Autonomous Shipping 2019 and Beyond

Workshop on Maritime Autonomous Surface Ships

Jim Covill

Lloyd's Register

CISMaRT
November 27-28, 2019

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Introduction - IMO MSC May 2018

For the purpose of the regulatory scoping exercise, "Maritime Autonomous Surface Ship (MASS)" is defined as a ship which, to a varying degree, can operate independently of human interaction.

To facilitate the progress of the regulatory scoping exercise, the degrees of autonomy are organized (non-hierarchically) as follows (note a MASS can be operating at one or more degrees of autonomy for the duration of a single voyage):

- Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated.
- Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location, but seafarers are on board.
- Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.
- Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.

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Reference: http://www.imo.org/en/MediaCentre/PressBriefings/Pages/08-MSC-99-MASS-scoping.aspx

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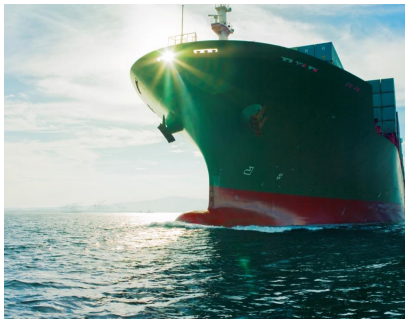
Maritime autonomy: Where are we now?

- The dawn of maritime autonomy is now
- Disruptive technology will reshape the industry – Fourth Industrial Revolution
- Adoption driven by cost efficiency and skills shortages
- Swarms (or pods) of small unmanned vessels
- Unmanned Warrior 2016, Trident Junction 2018
- IMO recognises the challenges



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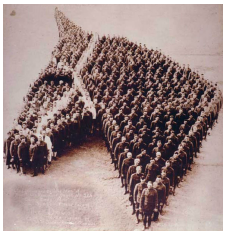
Autonomous technologies are brought to you by the fourth industrial revolution

- Previous three industrial revolutions:
  I. liberated humankind from using animal power,
  II. made mass production possible,
  III. brought digital capabilities to billions of people.
- Fourth Industrial Revolution is, however, fundamentally different. It is characterized by a range of new technologies that are fusing the physical, digital and biological worlds, impacting all disciplines, economies and industries.



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Fourth industrial revolution continued

- Three reasons why today's transformations represent not merely a prolongation of the Third Industrial Revolution
  i. Velocity,
  ii. Scope,
  iii. Systems impact.

- Current speed of breakthroughs has no historical precedent.
  i. Evolving at an exponential rather than a linear pace.
  ii. Disrupting almost every industry in every country.
  iii. Breadth and depth of these changes herald the transformation of entire systems of production, management, and governance.

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Just what is autonomy?

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Automation and autonomous systems

Automation is the technology by which a process or procedure is performed with minimal human assistance. Automation or automatic control is the use of various control systems for operating equipment such as machinery, boilers and steering and stabilization of ships, with minimal or reduced human intervention.

LR CLASS NOTATIONS

UMS, ICC, NAV1

Ships have operated successfully with periodically unattended machinery spaces (UMS) for > than 40 years.

Human intervention always possible

Autonomous systems

IMO Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.

AI the theory and development of computer systems able to perform tasks that normally require human intelligence

The fully autonomous systems will have no human intervention.

LR CLASS NOTATIONS

CYBER AL5

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Recent examples of empowering automation

Towards remote control safe operations

News Release

Rolls-Royce

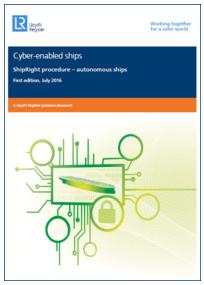
Trusted to deliver excellence

20 June 2016

ROLLS-ROYCE DEMONSTRATES WORLD'S FIRST REMOTELY OPERATED COMMERCIAL VESSEL

Rolls-Royce and global towage operator Svitzer have successfully demonstrated the world's first remotely operated commercial vessel in Copenhagen harbour, Denmark.

Earlier this year, one of Svitzer´s tugs, the 28m long *Svitzer Hermod*, safely conducted a number of remotely controlled manoeuvres. From the quay side in Copenhagen harbour the vessel's captain, stationed at the vessel's remote base at Svitzer headquarters, berthed the vessel alongside the quay, undocked, turned 360^0, and piloted it to the Svitzer HQ, before docking again.



