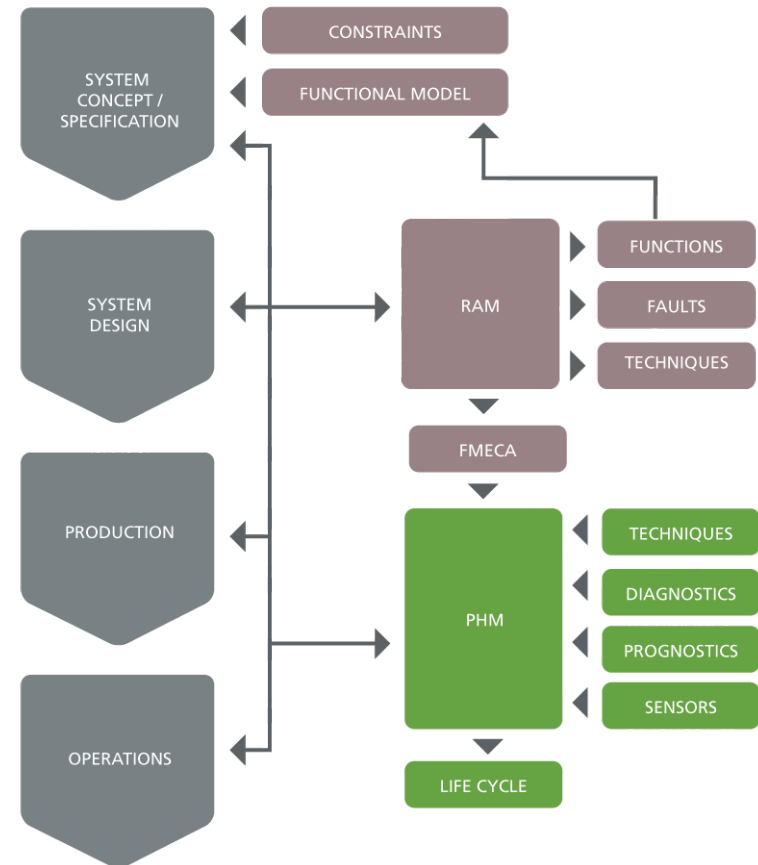


Challenges and Issues of enhancing and maturing PHM

Panel Presentation
Tuesday March 9, 2010

How does PHM fit?

- Optimal benefits offered by PHM are realized when integrated into the system development process
- PHM capability / design requires a continuous improvement process
- Direct linkages to functional silos within organisations required, including:
 - System engineers
 - Designers
 - Reliability engineering
 - Safety
 - Maintenance
 - Logistics



Key issues for PHM design

- Accurate FMECA for systems integrators as the basis for diagnostics
 - Standardised taxonomy of functional / failure concepts
 - FMECA needs to be updated as design matures and operational data becomes available
 - If the FMECA does not identify the failure modes – diagnostics can't cover it
- Diagnostics trade studies based on user defined parameters (cost / weight / coverage)
 - PHM capability trade-offs and system requirements to be considered during the PHM design process at all stages of the design process – concept to detailed
- Diagnostic design validation based on system model
 - Based on the FMECA / reliability data
 - Demonstrate PHM system capability to the customer

Challenges for PHM design

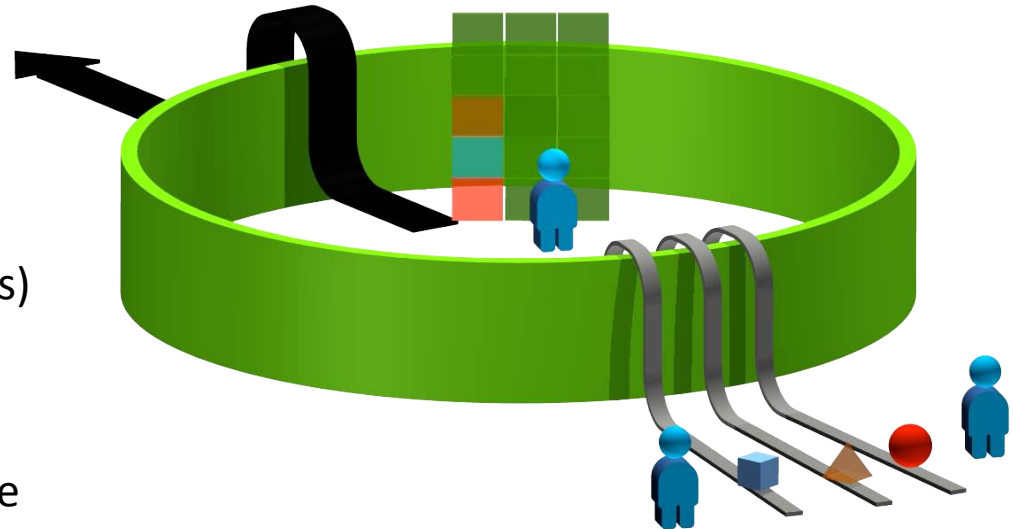
PHM silo has responsibility for the design, assessment and validation of diagnostic capability at the system level, but have the following constraints within the current standard industry practice:

- process gaps (data required provided late in design cycle)
- confidence gaps (quality / integrity / currency of source data [FMECA])
- legacy data (data remediation / reusability issues)
- technology gaps (PHM focused tools not previously available*)

