



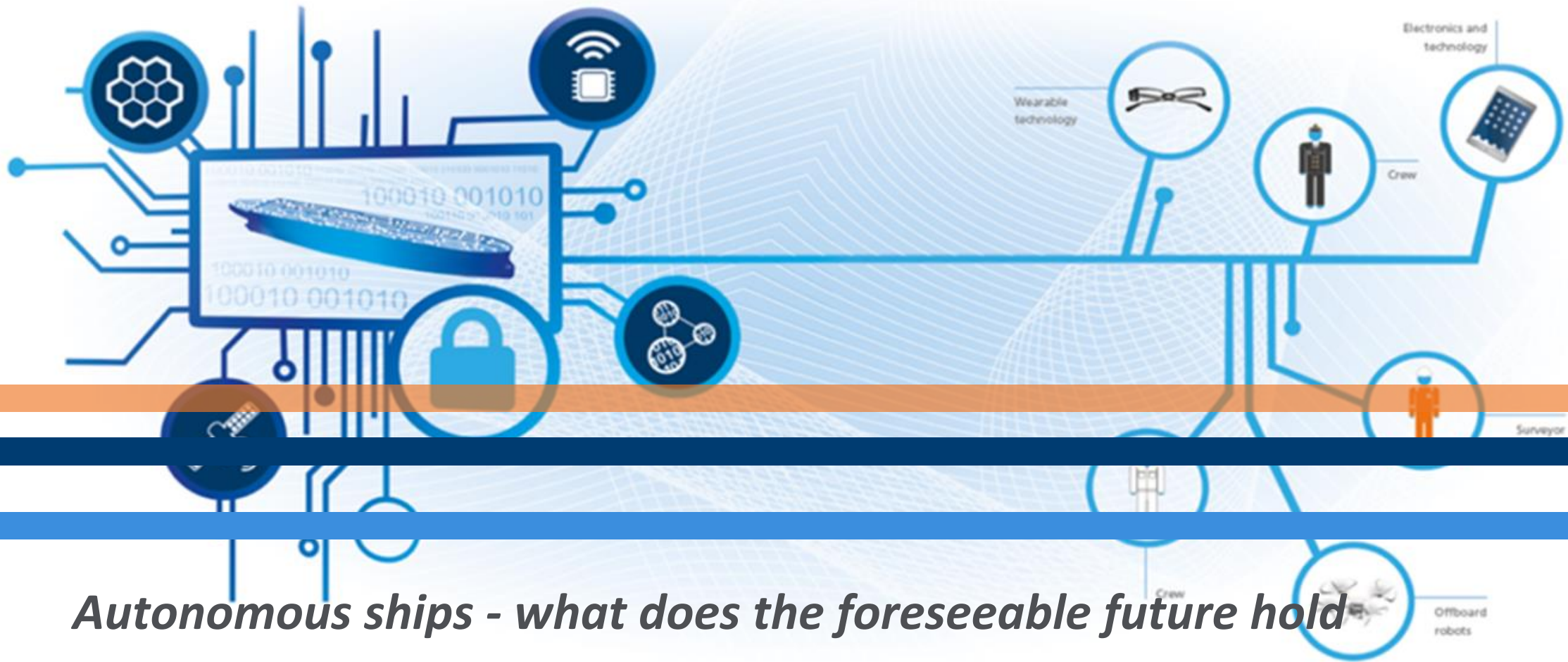
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Autonomous ships - what does the foreseeable future hold

Edward Fort, Global Head of Engineering, Lloyd's Register

Insurance Institute of London, Marine & Energy 06 December 2017

Autonomous ships - what does the foreseeable future hold

The world around us is set to become autonomous. What do we mean by autonomy and what does this mean for shipping both in the near future and in the longer term. The design of modern ship's with their complex, highly integrated, software controlled systems still assumes the presence of a crew on board capable of assuming control in the event of the unexpected and perhaps surprisingly much of the expected. While autonomy represents a solution to a number of major challenges the industry is facing unsurprisingly it also brings several challenges of its own

