Reducing supportability costs using PHM

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Background of PHM Technology

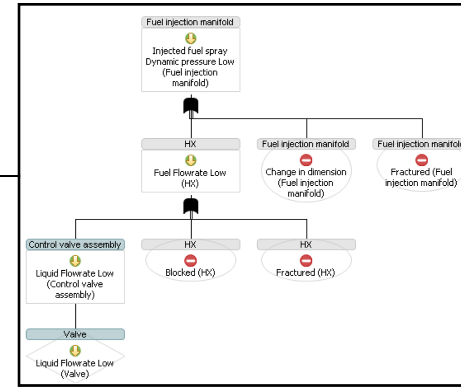
- Melbourne based company established 2006
- Principal Engineer – Dr Jacek Stecki
- Developed the Maintenance Aware Design environment (MADe) - a suite of modeling, analysis and decision support tools for safety and mission critical systems.
- Financially supported by US government programs including the Joint Strike Fighter, DARPA, US Navy Aviation SBIR and an Australian Department of Defence (New Air Combat Capability) technology maturation grant.
- Current clients include: NASA, NAVAIR, General Atomics, Thales

Maintenance Aware Design Environment (MADe)

MADe is a suite of software tools developed for design and analysis of complex systems. The analysis is model-based, using a functional-dependency approach to modeling.

Analysis simulates the system-wide effects of failures, to provide estimates for:

- Failure pathing / Fault Tree



- Criticality/risk analysis

Item ID	Item Name	Operation Mode	Function	Cause	Failure Mechanism	Effects: Local	Effects: Next	Effects: End	Detection Method	Criticality: O	Criticality: S	Criticality: D	Criticality: RPN	Remarks
	Fuel injection manifold		Distribute	Corrosive contaminant (Fuel injection manifold)	Erosion corrosion (Fuel injection manifold)	Injected fuel spray Dynamic pressure Low (Fuel injection manifold)	N/A	Injected fuel spray Dynamic pressure Low (FDS)		1.3	7.4	4.2	40	
	Fuel injection manifold		Distribute	Solid particle contaminants (Fuel injection manifold)	Buildup of debris (Fuel injection manifold)	Injected fuel spray Dynamic pressure Low (Fuel injection manifold)	N/A	Injected fuel spray Dynamic pressure Low (FDS)		2.9	7.4	4.2	90	

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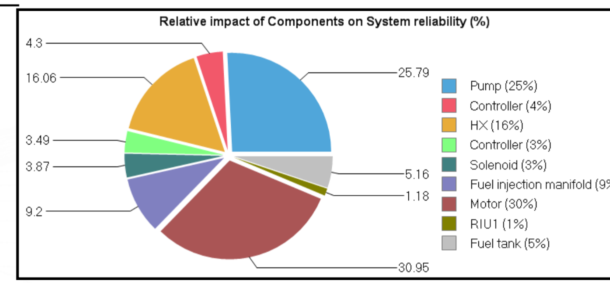
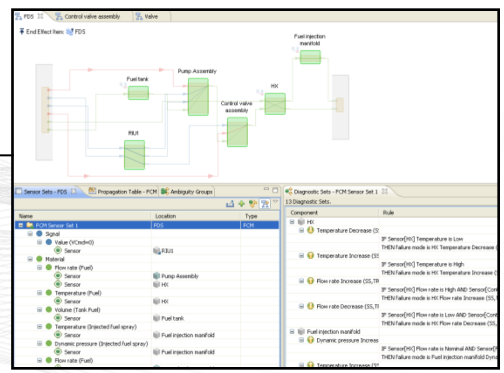
Item ID	Item Name	Operation Mode	Function	Cause	Failure Mechanism	Effects: Local	Effects: Next	Effects: End	Detection Method	Criticality: O	Criticality: S	Criticality: D	Criticality: RPN	Remarks
	HX		Increase	Solid particle contaminants (HX)	Buildup of debris (HX)	Fuel Flowrate Low (HX)	N/A	Injected fuel spray Dynamic pressure Low (FDS)		10.0	7.4	4.2	311	
	HX		Increase	High hydraulic load (HX)	Yielding (HX)	Fuel Flowrate Low (HX)	N/A	Injected fuel spray Dynamic pressure Low (FDS)		10.0	7.4	4.2	311	