* MADe was developed specifically to meet the requirements of PHM for the JSF program

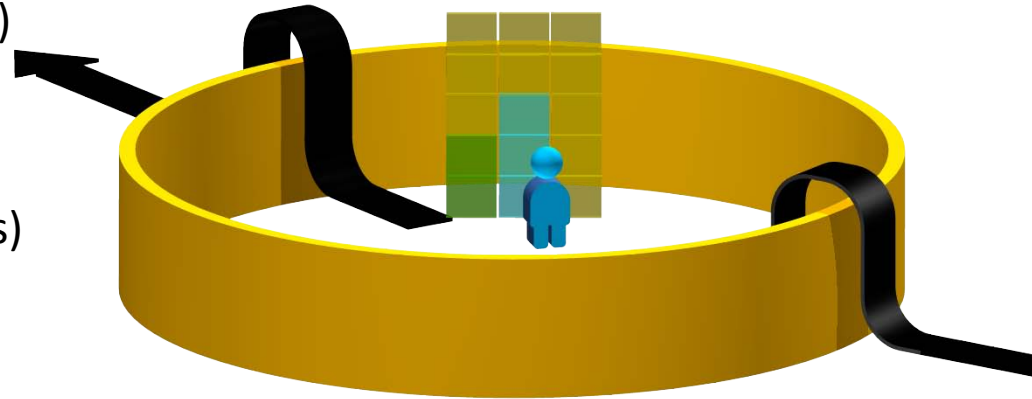
Current FMECA data sources

- data quality / consistency
(taxonomy of functional / failure concepts – even the published standards are not consistent)
- data integrity
(potential for human error in dependency mapping process, data integration issues from suppliers)
- data usability
(system model is required that can be used multiple silos for their specific requirements)



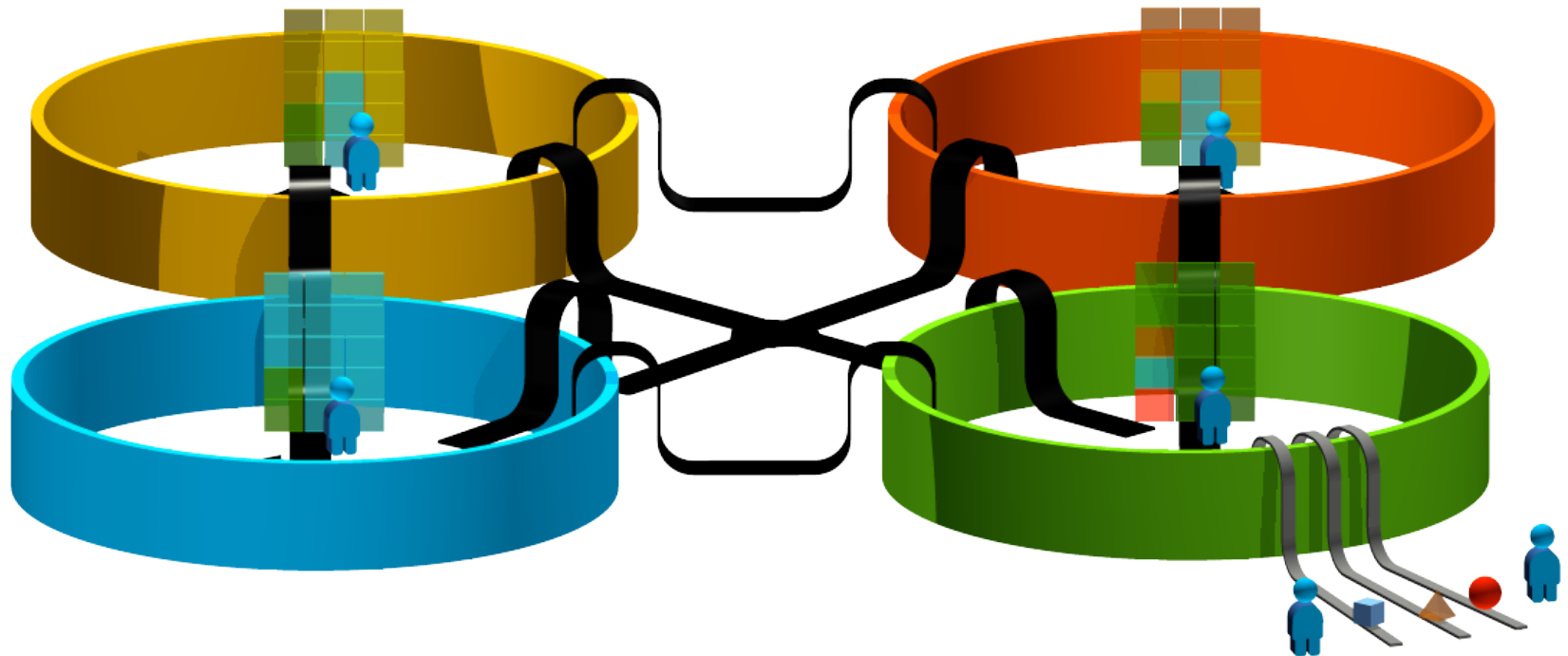
Current PHM design process

- process gaps
(no direct integration with related functional silos)
- confidence gaps
(quality / integrity / currency of data)
- legacy data
(data remediation / reusability issues)
- technology gaps
('integrated' PHM tools that utilize a common system model are not available)