Autonomous ships - what does the foreseeable future hold

- Autonomy, autonomous and autonomous systems
- Autonomy levels
- Autonomous ships and Cyber Enabled shipping
- Technical challenges
- Foreseeable future for autonomous ships

Autonomy, autonomous and autonomous systems

Autonomous vehicles or Unmanned Systems (UMS) are already established in many applications

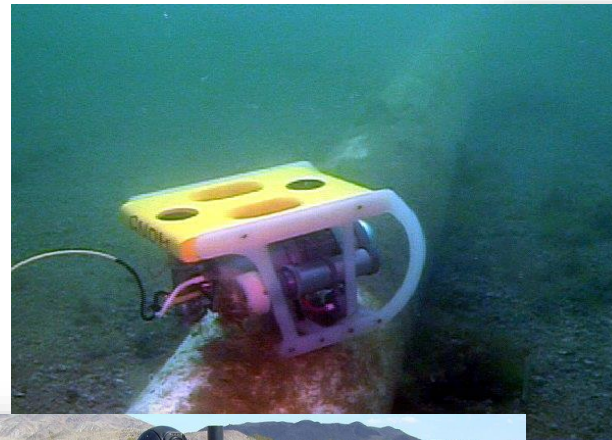
ROV – Remotely Operated underwater Vehicle

AUV – Autonomous Underwater Vehicle

UUV – Unmanned Underwater Vehicle

UAV – Unmanned Aerial Vehicle

UGV – Unmanned Ground Vehicle



Autonomy, autonomous and autonomous systems

More **autonomous vehicle** applications are beginning to emerge including

Self driving vehicle

Autonomous aerial taxi

Remotely operated surveillance drone



Autonomy, autonomous and autonomous systems

The development of military and industrial **Unmanned Systems (UMS)** and **Autonomous Vehicles** has without doubt been **demand-driven**. Is the same true for more recent developments?

Figure 25. Challenges to existing human-machine systems and opportunities for autonomous capabilities



Combines figures 1 – 4 in: *Technical Assessment: Autonomy*, DoD, Office of Technical Intelligence, Office of the Assistant Secretary of Defense for Research and Engineering, Feb 2015

Autonomy, autonomous and autonomous systems

Autonomy and autonomous

- Act separately, self-governing,
- Control over own actions,
- Self-directed behaviour,
- Modify own behaviour
- Adapt to changes in environment
- Independently compose and select actions




Autonomous systems

- Systems that are able to independently compose and adjudicate among a set of possible actions to accomplish goals based on their knowledge and understanding of the world and themselves, and able to adapt to dynamic contexts in their environment

Autonomy levels

Autonomy levels are “a set of progressive indices, typically given in numbers, identifying a UMS’s capability for performing autonomous missions”



Levels of Autonomy

(Sheridan, 1992)

1	Computer offers no assistance; human does it all
2	The computer offers a complete set of action alternatives
3	The computer narrows the selection
4	The computer suggests a single action
5	The computer executes that action if the human does not intervene
6	Allows the human limited time to veto
7	Executes automatically then notifies human
8	Informs human after automatic execution
9	Informs human after automatic execution
10	Computer decides everything and a human

Autonomy Levels for Unmanned Systems (ALFUS)

Autonomous Level Framework for Unmanned Systems (ALFUS)
The National Institute of Standards and Technology (NIST)

Environmental Complexity

- ✓ Terrain variation
- ✓ Object frequency, density, intent
- ✓ Climate
- ✓ Mobility constraints
- ✓ Communication dependencies

Mission Complexity

- ✓ Subtasks, decision
- ✓ Organisation, coordination
- ✓ Performance
- ✓ Situation Awareness

