Future trends in maintenance, training and qualifications

Professor Andrew Starr
Dr Muhammad Khan

Cranfield University

www.cranfield.ac.uk

Welcome to Cranfield

We create leaders in technology and management

We **unlock the potential of people** and **organisations** by partnering with business and governments to deliver **transformational research, postgraduate education** and **professional development.**

We are an exclusively postgraduate university located at the heart of the UK.

Professional development of high-performing leaders across the world

Aerospace, Engineering and Technology postgraduates

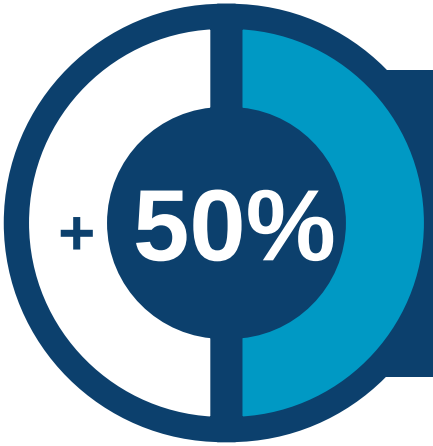
Customised Executive Education

A premier learning experience
for professionals

4,430 **Postgraduate**

760 **Doctoral**

20,000 **CPD**



- **Come from outside the UK (110+ countries)**
- **Study part-time while in employment**

Global reach

Contents

- Impact of current and upcoming technological advancements on existing maintenance approaches
- Readiness in industries to adapt the future trends in maintenance
- Training and qualifications

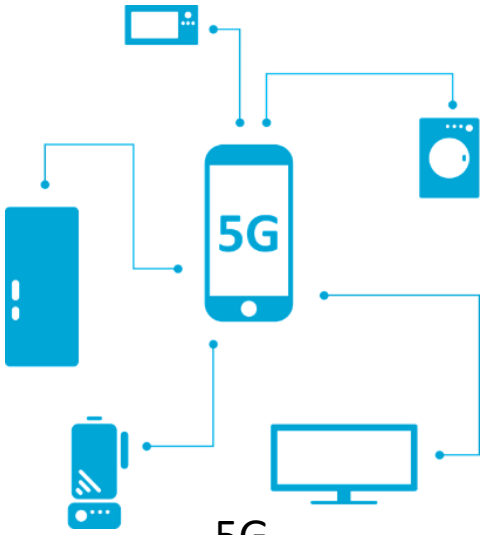
Over to Muhammad

Impact of Technological Advancement on existing Maintenance Approaches

Key technological advancements in discussion or under emphasis for post 2020

Automation

Artificial Intelligence



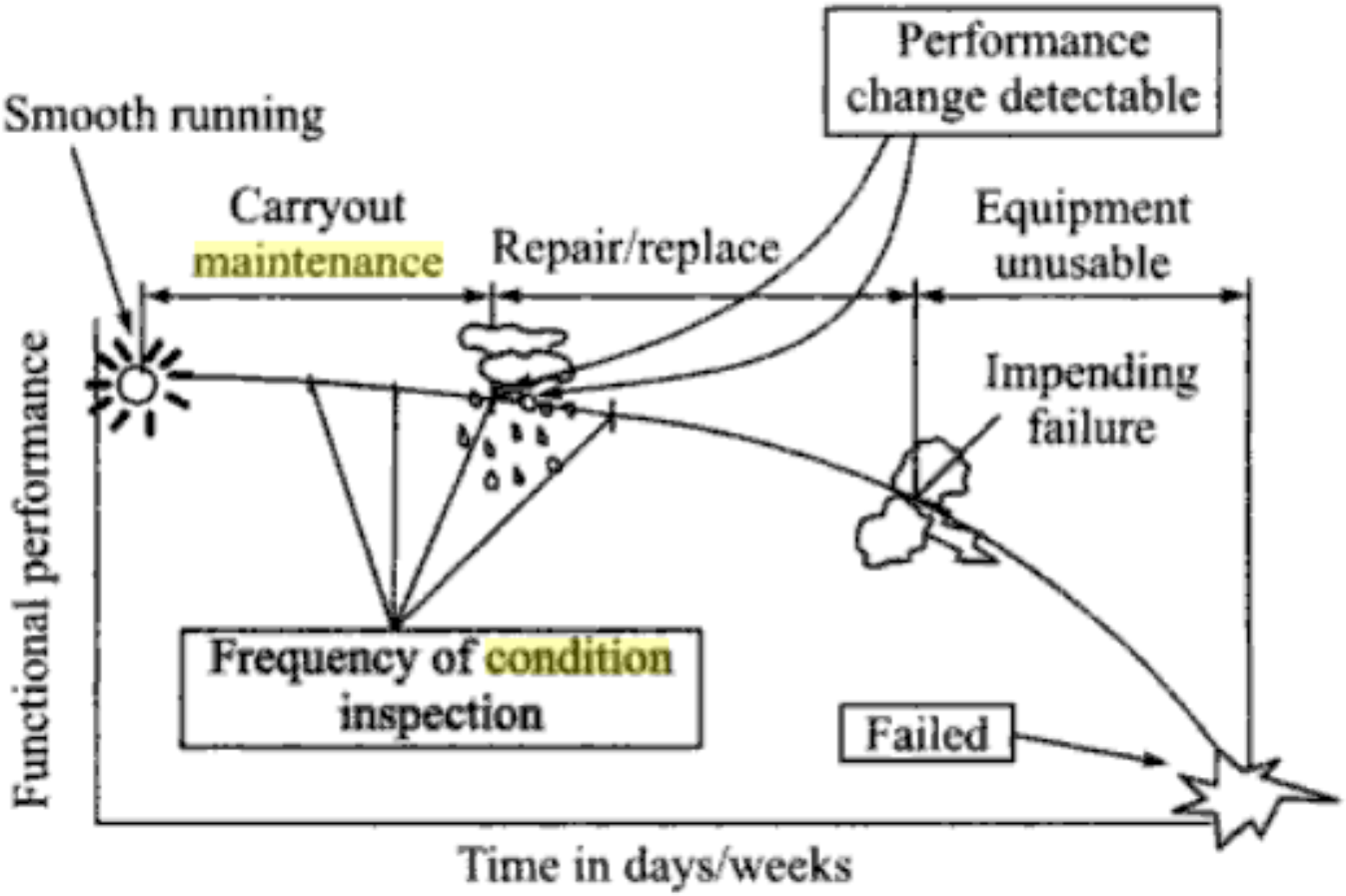
5G

Let just keep these terms for the time being and we will map their impact with maintenance approaches after a few minutes !