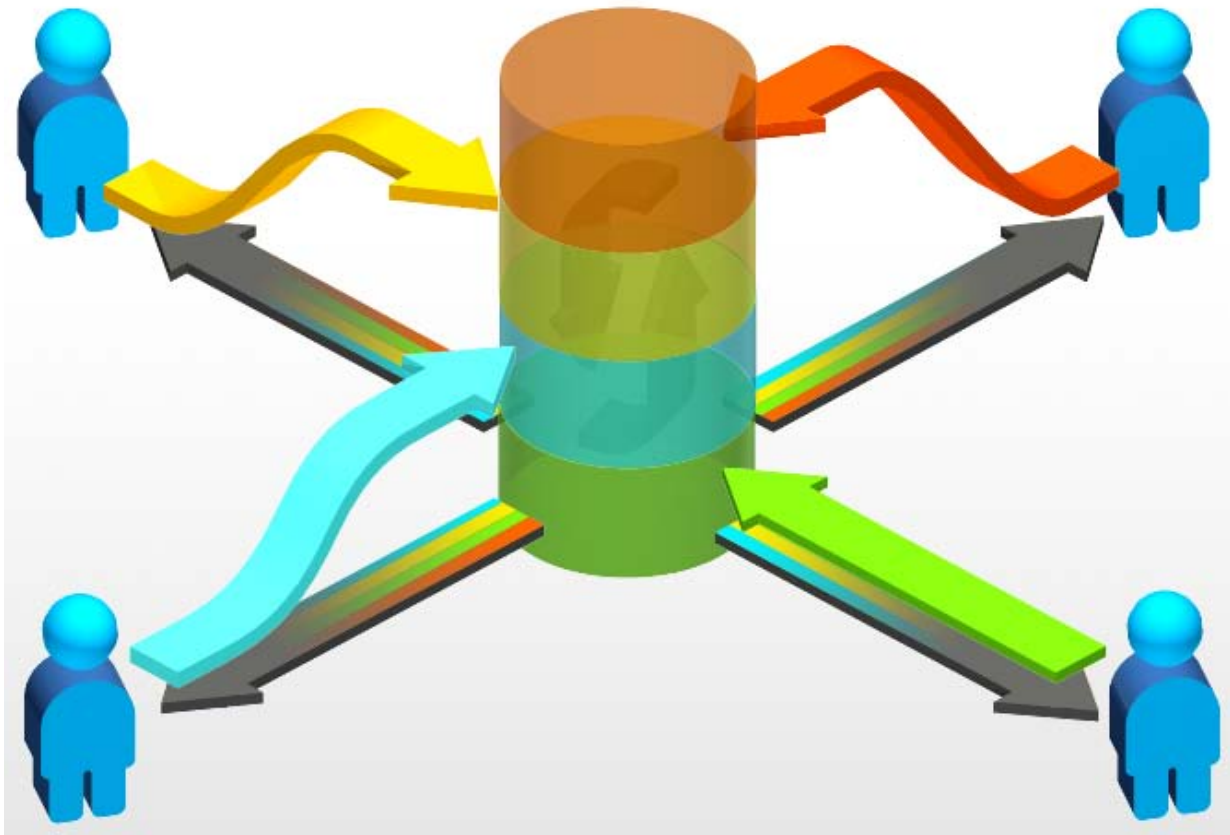
Complexity of process & data sources

Current process is not ideal and often results in the PHM design process not meeting stated goals (efficacy / cost)

