Image source: Siemens PLM

# Why Model-based RAMS is required to actualize CBM based on Big Data Analytics

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AA&S Conference - Washington 2019

# Executive Summary

- Interest in Condition Based Maintenance (CBM) has been reinvigorated by recent advances in the processing efficiency / cost of analytics ("Big Data") but can this potential be actualized for the aerospace sector?
- Reliability, Availability, Maintainability and Safety analysis (RAMS) conducted during the design process is based on 'physics of failure', and if conducted with a model-based approach provides both a Causation Model and Digital Twin of the system
- CBM requires detection and identification of failures during operations, and the capacity to iteratively determine and implement the appropriate maintenance
- Big Data uses algorithms with operational data to establish a Correlation Model for a system, but has 'Big Issues' with CBM: specifically the cost and risk of accurately 'training' algorithms for the complex, certified systems in aerospace.
- Model-based RAMS aligned with Big Data enables operators to actualize CBM at 'digital speed' (FDI, decision making, maintenance adaptation, certification, etc.)
- **The Take Away** - you need 'digitized' engineering knowledge to justify and realise the benefits of Big Data for CBM – data science cant do it 'stand-alone'

Image source: www.wearefinn.com

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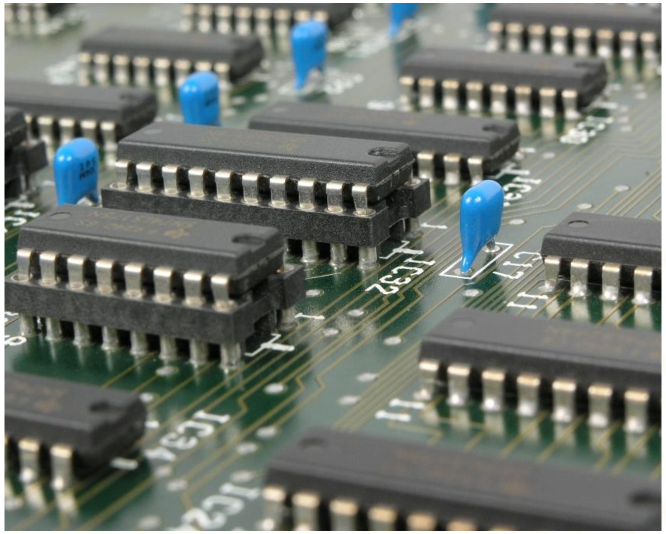
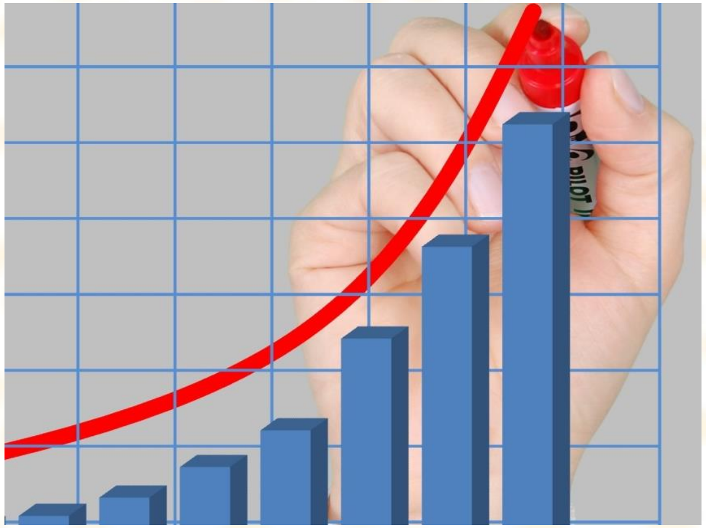
# Presentation Structure

- Aerospace systems – context and constraints
- Risk Identification (failures and defects)
- Advantages of Model-based RAMS
- Advantages of CBM
- Big Data analytic methods
- Big Data – the Correlation Bias
- CBM and Big Data Analytics
- Limitations of Big Data for CBM
- Big Data designed with RAMS
- CBM, Big Data and the Digital Twin
- Conclusion