Digitization

Existing Maintenance Approaches

Functional performance of an asset vs. time can be thought to identify the required approach of maintenance



Breakdown maintenance (BM)

After the failure has occurred, action is taken to rectify the problem by replacement or repair.

Some consequences may occur.

G-REDL, 2009

Breakdown maintenance (BM)

✓ For

- Planning is simple - the organisation need only adapt to match the failure rate;
- Work is not scheduled until it is really needed;

Breakdown maintenance (BM)

- Against
  - inconvenient breakdowns, e.g. when the plant is at full load, or while it is starting
  - hard to spot component faults, leading to expensive consequential damage
  - large standby breakdown crew
  - large spares inventory

G-REDL, 2009

Planned preventive maintenance

Planned preventive maintenance (PPM)

- based on time elapsed
- based on usage, e.g. running cycles
- carefully calculated intervals based on good data and logistics knowledge and skills

Picture courtesy Bombardier Transportation

Planned preventive maintenance

✓ For

- More effective use of time;
  - Good for resource planning e.g. staff loading and facilities
- Spares are only ordered as required;
  - Better for stores inventory; potential to adopt just-in-time or sub-contract

Picture courtesy Network Rail

Planned preventive maintenance

- Against
  - **Failures still occur**
    - Prior to calculated life
    - Random failures - likely in complex plant
  - Unnecessary maintenance performed before full useful life
  - Unnecessary strip down and changes (e.g. bearings) may cause problems.

Picture courtesy Bombardier Transportation – no endorsement or link implied

Condition Based Maintenance (CBM)

- Maintenance which is triggered by a change in a measured parameter which is indicative of machine condition or *health*.
- This may be a performance indicator, or a diagnostic measurement which gives early warning of deterioration.
- The observation of the indicator is called **condition monitoring**

Picture courtesy Rolls-Royce

Why use CBM?

- ✓ For: Early warning of failure
  - Better planning of repairs is possible, i.e. out of production/running time
  - Avoid inconvenient breakdowns
  - Avoid expensive consequential damage

Picture courtesy Network Rail

Why use CBM?

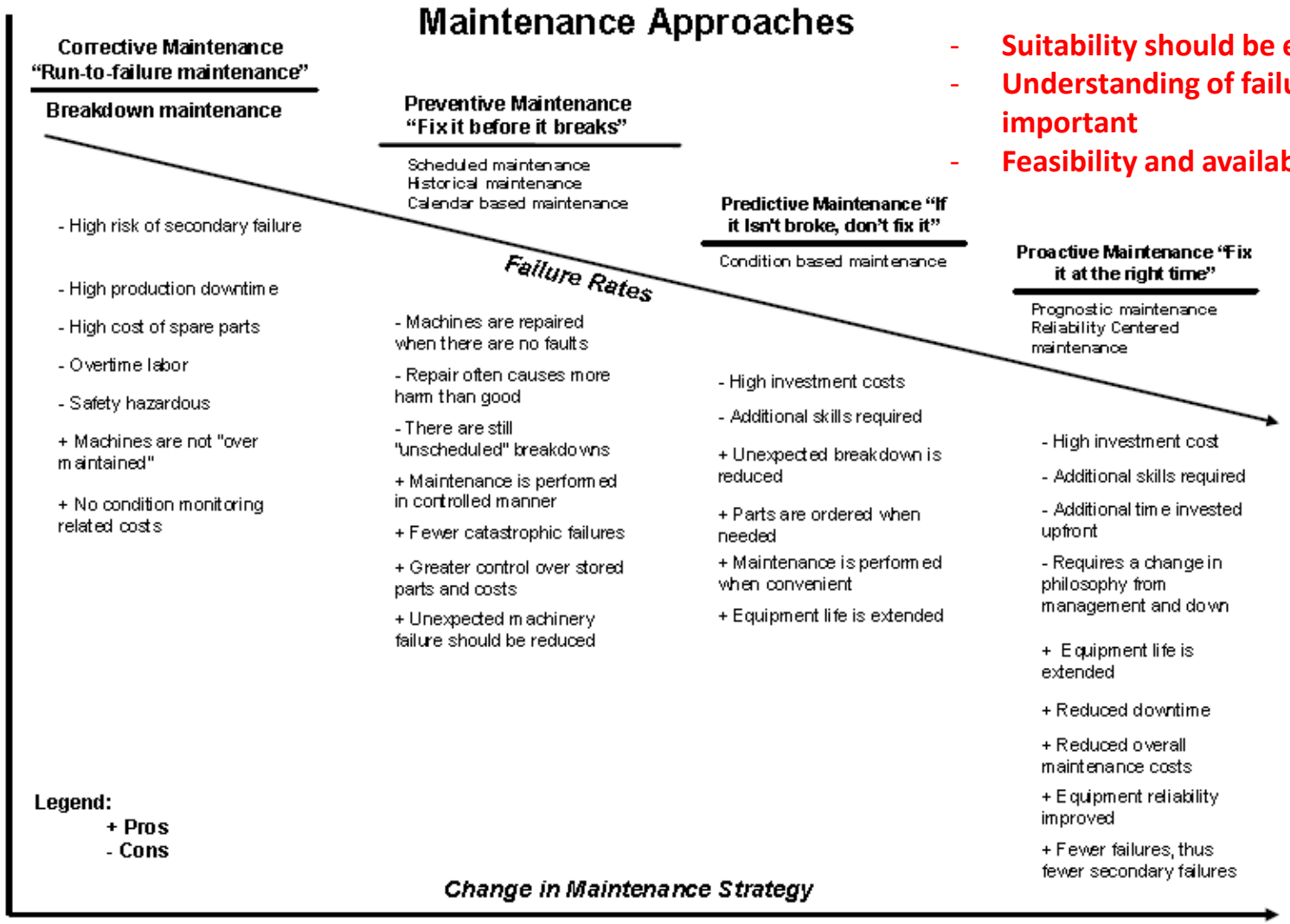
✓ For :

- The failure rate is reduced
  - Less on-line failures
  - better plant availability and reliability
- Reduced spares inventory
- Unnecessary work is avoided
- Use the full life

Rate of Failures and Maintenance Approaches

Which one should be chosen for your Industry ???

