

INDUSTRIAL AI

ML-Driven Prognostics and Health Management

November 12, 2018

Inaugral Lectures, Luleå University of Technology

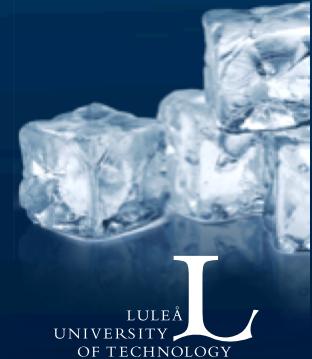
by

Abhinav Saxena, PhD

Adjunct Professor, Operation and Maintenance Engineering, LTU

Senior Machine Learning Scientist, GE Global Research, CA

Editor-in-Chief, International Journal of Prognostics and Health Management



FLOW

- Industrials
- What does safety and reliability mean for these systems
- What is AI and ML
- Use of AI & ML for PHM
- How AI&ML changing the analytics landscape
- Challenges that remain
- Q&A

INDUSTRIALS



Aviation



Healthcare



Transportation



Oil & Gas



Power Generation



Power Distribution



Renewables



Manufacturing



Water



Mining

...



TARGET COMPONENTS



Mechanical



Electronics



Electrical



Energy
Storage



Structures



Cyber Security



Networks

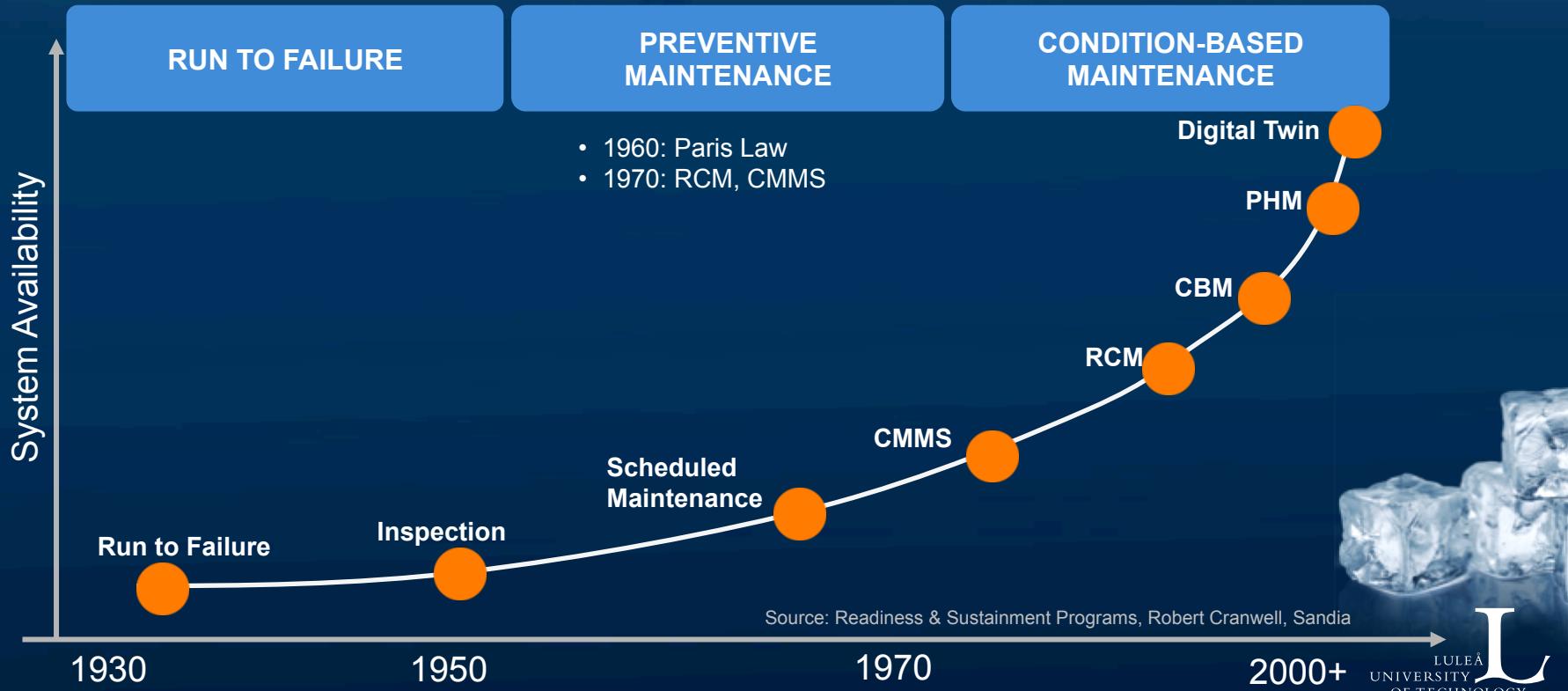


Maintenance

...