Image source: www.houseofbots.com

# Aerospace systems – context and constraints





**System Complexity**
(embedded / integrated)

**Distributed Design**
(data / analysis synchronicity)

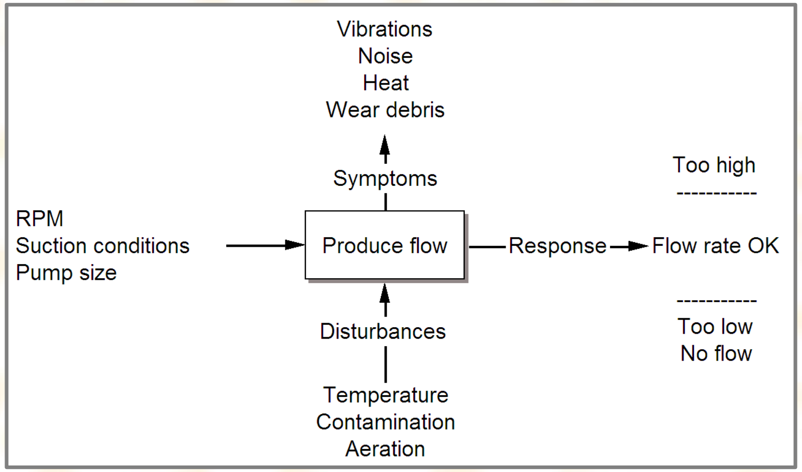
**Cost of Certification**
(schedule / resources)

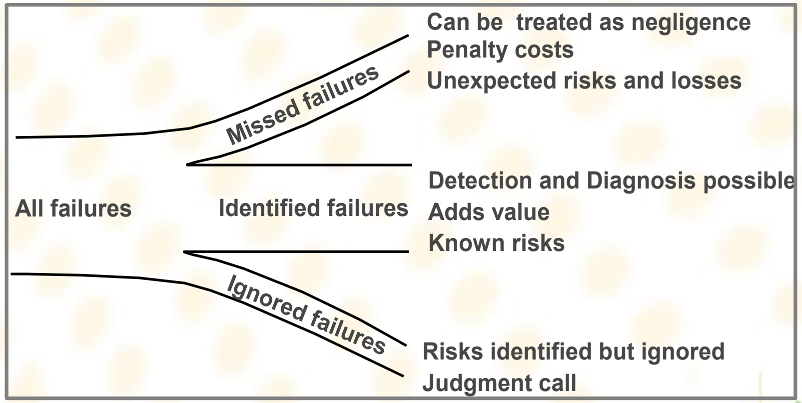
# Risk Identification (failures and defects)

RAMS for aerospace is the function of identifying and appropriately mitigating all possible failures for a design configuration, based on their potential impact on the equipment during operation (ARP 4761, MSG-3, etc.) using:

- Functional Hazard Analysis (FHA)
- Failure Mode and Effects Analysis (FMEA)
- Failure Mode, Effects and Criticality Analysis (FMECA)
- Fault Tree Analysis (FTA)
- Common Mode Analysis (CMA)
- Reliability Block Diagrams (RBD)
- Markov Analysis (MA)
- Reliability Centred Maintenance (RCM)
- Etc.