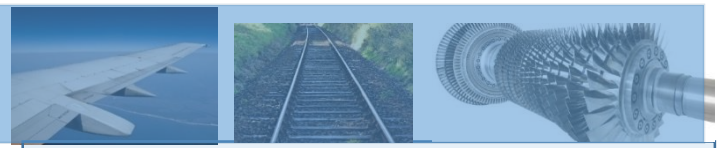
- **Suitability should be evaluated**
- **Understanding of failure is extremely important**
- **Feasibility and availability**



Any idea the terms seen in the start (Automation, AI, 5G and Digitization) will impact which of these approaches????

I think the last two will immensely change. Why?? Let see a conventional framework for them.

A conventional Asset Health Assessment Framework Used in existing Maintenance Approaches



Application: Structures/ machine components

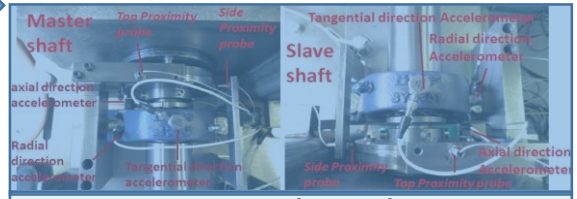
Failure mechanism, Operational loads, Allowance and requirement of sensing

Pool of NDT techniques

Selected NDT

Time domain

Raw data generation



NDT setup on the application

Software tools

Signal processing (Such as FFT or wavelet)

Sample down, de-noise data

Diagnosis parameters selection

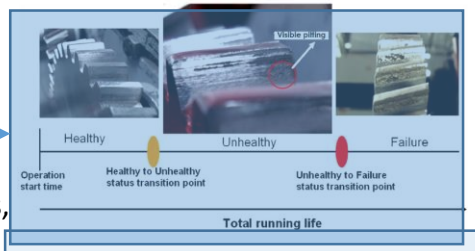
Pool of trend extractor techniques

Curve fittings, rule based, neural networks and others.

Established data repository

Historical data, Design and manufacturing specs and Prior beliefs of damage

RMS Values, envelop frequencies, Other statistical parameters



Diagnosis and Prognosis Module

Healthy or unhealthy
Lead time to failure

Towards a formation of a maintenance routine

Impact of Technological Advancement on NDT

Conventional NDT techniques are now being used with automation, intelligence, digitization and high data communication rates

Cranfield is currently working with an industrial partner to use laser vibrometery on drones for measuring vibration response of structures and machine components

Impact of Technological Advancement on NDT

- Fukushima Decommissioning is planned to be done in 40 years.

- Conventional (manual) NDT inspections are not viable and drones with non contact sensing equipment tools are required to address the challenge of highly radio-active environment.

- Cranfield has discussed possible solutions with Kyoto University Japan.

Fukushima, Japan

Impact of Technological Advancement on Data Processing and Communication

One of the current challenges remote inspections with non contact sensing is the transfer of measured data

Solution in Future …….. 5G

will change the NDT world and hence Maintenance Approaches.

Impact of Technological Advancement on Data Processing and Communication

- Issues of Big Data lead an emphasis on Artificial intelligence based algorithms to get the ideal trend for diagnosis and prognosis.

- Internet of Things (IOT) lead an emphasis on more digitization based cyber security and automation.

- Resolving Challenges with Big and IOT with mentioned tech advancements will change the Maintenance World.

Impact of Technological Advancement Diagnostics and Prognostics

- Digital Twins will change the inputs of Diagnostics and Prognostics module of conventional framework.
- Design and Operational Conditions will be configured in software to predict behaviour.

Impact of Technological Advancement Diagnostics and Prognostics

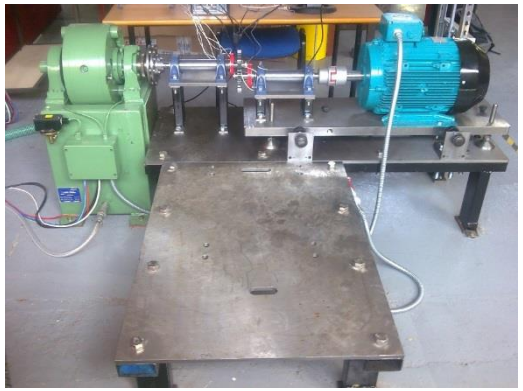
- Challenges of no historical data due to new design or failure conditions can be resolved more conveniently with digital twin as compare to 10 years ago.
- Data transfer and near real diagnosis are the biggest challenges to make practically a viable digital model for a maintenance routine.

- Cranfield MOD work for new failure conditions.

- Combined Misalignments were required to test the failure.

- Developed a customized test rig 10 years ago.

- But things can be revolutionized in with digital models to do real time diagnosis for real assets



Not the actual gear! But has the similar problem

Results: Transmission failure

Mapping of Maintenance Approaches

Automation

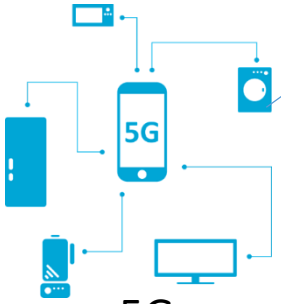
Can use automatic vehicle to troubleshoot the location of breakdown

Automatic Repair technologies can impact this approach such as Augmented Reality based Repair

Breakdown Maintenance

Artificial Intelligence

Perhaps no direct impact on maintenance routine



5G

Perhaps no direct impact on maintenance routine

Perhaps no direct impact on maintenance routine

Digitization

Mapping of Maintenance Approaches

Can use automatic vehicle to troubleshoot the location of unscheduled/sudden breakdown

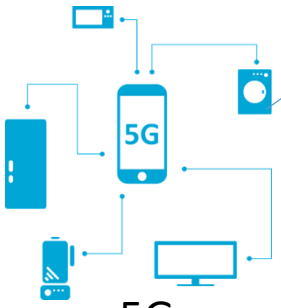
Automation

Automatic Repair and Replacement technologies can impact this approach such as Augmented Reality based Repair and Replacement

Preventive Maintenance

Artificial Intelligence

Perhaps no direct impact on maintenance routine



5G

Perhaps no direct impact on maintenance routine

Perhaps no direct impact on maintenance routine

Digitization

Mapping of Maintenance Approaches

Can use automatic vehicle to troubleshoot the location of sudden breakdown

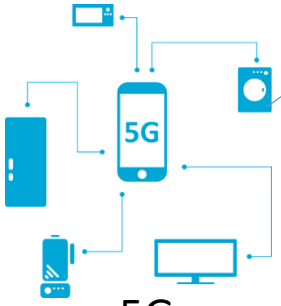
Automation

- Automatic inspection
- Automatic Repair and Replacement technologies
- Non contact based sensing will be the future