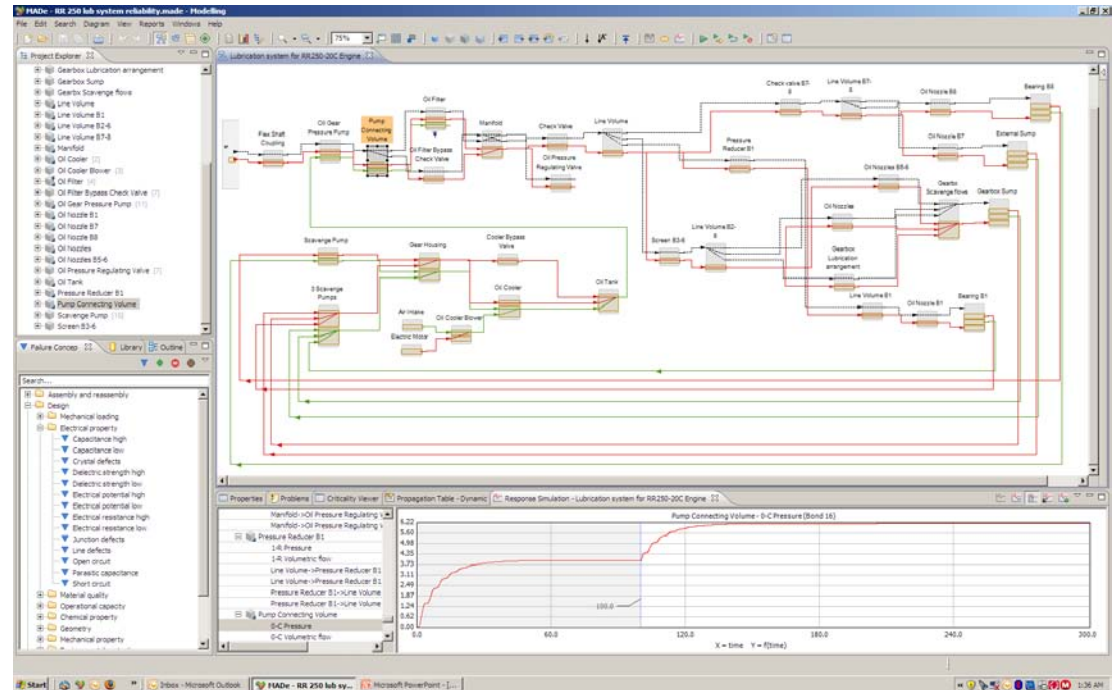
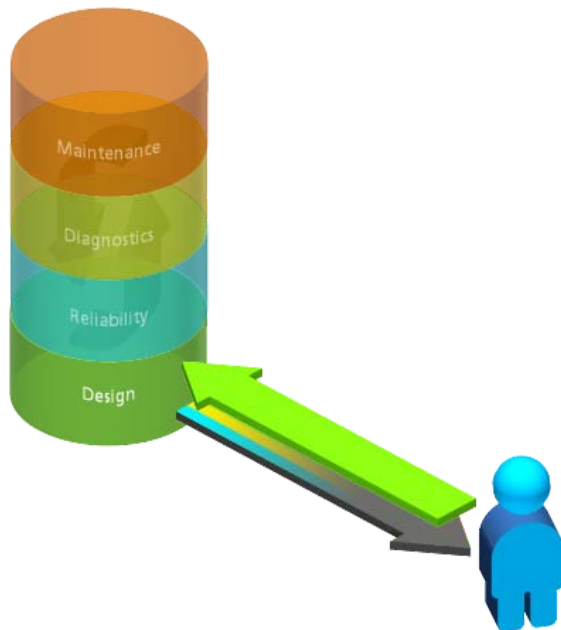


Optimal PHM design process

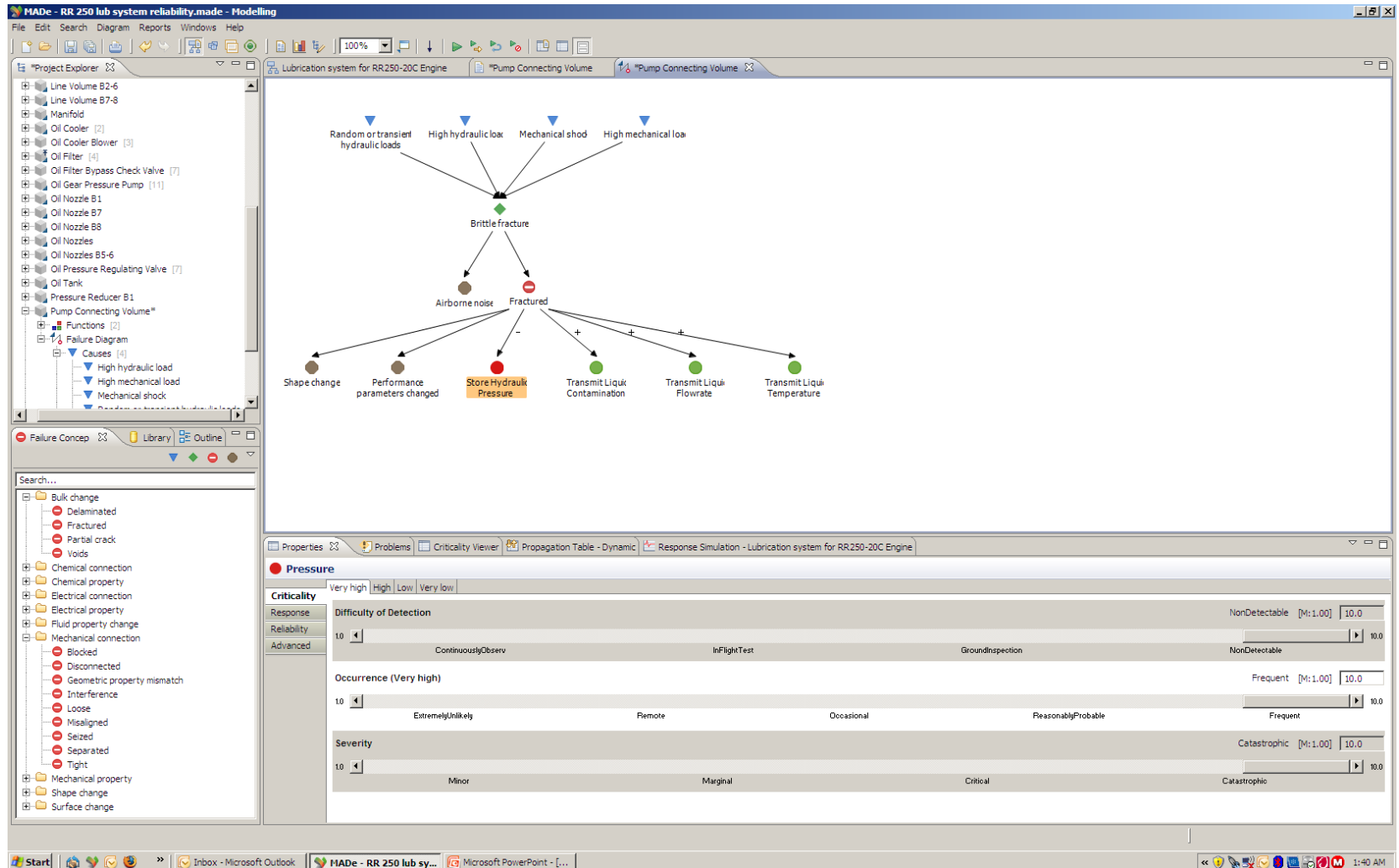
Using a unified system model that captures all relevant information and interfaces to all silos within the organisation offers improved design process for PHM

