MARITIME

Digital Twins

for Design, Testing and Verification of Autonomous Systems

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2011

"Software is eating the world."

–Marc Andreessen, VC

2017

Key digital trends shaping the (maritime) industry's future

Internet of Things
- Sensors everywhere
- 1 trillion connected devices in 2025
- 11 trillion USD revenues

Bandwidth
- 5G terrestrial network with 10 Gbps
- 50 Mbps satellite network in 2025

Cloud
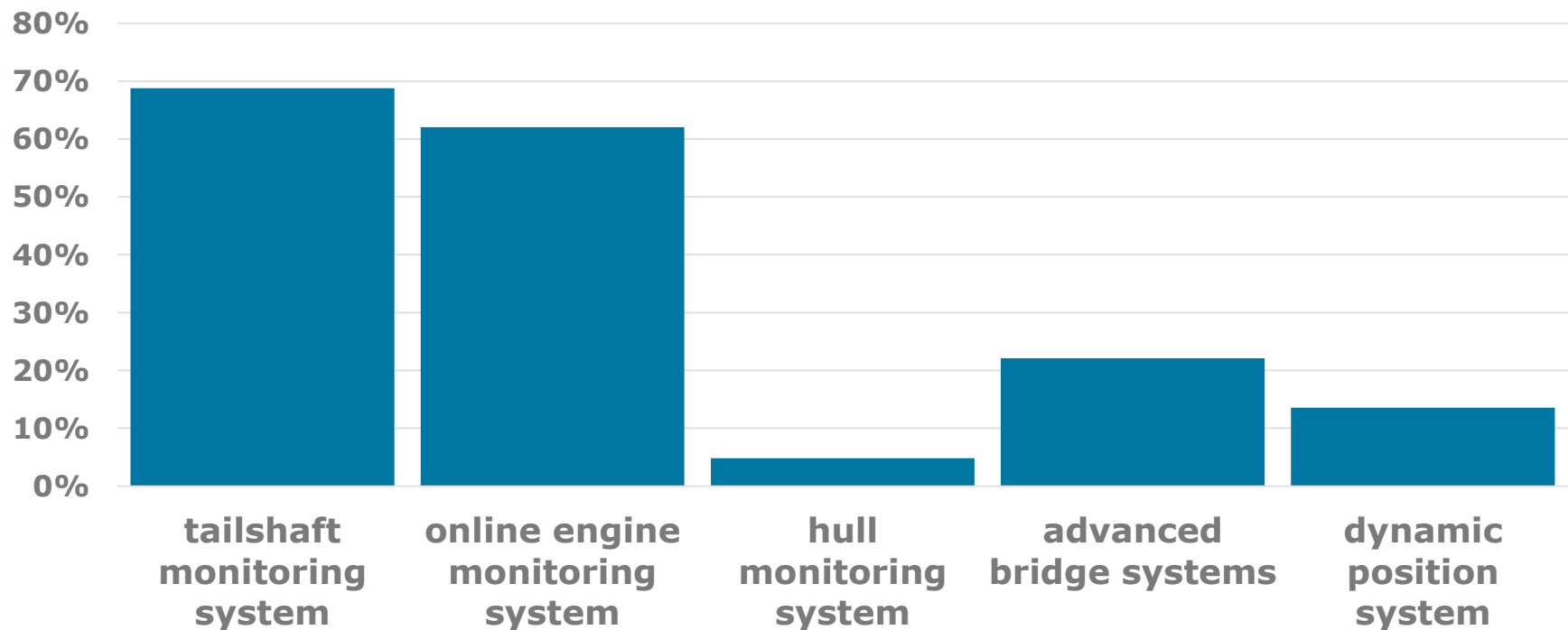- Computing and storage on demand
- 50% of IT infrastructure in 2020

Machine learning
- Taking off now, driven by consumer applications (Siri, Alexa, Google now)
- Essential to create insight from large data volumes

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Share of new vessels into DNV GL class (2015&2016) and equipped with

80%	
70%	
60%	
50%	
40%	
30%	
20%	
10%	
0%	

tailshaft monitoring system · **online engine monitoring system** · **hull monitoring system** · **advanced bridge systems** · **dynamic position system**

Source: DNV GL 2015&2016 data , MDT, own estimates

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Cyber-physical systems (CPS)

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"Cyber-physical systems (CPS) are engineered systems that are built from, and depend upon, the seamless integration of computational algorithms and physical components."