Predictive and Proactive Maintenance

Artificial Intelligence

- Tackle the issues of big data to do near real time diagnostics.
- Prognostics will be made by using AI based digital models to predict the behaviour based on design and operational specifications



5G

Will enhance the ability of data communication during Sensing, Inspection, Repair and Replacement

Will impact the diagnostics and prognostics inputs with the help of features like digital twins and non contact based digital sensing

Digitization

Readiness in industries to adapt the future trends in Maintenance

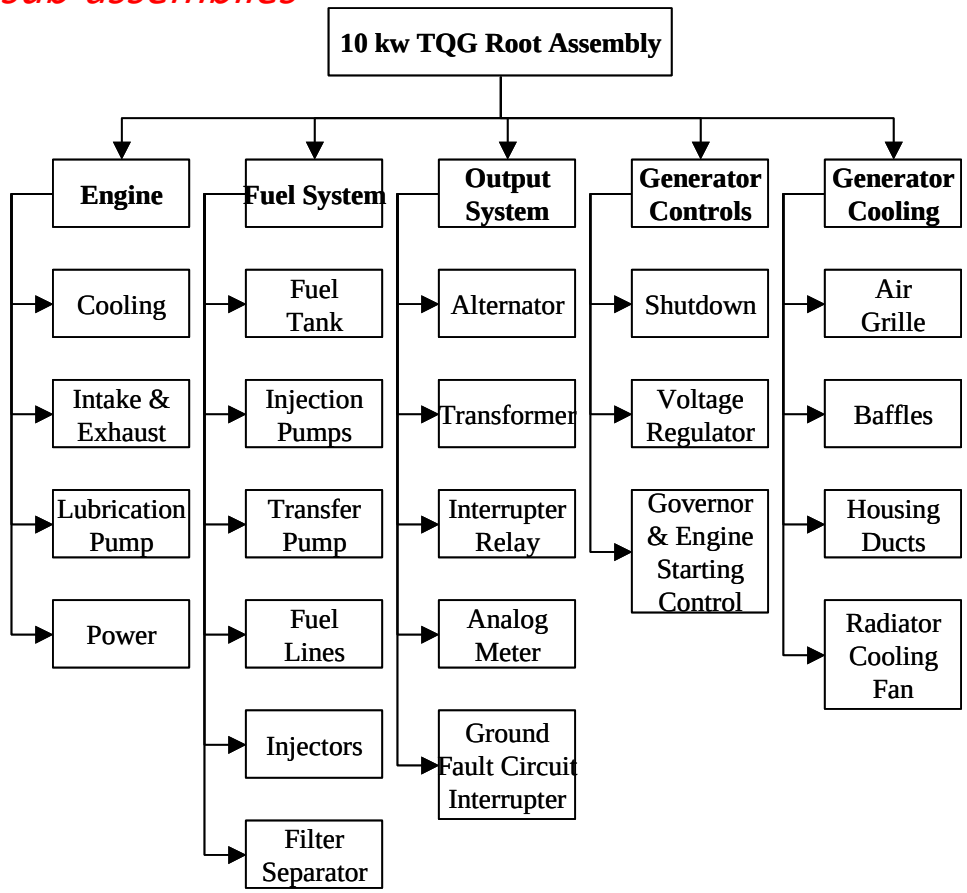
Key elements in industrial adaptability

- Staff responsible to devise and execute the maintenance approach
- OEM specifications
- Factors to consider in Suitability Identification

Let’s start in the reverse order to discuss these elements

Factors to consider in Suitability Identification

Complexity of assemblies and sub-assemblies



Military generators

S.No	Description of Equipment
1	Turbocharger (A & B)
2	Air cooler assembly
3	Fuel injection pump
4	Fuel injector
5	Cylinder head
6	Cylinder exhaust temp sensor
7	Electronic governor
8	Lube oil cooler
9	Lube oil self cleaned filter
10	L.O. thermostatic valve
11	Engine Starting air valve
12	Timing gear
13	Crankshaft
14	Piston / Connecting rod assambly
15	Cylinder Liner
16	Flywheel
17	Highly flexible coupling (LS3420G type)
18	Intermediate support bearing (ZZ320 Type)

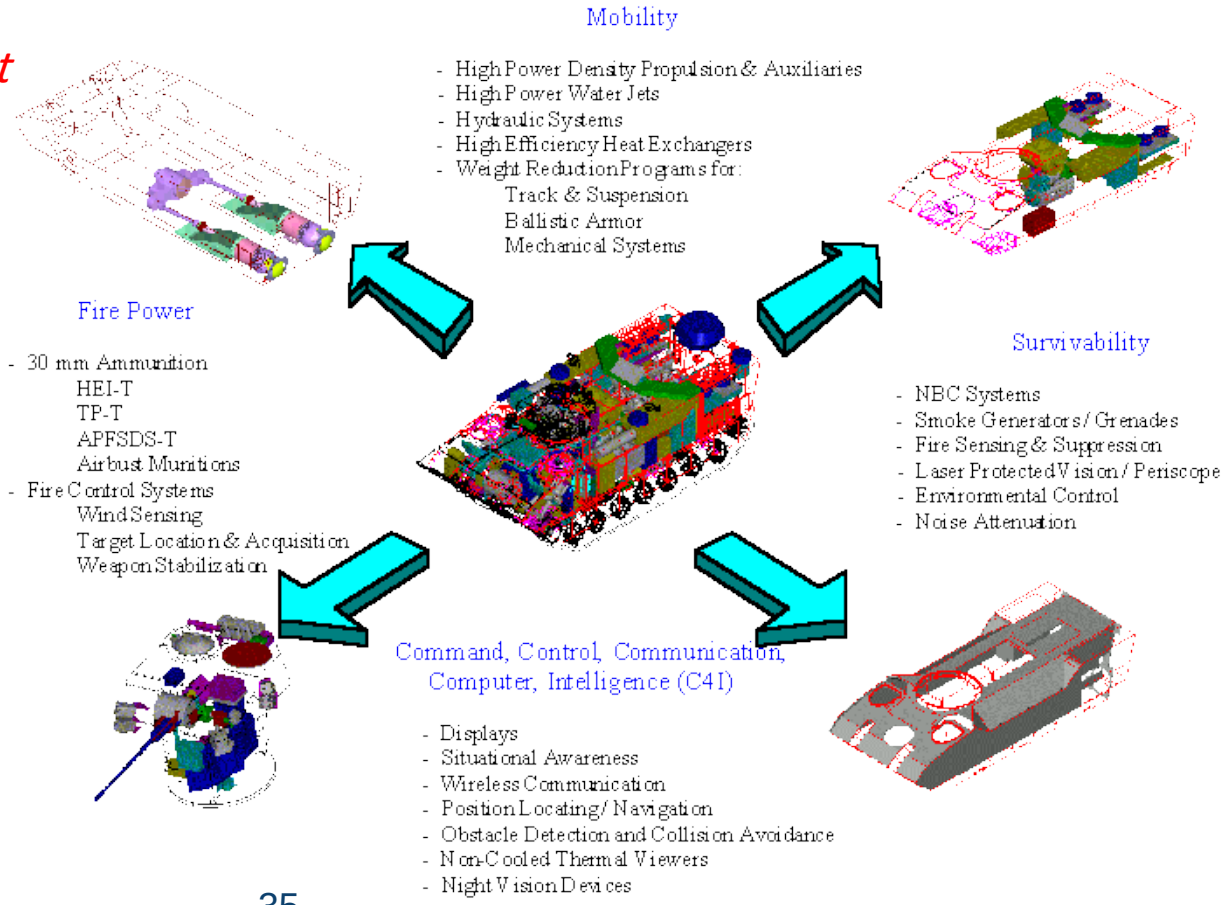
Ship propulsion system: 60 assemblies/subassemblies are identified having maintenance routines