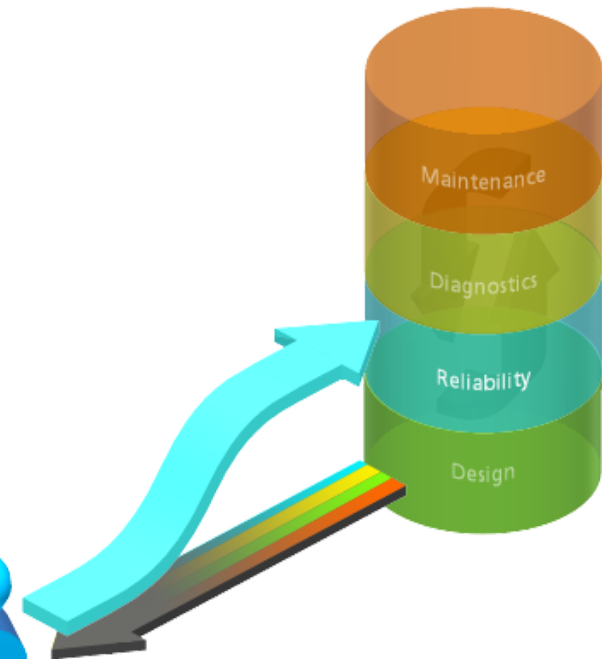


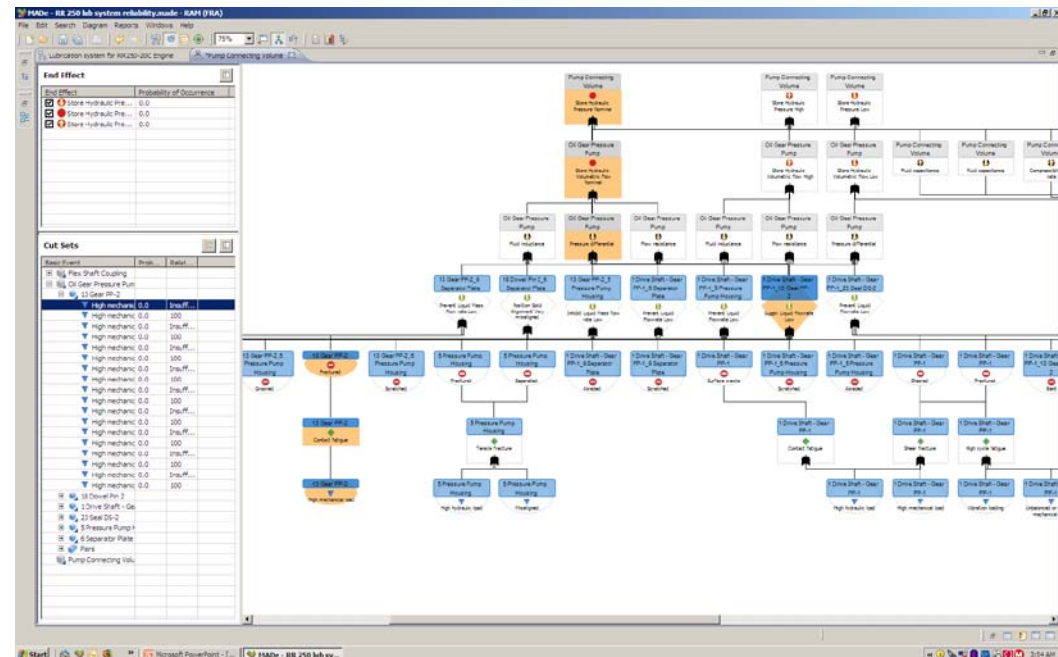
System Design and Definition



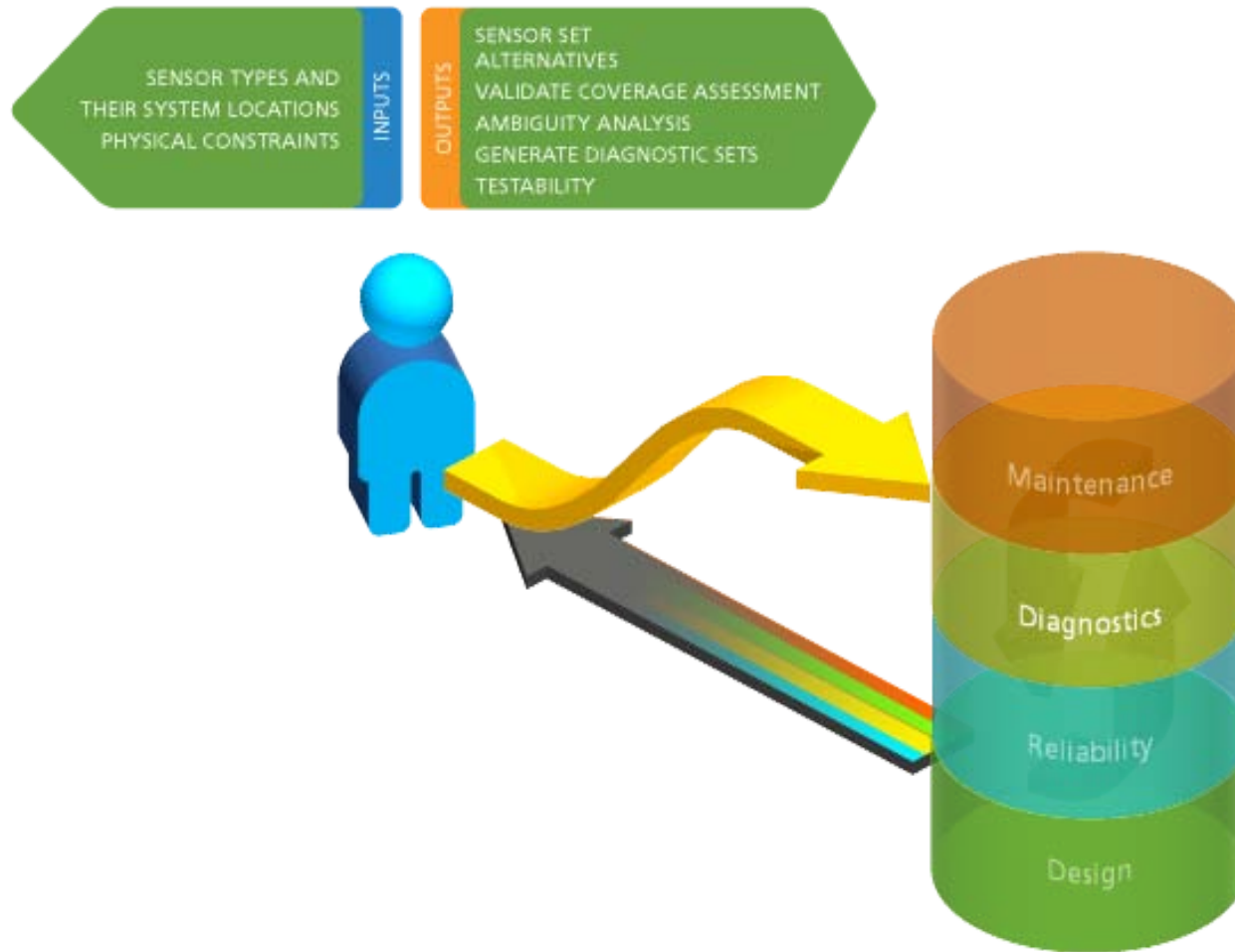
System Design and Definition