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The word "Cyber"

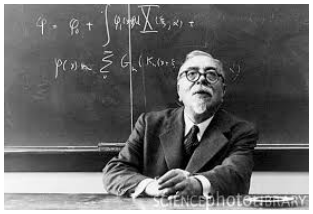
Until the advent of the internet, cyber was used in the formation of words relating to computers, computer networks, or virtual reality.

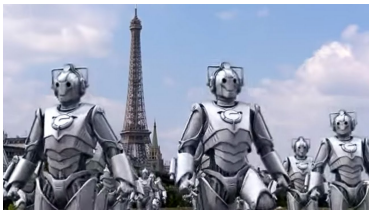
This usage can be traced to the word cybernetics, which was ushered into English in the 1940s by the scientist Norbert Wiener.

Cybernetics refers to "the study of mechanical and electronic systems designed to replace human systems."

It comes from the Greek term kybernḗtēs meaning "helmsman" or "steersman." The first instance on record of cyber as a combining form is from 1961 in the Wall Street Journal: "A major difference between the Cybertron and conventional computers … is the ability of the Cybertron to make use of raw data and signals."

In 1966, fans of the popular sci-fi show Doctor Who heard another cyber combining form: cybermen.





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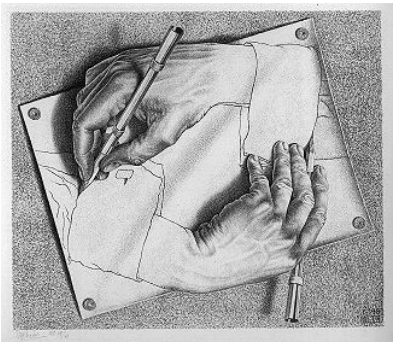
Key challenges and risks

- Rapid technological advancement
- Implementation to optimise business solutions
- Technology considerations:
  - Development, Validation and Verification
  - Integrating with existing assets
  - Reliability, dependability and safety
  - Affordability and the business case
- Rules, Standards and Regulations
- Social acceptance
- Human interaction and re-skilling



Drawing Hands – M.C. Escher 1948

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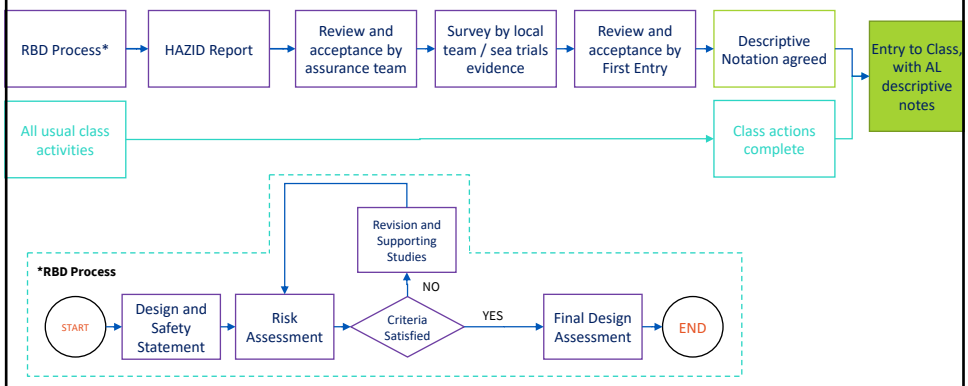
Cyber Enabled Ships – technical areas

9 Key Risk Areas for a Cyber Enabled Ship:

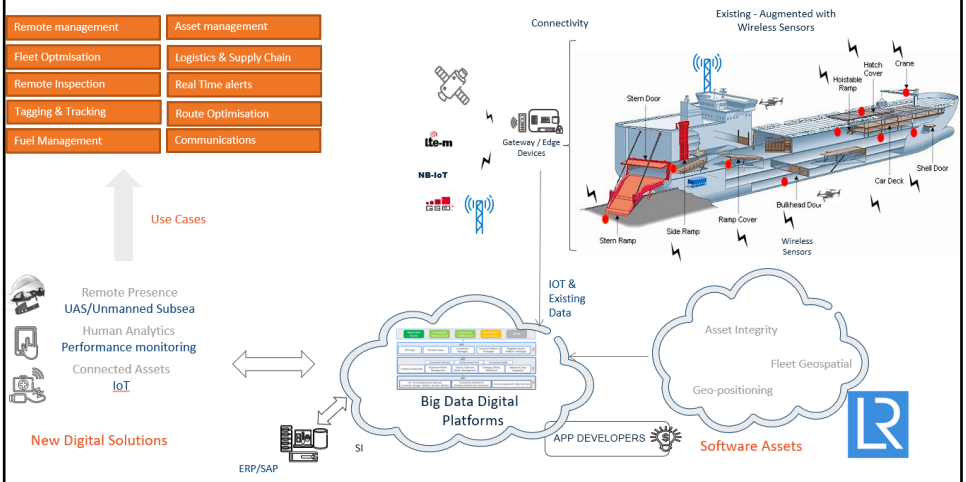
- **Human Interaction**
- **Data Quality**
- **System Architecture**
- **Hardware**
- **Software**
- **Communications and Network**
- **System Integration**
- **Configuration Management**
- **Cyber Security**