Factors to consider in Suitability Identification

Declare something as failed has different dynamics

Working on FUMS of USMC EFV:

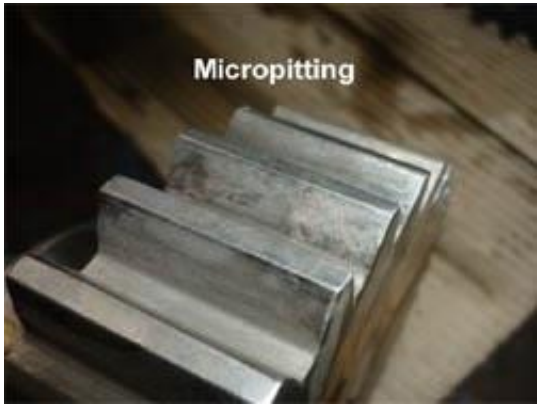
Turret Example while making Fault algorithm



Factors to consider in Suitability Identification

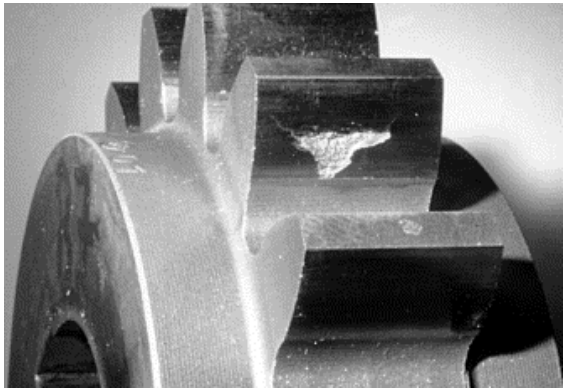
Declare something as failed has different dynamics

- *Lets see the teeth of two gears and guess which one is definitely failed.*



Located in aerospace transmission

As per BS-ISO standard 6336, a pit of 1mm or cumulative as a definite failure of gear



Mounted in a manual sugar cane machine.

Until the machine operates fine; no replacement

Depends on application

Factors to consider in Suitability Identification

Feasibility and Availability

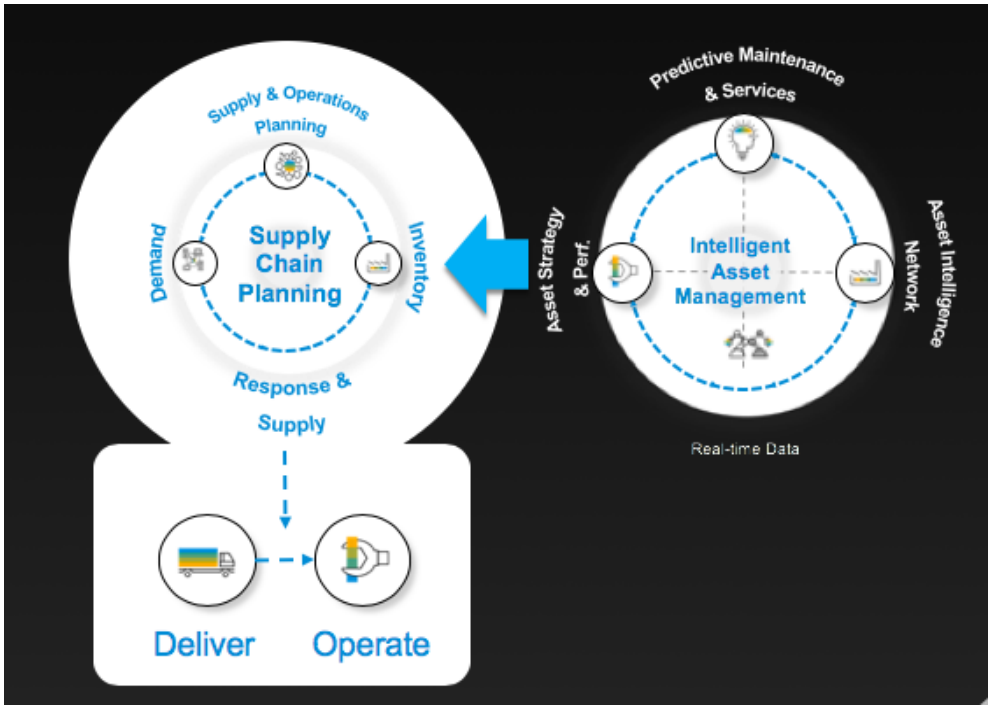
MOD Condition Monitoring Technology Assessment study

