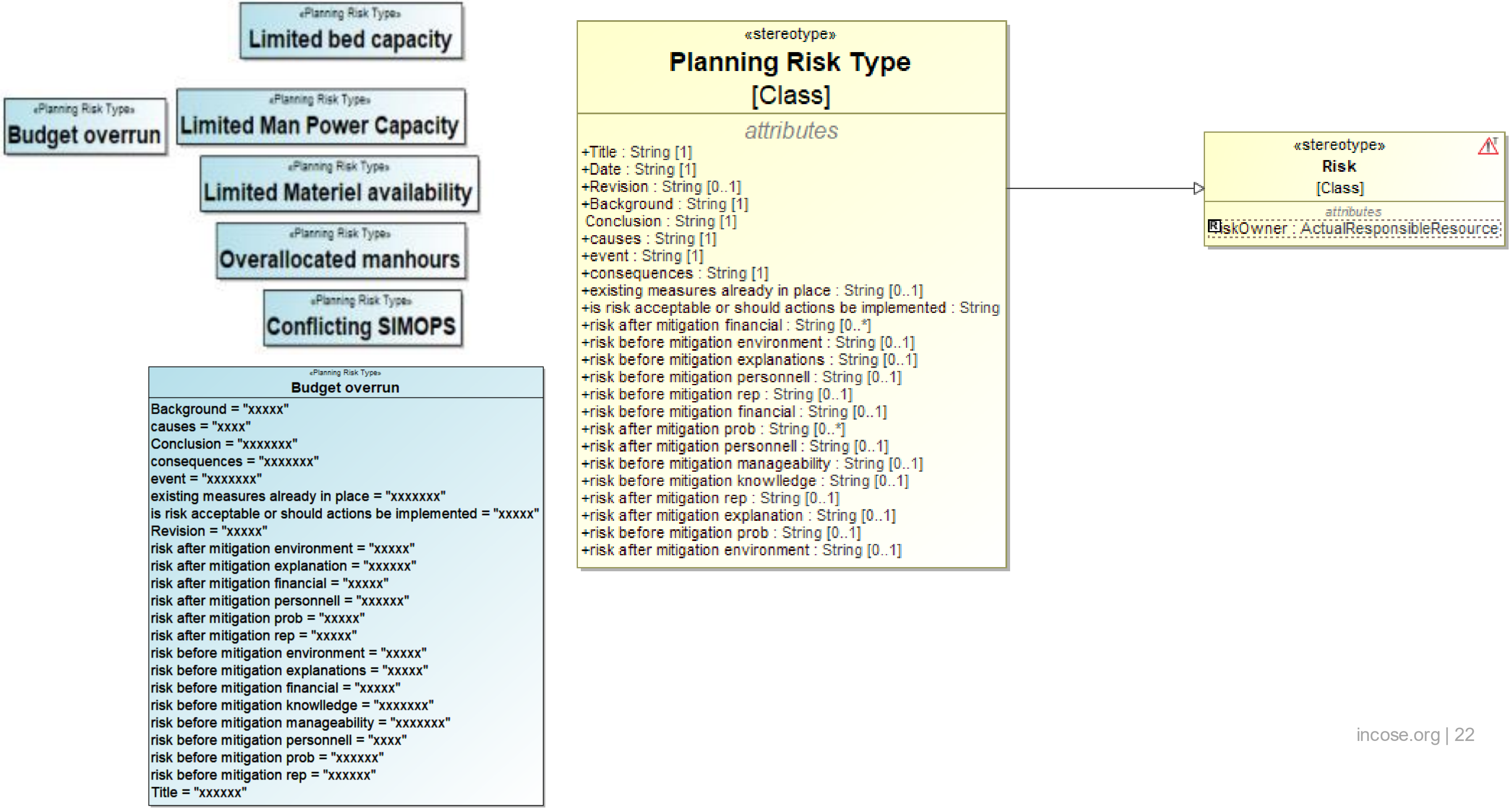
Using stereotypes to define maintenance planning data