Human

- ✓ Workload
- ✓ Operator

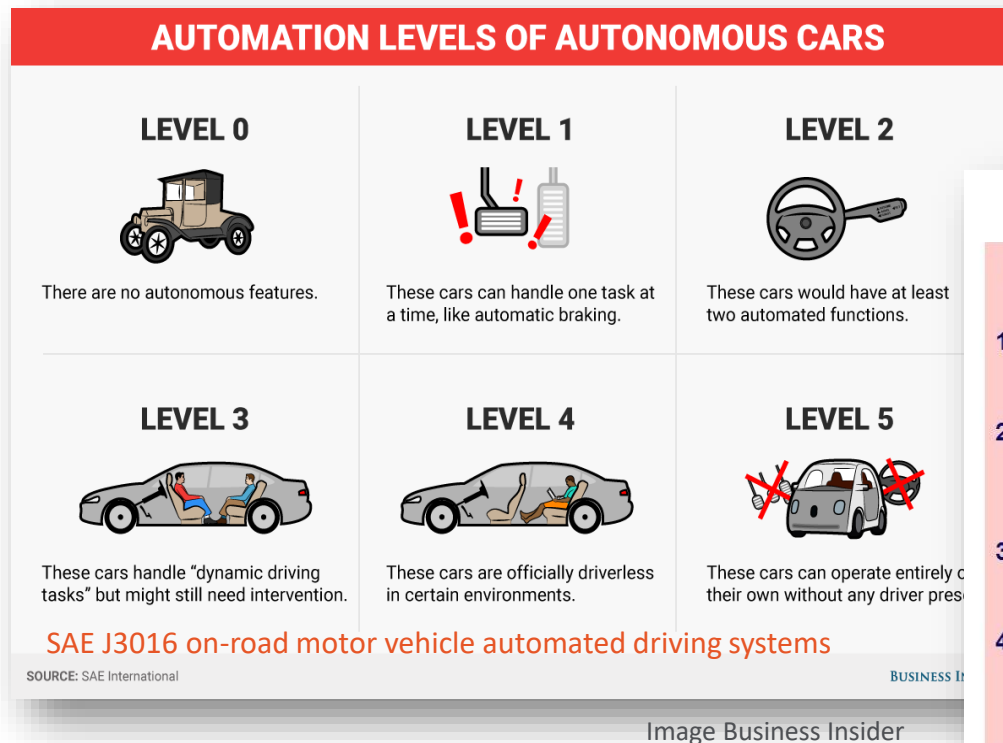
Essentially...

the degree of human/machine interaction



Autonomy levels

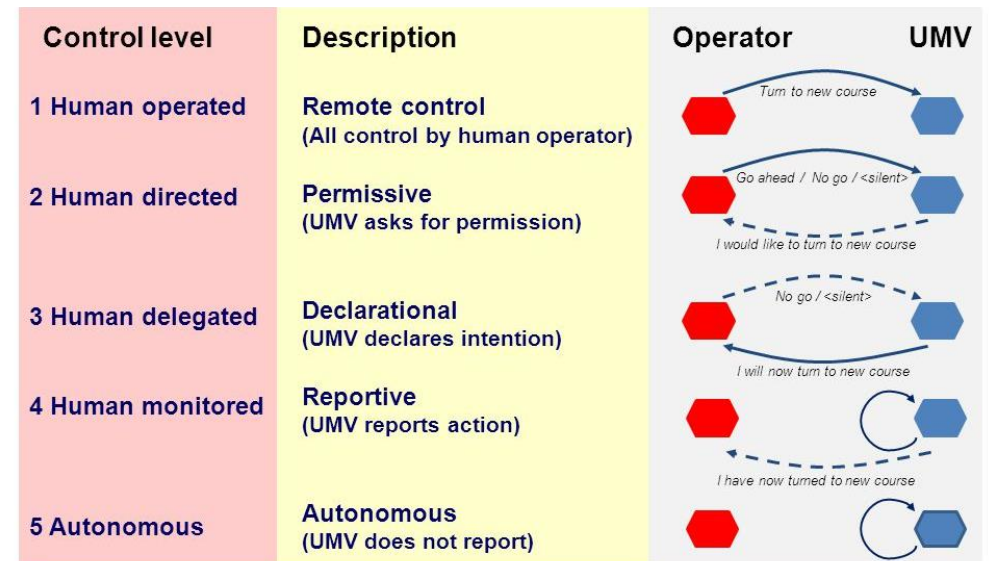
Different industries and different industry groupings are beginning to establish their own **autonomy levels** according to the needs of their application...



