SIEMENS DIGITAL INDUSTRIES SOFTWARE

# Maintenance Aware Design environment

Reliability, availability, maintainability and safety platform

### Benefits

- Accelerate development with model-based RAMS
- Enable concurrent RAMS at each stage of the lifecycle
- Integrate with the digital thread through PLM
- Promote continuous engineering innovation

### Summary

The Maintenance Aware Design environment (MADe) is a reliability, availability, maintainability and safety (RAMS) platform designed to identify and mitigate technical risk, optimize the design process, increase availability and promote continuous engineering innovation for complex engineering systems using the digital risk twin.

MADe combines modeling with analyses to enable trade studies on the safety, reliability and maintainability of complex engineering systems.

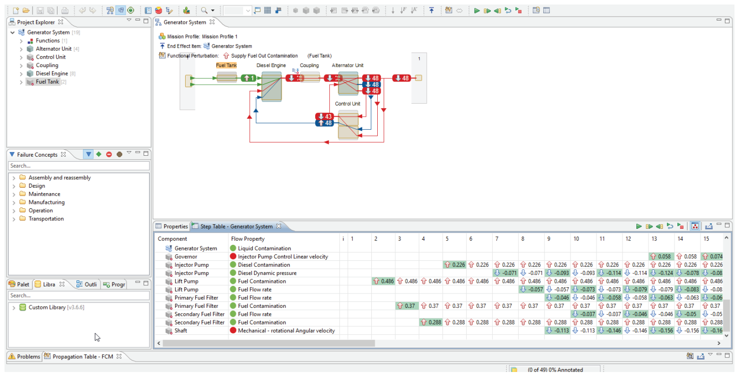
The MADe platform has three modules:

- MADe Safety and Risk Assessment (SRA)
- MADe Reliability, Availability, and Maintainability (RAM)
- MADe Prognostics and Health Monitoring (PHM)

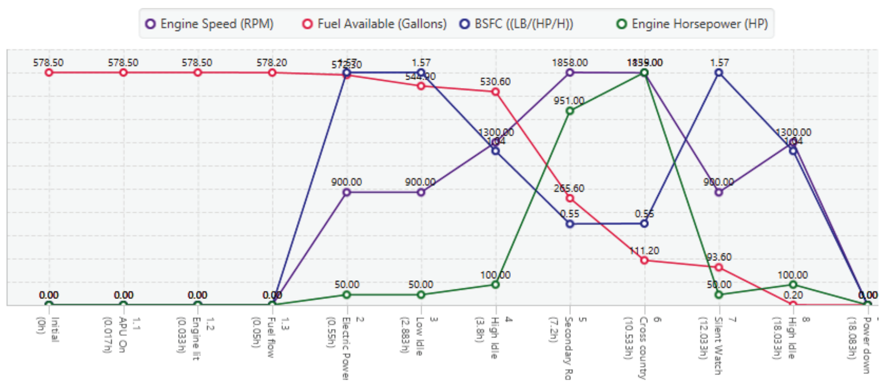
MADe enables the user to create a digital risk twin that ties together analyses across a range of engineering disciplines.

## Features

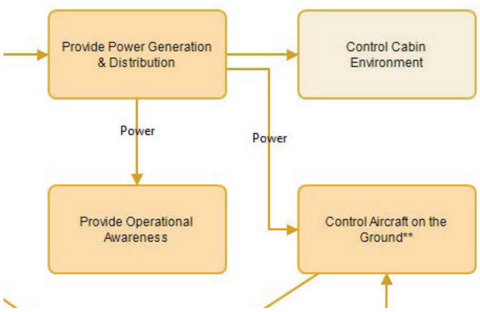
- Cohesive data structure ensuring consistency of data and management of system information and knowledge
- Hierarchy-based graphical representation (system --> subsystem --> component --> part)
- Comprehensive technical engineering taxonomies to describe the operational behaviors and failures in a system



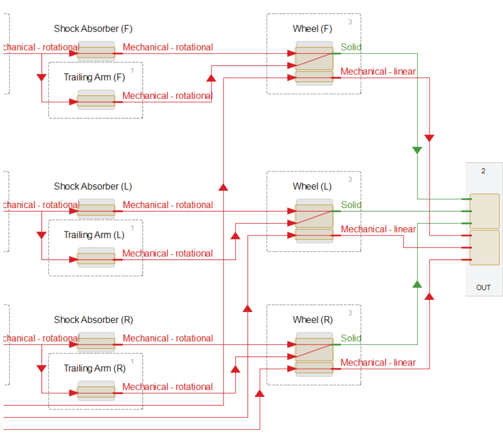
Automated dependency mapping (Failure Simulation)