National Science Foundation

Yes, it is complex (Why?)

DNV GL © 2014   13 June 2016

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Combining the continuous physical world and discrete software world
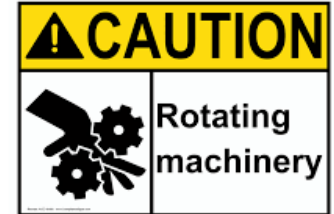
Real-time and network challenge

Humans in the loop and autonomy

Security challenge

«Old risks»
Machinery, structure, components – strenght, wear and tear

«New risks»
Cyber-physical systems with systematic failures – if wrong, always wrong

Safety

Cyber-physical system

Security

The "inner" threats:
- Bugs
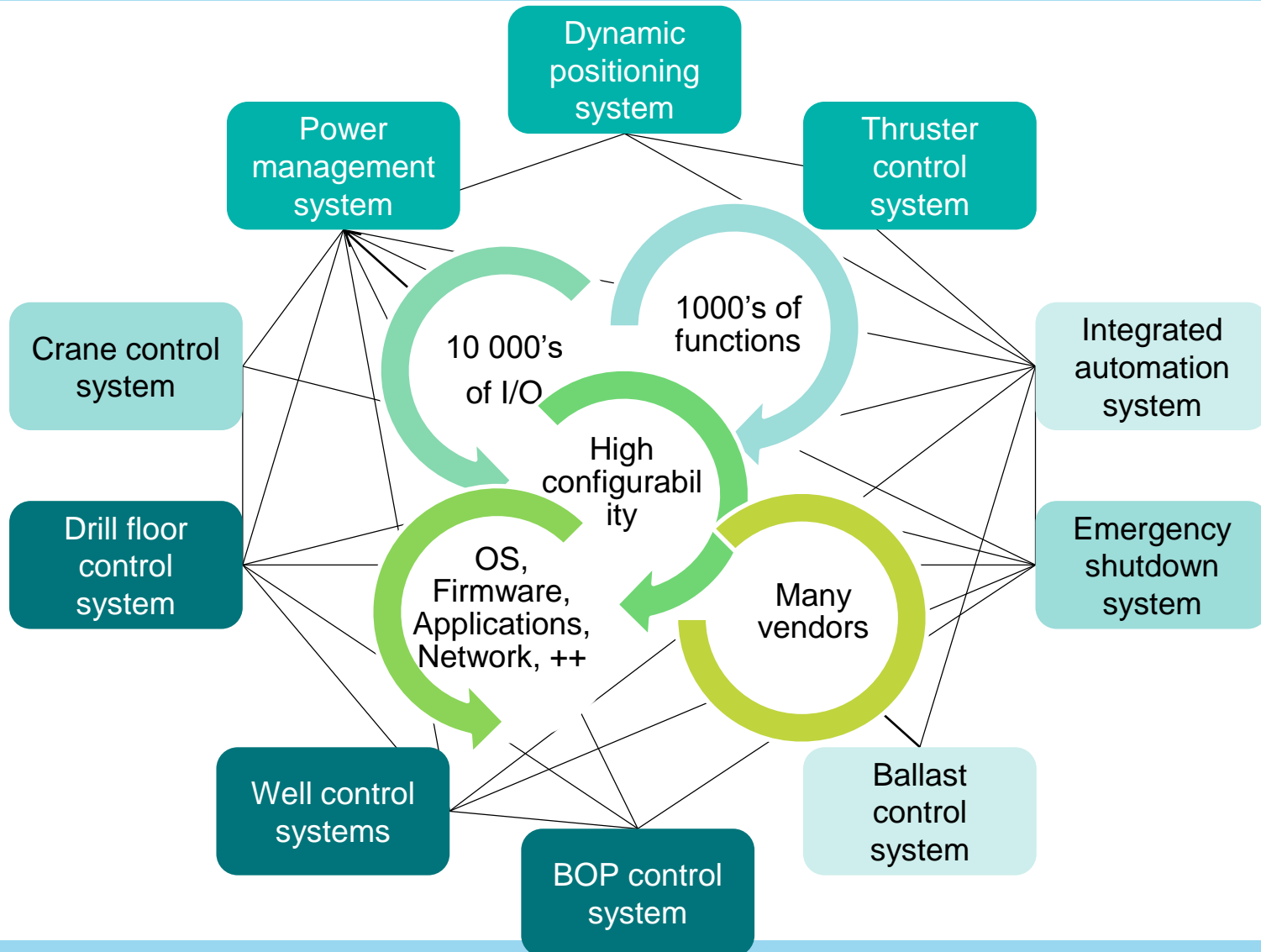- Design flaws
- Configuration errors
- …

