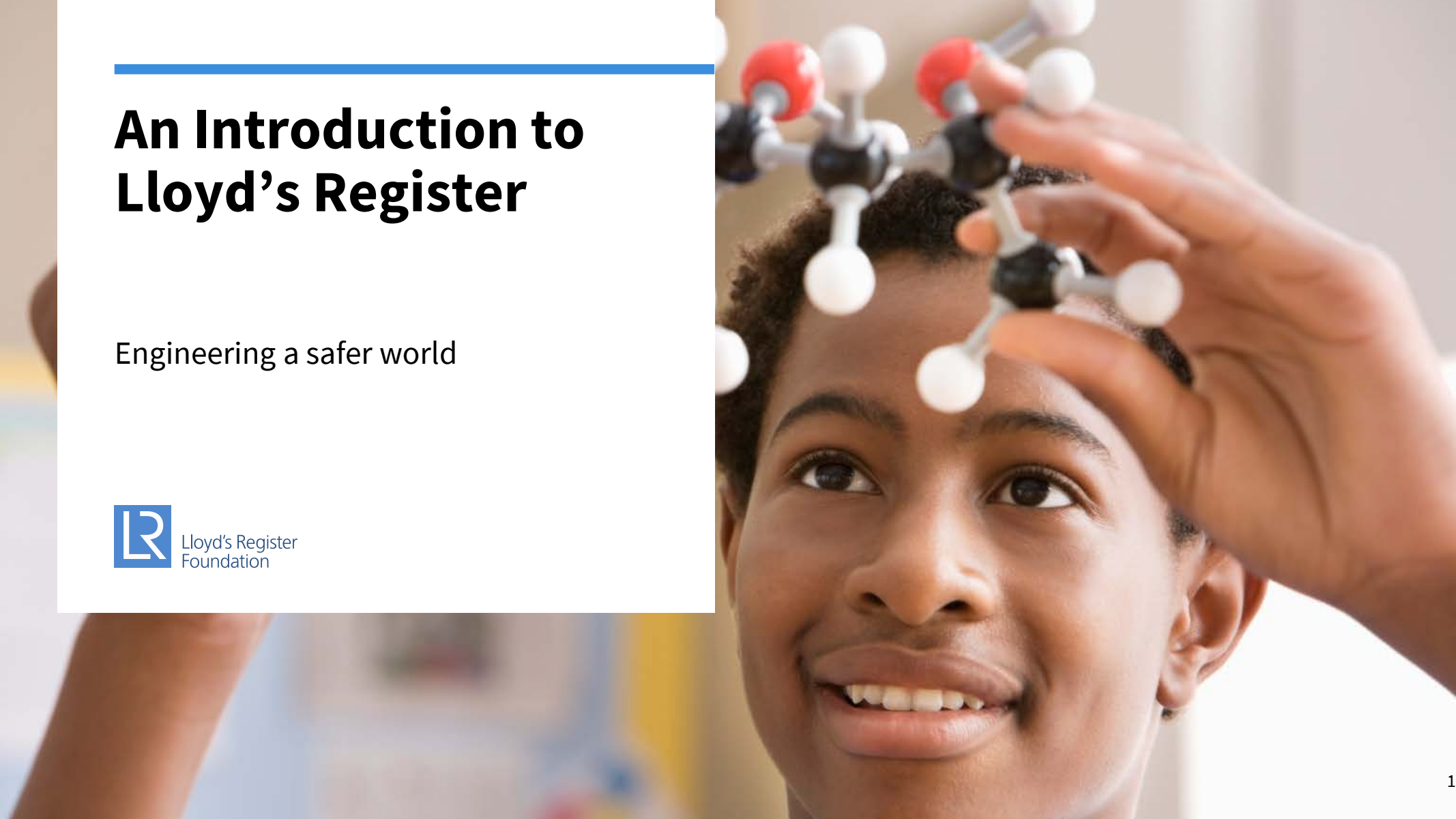
An Introduction to Lloyd's Register

Engineering a safer world

Lloyd's Register Foundation



How we started

Our heritage is genuinely historic

- Formed in 1760 in Edward Lloyd's coffee house to examine and 'classify' merchant ships according to their condition.
- We have over 250 years of global marine history
- The world's first ship classification society and this remains our core activity today.

…and more than 100 years serving other industries across society from energy and food safety to power and manufacturing.

Heritage an important part of our culture and forward-thinking approach to our business

Making a real difference.

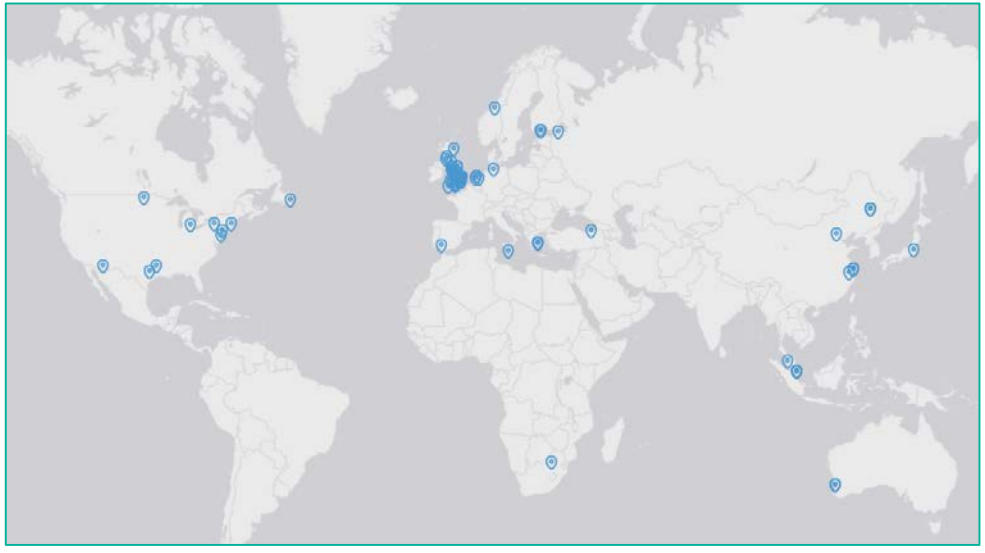
Critical infrastructure is vital to modern society.

Lloyd's Register Foundation is an independent **global charity** that helps to protect life and property at sea, on land, and in the air.

To do this, we support **education**, engineering-related **research, public engagement**, and promote **scientific excellence**.

Supporting global excellence

£120m	Total grants portfolio (July 2018)
85	Active grants
29	Countries
260	Publications by our grants community 2016
2.64 m	People engaged through our grants programme in 2016
4,525	Printed and digital copies of our Foresight Review distributed in 16/17