Mission profile definition




Functional diagram




System model

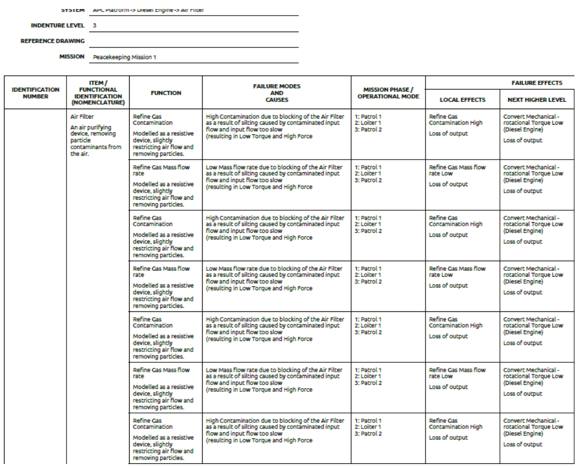
## MADe platform

The MADe platform provides a digital risk twin (a single source of truth) that contains system information embedded within a series of interrelated modeling perspectives to support and inform the design and RAMS process.

The system, how it interacts (automated dependency mapping) and its operating context (mission profile definition and environment), functional capabilities (functional diagram) and failures (failure diagram) are represented within the MADe platform software. This core framework of modeling sets the baseline for all forthcoming analyses, acting as the digital risk twin of the in-design or in-operation system.

## Key outputs

- Mission profile definition
- Functional diagram
- System model
- Automated dependency mapping (failure simulation)



SYSTEM APC Platform -> Diesel Engine -> Air Filter

INDENTURE LEVEL 3

REFERENCE DRAWING

MISSION Peacekeeping Mission 1

| IDENTIFICATION NUMBER | ITEM / FUNCTIONAL IDENTIFICATION (NOMENCLATURE) | FUNCTION | FAILURE MODES AND CAUSES | MISSION PHASE / OPERATIONAL MODE | FAILURE EFFECTS | |
|---|---|---|---|---|---|---|
| | | | | | LOCAL EFFECTS | NEXT HIGHER LEVEL |
| | Air Filter<br>An air purifying device, removing particle contaminants from the air. | Refine Gas Contamination<br>Modelled as a resistive device, slightly restricting air flow and removing particles. | High Contamination due to blocking of the Air Filter as a result of silting caused by contaminated input flow and input flow too slow (resulting in Low Torque and High Force | 1: Patrol 1<br>2: Loiter 1<br>3: Patrol 2 | Refine Gas Contamination High<br>Loss of output | Convert Mechanical - rotational Torque Low (Diesel Engine)<br>Loss of output |
| | | Refine Gas Mass flow rate<br>Modelled as a resistive device, slightly restricting air flow and removing particles. | Low Mass flow rate due to blocking of the Air Filter as a result of silting caused by contaminated input flow and input flow too slow (resulting in Low Torque and High Force | 1: Patrol 1<br>2: Loiter 1<br>3: Patrol 2 | Refine Gas Mass flow rate Low<br>Loss of output | Convert Mechanical - rotational Torque Low (Diesel Engine)<br>Loss of output |
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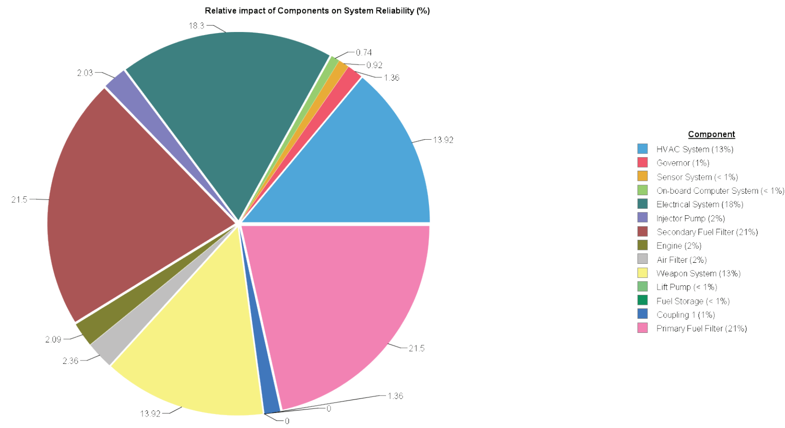
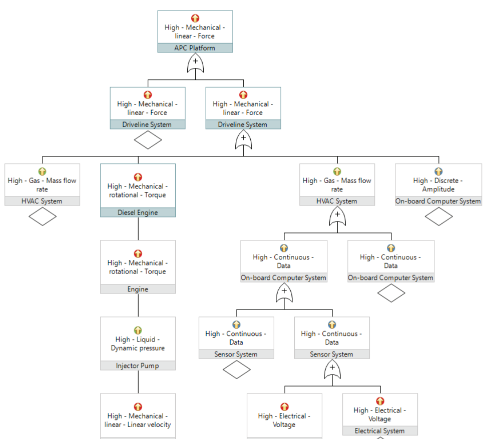
FMECA