Cyber Enabled Ships – assessment procedure

ShipRight - Risk Based Design (RBD) review process:



The Cyber Enabled Ship



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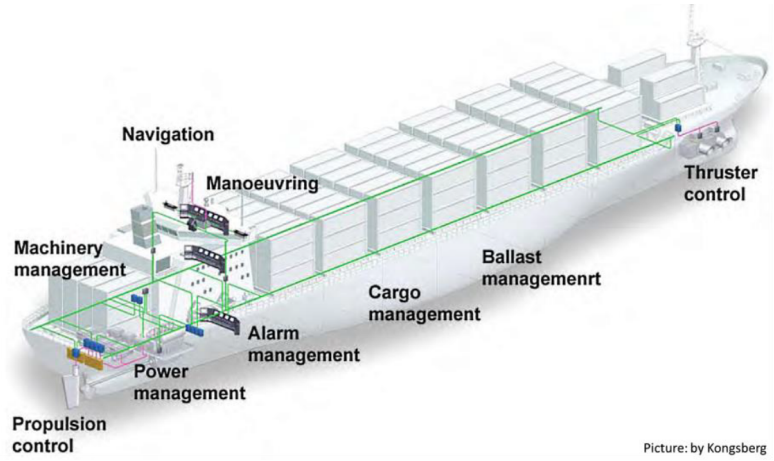
Every system on board is a target for automation

Autonomy-based efficiency and implementation of Autonomy Levels



Picture: by Kongsberg

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What can be connected in a Cyber Ship?

- Navigation (ECDIS, AIS, GPS,…)
- Communication
- Propulsion and Steering
- Power Generation, Management, and distribution
- Ventilation & chilled water
- Fuel, lubrication & other ancillaries
- Fire Fighting and Emergency Systems
- Flood / Stability
- Cargo Systems
- Accommodation Systems
- Dynamic Positioning

… nearly any system…

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LR digital compliance: recent news release

LR develops *Digital Compliance*, the first ever digital assurance framework

LR has developed an industry-first digital assurance framework, 'Digital Compliance' in collaboration with leading industry partners and in response to the growing interest in the use of digital twins within marine and offshore.

LR's newly released Digital Compliance has been validated through a co-creation project with GE, resulting in an Approval in Principle to 'Digital Twin READY' (the first level of compliance) for GE's Predix Asset Performance Management (Predix APM).

The increasing use and advancement of digital twins presents a significant opportunity to marine and offshore operators. Aspects of their operational performance and maintenance regimes can be improved and there is greater transparency and repeatability in demonstrating compliance with internal and external requirements.

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LR digital compliance: recent news release

LR announces the launch of prototype blockchain-enabled Class register at SMM

LR has created the first demonstrator that can register ships into Class using blockchain technology. This re-imagining of the Class register for the digital age and was announced last year (2018-SMM, leading international maritime trade fair 4-7 September in Hamburg.)

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Automotive autonomous levels

Autonomy in vehicles is often categorized in six levels: The level system was developed by the Society of Automotive Engineers (SAE).