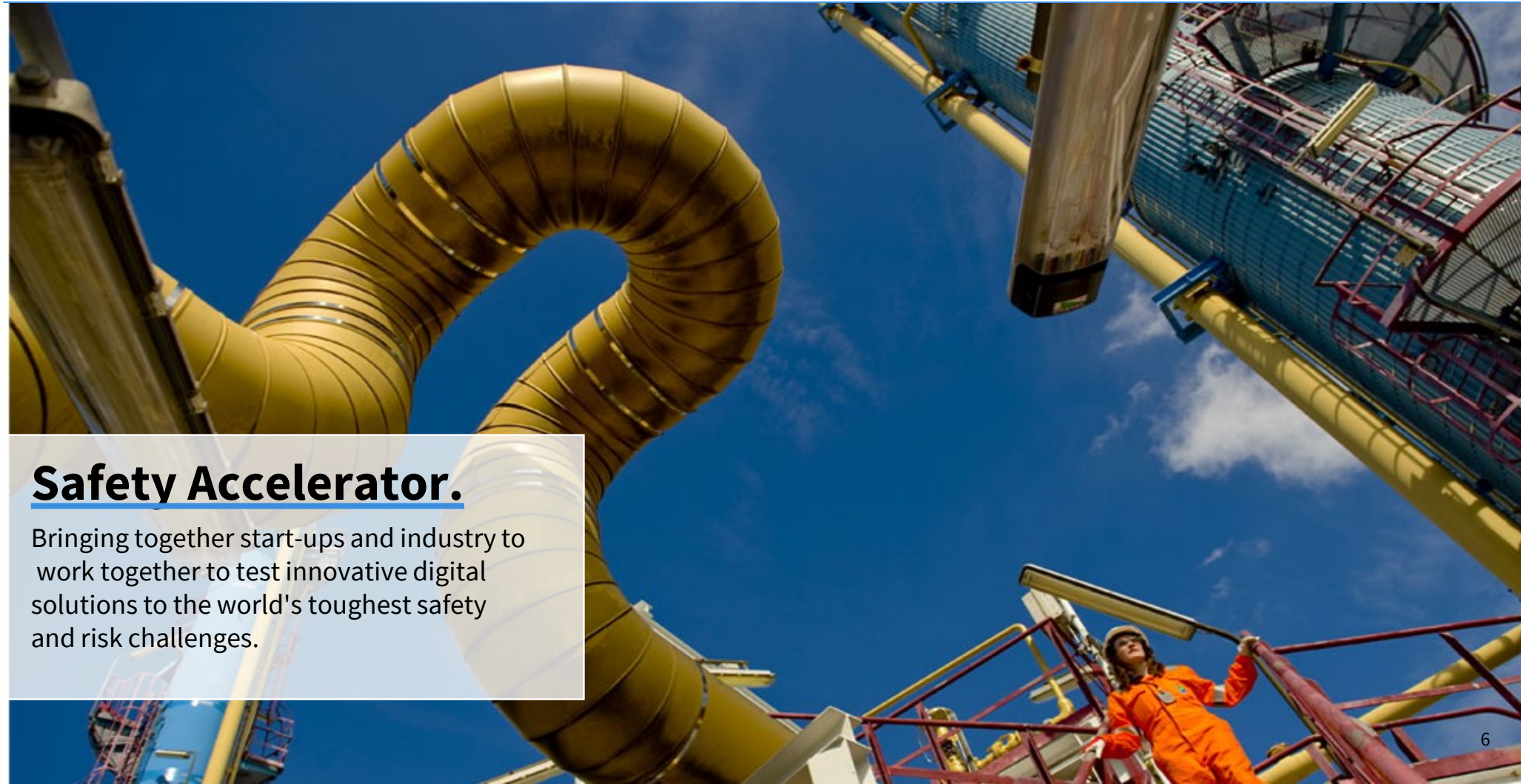
International reach of Foundation grants

Did you know?

Blockchain Labs.

Exploring how these technologies can transform the assurance and safety of shipping's critical infrastructure, and drive new business models.

Did you know?



Safety Accelerator.

Bringing together start-ups and industry to work together to test innovative digital solutions to the world's toughest safety and risk challenges.

Did you know?

MX3D bridge.

World’s first 3D printed bridge becomes a ‘living laboratory’ for research with a vast sensor network.

Did you know?

HiLo.

A predictive mathematical model using data to identify risk patterns to avoid major marine casualties.

Did you know..?

Autonomous shipping.

Joint Foundation and University of York £12m partnership programme announced, looking at the safety of robotics and autonomous systems (RAS).

Evolution of Maintenance Technology & LR's Digital Compliance Framework

Emmanuel Vergetis
Senior Consultant Marine & Offshore
South Europe

Lloyd's Register

SNAME Greek Section
Athens April 10th 2019

Contents

1. Background
2. Evolution of Maintenance Technology
3. Roadmap to Systems Effectiveness & Maintenance Optimisation
4. Digital Health Management
5. LR Digital Compliance Framework

The Industry 4.0, revolution

> ***We stand on the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to one another.*** *In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before.*

1784
Steam Power
Mechanical
Production

1870
Electricity
Mass Production

1969
Electronics
Automated
Production

Today
Cloud
IoT
Digital

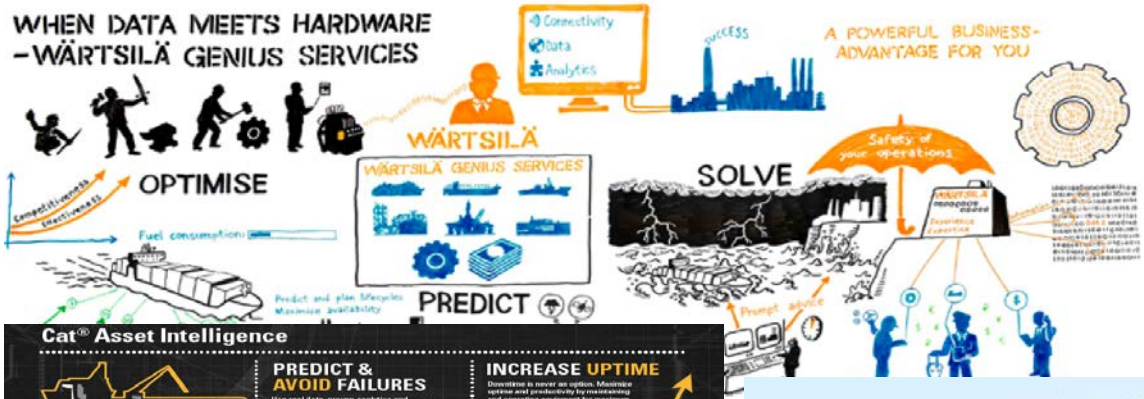
> *The First Industrial Revolution used water and steam power to mechanize production. The Second used electric power to create mass production. The Third used electronics and information technology to automate production.* ***Now a Fourth Industrial Revolution is building on the Third, the digital revolution that has been occurring since the middle of the last century.*** *It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres.*

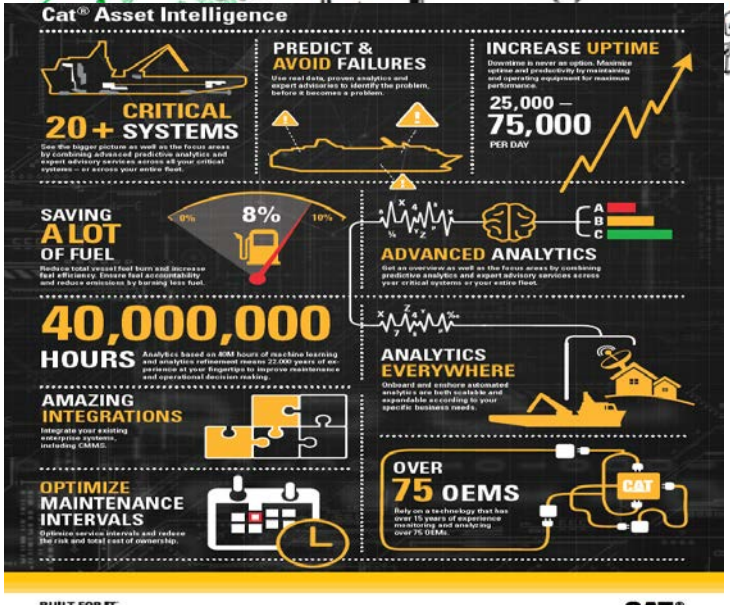
- **Klaus Schwab**, Founder & Executive Chairman, World Economic Forum