Critical item analysis




Fault Tree Analysis

## Key outputs

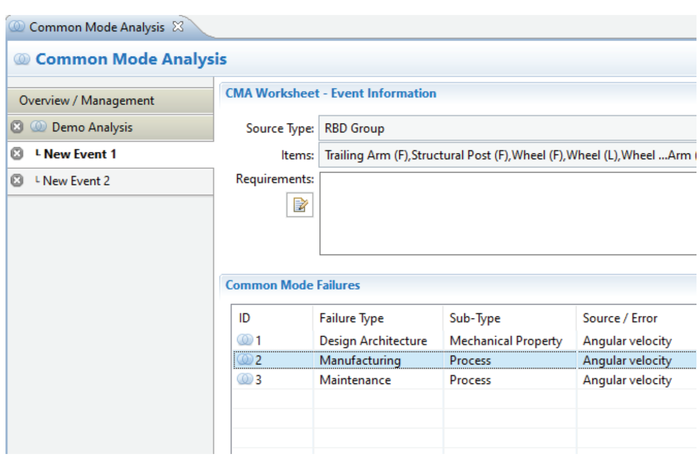
- FMECA
- Critical item analysis
- Fault tree analysis (FTA)
- Common mode analysis

Ultimately, safety and risk assessment informs design revisions and provides a path to system certification through prioritization of mitigation efforts based on analyses such as criticality analysis/failure modes, effects and criticality analysis (FMECA), fault tree analysis (FTA) and common mode analysis.

## MADe Safety and Risk Assessment

MADe Safety and Risk Assessment is used to analyze, understand and mitigate the risks in a design, and to establish and document the potential impact of failures on operations and the cost of ownership.

The SRA module allows the generation of a series of processes and analytical outputs addressing risk from a variety of viewpoints while maintaining the coherent framework of data as developed and coordinated in the MADe model.




Common mode analysis

## MADe Reliability, Availability and Maintainability

MADe Reliability, Availability and Maintainability is used to assess when failures in a system are expected to occur, how best to mitigate their risk and how this will impact system cost, safety and availability.

Analysis methodologies within MADe support RAM activities across the breadth of the design, operation and sustainment lifecycle. Reliability block diagrams (RBDs) developed on the basis of common configuration and structure from the MADe platform model capture item operation and failure dependencies. Item-level reliability based on available system information and maturity is input through direct entry of data, reliability allocation and reliability prediction models.

Maintenance approach development is facilitated in the RAM module through a number of alternate pathways including maintenance cost estimates, reliability centered maintenance (RCM), backfit RCM and maintenance actions creation. These pathways allow a flexible process for maintainability analysis,

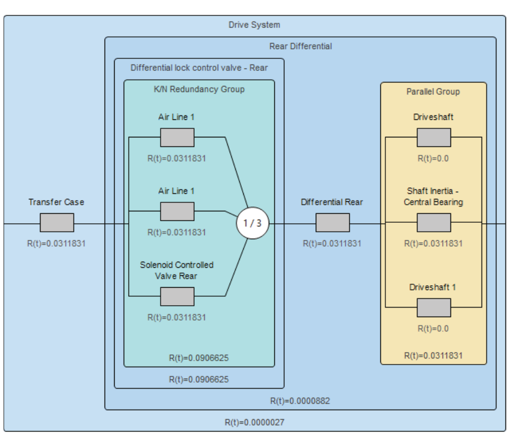

Reliability centered maintenance

tailorable depending on the user's required level of detail, traceability and standardization of process.