autonomous cars

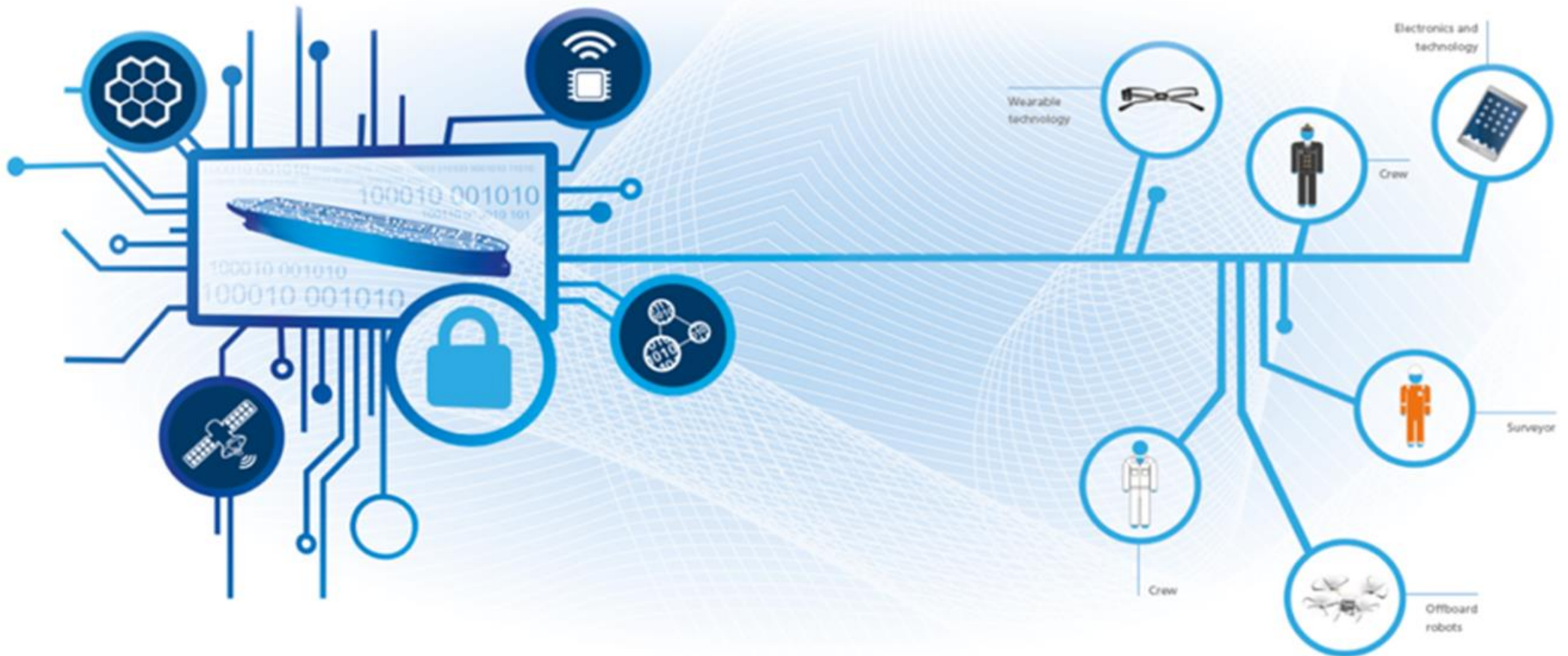
autonomous boats

Unmanned Maritime Systems - SARUMS



Autonomous ships and Cyber Enabled Shipping

Lloyd's Register considers autonomous ships an aspect of **Cyber Enabled Shipping** enabled by recent developments in digital and data technologies