**If you don't identify a potential risk you cant mitigate it.**

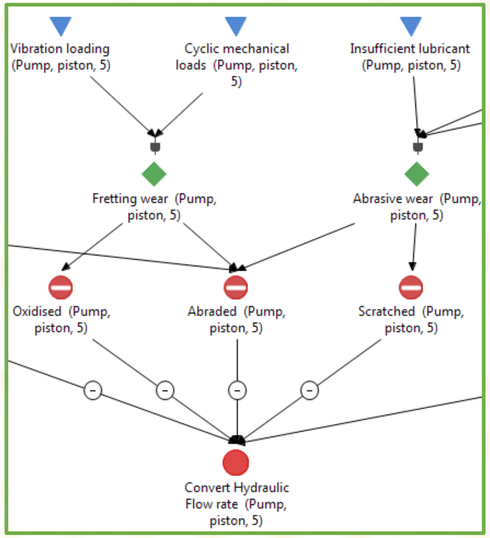


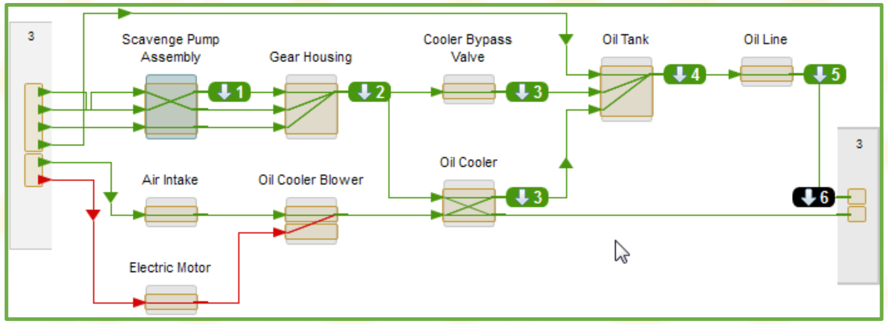
# Advantages of model-based RAMS

RAMS conducted concurrently using iterative analysis based on simulation generates automated analysis outputs, key advantages:

1. automated approach
2. objective process
3. integrated
4. consistency
5. configuration managed
6. reusability of data
7. knowledge capture / transfer



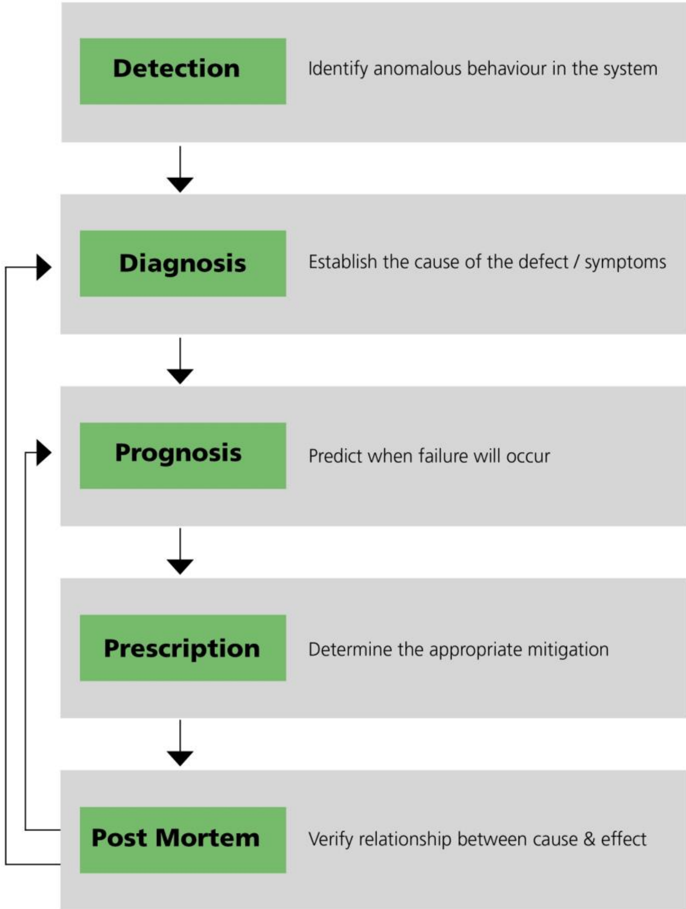

*Syndrome / Signature of failure*




**Result**: optimize system configuration to meet performance / safety requirements with the lowest cost of ownership – RAMS data becomes a Digital Twin for Failures