EVOLUTION OF MAINTENANCE PRACTICES



TECHNOLOGY

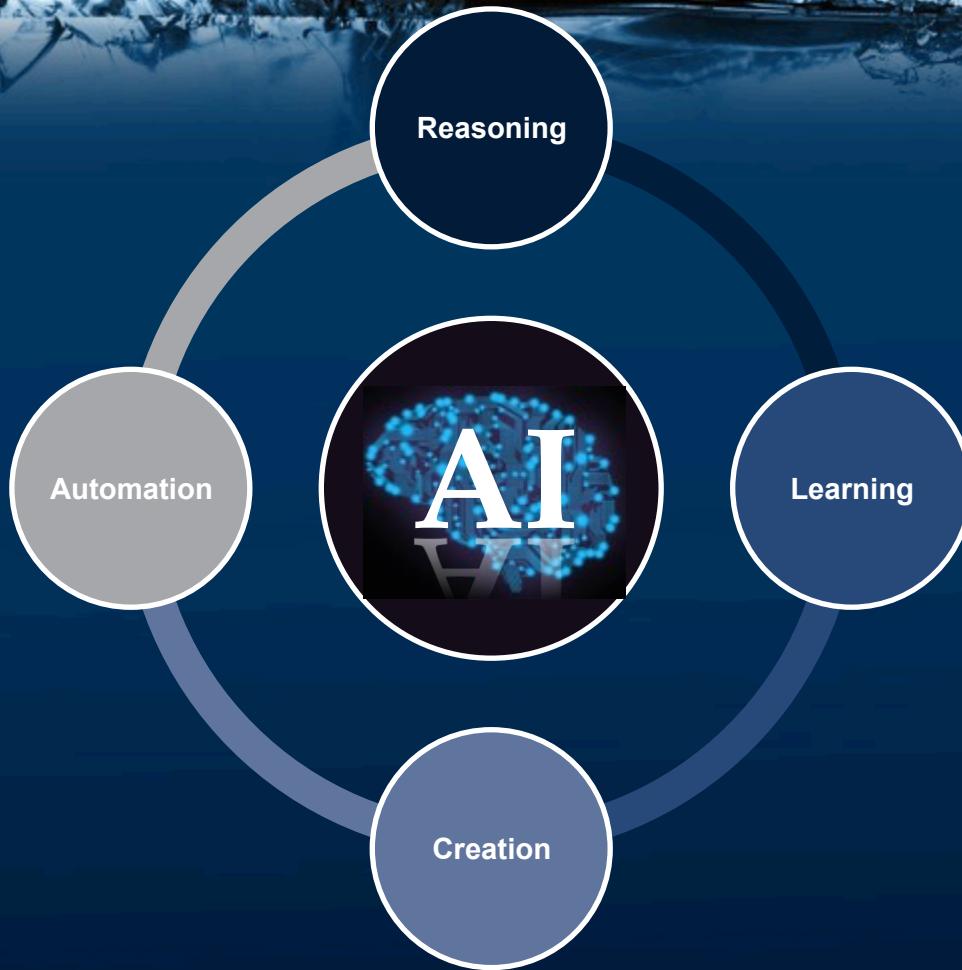
- PHM
 - Detection
 - Diagnostics
 - Isolation & Identification
 - Prognostics
 - Decision making
 - Design updates
 - ...