Autonomous ships and Cyber Enabled Shipping

For the foreseeable future the worlds shipping fleet will comprise ships with varying degrees of **cyber enabled access** to some or all of their systems on-board



AL0

- No cyber access



AL1

- Manual cyber access



AL2

- Cyber access for autonomous/remote monitoring



AL3

- Cyber access for autonomous/remote monitoring and control
- onboard permission required
- onboard override possible



AL4

- Cyber access for autonomous/remote monitoring and control
- onboard permission not required
- onboard override possible



AL5

- Cyber access for autonomous/remote monitoring and control
- onboard permission not required
- onboard override not possible

Autonomous ships and Cyber Enabled Shipping

Autonomy level AL1 - **Normal manning**. Its systems are **not externally accessible** for either monitoring or control. The majority of the worlds commercial fleet is AL1.



AL0

- No cyber access



AL1

- Manual cyber access

Autonomous ships and Cyber Enabled Shipping

Autonomy level AL2 - **Normally manning**. One or more essential systems are **externally accessible for monitoring**. Much of the tonnage delivered in recent years is AL2.



AL0

- No cyber access



AL1

- Manual cyber access



AL2

- Cyber access for autonomous/remote monitoring

Autonomous ships and Cyber Enabled Shipping

Autonomy level AL3 - **Normal manning**. One or more essential systems are **externally accessible for monitoring and control**. Some of the tonnage now being delivered is AL3.



AL0

- No cyber access



AL1

- Manual cyber access



AL2

- Cyber access for autonomous/remote monitoring



AL3

- Cyber access for autonomous/remote monitoring and control
- onboard permission required
- onboard override possible

Autonomous ships and Cyber Enabled Shipping

Autonomy level AL4 – **Reduced manning possible**. One or more essential systems are **externally accessible for monitoring and control**. Such ships are currently under development.



AL0

- No cyber access



AL1

- Manual cyber access



AL2

- Cyber access for autonomous/remote monitoring



AL3

- Cyber access for autonomous/remote monitoring and control
- onboard permission required
- onboard override possible



AL4

- Cyber access for autonomous/remote monitoring and control
- onboard permission not required
- onboard override possible

Autonomous ships and Cyber Enabled Shipping

Autonomy level AL5 – **Zero manning possible**. One or more essential systems are **externally accessible for monitoring and control**. Such ships are currently conceptual at this point in time



AL0

- No cyber access



AL1

- Manual cyber access



AL2

- Cyber access for autonomous/remote monitoring



AL3

- Cyber access for autonomous/remote monitoring and control
- onboard permission required
- onboard override possible



AL4

- Cyber access for autonomous/remote monitoring and control
- onboard permission not required
- onboard override possible



AL5

- Cyber access for autonomous/remote monitoring and control
- onboard permission not required
- onboard override not possible

Technical challenges

While the technology for autonomous ships is already available its introduction does pose some **major technical challenges** for traditional marine engineering systems including

- Equipment suitability
- Fault tolerance
- Software verification
- System scope
- System assurance