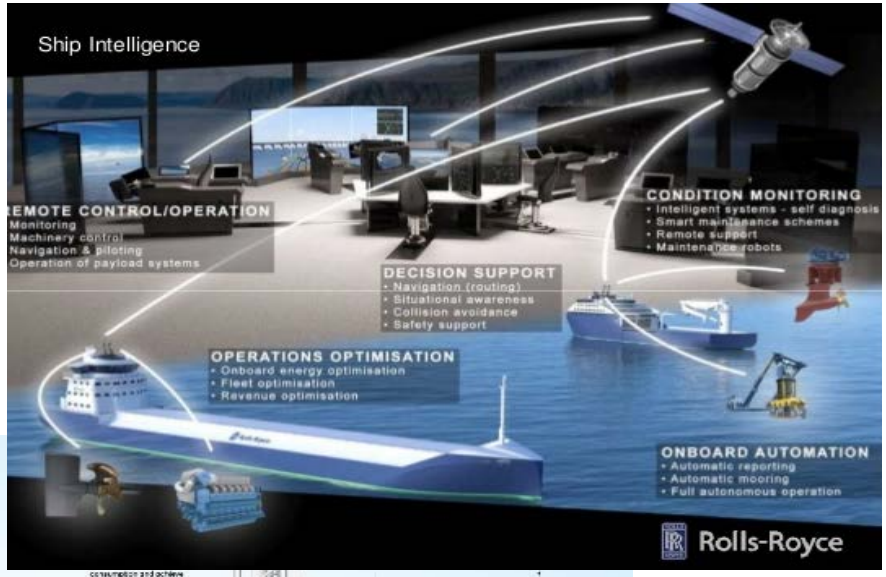
THE PERFECT STORM

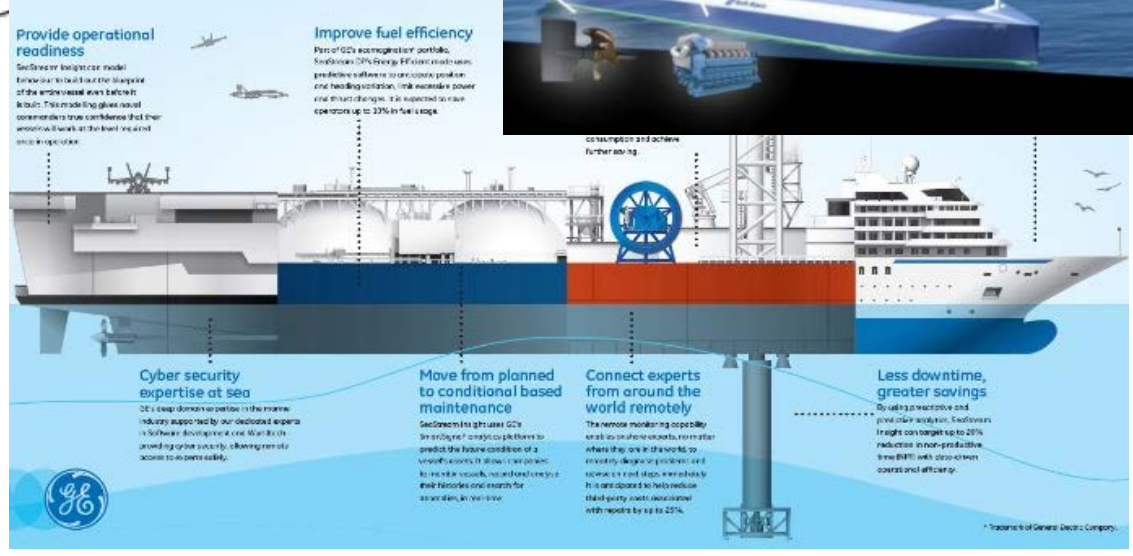
Periodic, Discrete, Time Based is being Disrupted

….to opportunistic, just-in-time maintenance



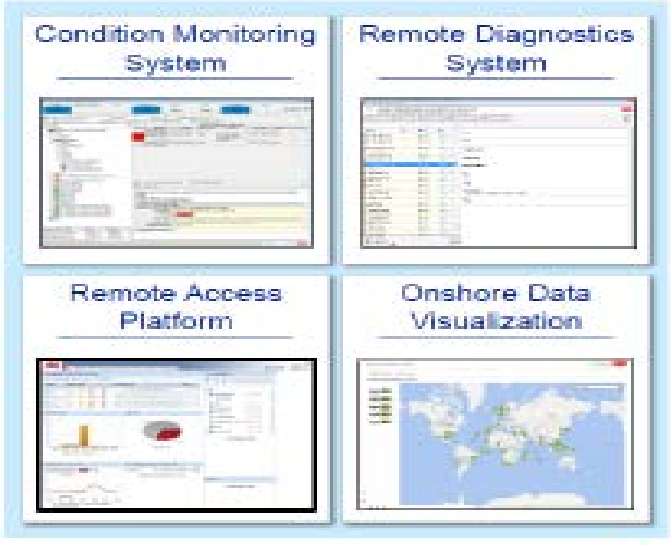






Periodic, Discrete, Time Based is being Disrupted

ABB Ability

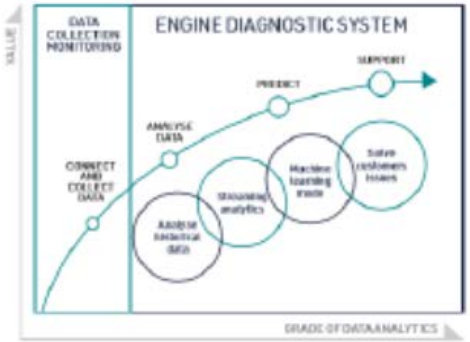


Win GD Integrated Digital Expert (WIDE)

WiDE

DATA COLLECTION AND MONITORING
ENGINE DIAGNOSTIC SYSTEM
REMOTE SUPPORT

WiDE is a comprehensive, integrated system for creating value from engine and ship data. WiDE allows the collection and analysis of ship and machinery data to predict component malfunctions, and support with live troubleshooting and diagnostic advice to the crew.



WiDE is based on the Data Collection Monitoring (DCM) unit for collecting and visualising the engine and ship data, as well as the Engine Diagnostic System (EDS) software. It analyses the data and creates valuable information.

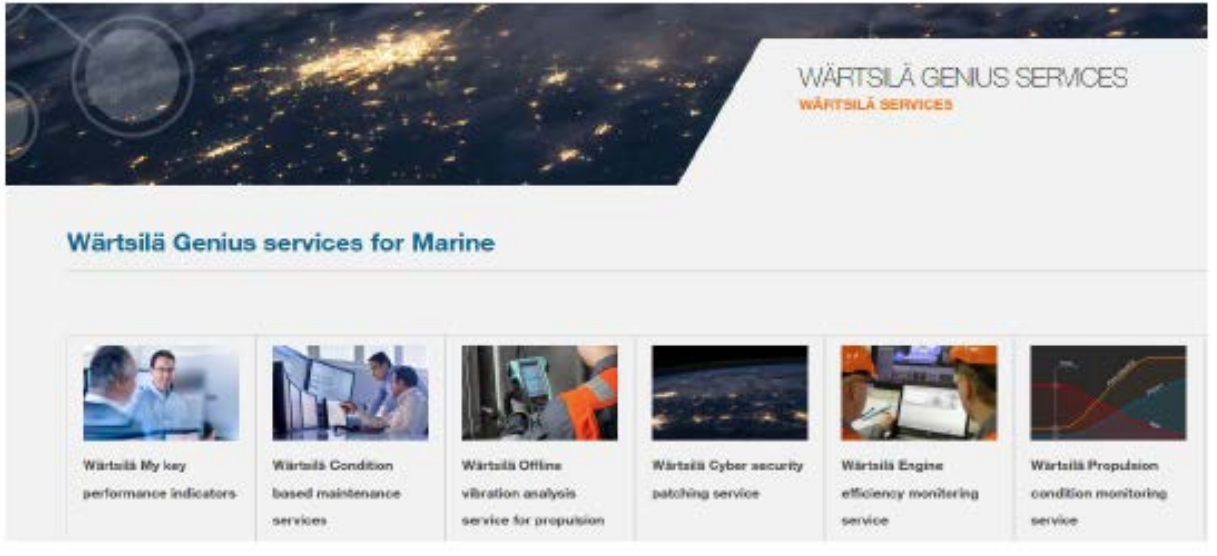
These capabilities are integrated into a user-friendly on-board system comprising state-of-the-art hardware, expert software, and efficient data analytics techniques.