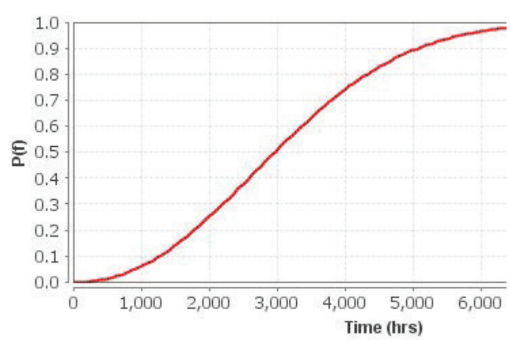
Availability as a function of reliability and maintainability is assessed and optimized through corrective action implementation across the full sustainment lifecycle.

### Key outputs

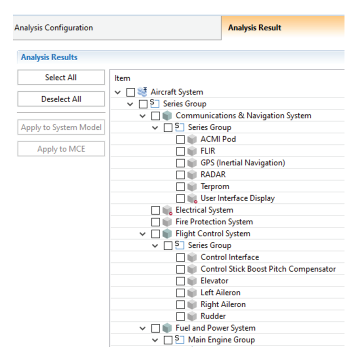
- Reliability block diagrams
- Reliability centered maintenance
- Reliability allocation
- Life distributions



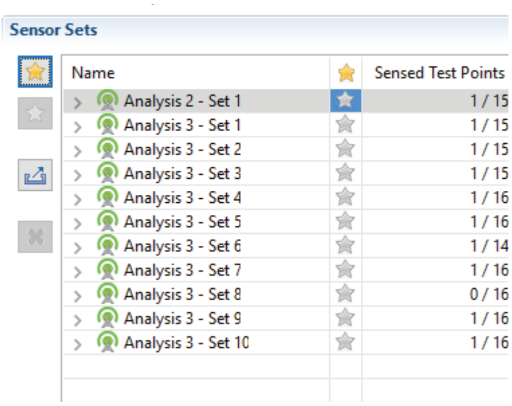

Reliability block diagrams



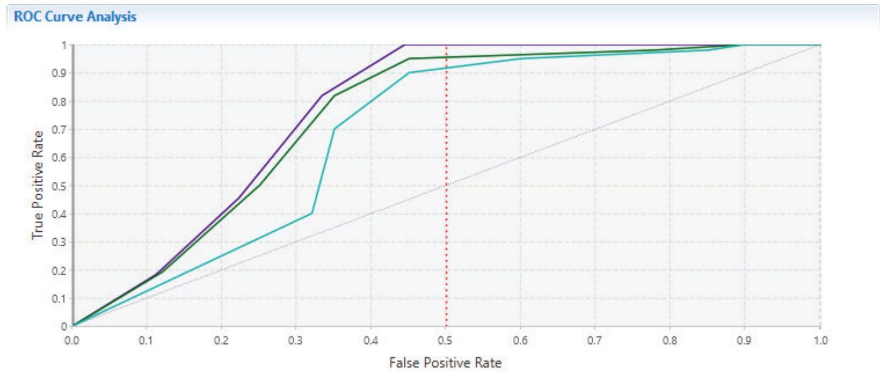

Life distributions




Reliability allocation




Automated sensor set generation




ROC curves

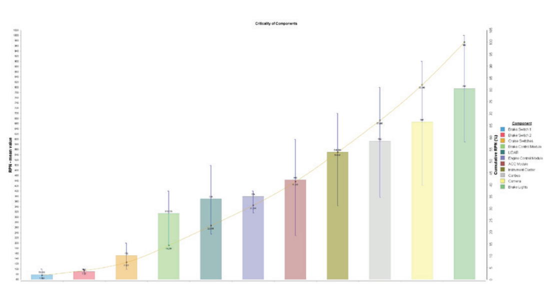
**MADe Prognostics and Health Monitoring**
The PHM module is used to design/validate the diagnostic requirements for condition-based maintenance (CBM) of complex systems in an integrated analysis solution.

Assessment of current (legacy) diagnostic capability and optimization (both new design and legacy) of sensor suites is autonomously conducted from an initial perspective of maximizing diagnostic coverage and minimizing sensor numbers. A detailed design for diagnostics is progressively developed using trade studies to optimize sensor hardware and combinations from a multi-factorial viewpoint (probability of detection, cost, weight, reliability).