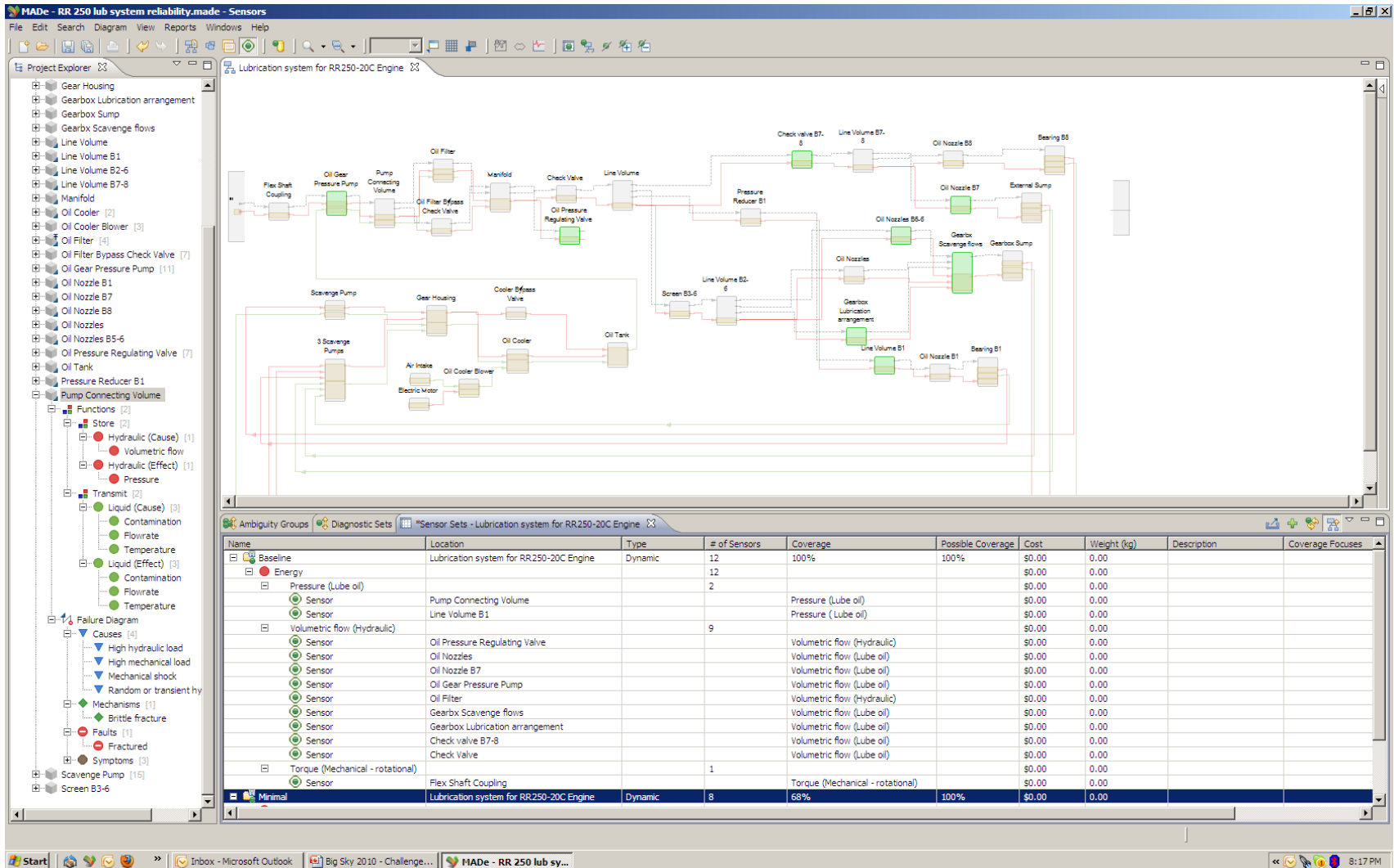




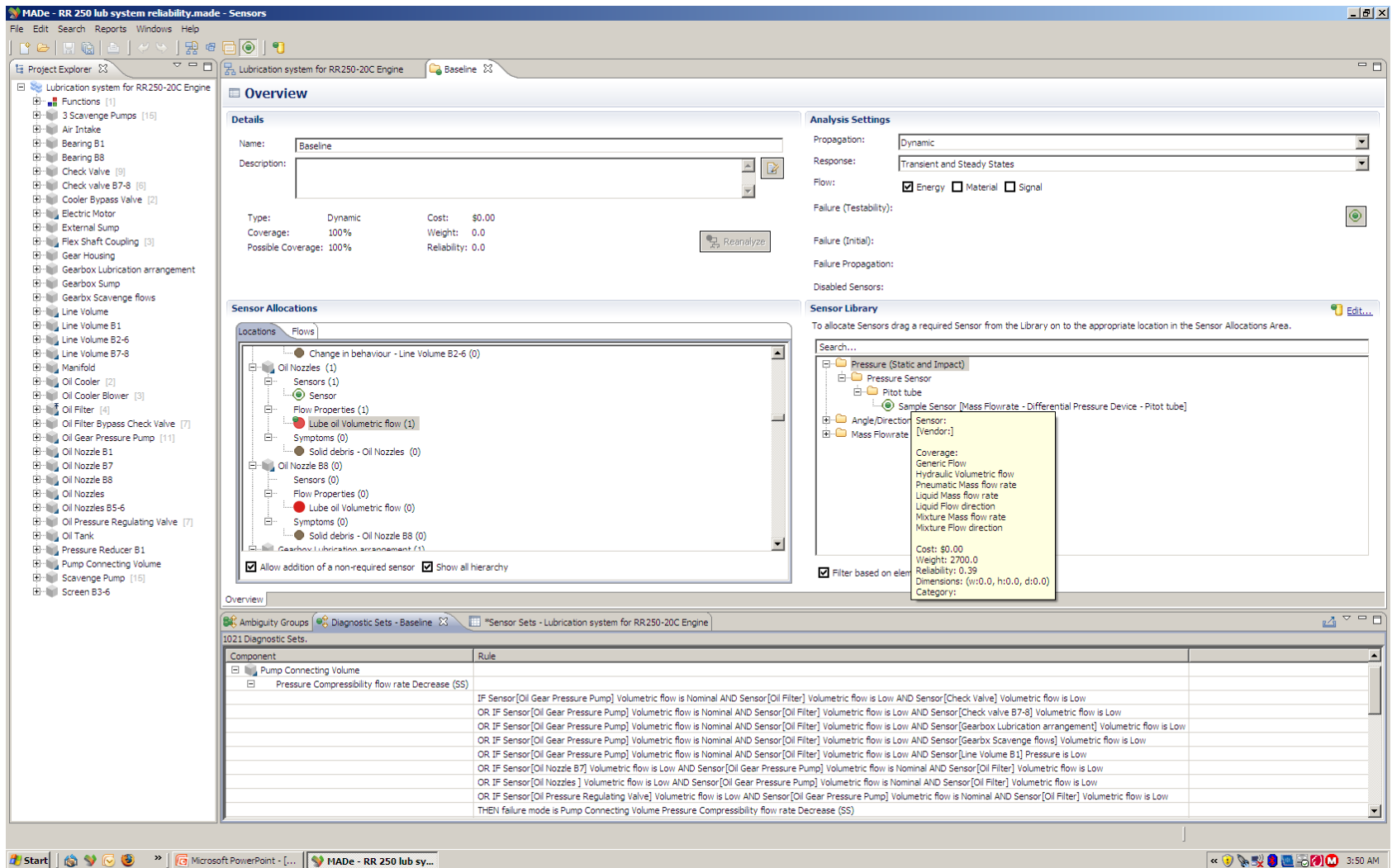
PHM Design and Validation



MADe - PHM system design



MADe – sensor set design



The screenshot displays the MADe software interface for sensor set design. The main window is titled "MADe - RR 250 lub system reliability.made - Sensors". The interface is divided into several panes:

- Project Explorer:** Lists components of the "Lubrication system for RR250-20C Engine", including Functions (1), 3 Scavenge Pumps (15), Air Intake, Bearing B1, Bearing B8, Check Valve (9), Check valve B7-8 (6), Cooler Bypass Valve (2), Electric Motor, External Sump, Flex Shaft Coupling (3), Gear Housing, Gearbox Lubrication arrangement, Gearbox Sump, Gearbox Scavenge flows, Line Volume, Line Volume B1, Line Volume B2-6, Line Volume B7-8, Manifold, Oil Cooler (2), Oil Cooler Blower (3), Oil Filter (4), Oil Filter Bypass Check Valve (7), Oil Gear Pressure Pump (11), Oil Nozzle B1, Oil Nozzle B7, Oil Nozzle B8, Oil Nozzles, Oil Nozzles B5-6, Oil Pressure Regulating Valve (7), Oil Tank, Pressure Reducer B1, Pump Connecting Volume, Scavenge Pump (15), and Screen B3-6.
- Overview:**
 - Details:** Name: Baseline, Description: (empty), Type: Dynamic, Coverage: 100%, Possible Coverage: 100%, Cost: \$0.00, Weight: 0.0, Reliability: 0.0. A "Reanalyze" button is present.
 - Sensor Allocations:** Shows a tree view of sensor allocations. The "Flows" tab is active, showing "Change in behaviour - Line Volume B2-6 (0)", "Oil Nozzles (1)", "Sensors (1)", "Flow Properties (1)", "Symptoms (0)", "Solid debris - Oil Nozzles (0)", "Oil Nozzle B8 (0)", "Sensors (0)", "Flow Properties (0)", "Symptoms (0)", "Lube oil Volumetric flow (0)", "Solid debris - Oil Nozzle B8 (0)", and "Gearbox Lubrication arrangement (0)". Checkboxes for "Allow addition of a non-required sensor" and "Show all hierarchy" are visible.
- Analysis Settings:**
 - Propagation: Dynamic
 - Response: Transient and Steady States
 - Flow: ☒ Energy ☐ Material ☐ Signal
 - Failure (Testability): ☒
 - Failure (Initial):
 - Failure Propagation:
 - Disabled Sensors:
- Sensor Library:**
 - Search: ...
 - Pressure (Static and Impact)
 - Pressure Sensor
 - Pitot tube
 - Sample Sensor (Mass Flowrate - Differential Pressure Device - Pitot tube)
 - Sensor: [Vendor:]
 - Coverage: Generic Flow, Hydraulic Volumetric flow, Pneumatic Mass flow rate, Liquid Mass flow rate, Liquid Flow direction, Mixture Mass flow rate, Mixture Flow direction
 - Cost: \$0.00, Weight: 2700.0, Reliability: 0.39, Dimensions: (w:0.0, h:0.0, d:0.0), Category:
 - Angle/Direction
 - Mass Flowrate

- Diagnostic Sets:**
- 1021 Diagnostic Sets.
- Component: Pump Connecting Volume
- Rule: IF Sensor[Oil Gear Pressure Pump] Volumetric flow is Nominal AND Sensor[Oil Filter] Volumetric flow is Low AND Sensor[Check Valve] Volumetric flow is Low OR IF Sensor[Oil Gear Pressure Pump] Volumetric flow is Nominal AND Sensor[Oil Filter] Volumetric flow is Low AND Sensor[Check valve B7-8] Volumetric flow is Low OR IF Sensor[Oil Gear Pressure Pump] Volumetric flow is Nominal AND Sensor[Oil Filter] Volumetric flow is Low AND Sensor[Gearbox Lubrication arrangement] Volumetric flow is Low OR IF Sensor[Oil Gear Pressure Pump] Volumetric flow is Nominal AND Sensor[Oil Filter] Volumetric flow is Low AND Sensor[Gearbox Scavenge flows] Volumetric flow is Low OR IF Sensor[Oil Gear Pressure Pump] Volumetric flow is Nominal AND Sensor[Oil Filter] Volumetric flow is Low AND Sensor[Line Volume B1] Pressure is Low OR IF Sensor[Oil Nozzle B7] Volumetric flow is Low AND Sensor[Oil Gear Pressure Pump] Volumetric flow is Nominal AND Sensor[Oil Filter] Volumetric flow is Low OR IF Sensor[Oil Nozzles] Volumetric flow is Low AND Sensor[Oil Gear Pressure Pump] Volumetric flow is Nominal AND Sensor[Oil Filter] Volumetric flow is Low OR IF Sensor[Oil Pressure Regulating Valve] Volumetric flow is Low AND Sensor[Oil Gear Pressure Pump] Volumetric flow is Nominal AND Sensor[Oil Filter] Volumetric flow is Low THEN failure mode is Pump Connecting Volume Pressure Compressibility flow rate Decrease (SS)

Questions / Comments?