Lloyd's Register

Periodic, Discrete, Time Based is being Disrupted

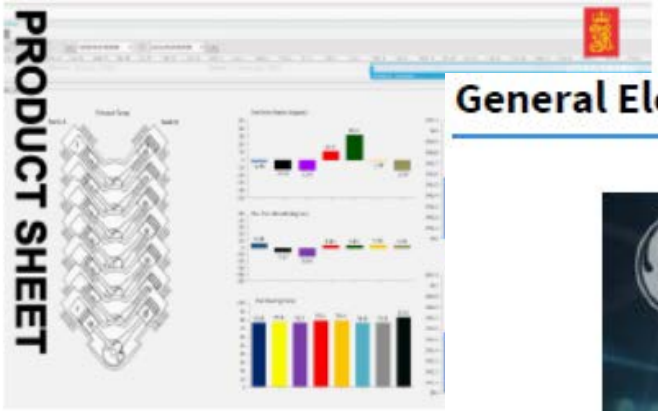
Cummins Connected Diagnostics

Wartsila Genius



Periodic, Discrete, Time Based is being Disrupted

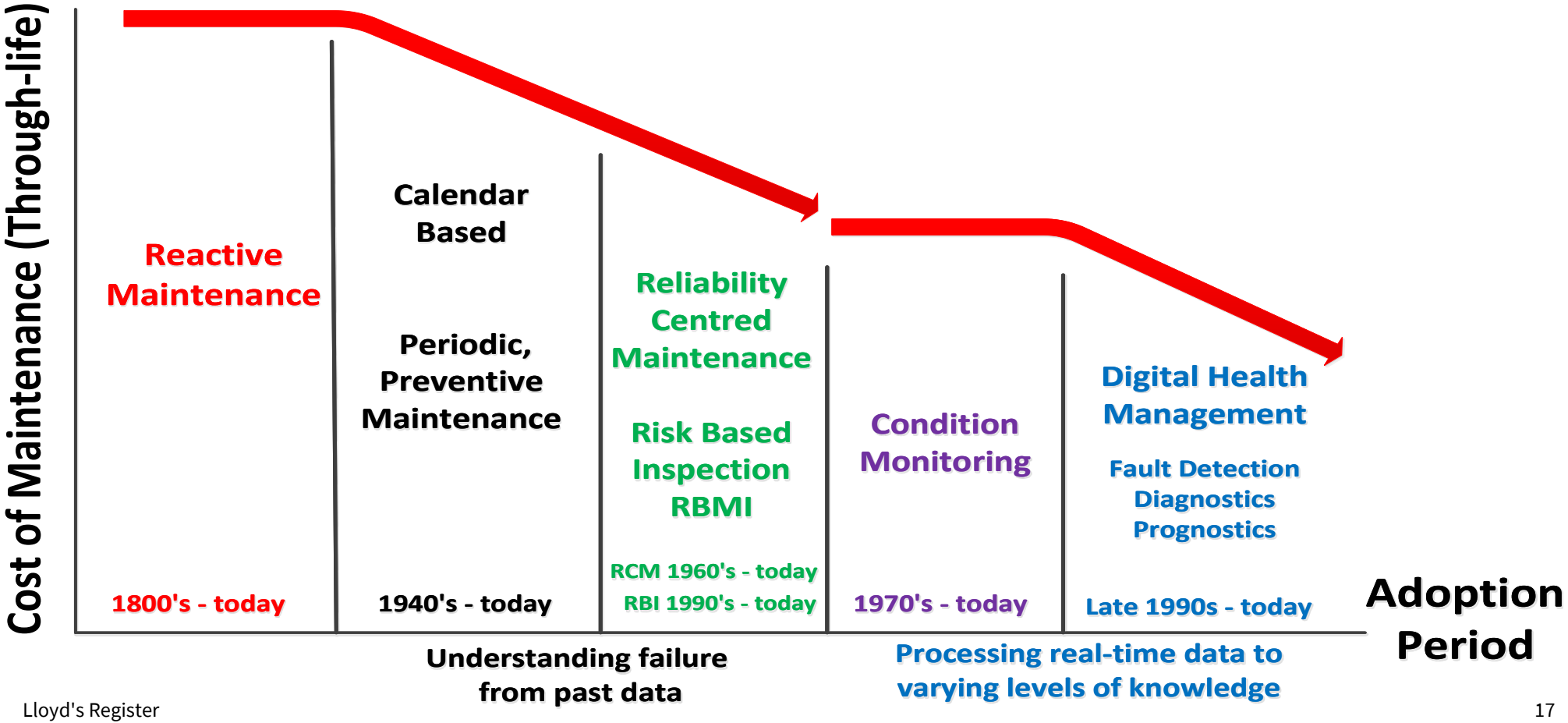
Kongsberg Predictive Maintenance



General Electric Predix

SKF Remote Diagnostics

Maintenance Technology History



Reactive Maintenance

Entire Life of the asset is consumed. However consequences are unpredictable and can be disastrous

BOILER EXPLOSION AT BEAVER MILLS, KEENE, N. H., MAY 22, 1893.

Source: Alamy, Boiler Explosion Beaver Mills

Source: St. Mary's Hospital Accident Investigation

Calendar Based, Preventive Maintenance

- Planned Maintenance Routines are typically built up from Original Equipment Manufacturer (OEM) recommendations in isolation from the specific application or asset.
- Little justification for maintenance interval and typically resistance to change without a good justification
- Maintenance burden typically remains constant over asset life despite changing production or use of the application and/or economic circumstances

Reliability Centred Maintenance(RCM)

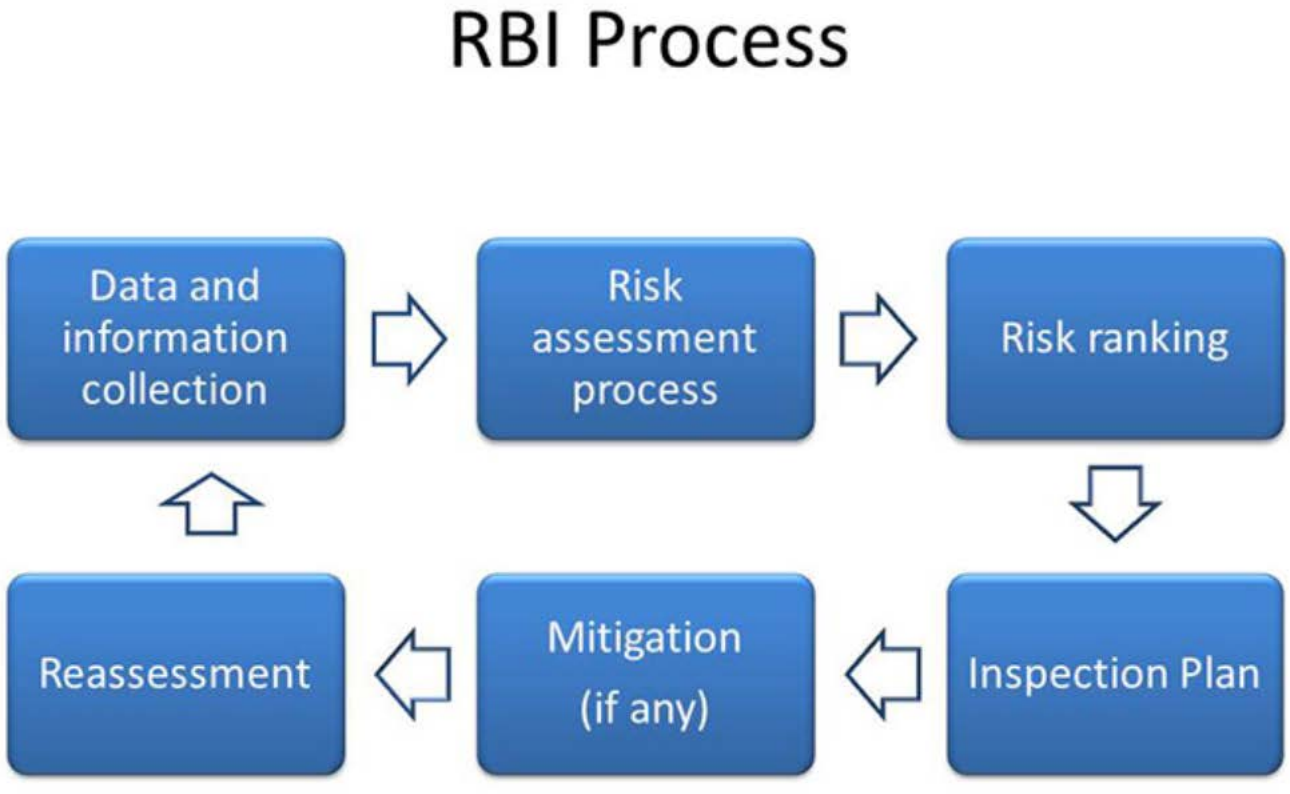
- RCM is a methodology that answers the following questions to determine an appropriate maintenance regime…

1. What is the item supposed to do and its associated performance standards?
2. In what ways can it fail to provide the required functions?
3. What are the events that cause each failure?
4. What happens when each failure occurs?
5. In what way does each failure matter?
6. What systematic task can be performed proactively to prevent, or to diminish to a satisfactory degree, the consequences of the failure?
7. What must be done if a suitable preventive task cannot be found?