Product	Manufacturer	Type	COTS product TRL	Diagnostic abilities / Possible decision type	Raw data type/ data connector and interpretation source	Complexity in required electronic harnessing (if any)	Complexity in retrofitting (if any)
Laser net fines	Lockheed Martin/ Spectro	Offline	9	Failure mode and severity, surface degradation/ Preventive	Oil debris images/Hard ware USB/ Dedicated Software to interpret	Not complex, workable with vehicle battery power, connectors required	Can work online but may involve complex retrofitting
Portable oil debris analyser	Khan et al (Journal of Industrial lubrication and Tribology. Vol67 (4), 2015.)	Offline	6	Failure mode, severity, surface degradation, wear source, predictive	Oil debris images/Hard ware USB dedicated software to interpret (with user friendly GUI)	Not complex, workable with Vehicle battery power connectors required	Can work online but may involve complex retrofitting
Pulsed electric chip detector	EATON	Inline/online	9	Large debris indicator	Light is illuminated on large size	Not complex, power module can get power from power switches run by battery	Need retrofitting with careful thought on flowrate

Factors to consider in Suitability Identification

Supply Chain and Inventory Problems

- Own site challenges
- Specially geo-political logistics situation
- You may imagine it can effect the maintenance routine and approach



All these factors needs subject matter experts.... Do we have them in industries????

OEM Specifications

- Always very useful but at a cost.
- Perhaps end in servicing contract with OEM to run operation smoothly.
- Developing world and Small and Medium Size industries more likely not to sustain expensive servicing in long terms.
- Maintenance approach is dictated perhaps not feasible for the working environment of the consumer
- Example: Shell Power Plant at Aberdeen.

Maintenance Management Personnel

- Scope of responsibilities of Maintenance Management Personnel makes their selection always challenging.

- Scope can not be fit in a single discipline such as Science, Engineering, Arts and Philosophy (Mobley)

- Almost impossible to find a staff equally qualified in all these disciplines.

- Selection is mostly rely on similar kind of experience.

- But Experience demonstrates: How to work with OEM based specs without the consideration of local challenges and environment.

Maintenance Management Personnel

- Spectrum of maintenance scope will be changed due to discussed future trends.

- Industries require Maintenance Personnel who are qualified academically with hand's on skills and can transform the existing industrial culture of OEM recommended maintenance to cost-effective and technically advance maintenance

- Academic and Training routes for such personnel will be discussed by Andrew next.

Training and qualifications

Leadership in asset management

- Direction for the **business**
  - Why is maintenance influential?
  - Understanding the impact
- Direction for **people**
  - Making the changes happen
- Direction for **assets** and **technology**
  - Setting the future agenda
- **Fusion** of business and technology

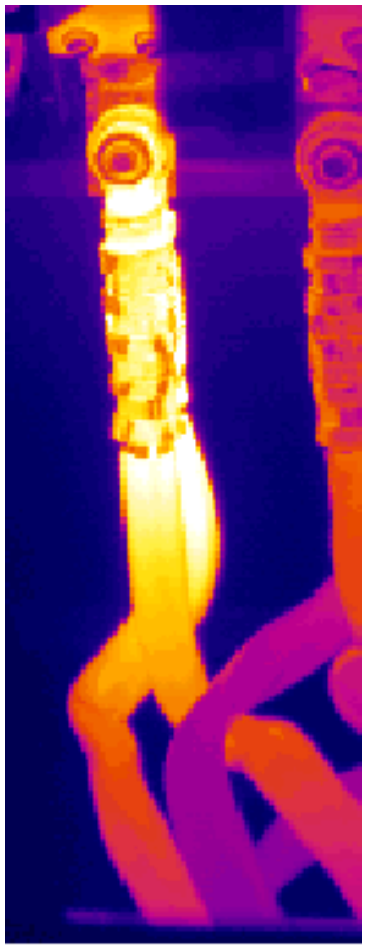
What is Leadership?

- The dignity, office or position of a leader
- Ability to lead
- Position or function of leading*
- Providing direction: rather than *driving*
- Going in front; setting an example
- To occupy the front place: be foremost

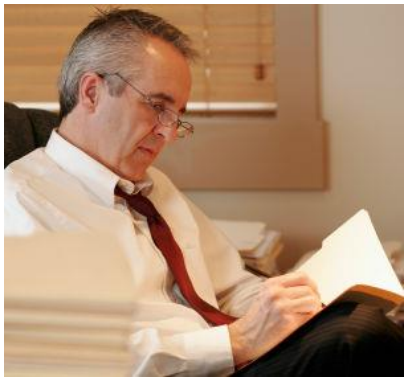
* (ca1570; OED)