# Advantages of Condition Based Maintenance (CBM)

- Improve visibility into failures (health state)
  - Enable Fault Detection & Isolation (FDI)
  - Understand impact of op-tempo / environment
  - Predict Remaining Useful Life (RUL)
- Optimise maintenance (Turn Around Time)
  - Increase lead time / intervals for maintenance
  - Optimise maintenance scheduling (“Sunshine”)
  - Ensure availability of the right tools, spares, trained resources, etc. are for the maintenance
- Optimise Cost of Ownership:
  - Increase Operational Availability (dispatch rate)
  - Reduce Average Maintenance per Flight Hour
  - Increase ‘Readiness Efficiency’



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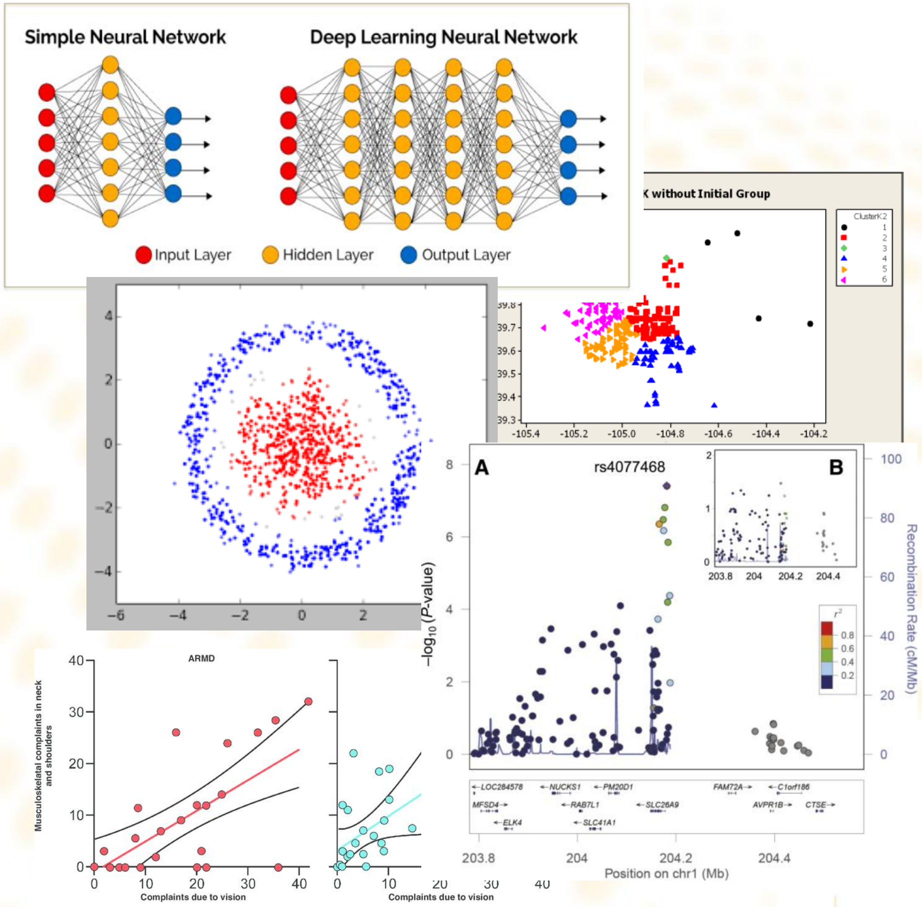
# Big Data Analytic Methods

- **Classification Analysis:** (e.g. neural networks, decision trees and support vector machines) uses a model for making predictions on data features according to specified criteria with a predefined set of classes and a rule-base classification (IF-THEN) to classify different categories.
- **Clustering Analysis:** (e.g. K-means algorithm, density-based spatial clustering) grouping data into separate clusters of similar objects according to identified characteristics.
- **Association analysis:** recognize groups of items that occur synchronously.  Criteria support and confidence level identify the most important relationships among the related items.
- **Regression Analysis:** (e.g. linear regression, non-linear regression and exponential methods) measure the dependent variable given one or several independent variables to establish logical relationships based on the best fit for a set of data.