METHODS

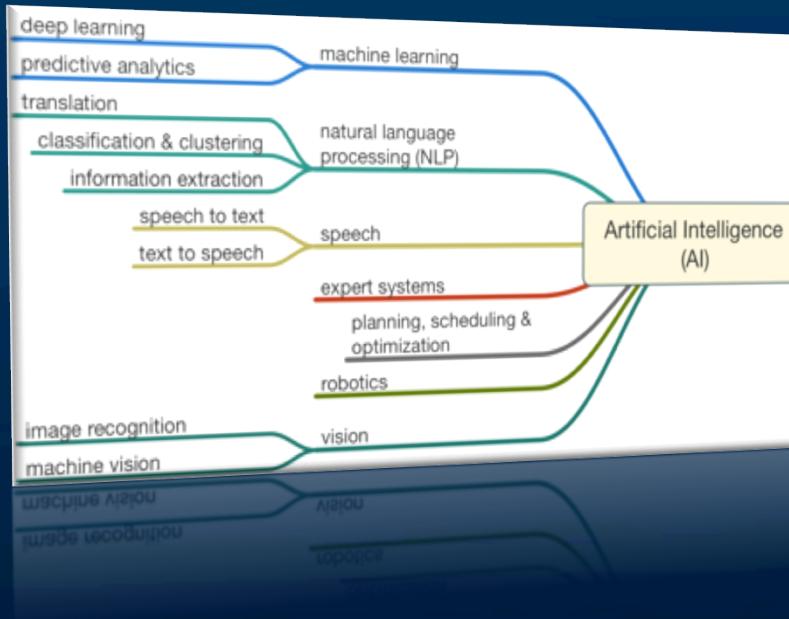
- Physics based
- Data Based
- Hybrid



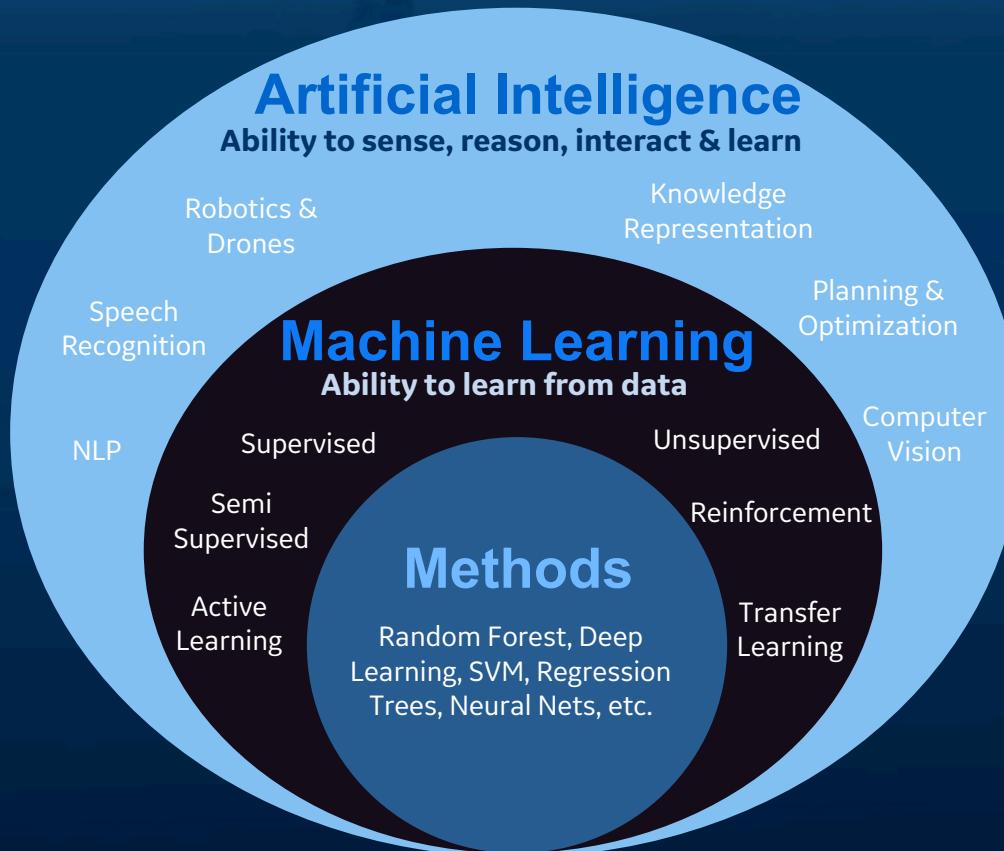


AI DEFINITION

Artificial intelligence (AI) is the ability of a computer or computer-controlled system to perform tasks commonly associated with intelligent beings.