- System reliability and availability



- Sensor requirements



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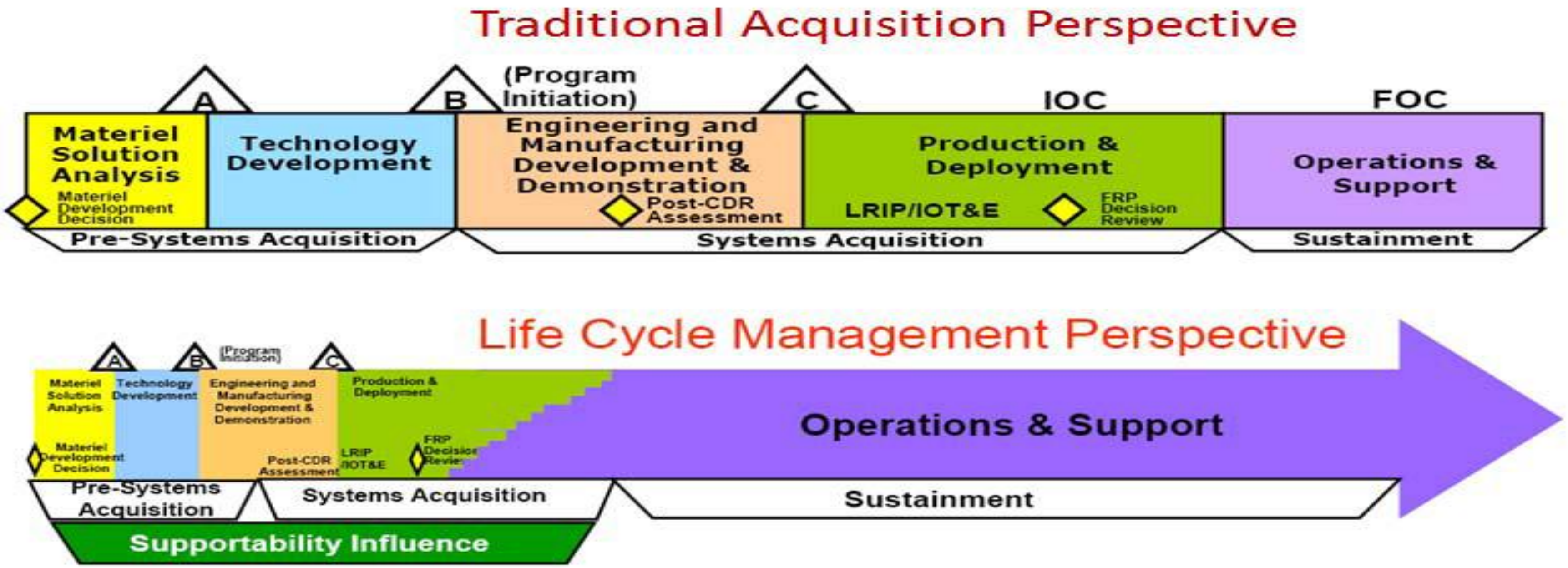
Defence environment

- management focus on risk mitigation, productivity & cost reductions
- systems are increasingly complex (multi-domain / hierarchical)
- stringent requirements for safety, reliability and affordability
- constant technology upgrades and redesign
- most systems significantly exceed their expected life
- **support costs (maintenance / logistics) are significant (eg. Collins)**
- push towards ‘power by the hour’ model(PBC / VBL)

Drivers for supportability

- financial and strategic imperatives for improving system affordability
- financial and strategic imperatives for improving operational availability
- through life costs increasingly relevant for defence customers