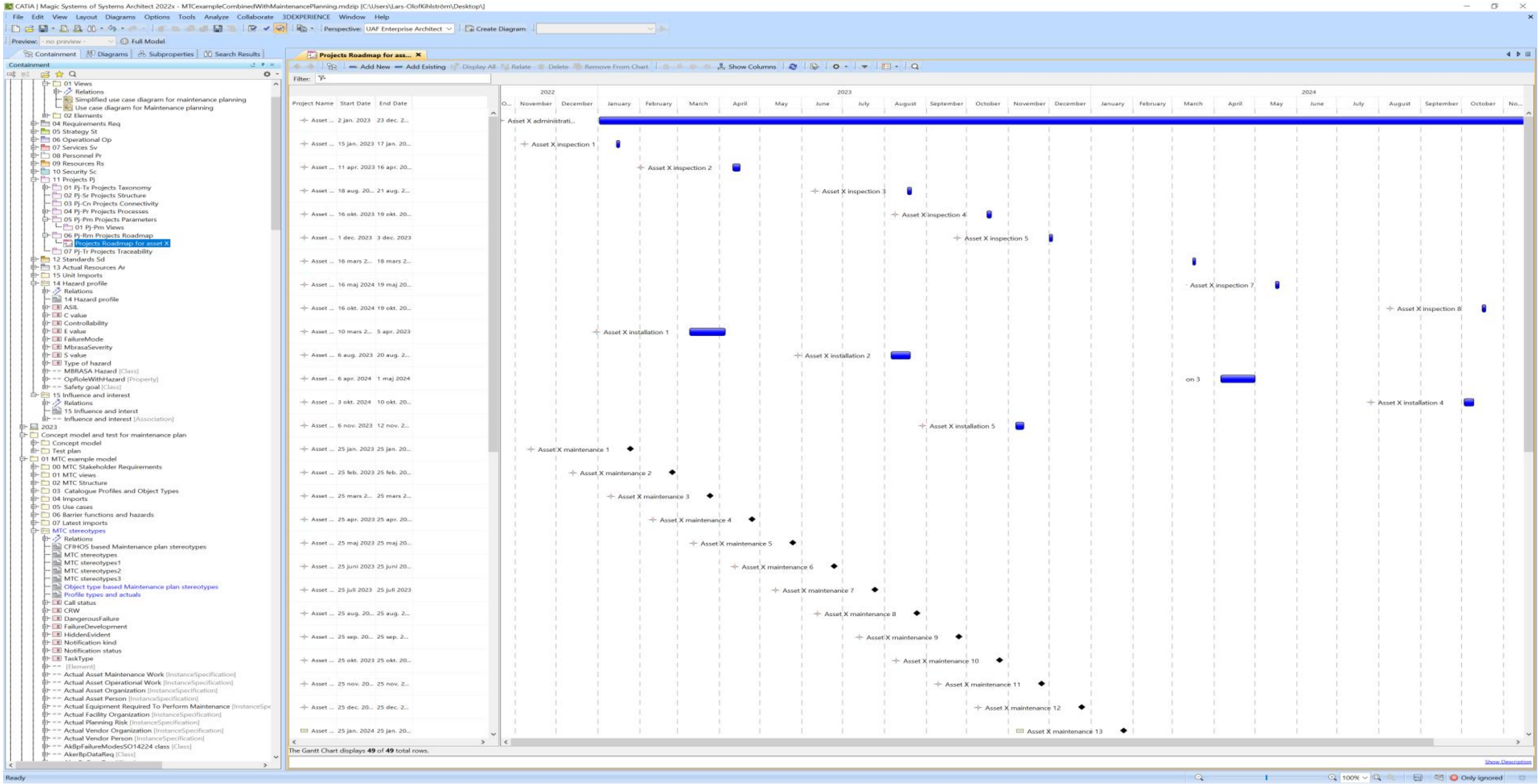
List of On-Off valves

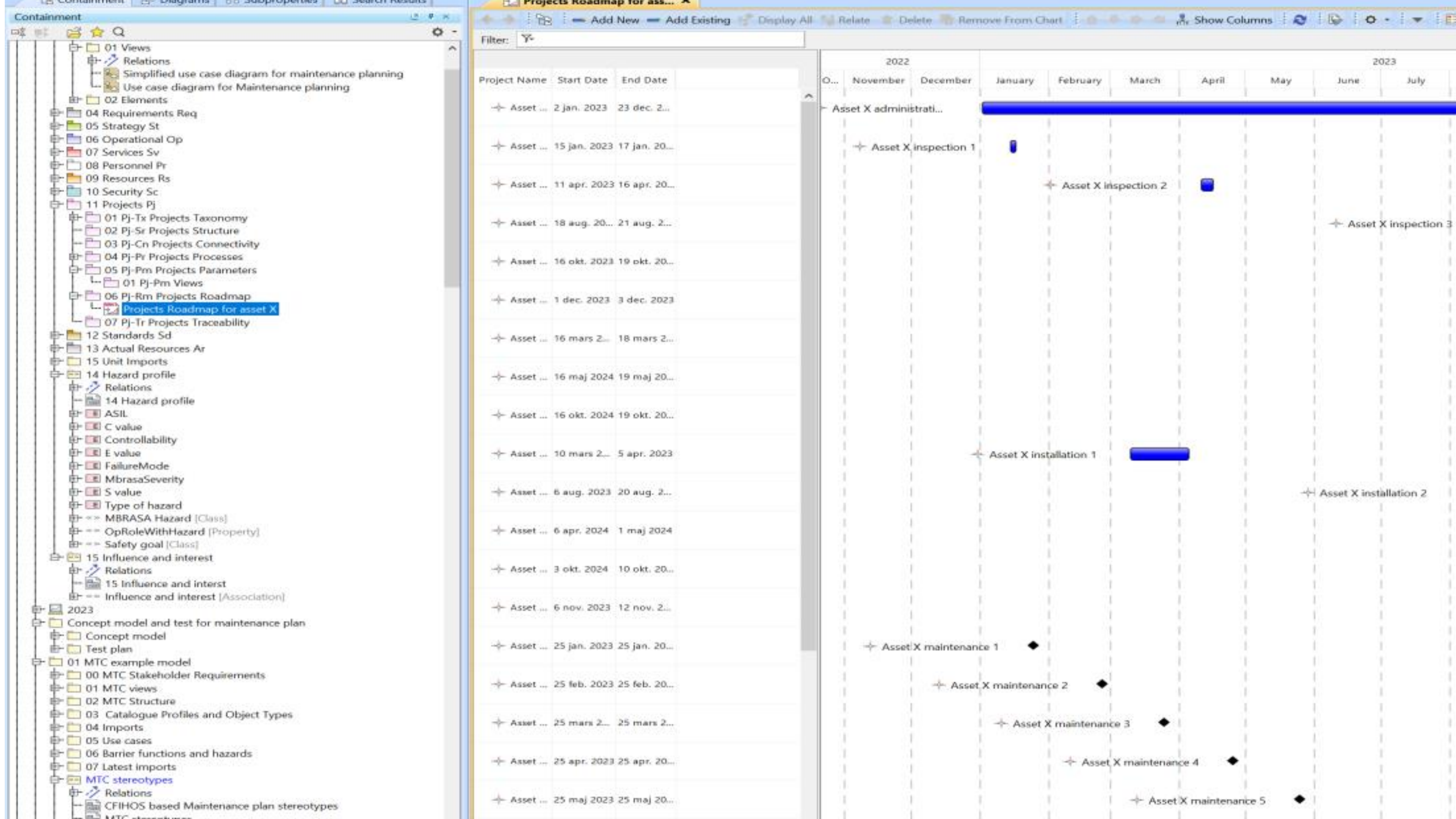
OBJECT TYPE	OBJECT TYPE DESCRIPTION
VAL-BAL	Ballast valve
VAL-BIL	Bilge valve
VA-ESDVBD	Blow down (ESDV)
VA-ESDVB	Sectioning valve CR
VA-ESDVG	Offloading ESDV
VA-ESDVOL	Riser ESDV (barrier)
VA-ESDVR	HIPPS/IOPPS valve
VA-HIPPS	PSD valve
VA-PSDVG	PSD valve – general
VA-PSDVIL	PSD valve with IL R
VA-PV	Pilot valve
VA-SOL	Solenoid-safety/crit