- **Level 0: No automation.**
- **Level 1: Driver assistance - The vehicle can control either steering or speed autonomously in specific circumstances to assist the driver.**
- **Level 2: Partial automation - The vehicle can control both steering and speed autonomously in specific circumstances to assist the driver.**
- **Level 3: Conditional automation - The vehicle can control both steering and speed autonomously under normal environmental conditions, but requires driver oversight.**
- **Level 4: High automation - The vehicle can complete a travel autonomously under normal environmental conditions, not requiring driver oversight.**
- **Level 5: Full autonomy - The vehicle can complete a travel autonomously in any environmental conditions.**

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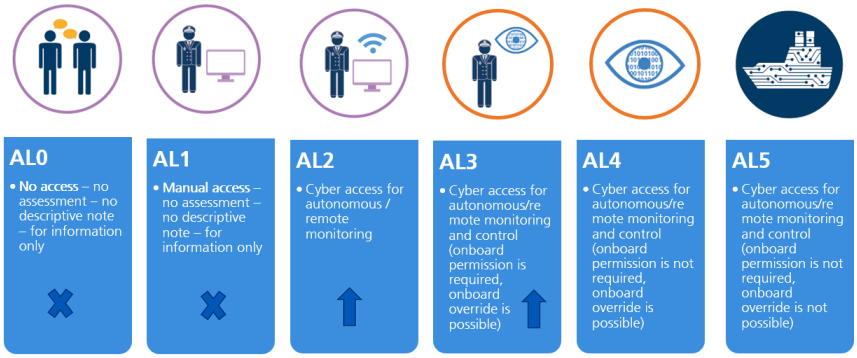
Cyber-enabled ships: autonomous levels

LR has classified cyber enabled technology in five types for autonomy/remote access



Cyber–enabled systems are systems installed onboard ships that would conventionally be controlled by the ship's crew but which, through recent advances in IT and operational technology, now include the capability to be monitored, or monitored and controlled, either remotely or autonomously with or without a crew onboard the ship.

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New regulations and standards emerging to manage automated ships and associated cyber risks

Lloyd's Register Cyber Notations:

- Cyber SAFE
- Cyber SECURE
- Cyber Maintain
- Cyber Perform

Lloyd's Register Cyber Type Approval of "Smart" Components:

- Approved "Cyber TYPE"

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LR: Cyber Notation

Cyber SECURE	Foundation to build notation, considered mandatory. Indicates that the security of systems with remote access have been assessed.
Cyber SAFE	Indicates that systems essential for the operation of the ship that have remote access or autonomous functions are assessed
Cyber MAINTAIN	Indicates that intelligent condition monitoring using data analytics to optimize maintenance systems. Digital Health Management
Cyber PERFORM	Indicates that data Analytics are used to enhance vessels system performance

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LR Cyber class notations

Example of combined Cyber descriptive notes is as follows:

Cyber_ AL2_ SAFE_ SECURE (Steering)

- Steering system cyber enabled
- Cyber security of cyber enabled systems assessed
- Cyber access of systems providing optimization functions assessed
- Cyber access for remote or autonomous monitoring provided
- One or more of the ship's system(s) are cyber enabled and assessed by LR

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Example - MV *COSCO Shipping Aries*

MV *COSCO Shipping Aries* is the first ever container ship to receive Lloyd's Register's cyber–enabled ship descriptive note, "Cyber AL3 Secure Perform", for its energy management system.

The ship complies with the revised version of Lloyd's Register's cyber-enabled ships ShipRight procedure, issued in December 2017.

AL3 is defined by Lloyd's Register as "cyber access for autonomous/remote monitoring and control (onboard permission is required and onboard override is possible)."

AL3

- Cyber access for autonomous/remote monitoring and control (onboard permission is required, onboard override is possible)

Cyber-enabled ships: first delivery

AL-SAFE (AL2 (Navigation System, Car System), AL3 (Air Handling Unit)))

This certificate replaces the Certificate No. BUS 1540002 issued on 27 April 2017, which is hereby cancelled.

Certificate no: BUS 1540002/A1
Page 1 of 3

Certificate of Class

This certificate is issued to the TRAMMO DIETLIN
LR Number 9540079
Date of Build 27/06/2017
Port of Registry Singapore
Gross tons 25,608

to confirm that having been surveyed by Lloyd's Register Asia and having been found in compliance with the Rules and Regulations for the Classification of Ships, the aforesaid ship has been assigned the class

✠100A1, Liquefied Gas Carrier, Ship Type 2G, Anhydrous Ammonia, Butadiene, Butane, Butane-Propane mixture, Butylenes, Propane, Propylene in Independent tanks, Maximum Specific Gravity 0.7, Partial loading Vinyl Chloride Monomer with Maximum Specific Gravity 0.87, Maximum Vapour Pressure 0.25 bar (0.45 bar in harbour), Minimum Cargo Temperature Minus 48 deg. C. ShipRight (ACS(B), CM, SDA), +LWS, LI