Image Kongsberg

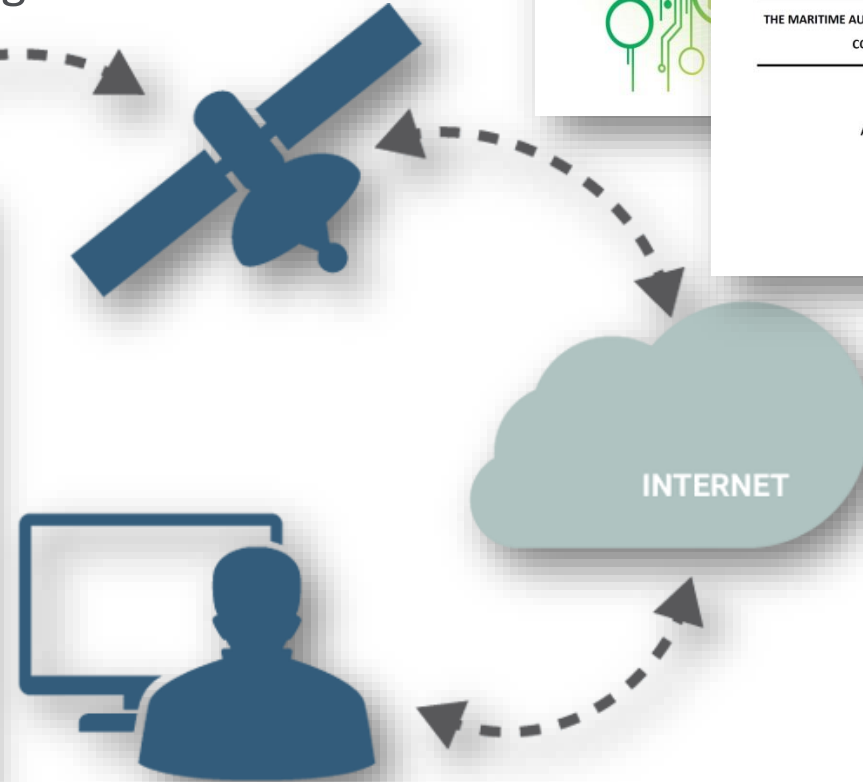
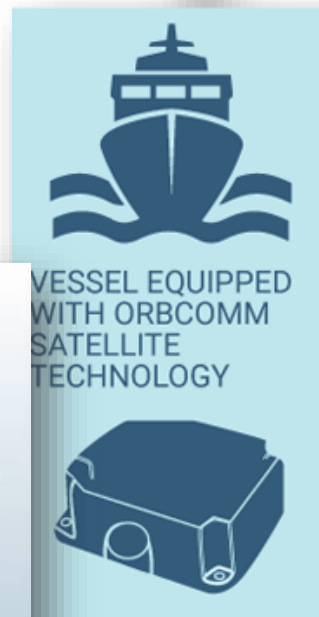


Image Orbcomm



Foreseeable future for autonomous ships

LPG Carrier AL2 (*Navigation, Cargo Handling, Machinery*) **AL3** (*HVAC*)

Bulk Carrier AL2 (*Navigation, Propulsion, Steering*)



AL2

- Cyber access for autonomous/remote monitoring

AL3

- Cyber access for autonomous/remote monitoring and control
- onboard permission required
- onboard override possible



Foreseeable future for autonomous ships

Harbour tug AL3 (*Navigation, Propulsion, Steering*) - Phase 1



AL3

- Cyber access for autonomous/remote monitoring and control
- onboard permission required
- onboard override possible



AL4

- Cyber access for autonomous/remote monitoring and control
- onboard permission not required
- onboard override possible

Foreseeable future for autonomous ships

So are autonomous ships an example of technology looking for an application...

*Without doubt **autonomous ships** can be expected to operate with **optimum efficiency** however from a safety perspective **autonomous ships** should solve the ever widening gap between the complex, interdependent, software driven systems being installed on modern ships and the competence and capability of the ships crew to **operate and maintain those systems***