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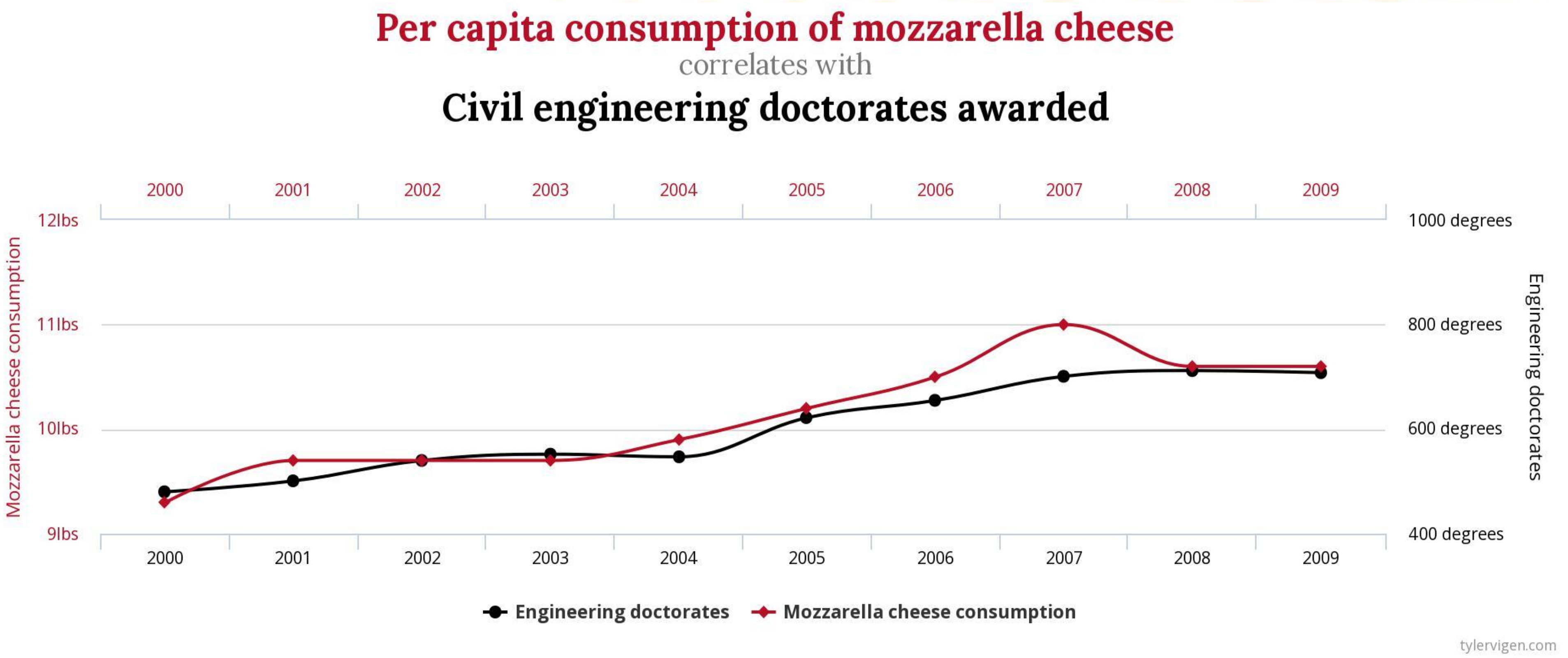
# Big Data – the Correlation Bias




http://www.tylervigen.com/spurious-correlations

# CBM and Big Data Analytics

Big Data can potentially be used in CBM to identify system degradation using operational data, key factors simplifying the business case / implementation of Big Data include:

Sensor technology:
- cost of sensors rapidly decreasing
- wireless data transmission simplifies certification

Data management:
- data collection (wireless)
- data aggregation (Data Lakes)
- Moore's Law continuing impact on cost of storage

Big Data Analytics
- Machine Learning
- Synthesize large, disparate data sets

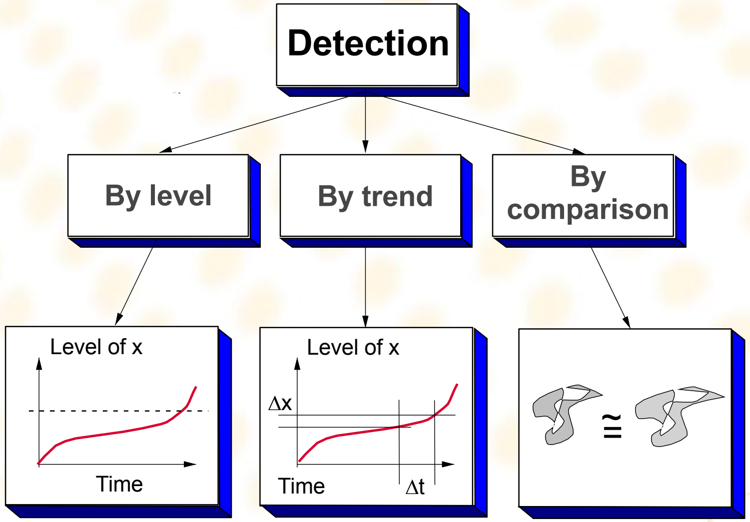




Image sources: cloudpulserat.com and www.boeing.com



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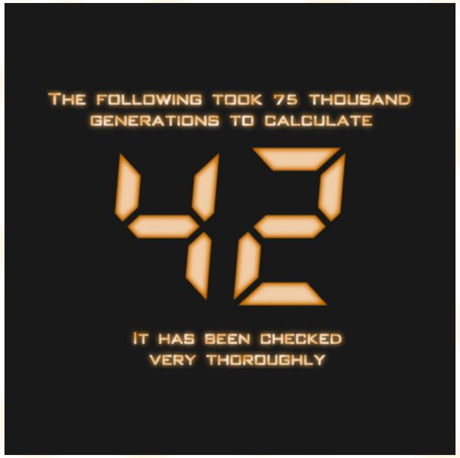
# Limitations of Big Data for CBM

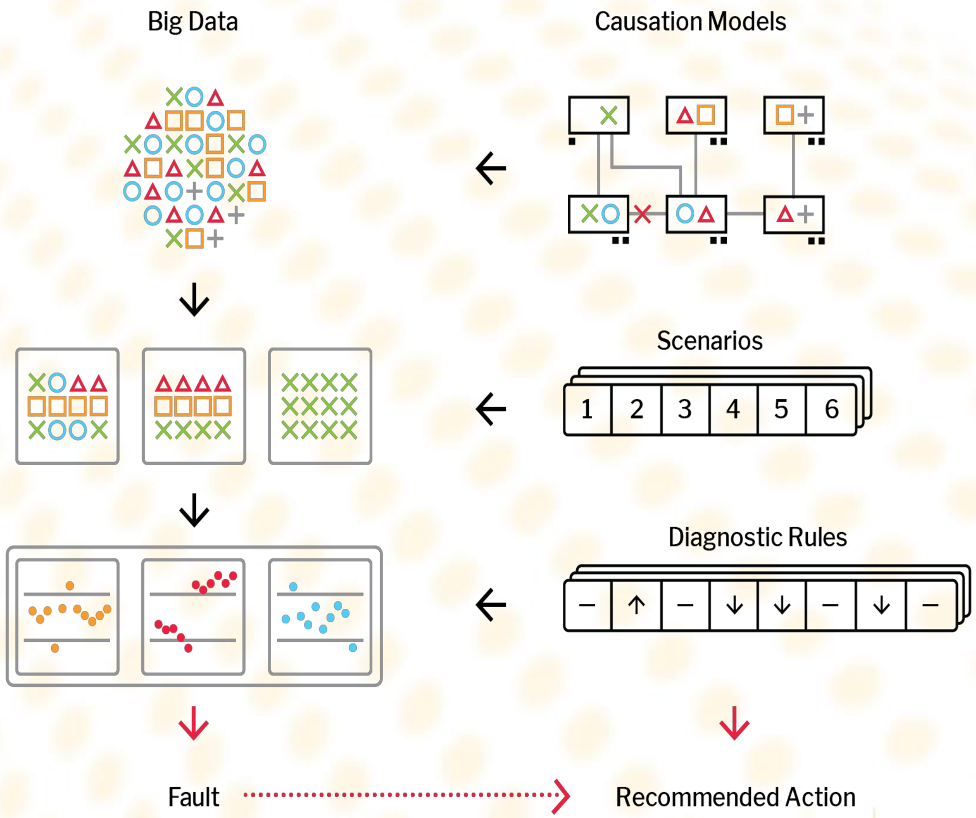
- Data driven approaches require failures to occur in order to identify them in the future
- Training regimes – no margin for error with mission/safety-critical systems
- Inherent diagnostic infrastructure is typically designed for control - not to assess equipment health state (but can be leveraged for system health monitoring)
- Certification of additional sensors is expensive and time consuming (technical & economic trade studies / design approval)