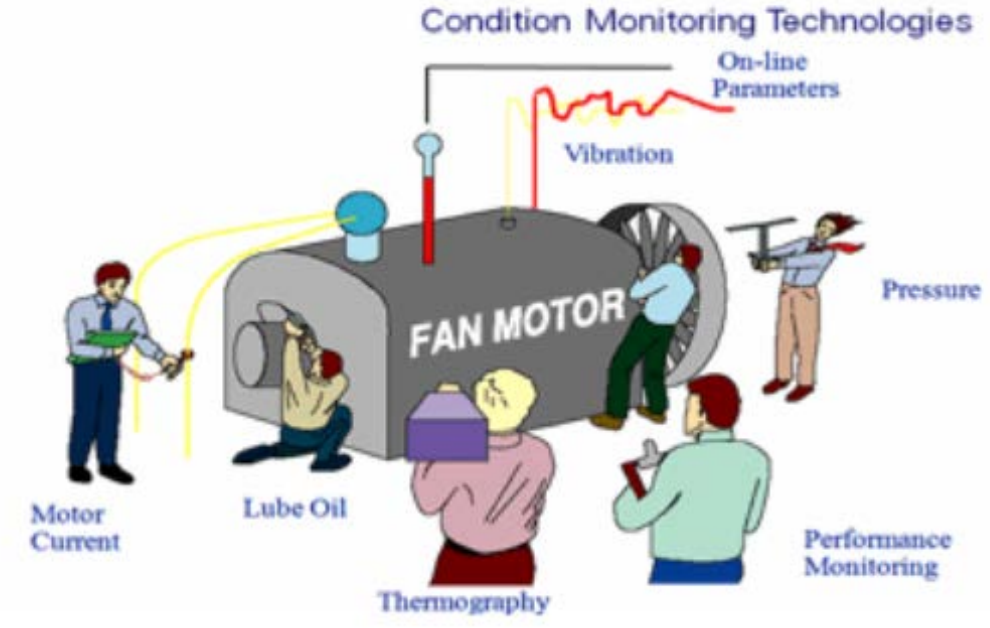
Risk Based Inspection (RBI), Risk Based Mechanical Inspection (RBMI)

Maintenance determined by knowledge of the asset (design, functionality, operation) and past asset failure modes (consequence, occurrence).

Resource intensive (level of expertise, time spent) and requires continued commitment to update the initial results i.e. a feedback loop to determine if the inspection, maintenance processes are effective.



Condition Monitoring – Individualised, Periodic Insights



Monitoring uses real-time data. The SME collects and process the data to generate **the periodic "Condition Monitoring Report"**. The better the knowledge and experience of the SME - the higher the value of the information

Source: NI CM Article

Evolution of Condition Monitoring

1970s

Exceedance recording

Temp, RPM, Vibes

1980s

Damage accumulation
Remaining Useful Life
(post flight calculation)

Temp, RPM, Throttle position

Goal: reduce uncertainty and retain conservatism in estimating component life limit

Method: rainflow cycle counting, limits monitoring

1990s

Digital Fuel Controls

Engine data collection

Condition Monitoring

Fault Detection and Isolation (Diagnosis)

1990s – 2000s

Prognosis – time to failure, recommended maintenance action

Goal: Extend time between overhauls by automatically detecting incipient failures in real time with embedded sensors

Method: vibration monitoring, oil debris detection, performance trending

Source: ADS 79E HDBK

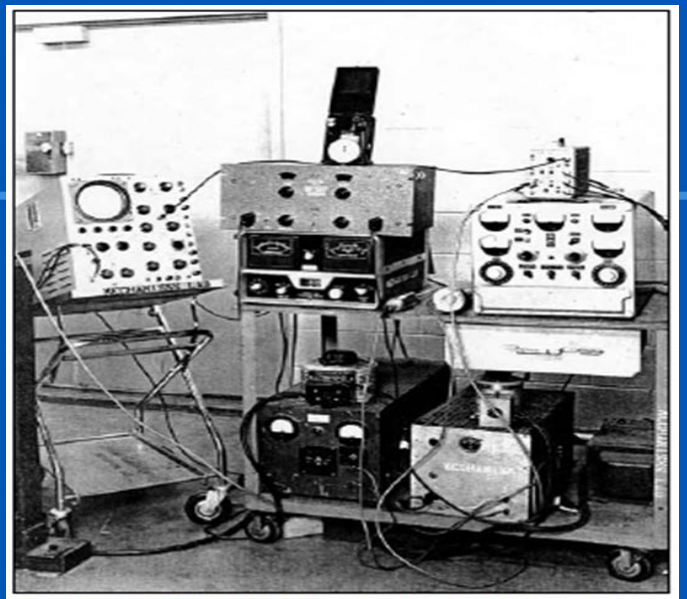
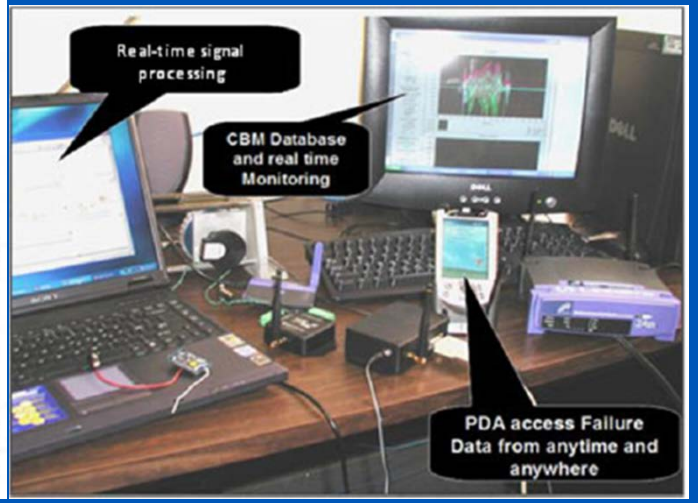


Figure 5. Late 1960s laboratory vibration measurement instruments.



Age of Analytics – Advancement of Diagnostics & Arrival of Prognostics

Sensing Techniques

	Physics of Failure Techniques			Machine Learning Techniques						
Diagnostic model/ monitoring technique	Knowledge-based					Data-driven				
	Rule-based	Causal fault	First principle	Statistical methods	Case-based reasoning	Neural network	Classification trees	Random forest	Logistic regression	Support vector machines
Vibration	M	D	P	M	D	D	—	D	—	—
Thermography	M	—	—	M	—	D	—	P	—	—
Oil analysis	M	P	—	M	D	D	—	D	D	D
Process parameters	M	—	D	M	M	M	M	M	M	M
Performance	M	—	D	M	M	M	M	M	M	M
Acoustic emission	M	—	—	M	—	D	P	D	—	—
Acoustic monitoring	M	—	—	M	—	D	—	D	—	—
Electrical monitoring	M	—	—	M	—	D	—	—	—	—

M: Mature and commonly applied in industrial applications.

D: Under development and some initial applications.

P: Promising and potential.