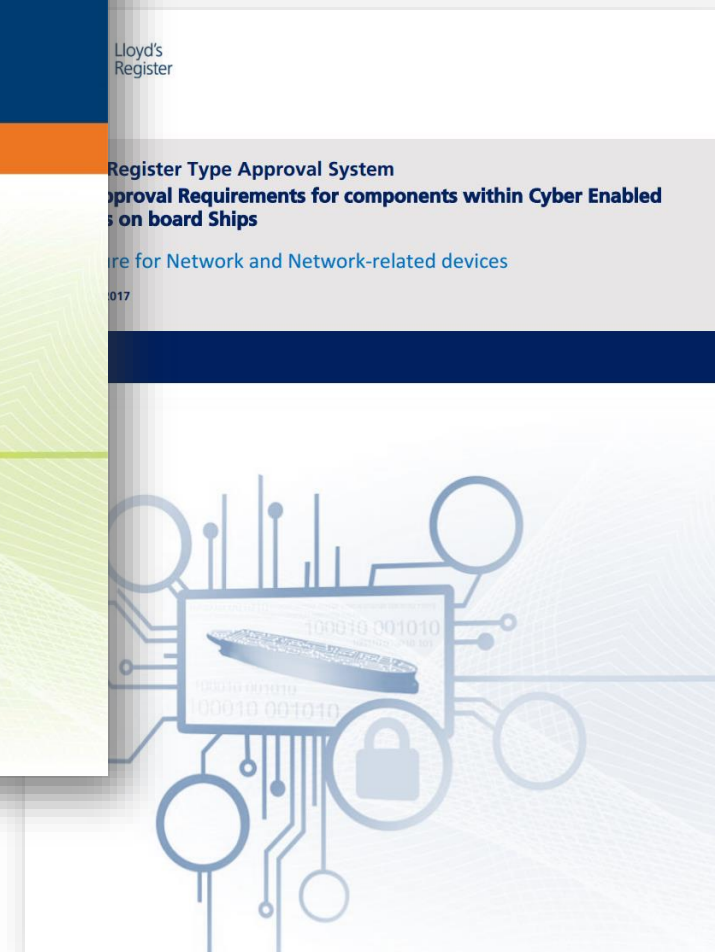
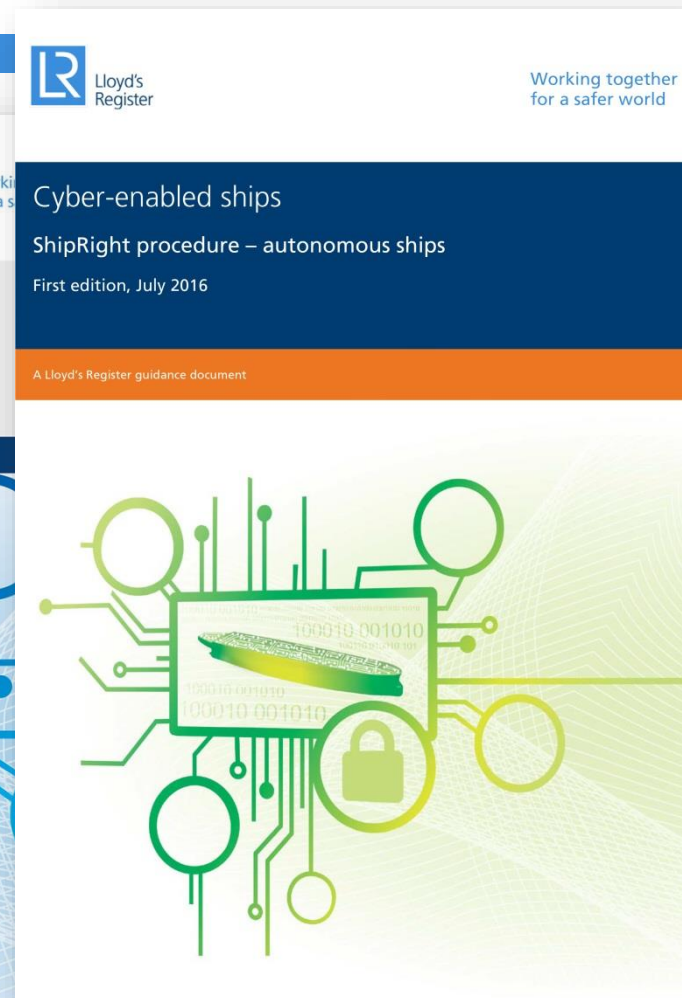
However autonomous ships could ultimately provide solutions to what are arguably the biggest challenges the shipping industry faces...

Autonomous ships** without the crew onboard would eliminate the single biggest cause of accidents and incidents onboard ships – **human Error**. And if that's not enough, **autonomous ships** without the cost of the crew onboard might make increased numbers of much slower significantly more fuel efficient ships a major part of the solution to the greatest challenge that ships will need to overcome – **decarbonisation

Foreseeable future for autonomous ships



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