AREAS OF AI RESEARCH



INDUSTRIAL AI



INDUSTRIAL APPLICATIONS OF AI

Design & Manufacturing

Design Acceleration

Design Optimization

Additive Manufacturing

Customer Operations

Early Warning Prediction

Performance Forecasting

Video Analytics

Performance Optimization

Damage Prognostics

Network Optimization

Inspection Services

Cyber Security

Maintenance Record Mining

Services Productivity Automation

Forecasting Applications

Financial Risk

Field Service Scheduling

Dynamic Optimization

Shop Automation

Fleet Segmentation

IT Automation

Verification & Validation

INDUSTRIAL APPLICATIONS OF AI IN GE

Prognostics

Failure Prevent – Early Warning

Root Cause Identification

Performance Forecasting

Damage Prognostics

Fleet Benchmarking

Optimization

Performance Optimization

Shop Workscope Optimization

Inspection Optimization

Field Engineer Optimization

Operations Optimization

Knowledge

Auto Suggest for Twins

Healthcare Workflow Automation

Context

Text & Voice

Problem Solution Database

Emerging Problem Prediction

Voice Guided Radiology

Talking Digital Twins

Parts Search

Image & Video

Automated Radiology (US, MR, CT)

Automated Defect Quantification

Video Tracking for Security

Digital Ghost for Security

Robotics

Drone-Based Inspection

Sub-Sea Inspection Robots

Plant Inspection Robots

Learning

Learn from Simulation

Learn from Peers

Learn from Humans

Learn from Inspection

Assurance

Model Health

Model Tracking

Model Audit

Model Provenance

CONSUMER – DIGITAL TRANSFORMATION & AI



43 yrs.
Trillion \$



25 yrs.
Trillion \$



20 yrs.
Billion \$

digital
model

insights



Demographic

- Female
- Age 25-34
- Income < \$70K

Parents live
~ 600 miles
1st child,
5-10 months
Spends \$1.2K
/month online



Psychographic - Model of ONE

- Female
- Age 25-34
- Income < \$70K

business
outcome

system



Segmentation



Profiling, Prediction - P&L of ONE



transformation
& expansion

platform



Books



New Industries, Services - Platform for ALL

INDUSTRIAL – DIGITAL TRANSFORMATION & AI



digital model



Flying in
Asia-Europe Route

2-3 Service
Years

insights

Fleet

Flying
Singapore-London
2.6 Service
Years
Last inspection
distress ranking < 2



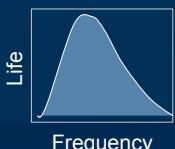
Flies 80% between
Coastal Airports
Temp. T49
delta < 10F
Due for overhaul
in 7.1 months

Per Asset ... PER FLIGHT - Model of ONE

business outcomes



Fleet life and performance



system

Fleet Analytics

Individual life and performance



Time

Per Asset Analytics - P&L of ONE

transformation
& expansion



platform

Services & Products

Customized Optimizers
Digital Twin + Edge Controls



HOW MACHINES LEARN



Text, images, speech & videos

- 350M photos/day
- 4.5B likes/day
- 3.5B Google searches/day
- 304 M active Amazon users

Feed Back Type

- Search relevance
- Likes
- Clicks
- Product reviews
- Tagging
- Rating

Consumer Internet:
Discrete,
High Events



Sensor time series, text & images

- 173000+ monitored assets
- 250M/samples/day- CCGT plant
- 3 Trips/year for GT
- 29 Events/1M flights for a/c engines
- 1 Inspection/Year

Feed Back Type

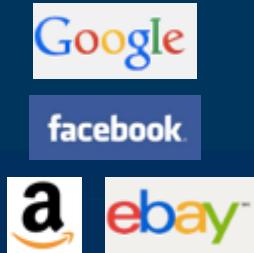
- Inspection results
- Failure events
- Domain knowledge
- Feedback loop slow