The "external" threats:
- Hackers
- Malware
- Cyber crime
- …

# Control systems on a modern drilling unit

Dynamic positioning system

Power management system

Thruster control system

Crane control system

Integrated automation system

Drill floor control system

Emergency shutdown system

Well control systems

BOP control system

Ballast control system

1000's of functions

10 000's of I/O

High configurability

OS, Firmware, Applications, Network, ++

Many vendors
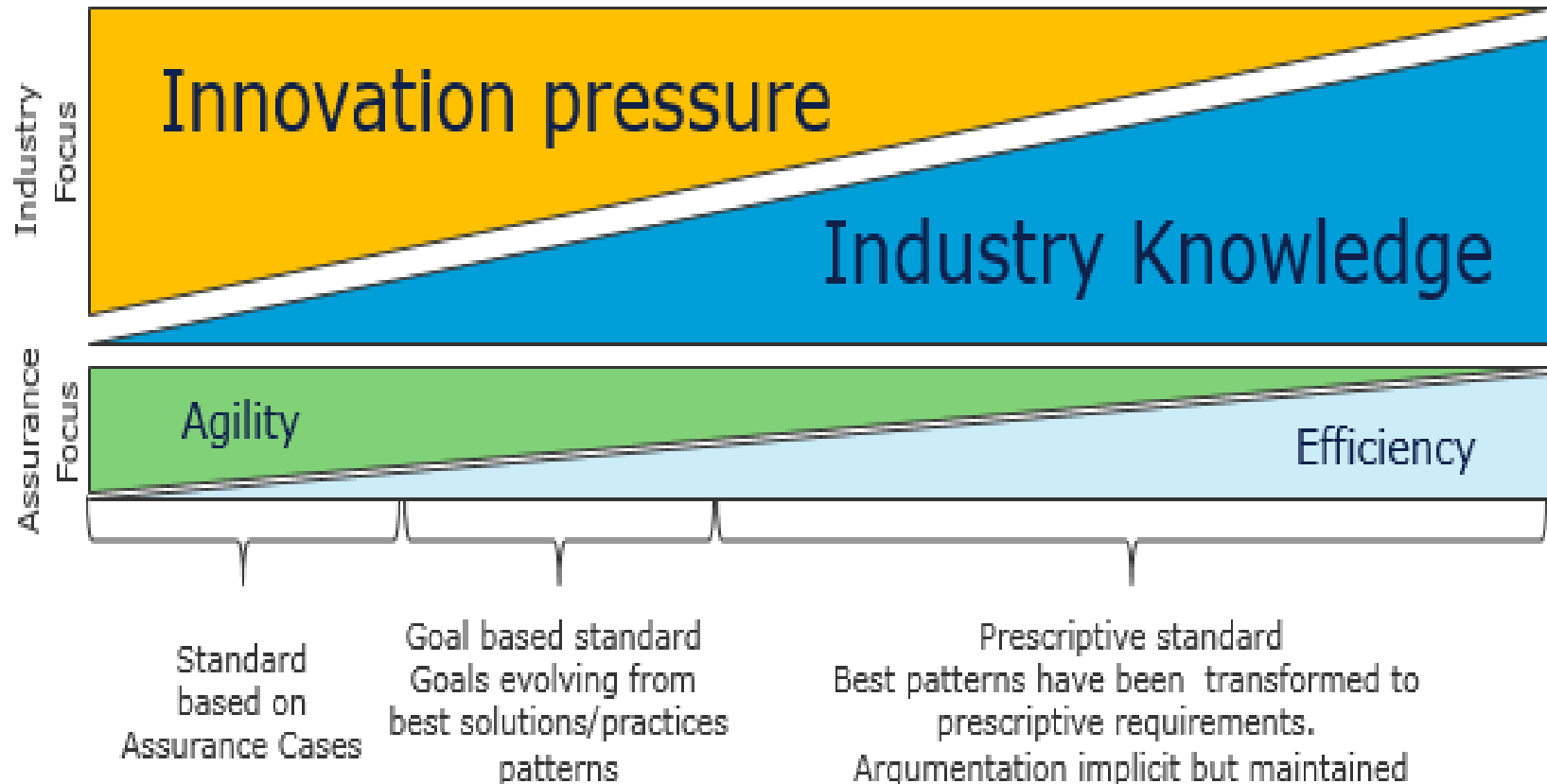
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Emergent system properties