✠ LMC, UMS

✠ Lloyd's RMC (LG)

Descriptive Notes : ShipRight(BWMP(S, T), IHM, SCM, AL-SAFE (AL2 (Navigation System, Cargo System and Machinery System), AL3 (Air Handling Unit)))

Date Special Survey Assigned 27 April 2017
This Certificate is valid until* 26 April 2022

* Unless extended after completion of a Special Survey (see page 3) or in accordance with Part 1, Chapter 2, Section 3.5.9 of the Rules and Regulations (see page 3) and is subject to surveys as prescribed (see page 2) being satisfactorily completed. (See notes 1 to 4, page 3)

Issued at Busan Port
on 28 April 2017

S. M. Jeong
Surveyor to Lloyd's Register Asia

A subsidiary of Lloyd's Register Group Limited

Note: 1. To establish the classification status of this ship, the Class Direct web site and the Interim Certificates issued on completion of classification surveys should be consulted in addition to this certificate. Access to Class Direct is available via http://www.classdirect.org.

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Form 1717 (2014.06)

Then and now

Vibration sensing and Recording 60s

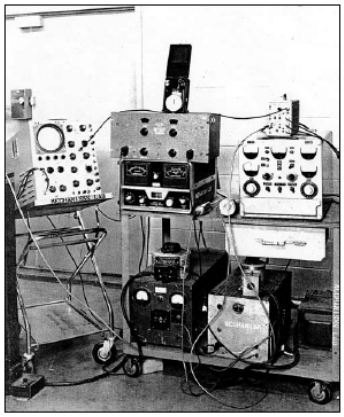


Figure 5. Late 1960s laboratory vibration measurement instruments.

State of the art multi-equipment sensing, signal conditioning and processing 80s and early 90s

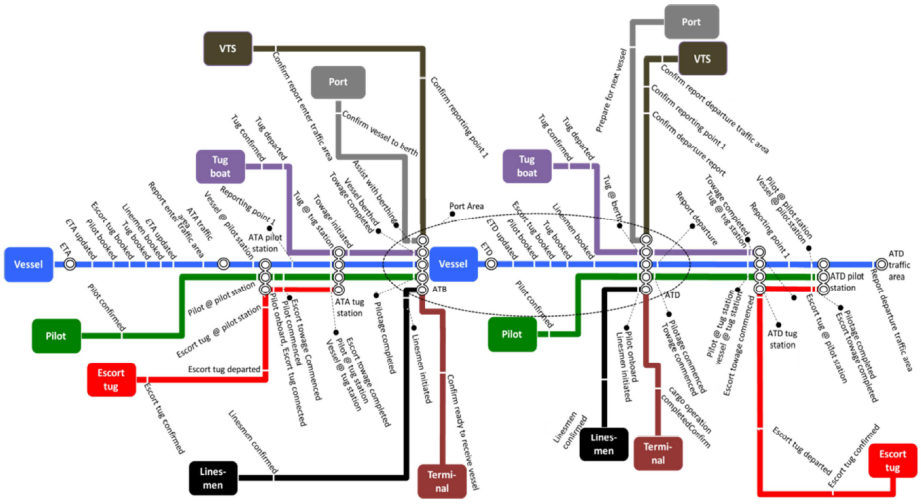
Figure 19. Analysis van – from outside showing reeled extension cable for connection to remote sensors.

Figure 20. Analysis van – inside view of instrumentation; note the real time frequency analyser and plotter similar to those shown in Figure 15.