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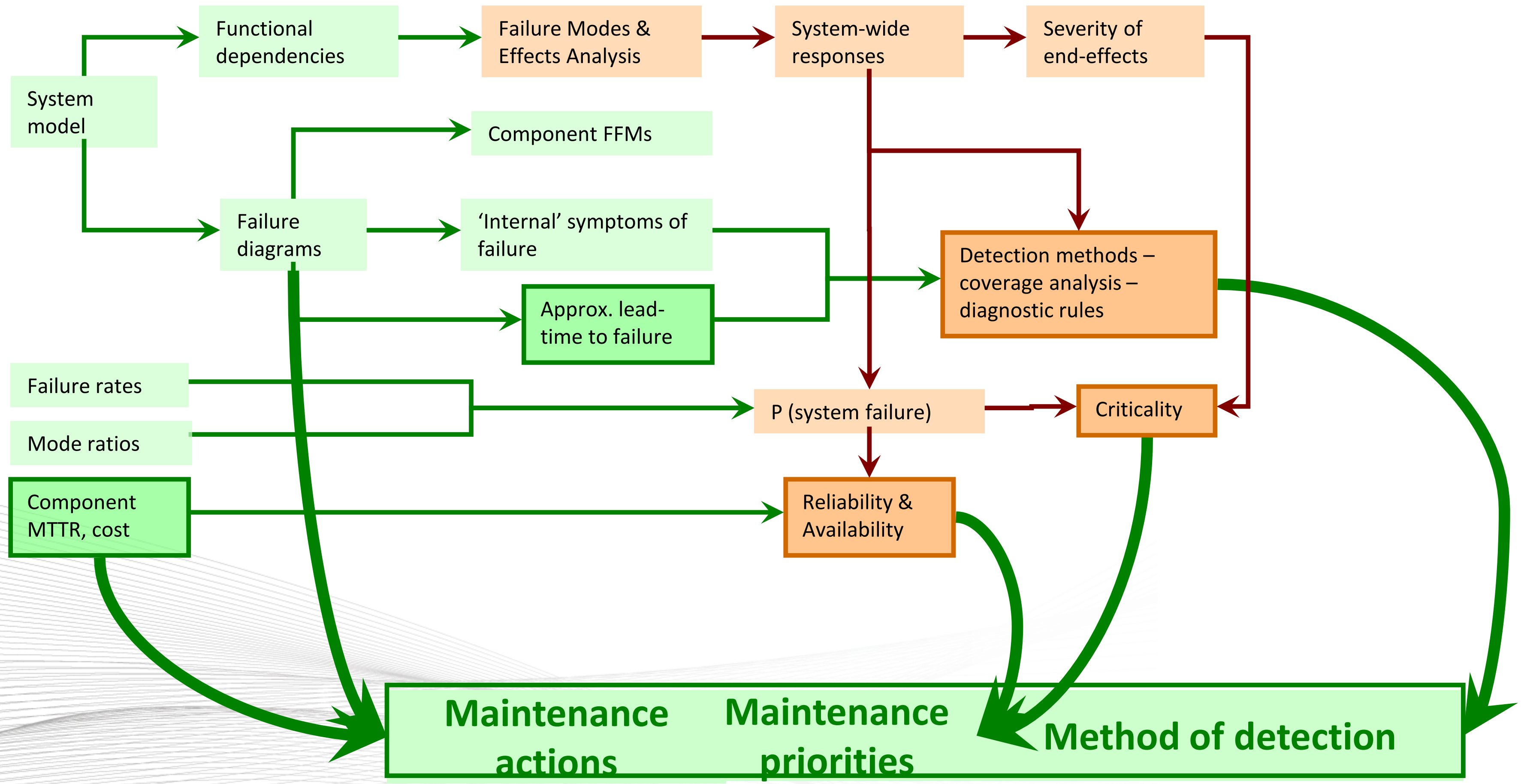
Maintenance decisions