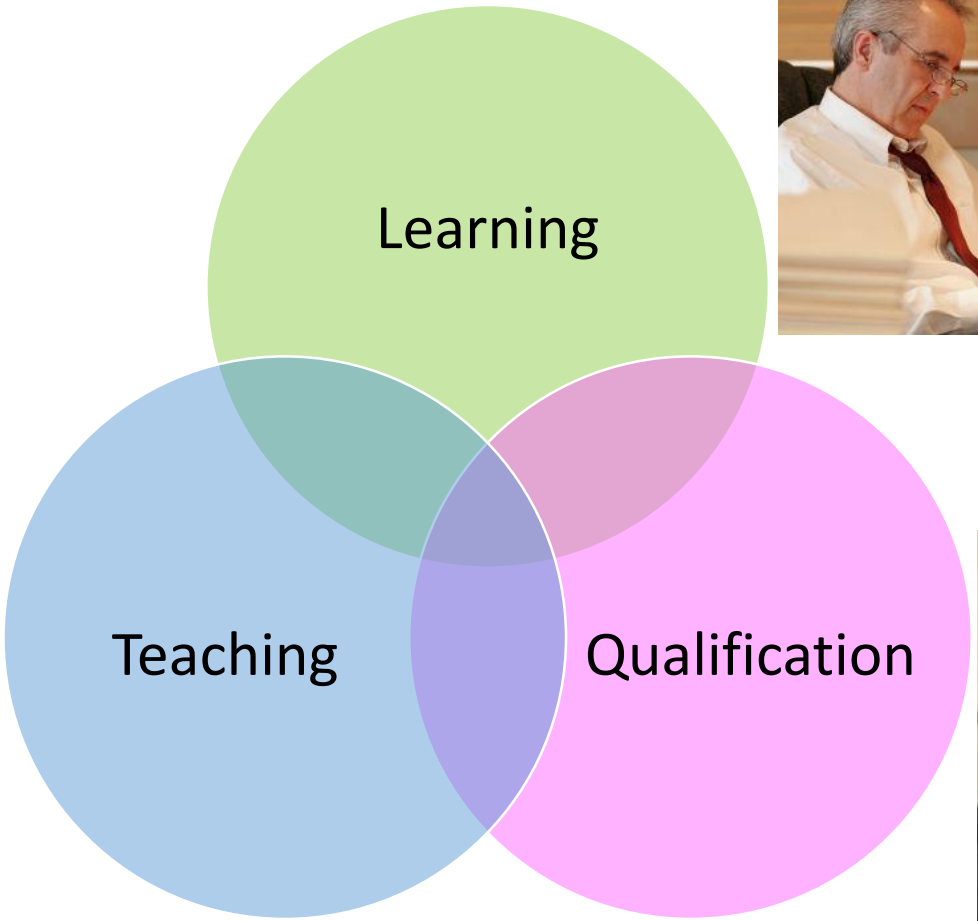
Leadership development

- Improving capacity to lead
- Finding the ways to achieve high performance
- Testing future options and risks:
    - For organisation and individuals
    - For technology
    - For financial success



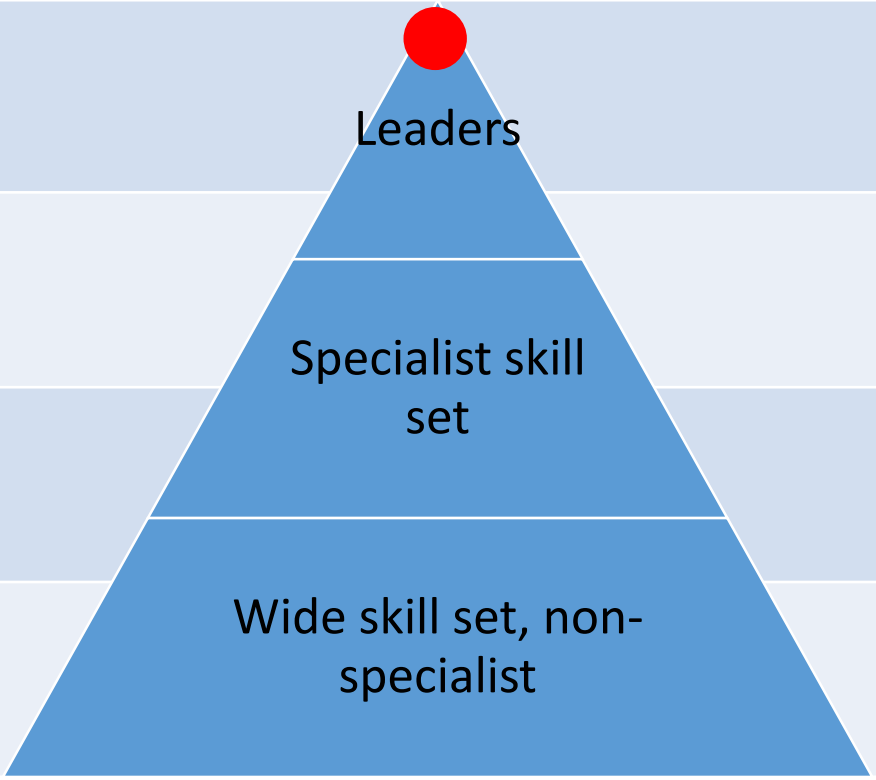
Education





Levels for leaders?

	Technical	Business
Postgraduate		
Degree		
College		
School		



Accredited bachelor degrees include…

commercial and economic context

systems approach

environment

performance

sustainability

management techniques

Problem solving

Cost drivers

Risk assessment

egal framework

IP and contracts

Uncertainty

Health & safety

Codes of practice and standards

QUALITY

but...

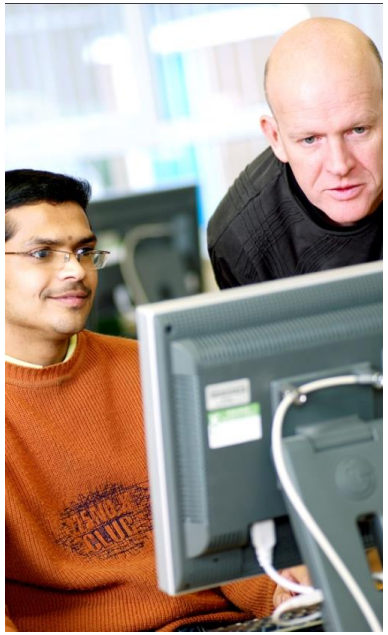
"... graduates in engineering sciences are largely ignorant of the in-service support arena ...

... we are completely lacking a pipeline of talent with pre-existing knowledge and skills …"

Rolls-Royce

Training is important…

- Updating
  - Standards
  - Systems
  - Technologies
- Skills
- Knowledge
- Compliance



Qualifications offer more

- Recognition
- License to practise
- Reward

- Professional certification e.g.
  - Chartership
  - Standards training
  - Professional societies e.g. EFNMS Certified Expert, or IAM Diploma

- Postgraduate qualifications
  - Certificate
  - Diploma
  - Masters
  - Doctorate

Apprenticeships

UK Apprenticeship levy

- Employers with a salary bill over £3m (€3.4m, $3.8m) each year must pay apprenticeship levy of 0.5% to UK Treasury from 6 April 2017
- £2.2bn budget 2018-19
- Funds in the “apprenticeship service account” can only be used to pay for apprenticeship training
- All apprentice levels eligible – from junior to postgraduate (level 2-8)
- Training/education provider bills UK Treasury via Department for Education
- Use it or lose it – 24 month expiry.

Institute for Apprenticeships & Technical Education

› Apprenticeship standards

Subscribe to our Standards RSS Feed

SEARCH THE APPRENTICESHIP STANDARDS

Filter the results

Keywords

If you wish to see all apprenticeships available (including frameworks) use the apprenticeship finder or find apprenticeship training tools provided by ESFA.