Today

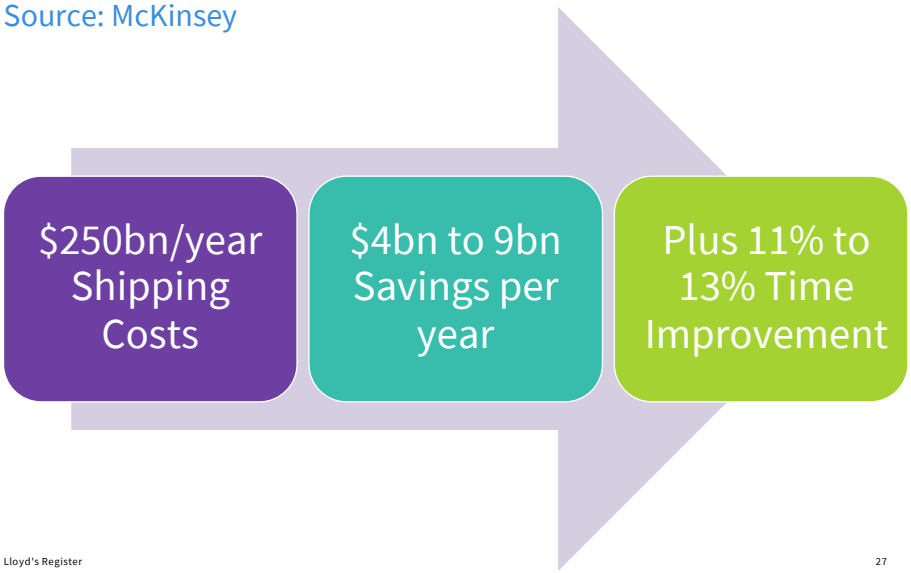
Every shipping operation is a target for "autonomy"

States and milestones for the port call process



Impact of autonomous ship navigation

Source: McKinsey



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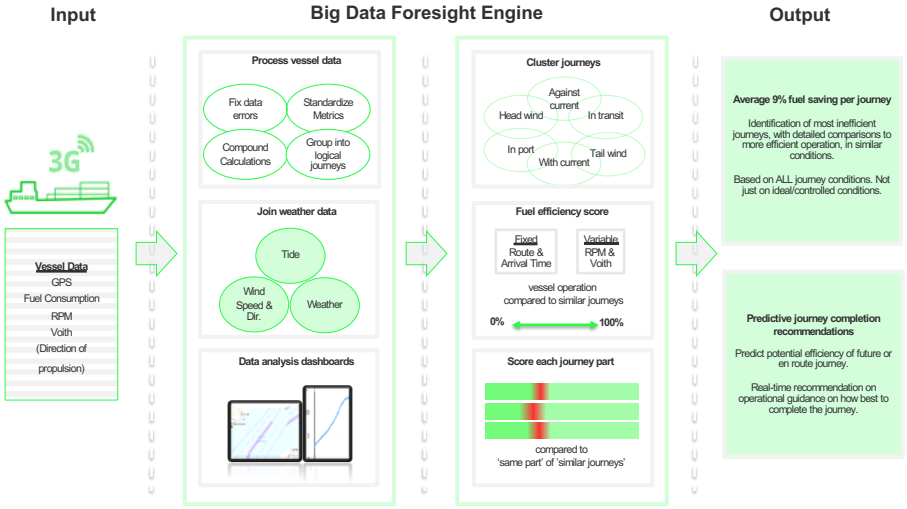
New examples of empowering automation

Acting on real-time understanding of energy flows, saving fuel



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In partnerships with qio

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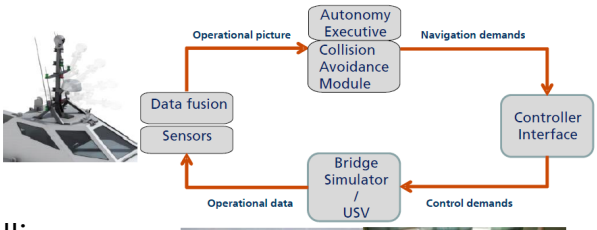
Opportunity: Autonomous navigation system

"Information – Knowledge – Analysis/Decision Making – Action" Loop



MAXCMAS

- Artificial intelligence
- Sensors and situational awareness
- Connectivity
- Cybersecurity

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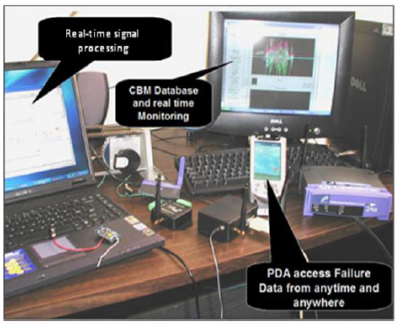
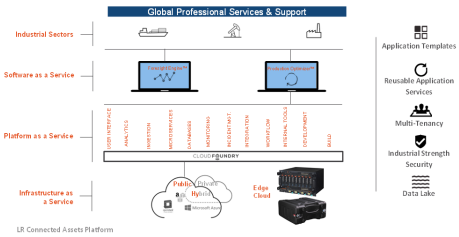
Autonomy enabled by new technology: Big Data Platform