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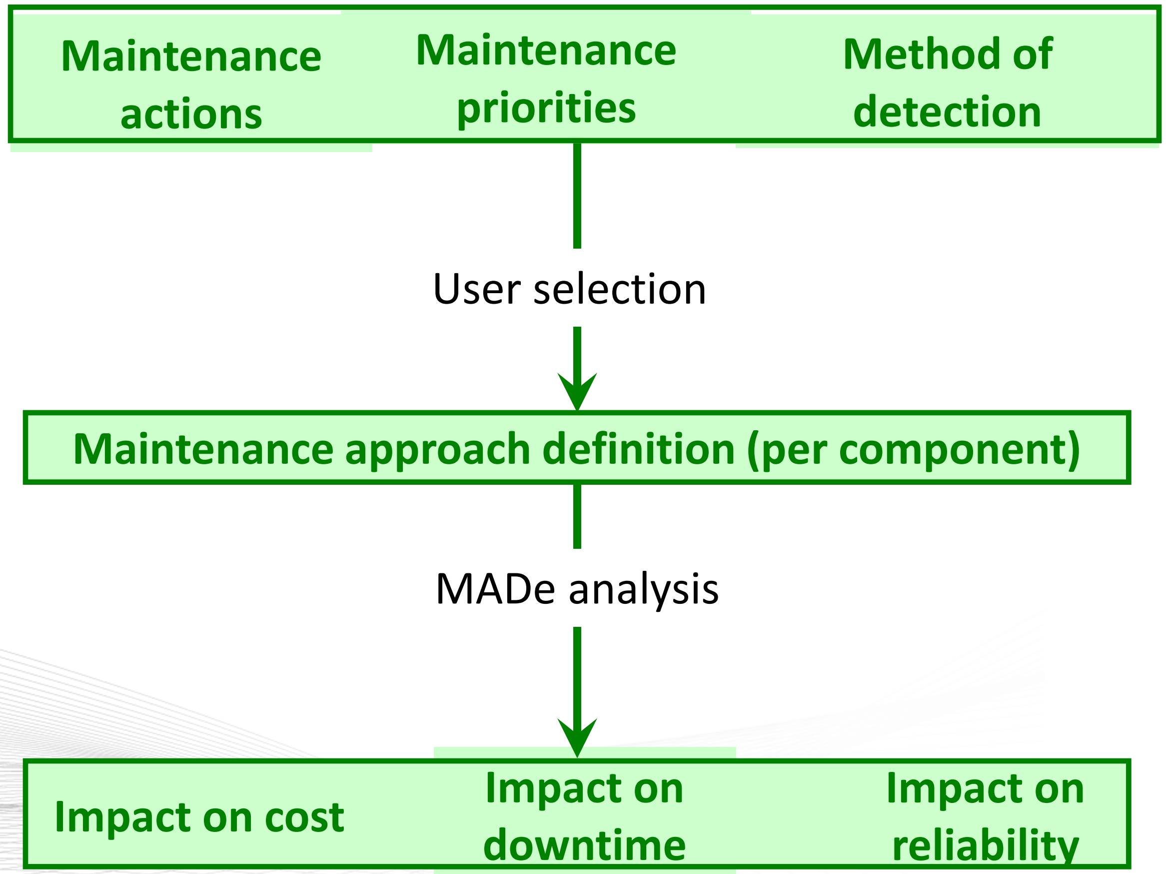
Aspects of maintenance decisions

• Which failure modes are high priority?	•Risk priority: severity & probability/frequency •Cost of failure •Impact of failure on system reliability/availability
• How will failure be detected?	•Scheduled inspections/tests between missions/op cycles •Reactive, as required, between missions/op cycles •Scheduled during operation •Reactive test/monitoring, during operation •Continuous monitoring, during operation
• What actions will be taken to prevent/respond to failure?	•Repair - Adjust/Modify/Overhaul •Replace •Increase inspection/monitoring •Change operating mode - reduce op load/reduce op time/redundancy switching •Redesign – decrease failure rate/decrease cost of component
• What is the effectiveness of the approach taken?	Impact on: System reliability System operating cost System downtime (availability)