Source: ISO 13379-1 published 2012

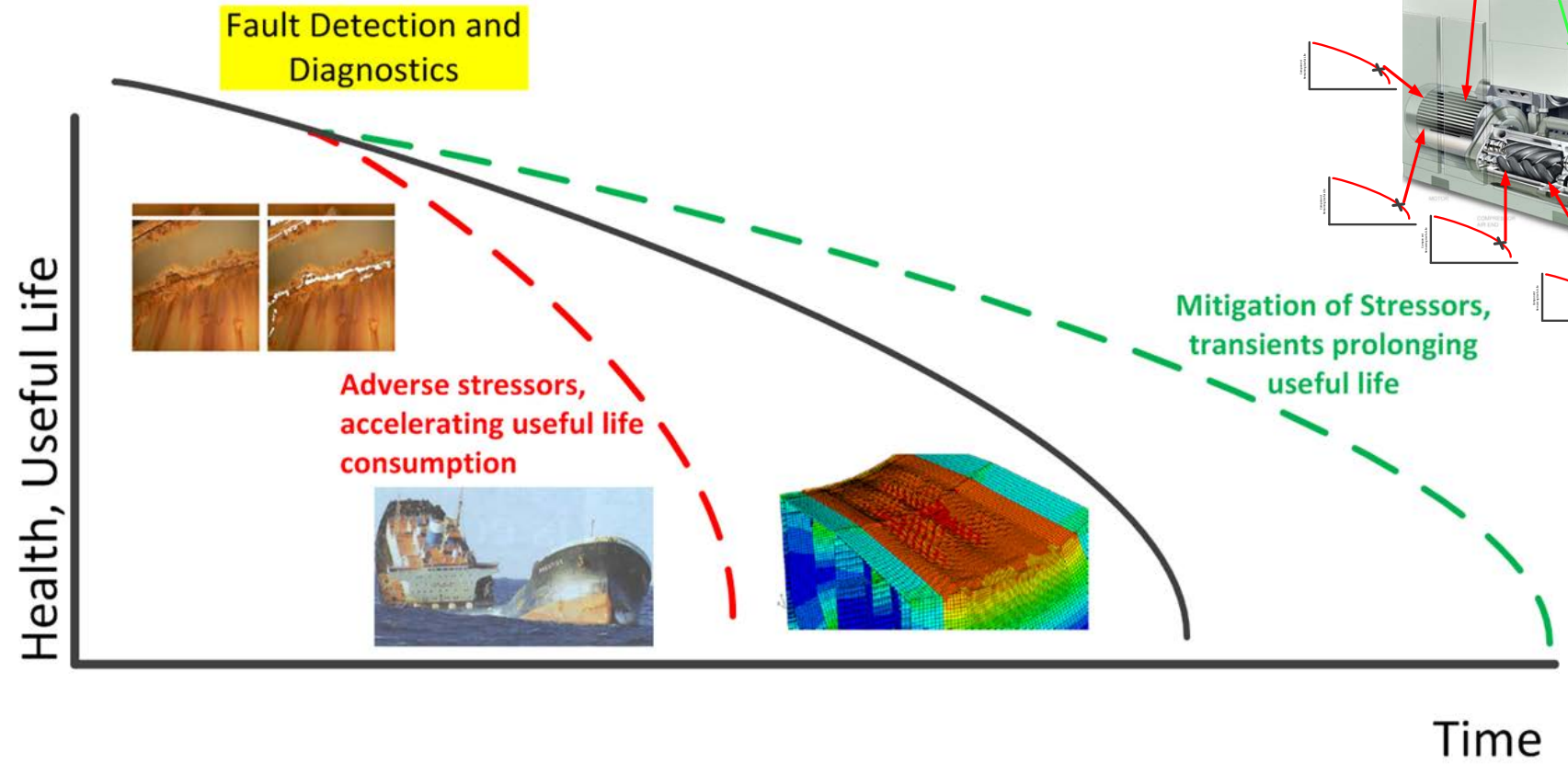
ISO 13379-1 showing Sensing Techniques and Analytics

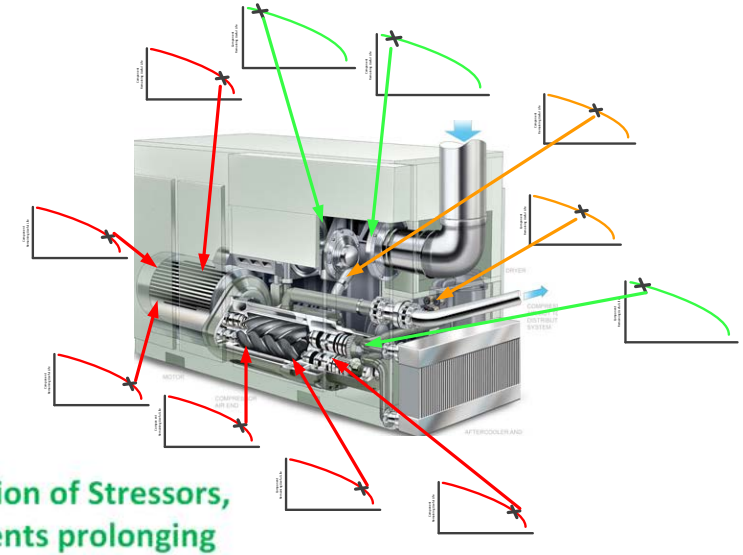
Today sensing, connectivity, computing and UI/UX hardware are more sophisticated and affordable than ever.

Furthermore the increasing use of algorithms – both physics based and data driven has grown exponentially.

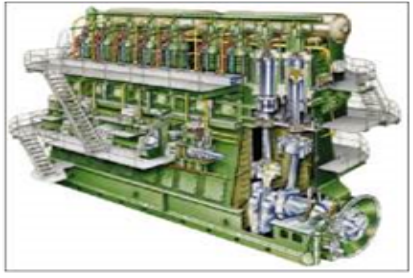
Digital Health Management (DHM) Technology

Digital Twins are fundamental to DHM



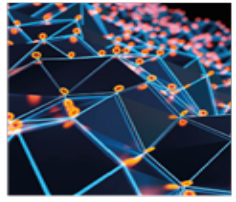


Digital Twins are fundamental to DHM



Sensor Conditioning
E.g. adjusting for drift, bias, fault, sensor level

Sensor Data



Data Processing
"signal conditioning"

State Detection

Fusion and weighting of Model Based and Data Driven Techniques based on multiple data

Features Extraction

Diagnostics, Prognostics

Aggregated First principles, empirical, simulation models

Physics of Failure (multi-physics) Based Techniques

FMECA, FTA, ETA, first principles derived failure modes

Simulated Failure Models

Synchronised, Historical, Operational, Maintenance, Failure Data

Machine Learning Techniques

Results Management

Roadmap to Systems Effectiveness & Maintenance Optimisation

Maintenance Strategy based on existing AMOS or equivalent data

RCM Applied

Apply Condition Monitoring

Apply Condition Based Maintenance

Take Advantage of your investment.

(LR's MCBM-CBM & Digital Maintain Descriptive Notes)

Take Advantage of your investment.