Systems thinking practitioner — ST0787

In development | Level 7 | 30 months

Current status

☑ Proposal ☑ Standard ☐ Assessment plan

Technical specialist in nuclear engineering, science or technology

Proposal in development | Level 8

A proposal to develop an apprenticeship standard for this occupation is currently being worked on

Through life engineering services specialist (degree) — ST0740

Approved for delivery from 21 Aug 2019 | Level 7 | 24 months | Max funding: £17000

Develop and deliver the support services that keep engineered assets working better and for longer

506 approved to date, 155 more in development

Aims of the courses

- Foundation for future leaders for change in asset and maintenance management
- Maximise the value in service of complex, long-life product systems
- Understand the benefits of management and technical advances

New titles

MSc Maintenance Engineering and Asset Management

- Intended for the international market
- For both fresh graduates and industrial personnel

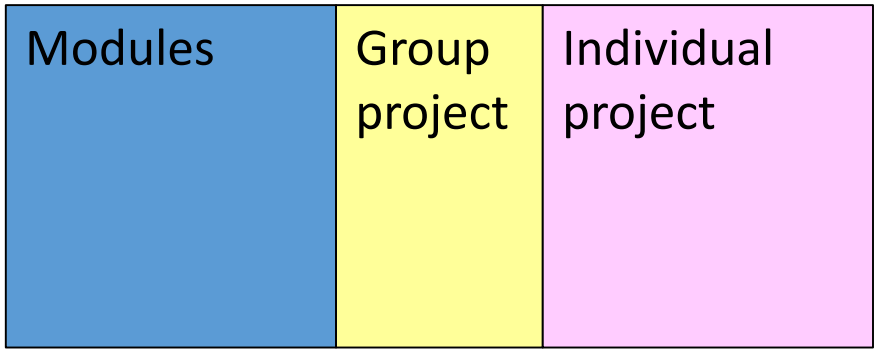
MSc Through-life Systems Sustainment

- Apprenticeship version for the UK employed professional
- Open version for the international market
- For candidates with 3-10 years experience

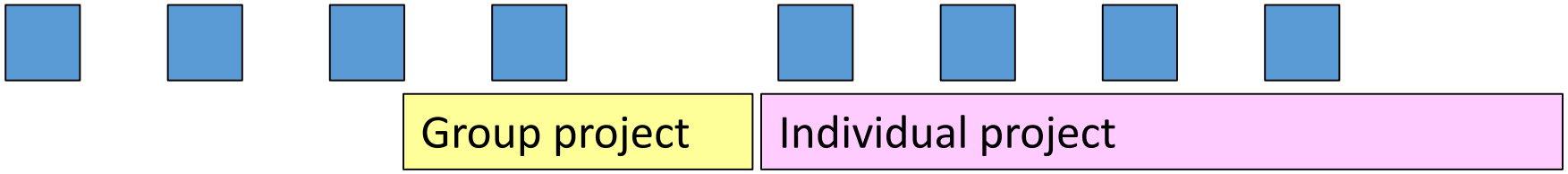
Structure

- 2-3 years part time
- 8 taught modules
  - Each an intensive 1-week programme
    - also available as short courses
  - 40% credits
- Group project
  - Real project for industry
  - 20% credits
- Individual project and thesis
  - 40% credits
  - Company or university based
- Assessed by examination and relevant course work

Modes of study



Full-time study (usually one year)



Part-time study (usually 2 years)

Overall 200 credits – ca 2000 hours study

UK 2016-17: 96,465 entrants studying eligible* masters' courses (* for loans)
Source: Office for Students

MSc Maintenance Engineering and Asset Management

Aims

- Fulfil the need of the industry by devising a postgraduate (PG) level course that can produce qualified personnel capable of implementing the fundamental and the advanced maintenance skills and strategies.

- Graduates can transform the existing industrial culture of OEM recommended maintenance to a cost-effective suitable maintenance.

- Provide skills with the consideration of future technological trends

MSc Maintenance Engineering and Asset Management

Modules

- Fundamentals of Maintenance
- System Availability and Maintainability
- Failure of Materials and Structures
- Condition Based Maintenance
- Maintenance Planning and Control
- Asset Management
- Diagnostics and Prognostics
- Probability and Statistics in Risk and Reliability Engineering

Academic teaching is blended with hand's on lab sessions

Aims, teaching content and delivery make this course different from other courses offered globally

See details on www.cranfield.ac.uk/meam

MSc Through-life Systems Sustainment

Modules

- Managing Assets and Value
- System Effectiveness
- Leadership and Change Management
- Optimising Whole Life Cost and Performance Management
- Operational Availability and Risk
- Through-Life Business Models and Servitisation
- Information Management
- Diagnostics and Prognostics

Projects

- Group projects – examples
  - Life cycle cost models
  - Knowledge base for deterioration mechanisms
  - Diagnostics and prognostics technology to reduce total through-life costs in complex systems
- Individual projects – examples
  - Extension analysis of the Victoria Line rolling stock base maintenance interval
  - Analysis of corporate customer requirements
  - Intelligent maintenance workscopes for military gas turbine engines
  - Investigation of root cause of no-fault-found unit removals in civil aviation, and the effectiveness of treatment options

Project assessment

- Group projects (40 credits)
  - Presentation at seminar for delegates and sponsors – often at a company location
  - Report
  - Individual learning reflection
- Individual projects (80 credits)
  - Thesis
  - Poster
  - Viva examination & defence

Who attends our courses?

- Industrially sponsored graduates
- Experienced people who contribute to the course
- Good degree (or equivalent)

"The course is well structured, intense and enjoyable. Cranfield University academics are supported by industry experts and this mix of teaching styles works for me. In the day job it would take many years to gain the same depth and breadth of topic understanding that we will enjoy after our two years of study."

Jonathan Neal MIMMM CEng MA(Cantab.), MSc
Capability Development Manager, Engineering for Services, Rolls-Royce plc

Alumni - where are they now?

- CG – Asset maintenance manager, Tonolli, Canada
- PG – Asset management champion, Gatwick Airport
- DG – Consulting partner, Pragma Acuity
- BEI – Chairman of the Icelandic Maintenance Association
- RM – Professor, Indonesia
- AM – Business owner, Pragmatic Maintenance & Reliability
- KO – Head of Maersk Drilling Maintenance Support

Benefits for employers

- Creating future leaders
  - focussed staff development and coaching
- Building a network of professionals
- Working with the day job
  - flexible start dates and progress
  - modules focused on one week each
- Relevant course works and projects – quick payback
  - sponsors nominate the topics
  - projects conducted in the workplace

Conclusions

- Asset management needs leadership and building of capacity
- Professionals in asset management need:
  - postgraduate qualifications
  - a network of peers
- Apprenticeships have motivated employers
- Courses must be relevant and accessible

Thanks for listening

Professor Andrew Starr

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