# Big Data designed with RAMS

Failure identification based on functional behaviour of the system and associated physics of failure (a causation model) enables engineering knowledge to be applied to Big Data / analytics:

- define what failures can occur
- define dependency mapping of potential failures ('signature' or 'syndrome' of failure)
- accelerate 'training' for data analytics



# CBM, Big Data and the Digital Twin

- Engineering data is generated and captured in model-based tools that feed into the Digital Twin and provide the inputs for reliability, maintainability, safety, and diagnostic analysis (RAMS-D)
- Digital Twin ensures that operational data can be used to optimise supportability, and provides a closed loop back to design (upgrades / modifications)

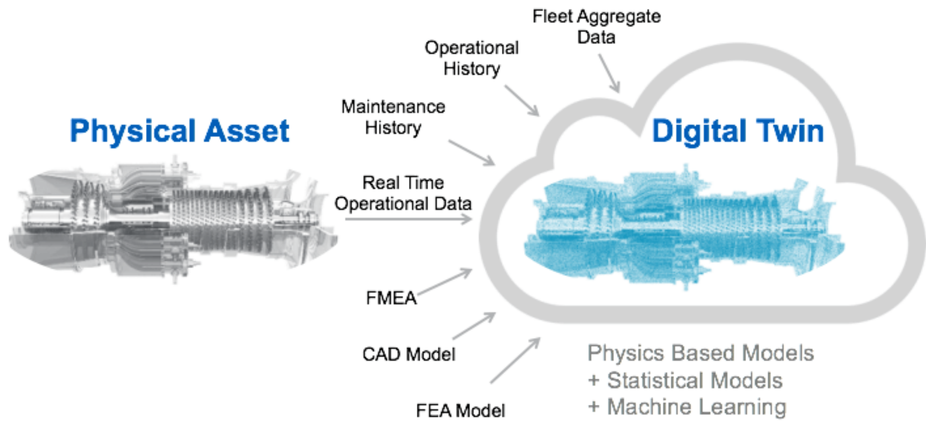




Image source: Siemens PLM & Loginworks.com

# Summary

A purely data driven approach to CBM has too much risk for complex, safety critical systems in aerospace.

CBM is an engineering problem – not simply a data science problem, you need engineering knowledge to solve it effectively (correlation informed by causation)

Combining model-based RAMS with Big Data to design and manage CBM enables an integrated approach that will increase the likelihood that the expected benefits wi be realised (actualized)