LR Digital Compliance Framework

Optimize Planned Maintenance

Routine Condition Monitoring

CBM

Class Approval of Maintenance Scheme

Digital Health Management

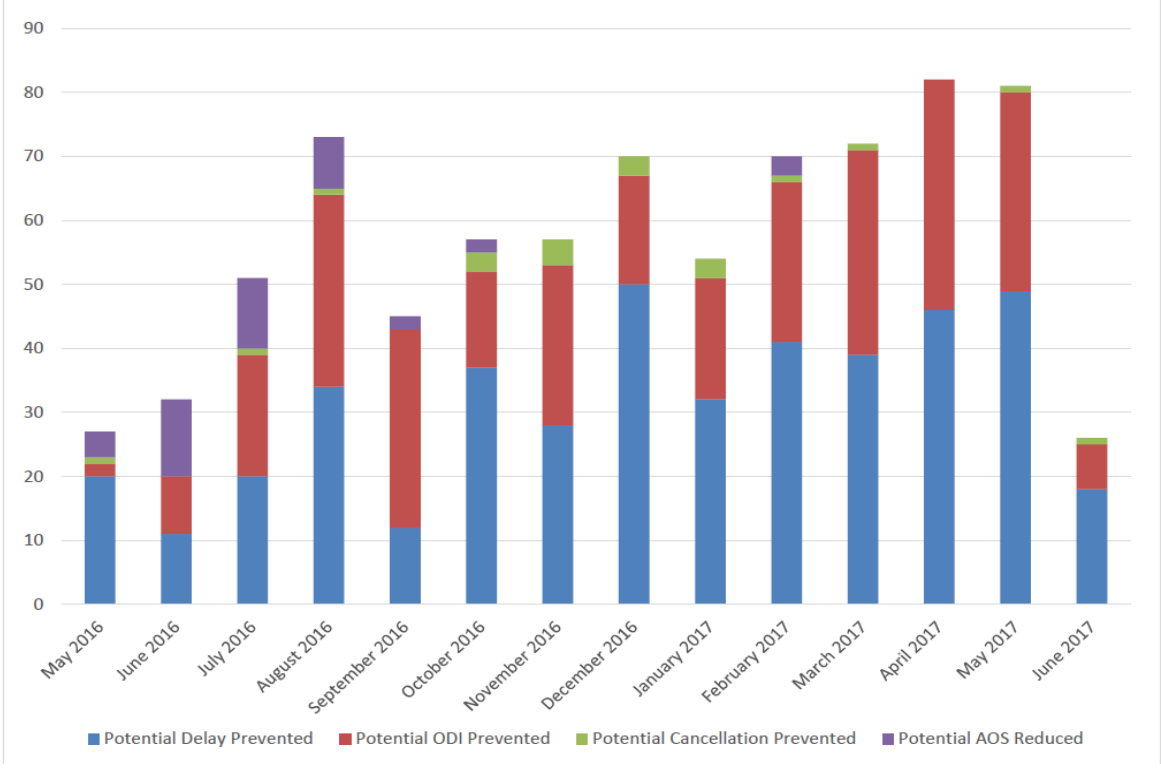
Why Digital Health Management?

DHM Drives Business Results (Aviation)

Predictive Benefits

DELTA TechOps

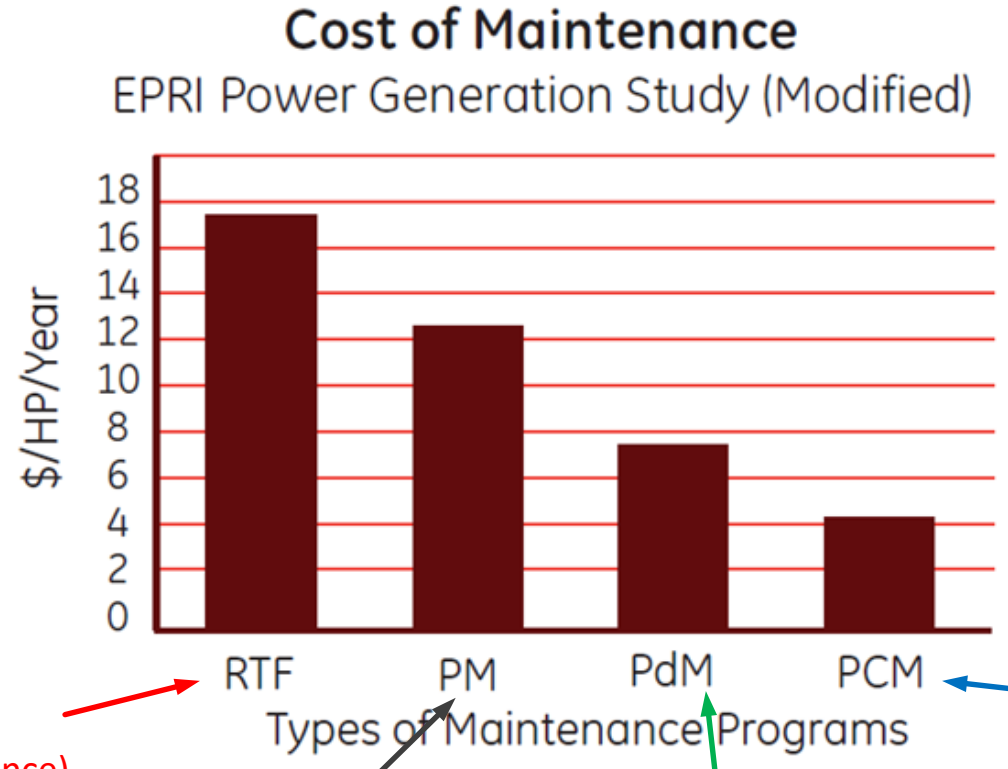
~1000 potential delays, cancellations, ODI's Mitigated in past 12 months!



Delta TechOps Develops Innovative Structural Health Monitoring Application

Source: Delta Tech Ops SHM Management

DHM Drives Business Results (Power Generation)



65% Maintenance saving comparing calendar based maintenance with DHM

Prioritised Corrective Maintenance (DHM enabled maintenance)

Run to Failure (Corrective Maintenance)

Preventive Maintenance (Calendar based maintenance)

Predictive Maintenance (Fault Detection, Diagnostics, Prognostics)

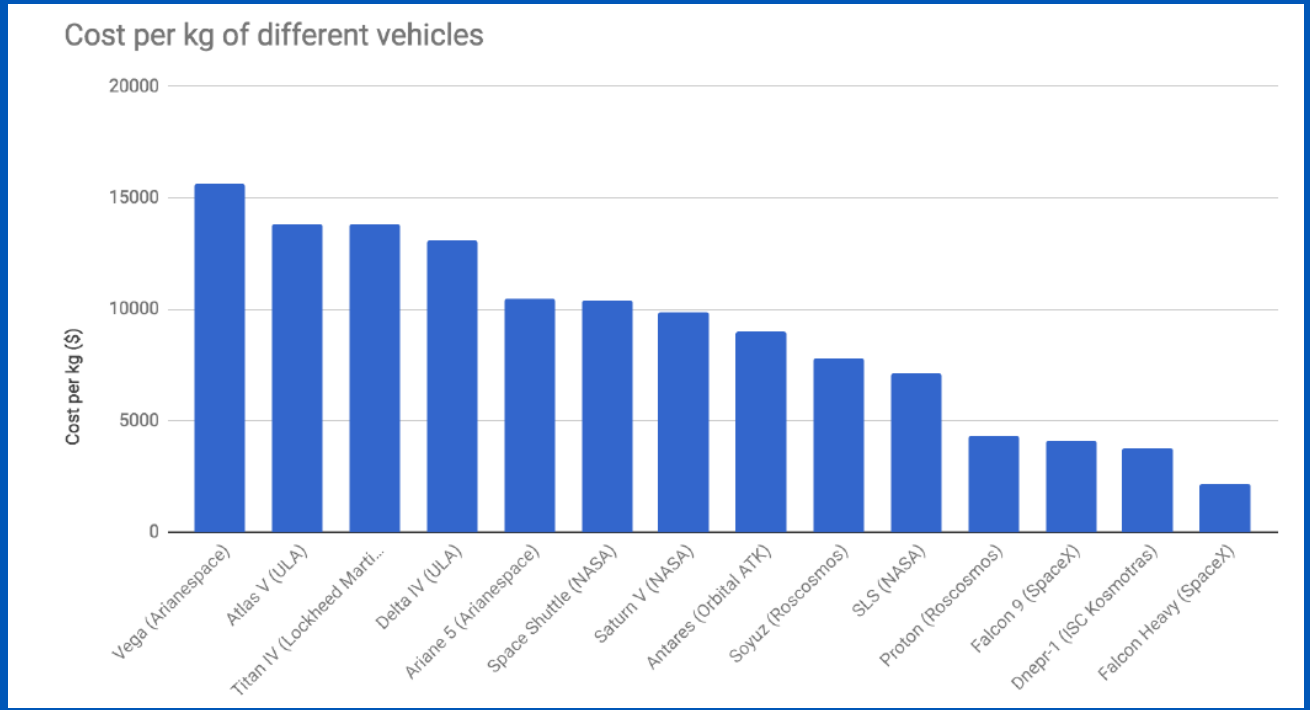
Source: EPRI with LR annotations
(Electric Power Research Institute)

DHM (and Autonomy too!) **Disrupted the Space Industry**

Autonomy and DHM (i.e. reusable rockets) are the two biggest reasons why Space X and their contemporaries can launch assets into space 80% cheaper than United Launch Alliance and other incumbents.