Analysis of maintenance approach



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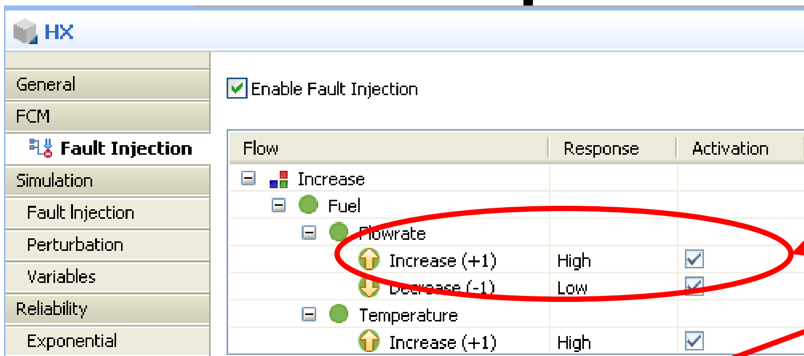
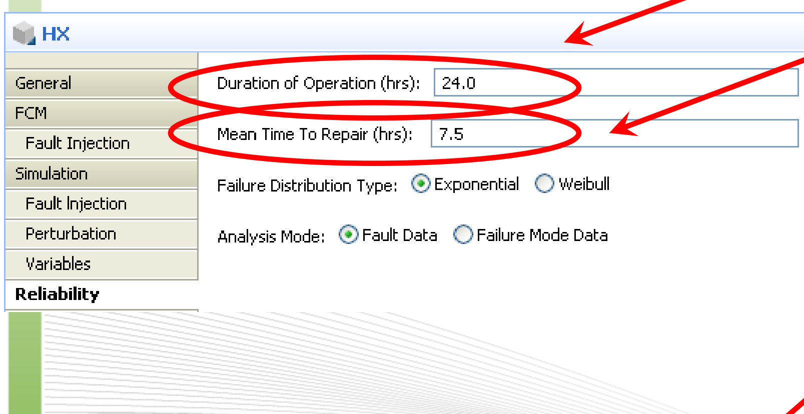
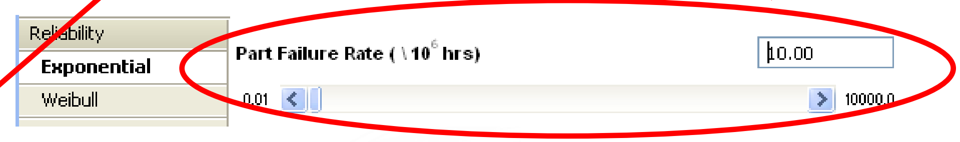
Component Failure (FFMs)

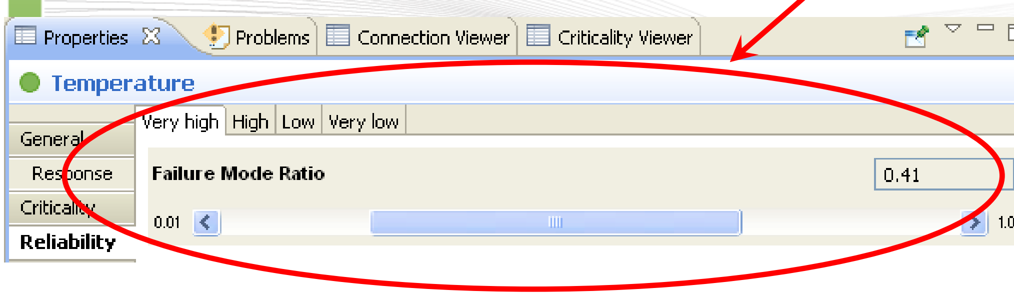
If component has only hypothetical ('injected') FFMs the following information may be available:

- Magnitude of response
- Duration of operation
- MTTR
- Failure rate
- Failure mode ratios









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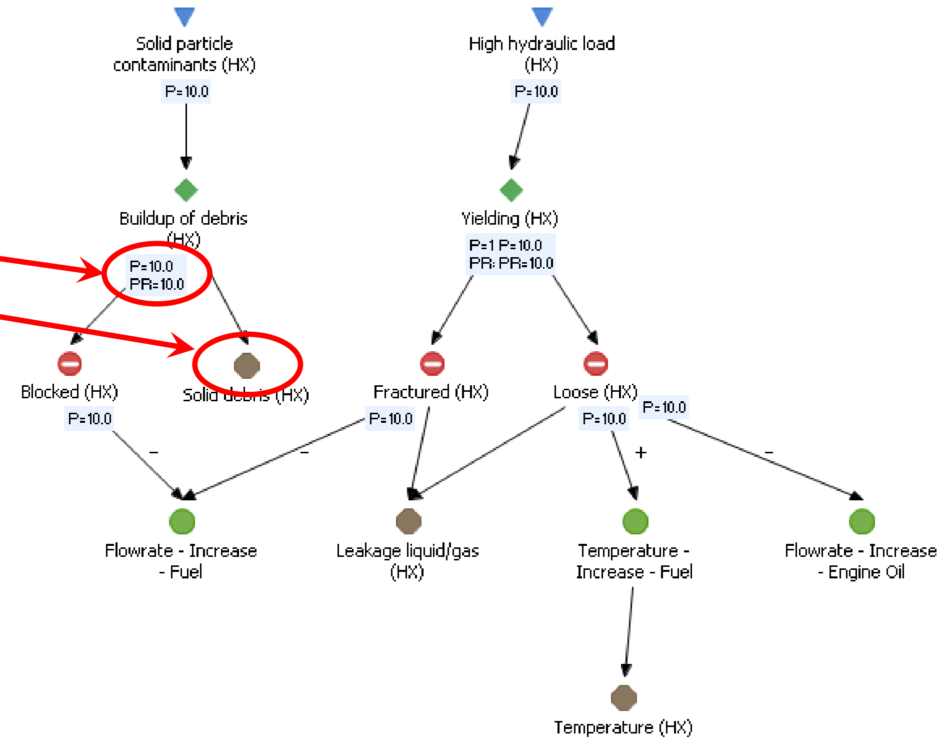
Component Failure (FFMs)

If component has failure diagram we have the following additional information:

- Progression rate (PR)
- Symptoms (brown icons on the diagram)



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Introduction to PHM

- Prognostics and Health Management (PHM) and Condition Based Maintenance (CBM) are approaches to increase the failure free operating time of a system – ‘increased availability’.
- PHM is an enabling discipline consisting of technologies and methods to assess the reliability of a product in its actual life cycle conditions to determine the advent of failure and mitigate system risk.
- PHM is a core attribute of most new defence systems (e.g. JSF / BAMS)

Definition of PHM

- Integrate sensor data and prediction models to provide in-situ assessment of the extent of deviation and degradation of a product from its expected normal operating conditions.

- Aims to achieve improved reliability and maintainability of systems by applying failure analysis, model-based monitoring, and artificial intelligence technology to predict when a system will need to be serviced or replaced.

- Sound knowledge of possible failures (including the site, mode, cause and mechanism) is necessary for the implementation of a PHM system. Such knowledge is important to identify the system parameters that are to be monitored.