Industrial Internet:
Continuous,
Low Events

Industrial Data & Feedback Loop are Different

MACHINE LEARNING PIPELINES

Consumer Internet Use Cases



Customer
Segmentation

Sentiment Analysis

Search Engine

Ads Targeting

Recommender
System

Customer Churn

Industrial Internet Use Cases



Early Warning

Analytics Based
Maintenance

Performance
Optimization

Work Planning

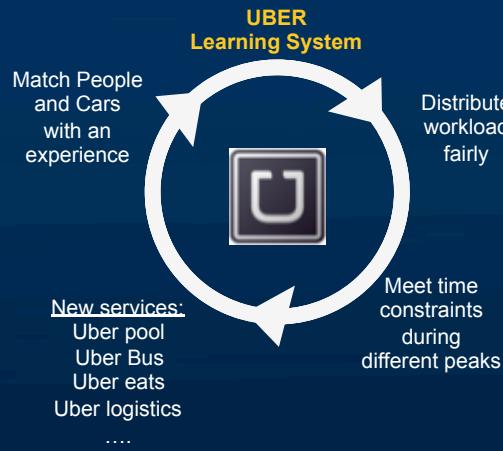
Work Optimization

Services Optimization

Industrial Machine Learning Pipeline is Different

FROM MACHINE LEARNING TO LEARNING SYSTEMS

Uber Efficiency