Space X Falcon 9

Source: Space X



Source: CB Insights Space X tear down Analysis

DHM Benefits a Spectrum of Maritime Stakeholders

Maintenance engineers and Chief Engineer
- Opportunistic maintenance
- Maximise uptime
- Minimise unnecessary maintenance

Vessel Superintendent
- Spares Positioning
- Reduced Spares Count
- Logistics Efficiency

Flag Administration
- Increase Asset Safety
- Eliminate Catastrophic Failures

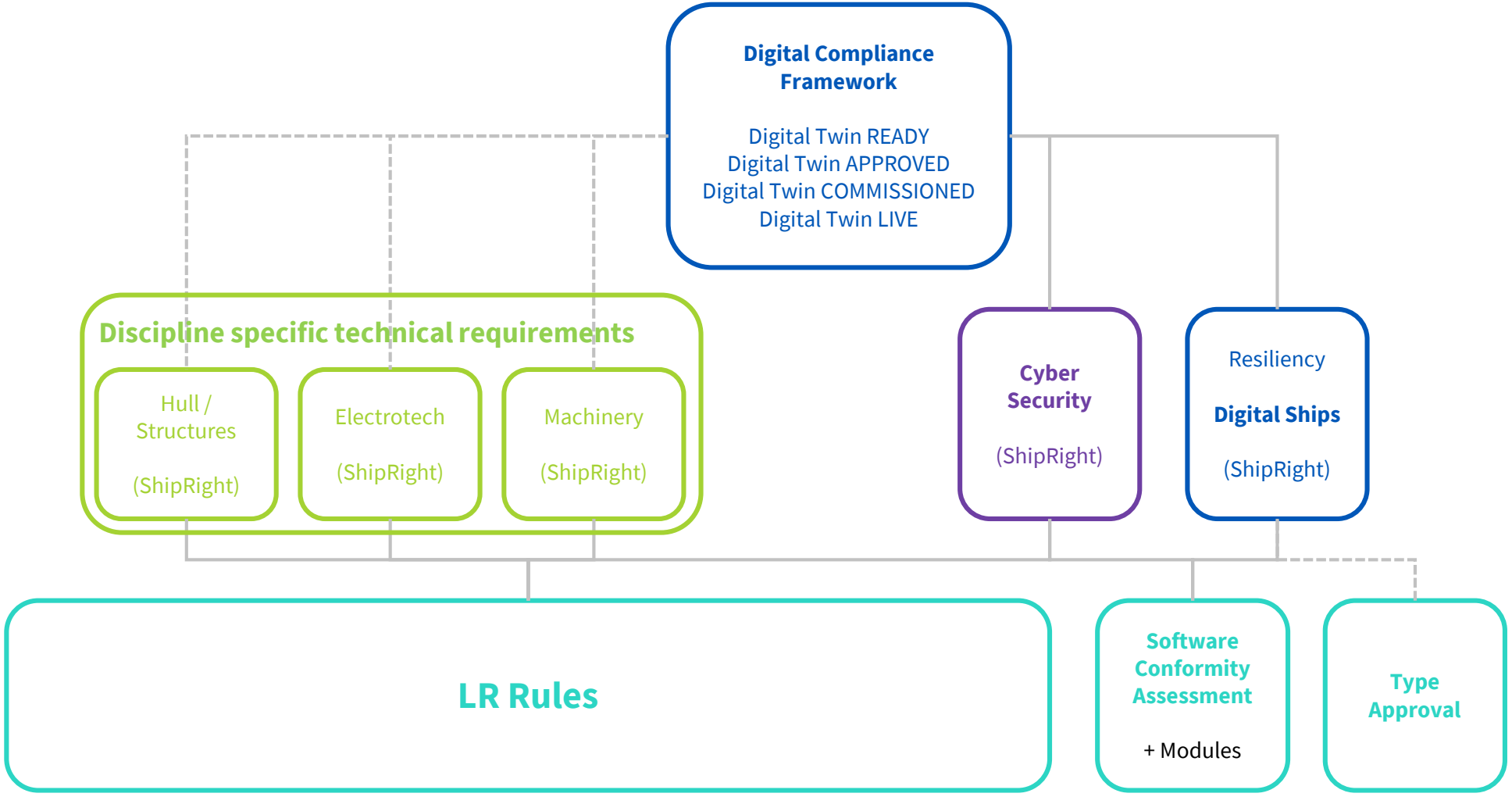
Manufacturers, Shipyards,Service Providers
- Re-defining and exceeding customer expectations
- ”As a service” business models
- Through-life monetisation of asset activities.

Shipping Company Managing/Technical Director
- Best Lifecycle Cost
- Business Planning
- Maximising Capability

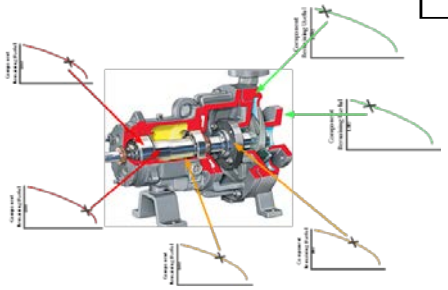
Insurers
- Enhancement of actuarial science, accurate pricing of risks
- Objective evidence for claims
- Better management of insurance premiums

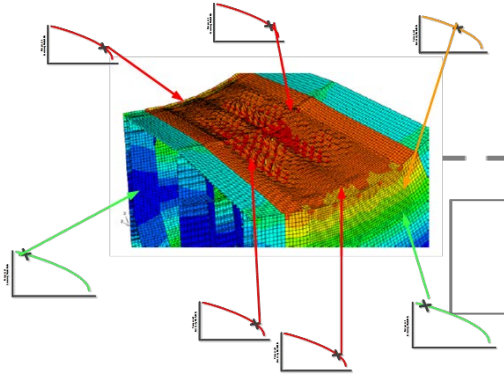
LR Digital Compliance Framework

Digital Compliance in Wider Context of LR Rules



Digital Class/ Digital Compliance Framework – 4 Approval Levels





Digital Class

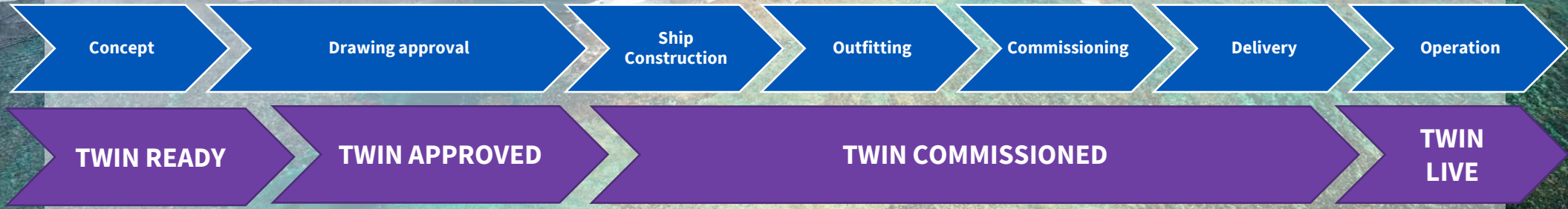
Supporting Requirements		LR Approval Level	
		Digital Twin READY	DHM Provider approved
		Digital Twin APPROVED	Asset specific digital twin developed and approved at DHM Provider
Digital Maintain*	DHM system integrated with vessels systems	Digital Twin COMMISSIONED	Asset specific digital twin approved and commissioned at The DHM Operator
ShipRight MPMS	Approval for a flexible maintenance regime	Digital Twin LIVE	Digital twin function and performance demonstrated over time

The DHM Provider

The DHM Operator

*Lloyd's Register Digital Ships ShipRight Procedure

The New Classification Continuum



- ✓Trust the individual Twin
- ✓Achieve confidence in the performance of each digital twin
- ✓Improve the performance of each digital twin through validation

Thank you

Please contact:

Emmanuel Vergetis,

Senior Consultant, Marine & Offshore South Europe

Lloyd’s Register Marine & Offshore

T: +30 210 4580841 E: emmanuel.vergetis@lr.org

Hellenic Lloyd’s S.A., 87 Akti Miaouli, 185 38, Piraeus, Greece