Requirements of PHM

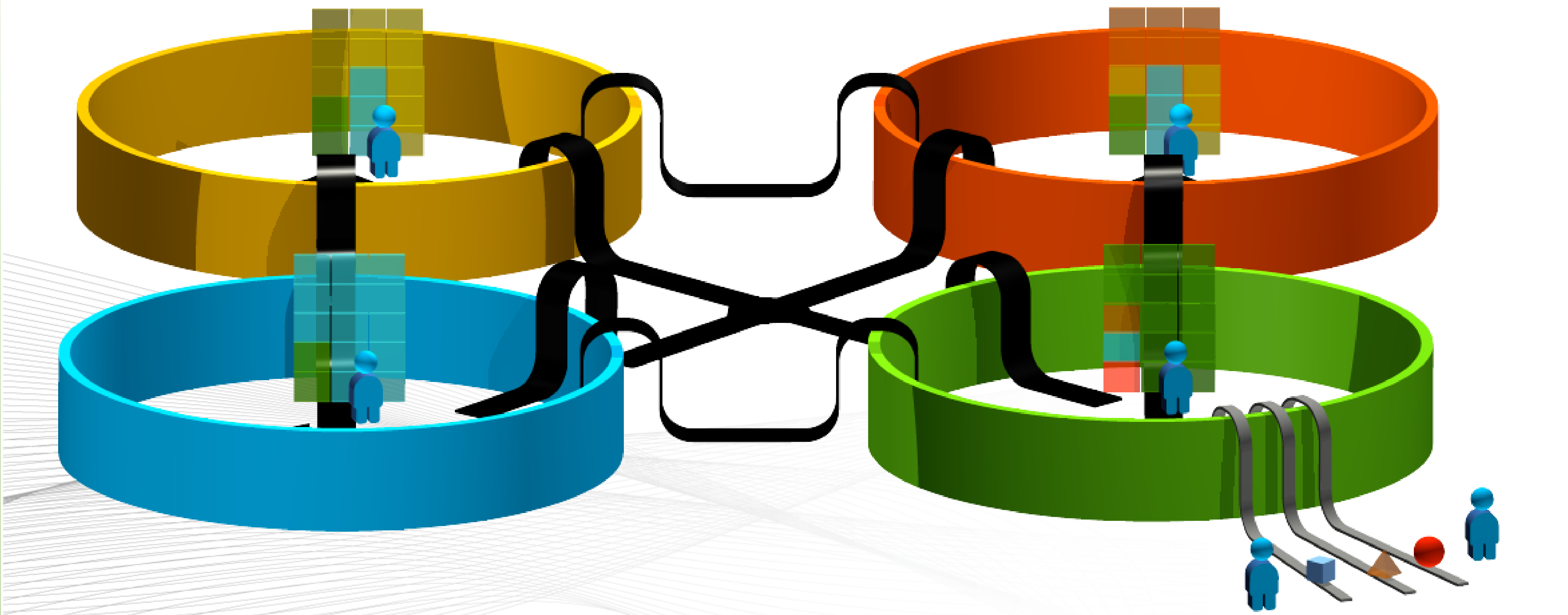
- Accurate FMECA – if you don't identify failure modes you can't cover them
- Diagnostic design validation based on accurate system model
- Capability trade-offs and system requirements considered during iteratively during design process and throughout system life
- PHM outputs to be integrated with maintenance, logistics, etc.
- Trade studies of PHM capabilities based on user defined parameters (cost / weight / coverage)