Risk type definition and example



Planning Model Gantt Chart




Containment
01 Views
Relations
Simplified use case diagram for maintenance planning
Use case diagram for Maintenance planning
02 Elements
04 Requirements Req
05 Strategy St
06 Operational Op
07 Services Sv
08 Personnel Pr
09 Resources Rs
10 Security Sc
11 Projects Pj
01 Pj-Tx Projects Taxonomy
02 Pj-Sr Projects Structure
03 Pj-Cn Projects Connectivity
04 Pj-Pr Projects Processes
05 Pj-Pm Projects Parameters
01 Pj-Pm Views
06 Pj-Rm Projects Roadmap
Projects Roadmap for asset X
07 Pj-Tr Projects Traceability
12 Standards Sd
13 Actual Resources Ar
15 Unit Imports
14 Hazard profile
Relations
14 Hazard profile
ASIL
C value
Controllability
E value
FailureMode
MbrasaSeverity
S value
Type of hazard
MBRASA Hazard [Class]
OpRoleWithHazard [Property]
Safety goal [Class]
15 Influence and interest
Relations
15 Influence and interst
Influence and interest [Association]
2023
Concept model and test for maintenance plan
Concept model
Test plan
01 MTC example model
00 MTC Stakeholder Requirements
01 MTC views
02 MTC Structure
03 Catalogue Profiles and Object Types
04 Imports
05 Use cases
06 Barrier functions and hazards
07 Latest imports
MTC stereotypes
Relations
CFIHOS based Maintenance plan stereotypes
Projects Roadmap for ass...
Add New
Add Existing
Display All
Relate
Delete
Remove From Chart
Show Columns
Filter:
Project Name
Start Date
End Date
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Asset ... 11 apr. 2023 16 apr. 20...
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Asset ... 1 dec. 2023 3 dec. 2023
Asset ... 16 mars 2... 18 mars 2...
Asset ... 16 maj 2024 19 maj 20...
Asset ... 16 okt. 2024 19 okt. 20...
Asset ... 10 mars 2... 5 apr. 2023
Asset ... 6 aug. 2023 20 aug. 2...
Asset ... 6 apr. 2024 1 maj 2024
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Asset X inspection 2
Asset X inspection 3
Asset X installation 1
Asset X installation 2
Asset X maintenance 1
Asset X maintenance 2
Asset X maintenance 3
Asset X maintenance 4
Asset X maintenance 5

Failure Rate Considerations and Impact on Plan

- Operational experience provides critical input for refining maintenance procedures and addressing deviations from performance targets.
- Two methods are commonly used to update failure rates:
  - Estimating dangerous undetected (DU) failure rates based solely on operational data
  - Bayesian failure rate estimation, which combines prior knowledge with operational data
- Research recommends the Bayesian approach as the more robust and accurate method.