One knows All know

Google & Tesla Driverless Car Learning System



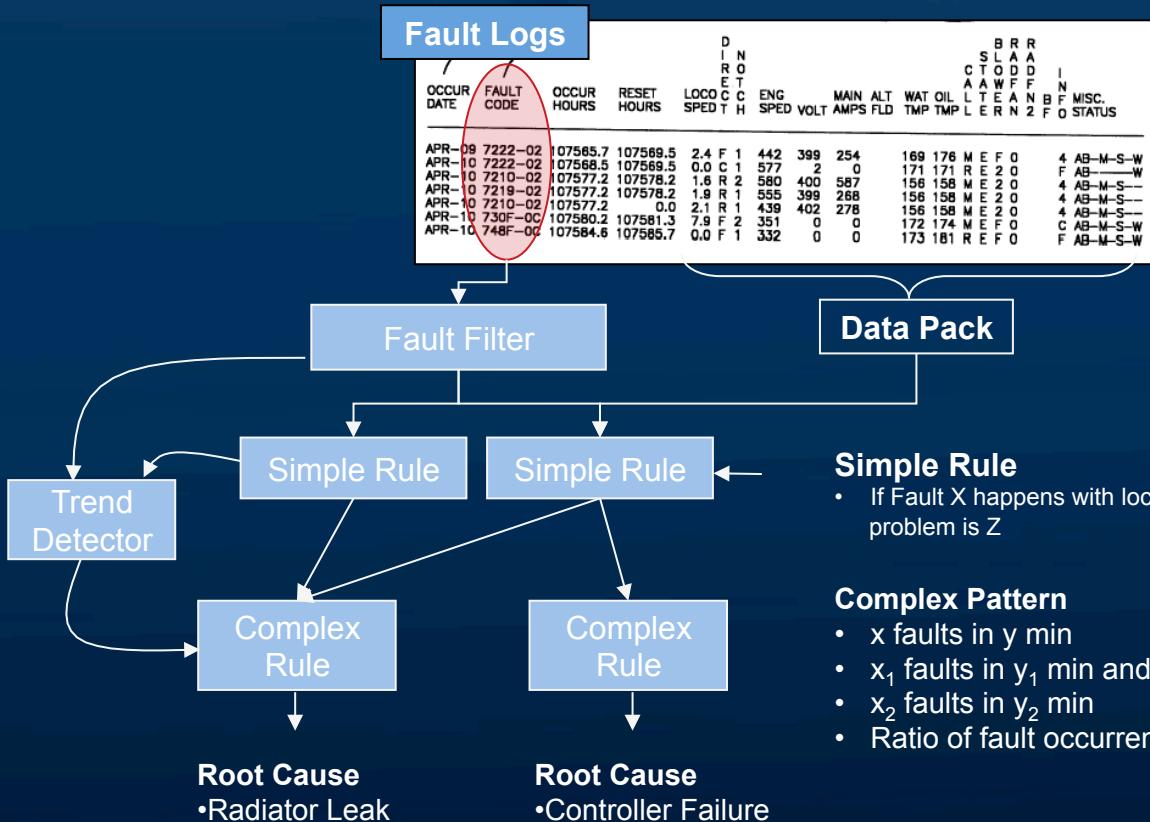
Real-time Optimization



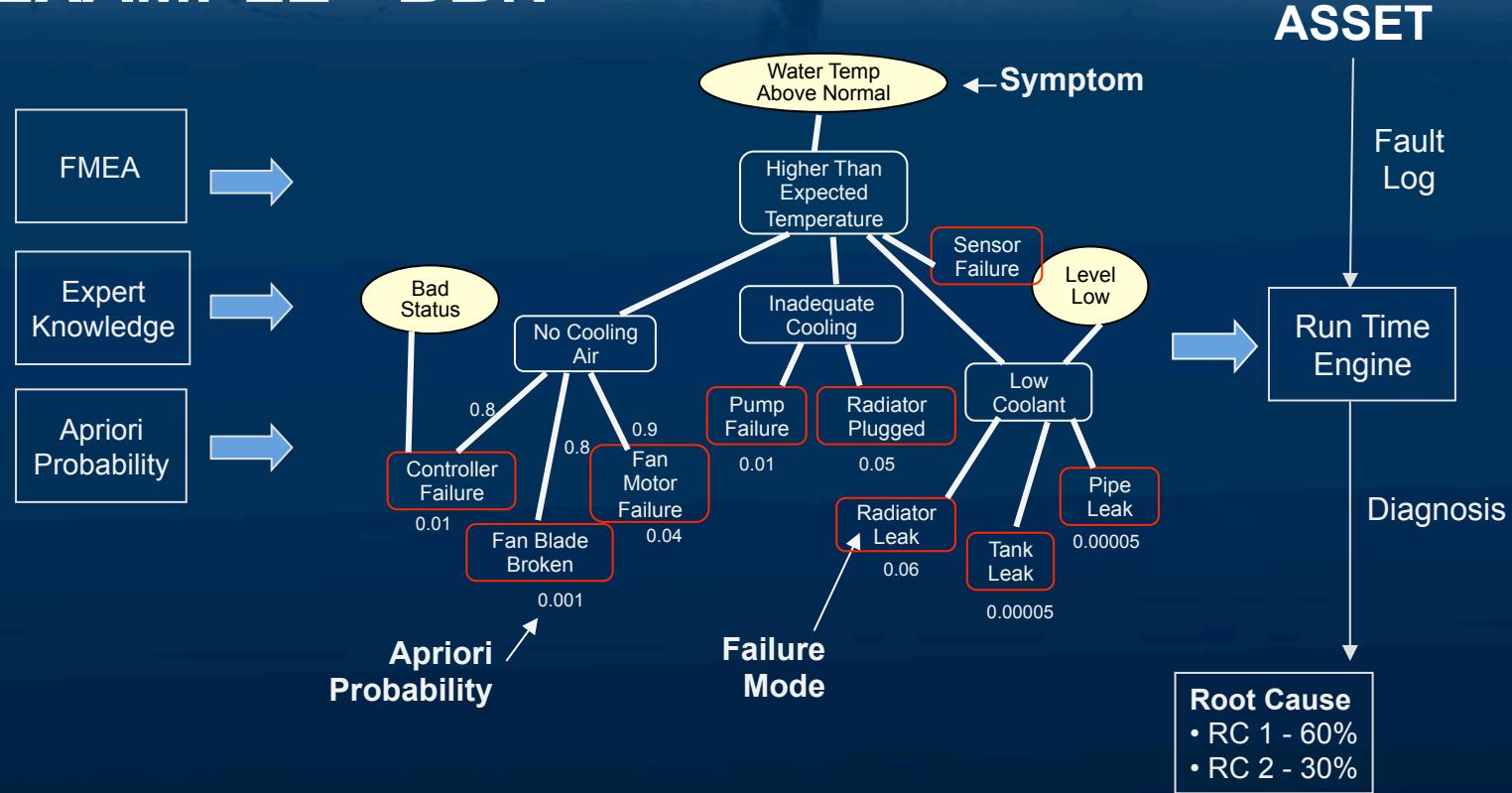
EXAMPLES



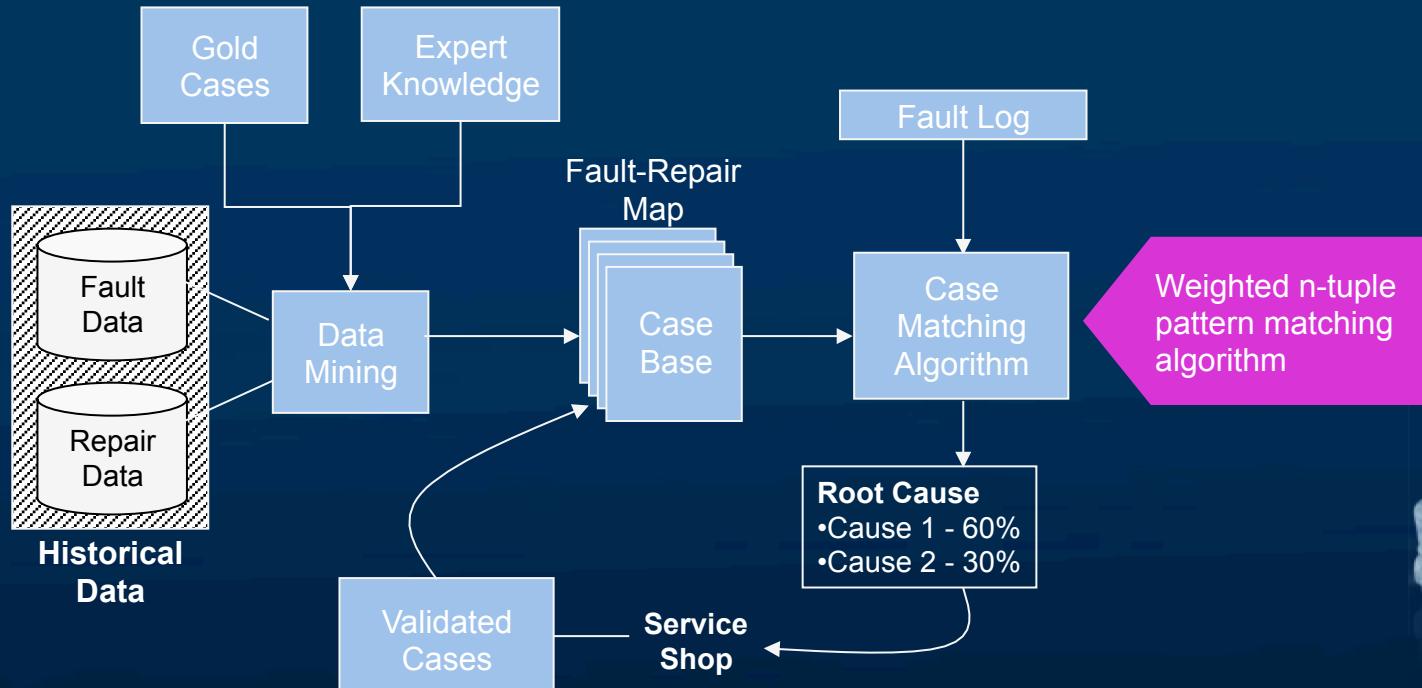
EXAMPLE: RULE-BASED SYSTEM



EXAMPLE - BBN



EXAMPLE - CBR



EXAMPLE - DEEP LEARNING

Auto Inspection

Domain Knowledge:

- Hardware geometries
- 3D Mapping

Deployed:

- Auto inspection and distress ranking of parts in shops
- 98% accuracy in shop production environment

Medical Imaging

Domain Knowledge:

- Physics of image formation
- Anatomical modes of variation
- Biological pathways

Deployed:

- 10-50 % accuracy improvement in MRI and ultrasound imaging
- 25-50% dev. time reduction

Sensor Time Series

Domain Knowledge:

- Variable selection from physics
- Domain guided applications

Deployed:

- Data imputation (98% accuracy)
- Anomaly detection application (limited scale)

- Given the maturity of DL, new applications are emerging by the day
- Common pattern is emerging which requires use of domain knowledge for successful application

Data + Domain + Deep Learning