90's edge computing





LR Connected Assets Big Data Platform

The deployed architecture and connectivity journey: Edge computing (on-premise computing)

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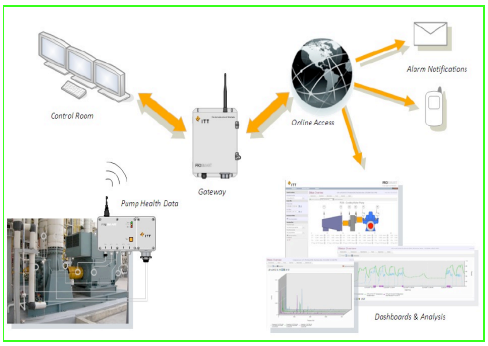
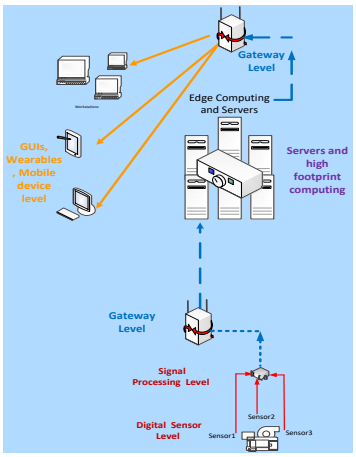
LR Digital Compliance

The new architecture for big data analytics on ships



Source: ITT Smart Pump solution

New Cyber-enabled Architecture on board



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Autonomous systems in marine and "The Gap"

Human intervention, supervisory control aided by automation

In 5-10 years, autonomy with non-deterministic perception, reasoning, judgement and actuation capabilities

AL0

AL1 — **Crewed manual** operator takes decisions and executes operation. Responsibility onboard.

AL2 — **Crewed automated** system's decisions & operations. Onboard action or supervision required. Responsibility onboard.

AL3 — **Crewed remotely controlled** system's decisions & operations. Offship operator's action, on/ offship supervision required. Responsibility onboard.

"The Gap"

AL4 — **Unmanned remote controlled** system decisions & operations. Offship operator's action or supervision. Responsibility offship.

AL5 — **Unmanned autonomous** Self-operating system. Decisions and operations without the need of an operator's intervention or supervision. Responsibility where?

Autonomy determining the best course of action with some effecting pre-determined actions.

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Assurance of Safe, Trustworthy AL4,5 Autonomous Systems

How do we assure AL 4,5 autonomous systems that are cognitive, adaptive and non-deterministic to ensure they can recognise and modify their behaviour in response to the external environment, loads, stressors and other dynamic factors?

The LR Cyber Enabled ShipRight Document provides the building blocks by identifying issues (both individual and integrated) that affect the performance and safety of autonomous systems.

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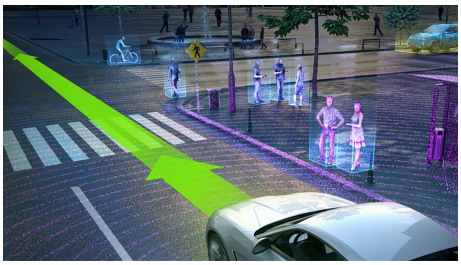
Maritime law thoughts



- Who is 'responsible' for an autonomous vessel
  - Captain ?
  - Owner ?
  - Charterer ?
  - Programmer ?
  - Onshore Staff ?
  - ? (ex. Ship itself)
- Manning Requirements
- Maritime Search and Rescue

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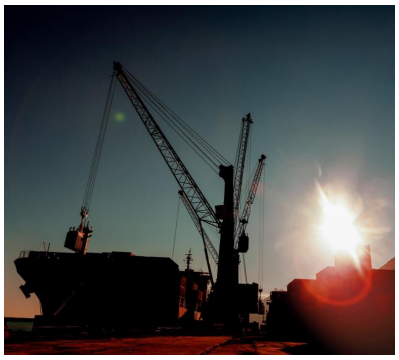
Final thoughts and questions



- Adoption of disruptive technology
- Change the way we interact with the oceans
- Critical to support global prosperity
- A powerful enabler
- Closing "The Gap"
- Now is the opportunity to shape our future

The majority of insured marine losses arise from human error. If MASS can eliminate the capacity for human error and reduce the number of casualties and incidents then MASS is a positive step forward.

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Thank you et merci

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