The Approach

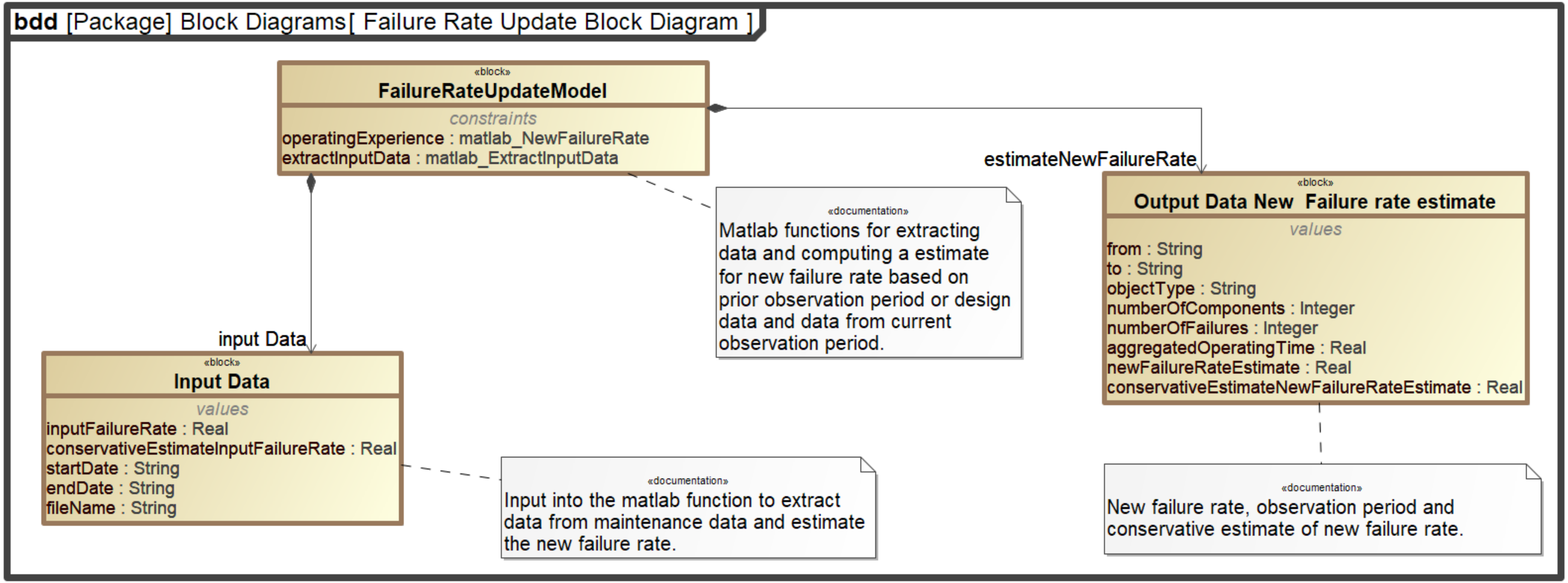
Steps to Update Failure Rates Using Operational Data:

1. **Identify Equipment Group**
   - Select components with similar types, functions, and expected failure behavior.
2. **Define Observation Period**
   - Choose a duration long enough to provide meaningful aggregated operating time for statistical confidence.
3. **Aggregate Operating Data**
   - Calculate the total operating time and the count of dangerous undetected (DU) failures across the group.
   - Sum the individual operational times within the selected period.
4. **Apply Adjustments**
   - Account for components added or removed during the period.
   - Exclude items not tested, not activated, or in passive standby.
   - Remove time contributions from out-of-service components.
5. **Update Failure Rates**
   - Calculate uncertainty parameters and apply the selected estimation method to revise the failure rate.