PHM design issues

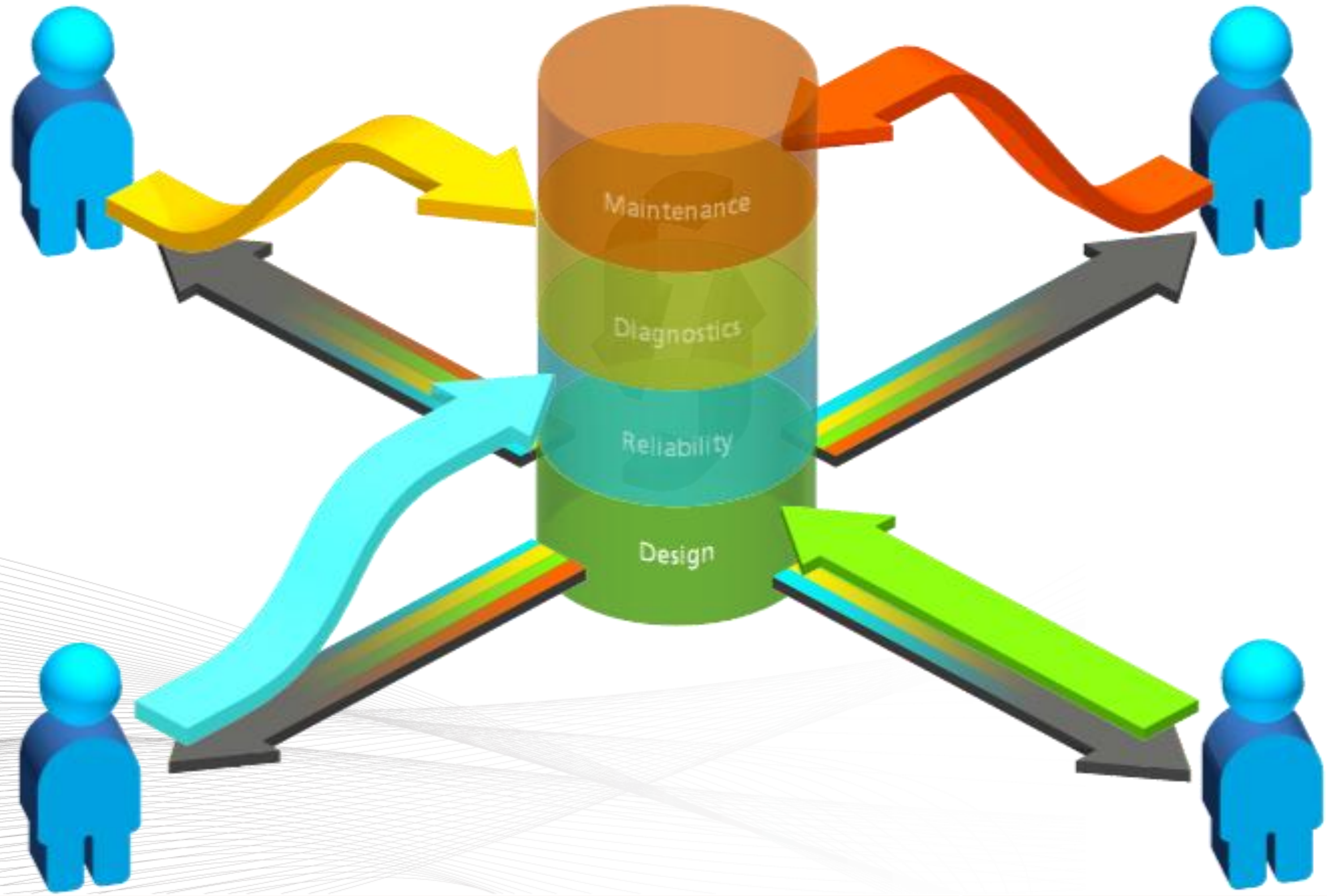
- design process (concurrent engineering)
- data integrity (quality of failures data, complex dependency modelling)
- data consistency (standardised taxonomies)
- data availability (accessible to the customer / maintainer)
- data currency (not easily updated to reflect technology upgrades or redesign)
- data usability (integration with other analysis and design tools)

Current PHM design process

- supply chain integration
- functional silo / department integration



Optimal PHM design process



Demonstration of MADe

DSTO Seminar
March 2011

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Summary

- PHM / CBM can optimise supportability – reduce cost and maintain availability
- PHM (and CBM) can be applied to new and legacy systems
- MADe has the capabilities to support PHM design and validation