The key question the PHM module aims to address is whether any specific sensor "buys its way onto the system." The output of this process in MADe is an optimal set of sensor locations, a set of physical sensor hardware decisions and diagnostic rules describing how those sensors will be utilized in operation.

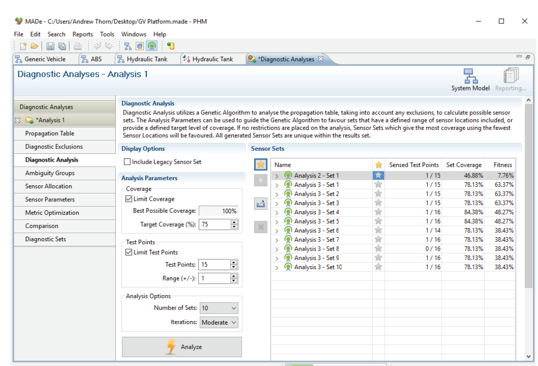
**Key outputs**

- Automated sensor set generation
- Receiver operating characteristic (ROC) curves
- Diagnostic rules
- Sensor set trade studies

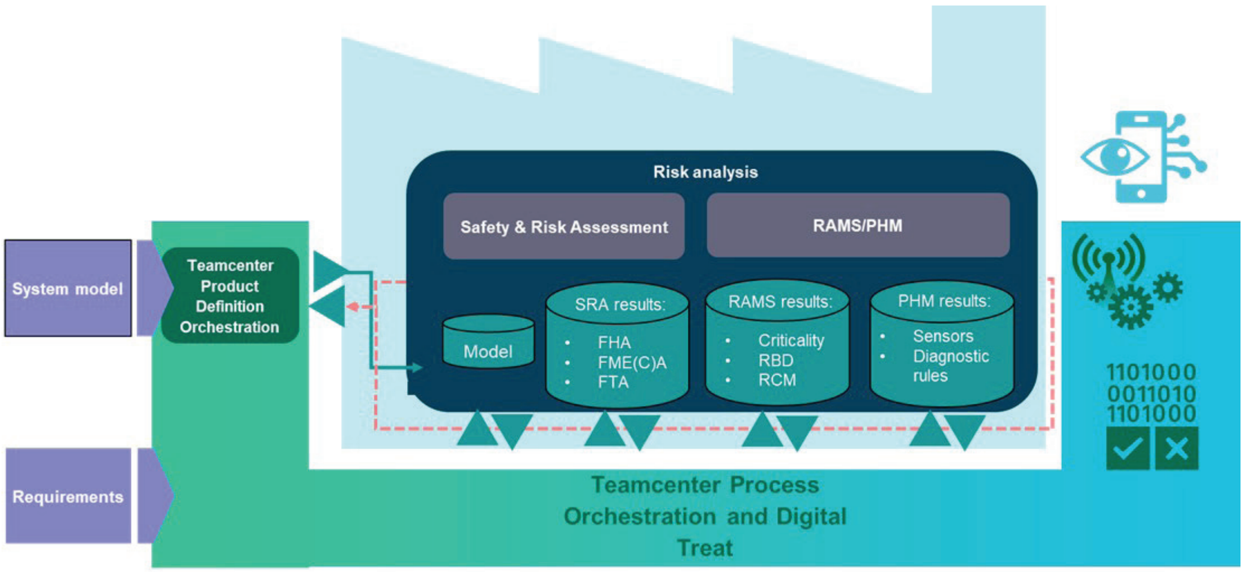


Criticality of components


Sensor set trade studies



Diagnostic rules




A comprehensive digital risk twin

**PHM MADe, enabling a digital risk twin in your design process**

Digitalization is permanently changing the way industries across the globe conduct business. The advantages of digitalization are quickly becoming the difference between companies that advance in a competitive market place and companies that fall behind. Digitalization is not just about creating and sharing data, it's about seamless data integration.

Siemens Digital Industries Software is helping customers meet their rapidly changing needs through flexible and adapable software and business solutions. The Siemens comprehensive digital twin is a virtual representation of a product or process in the correct context of users or teams. In order to be useful, a digital twin must be tied to the latest authorized configuration. The Siemens digital twin extends beyond the standard definition of the digital twin because it represents a digital twin of the design, its risk, performance, etc. and is part of an open ecosystem connecting tools from multiple vendors.

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