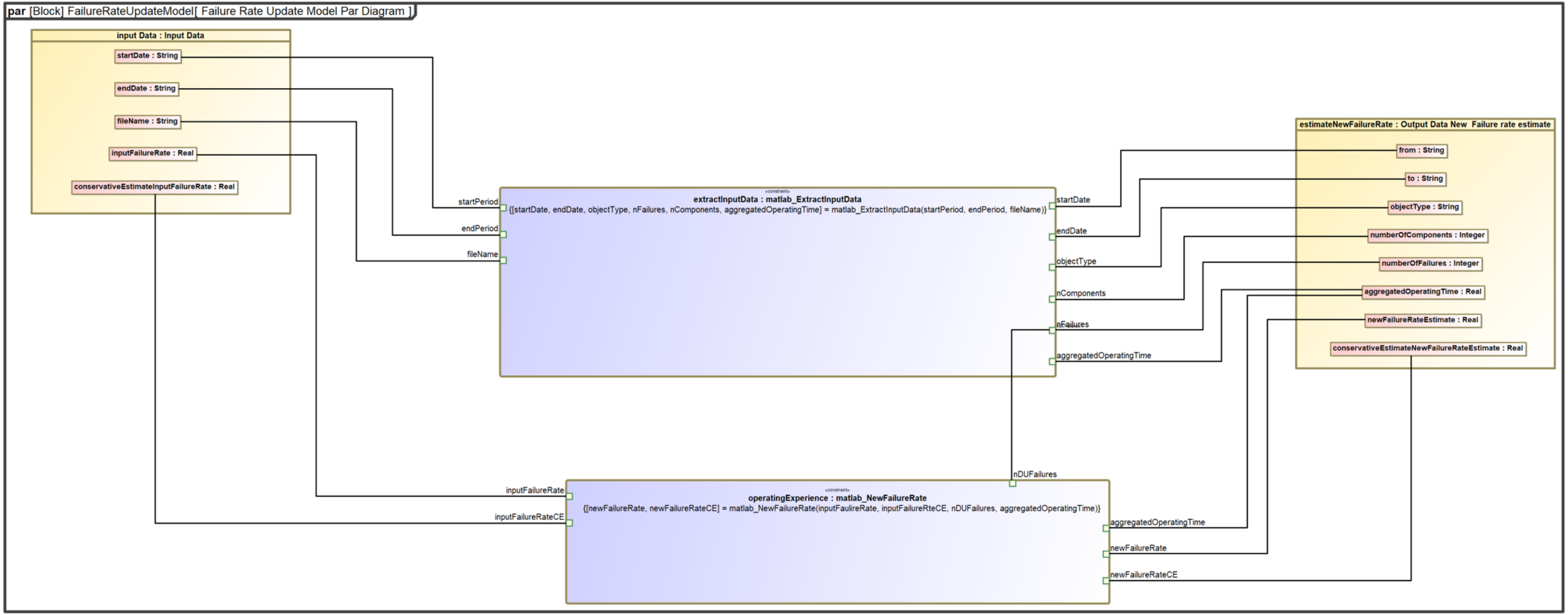
Input Parameters for Updating Failure Rates

Parameter	Denomination	Description
$\lambda_{\mathrm{DU},i-1}$	per hour	Input failure rate – from design ($i = 1$) or previous period ($i > 1$)
$\lambda_{\mathrm{DU\text{-}CE},i-1}$	per hour	Conservative estimate of input failure rate (as a means of expressing failure rate uncertainty)
n_i		No. of tags within equipment group in operation during period i
x_i	-	No. of DU failures within the equipment group during period i
t_i	hours	Length of period i
T_i	hours	Aggregated operating time for period i, $T_i = n_i \cdot t_i$

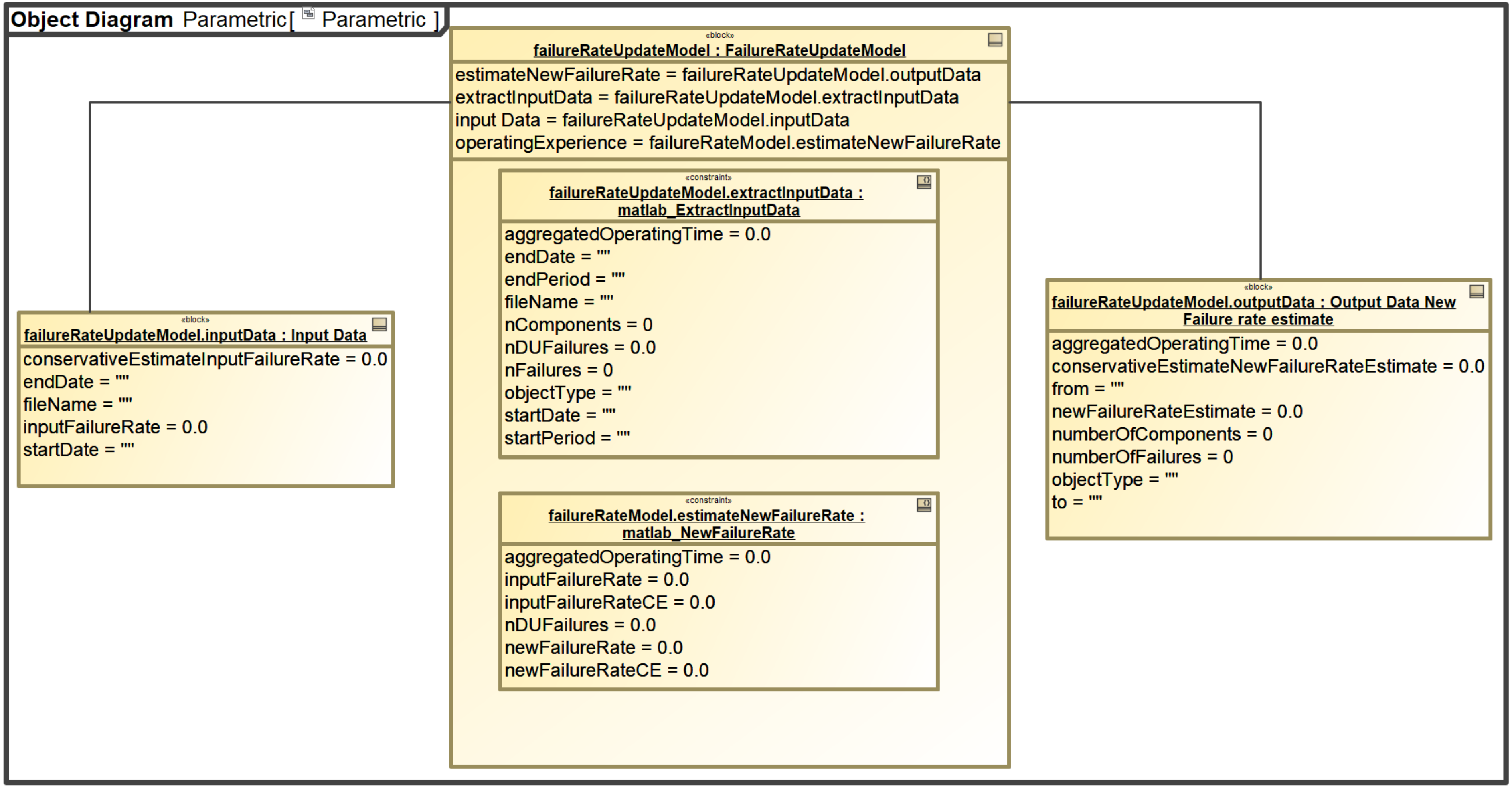
Failure Rate Update Model



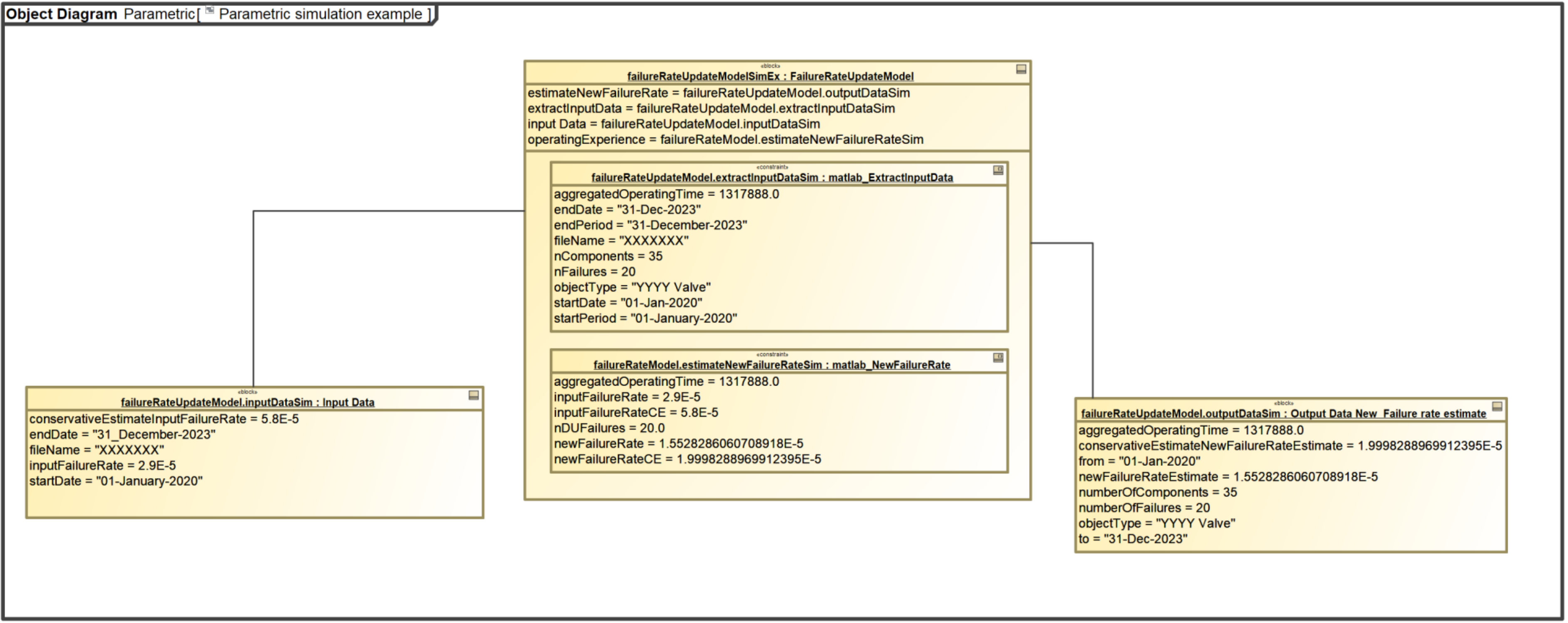
Parametric Model for Failure Rate Update Model



Instance Model and Simulation Example



Instance Model and Simulation Example



Conclusions

- Model-Based Systems Engineering (MBSE) is a proven methodology that supports system development and maintenance across the full lifecycle.
- In the maintenance domain, MBSE offers economic value by increasing efficiency, reducing costs, and enhancing system reliability.
- It enables predictive maintenance, better resource allocation, and cost optimization through greater system transparency and early issue detection.
- MBSE supports data-driven decisions and enhances cross-disciplinary communication, providing a strong foundation for robust and cost-effective maintenance strategies.
- However, adoption of MBSE in the oil and gas industry remains limited.
- This presentation demonstrates how Model-Based Systems Engineering (MBSE) can be practically applied to maintenance planning within this context.

Recommendations

- **Establish a maintenance planning strategy** that aligns with data quality and governance practices, in line with organizational data management specifications.
- **Enhance integration** of the initial planning model with both technical life extension strategies and asset-level integrated planning.
- **Strengthen ties to data governance** to ensure consistency, quality, and traceability.
- **Pilot the model on a selected asset** — apply, test, and iterate using real operational data that has undergone quality control and governance.
- **Address technical enablers**, including interoperability between software systems, standardization of data formats, and data availability.
- **Secure leadership support** across organizational levels to ensure adoption and execution of the proposed actions.

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