Emergence is a process whereby larger entities arise through interactions among smaller or simpler entities such that the larger entities exhibit properties the smaller/simpler entities do not exhibit.
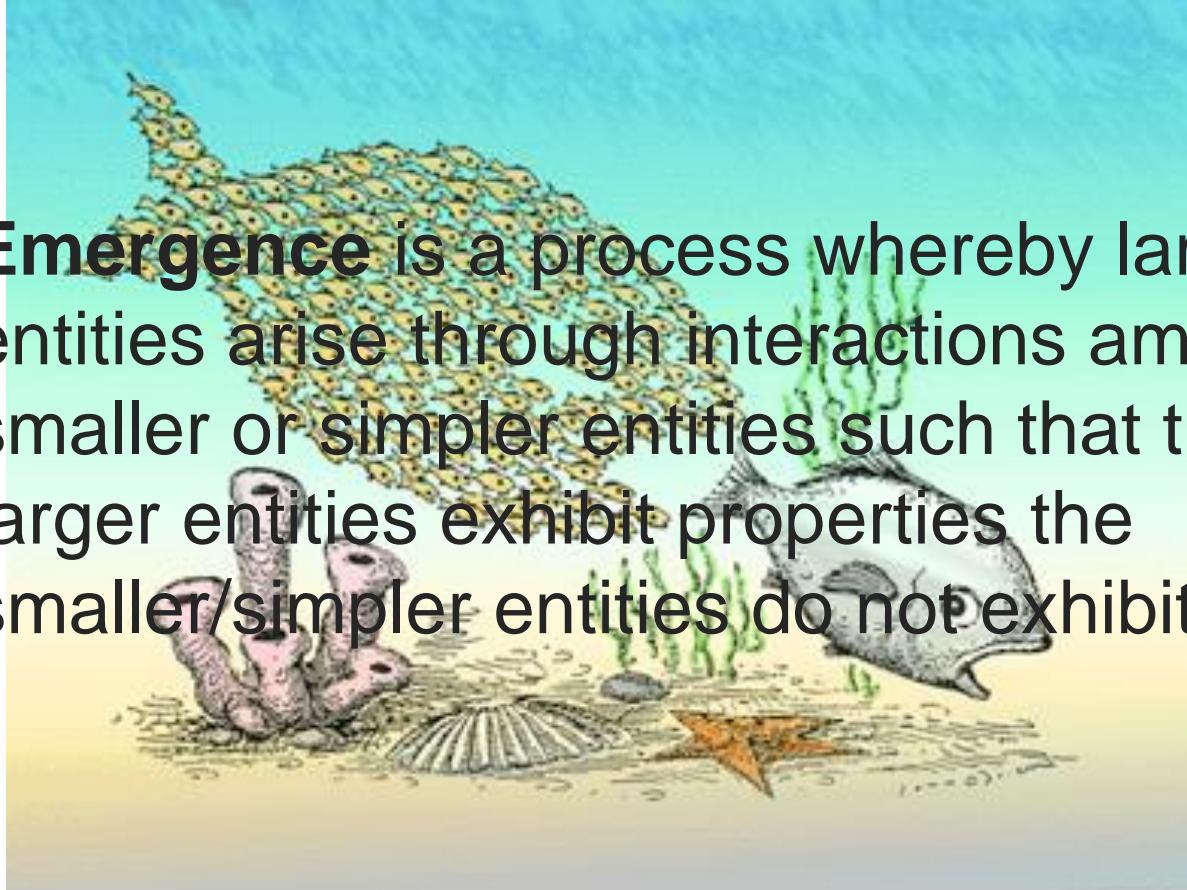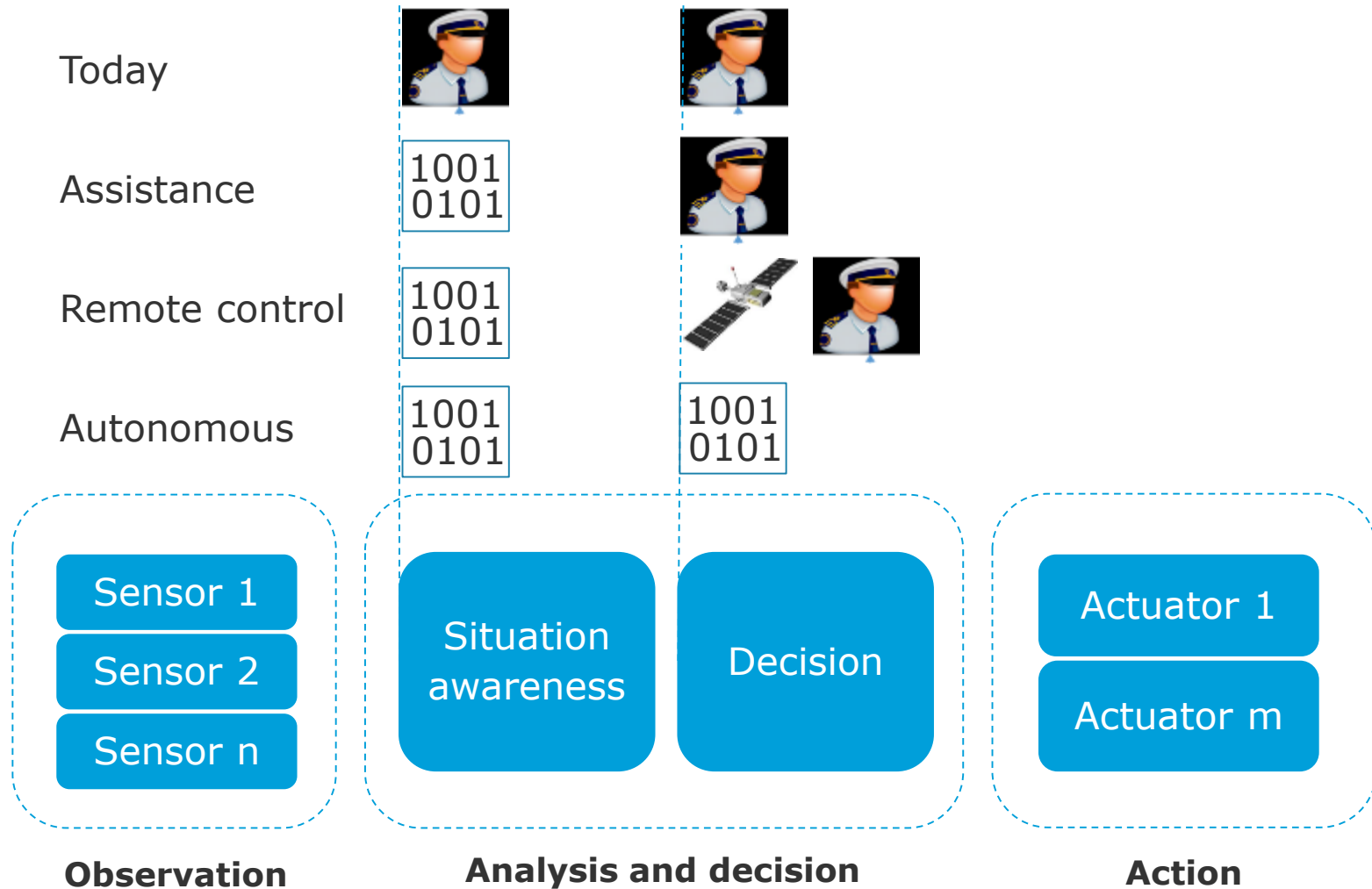
… or "integration issues" as they're often called

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Verification of Autonomous Systems

DNV·GL

The verification challenge

Navigation with different levels of human interaction

Today

Assistance
1001
0101

Remote control
1001
0101

Autonomous
1001
0101
1001
0101

Sensor 1	Situation awareness	Decision	Actuator 1
Sensor 2			Actuator m
Sensor n			

Observation   **Analysis and decision**   **Action**
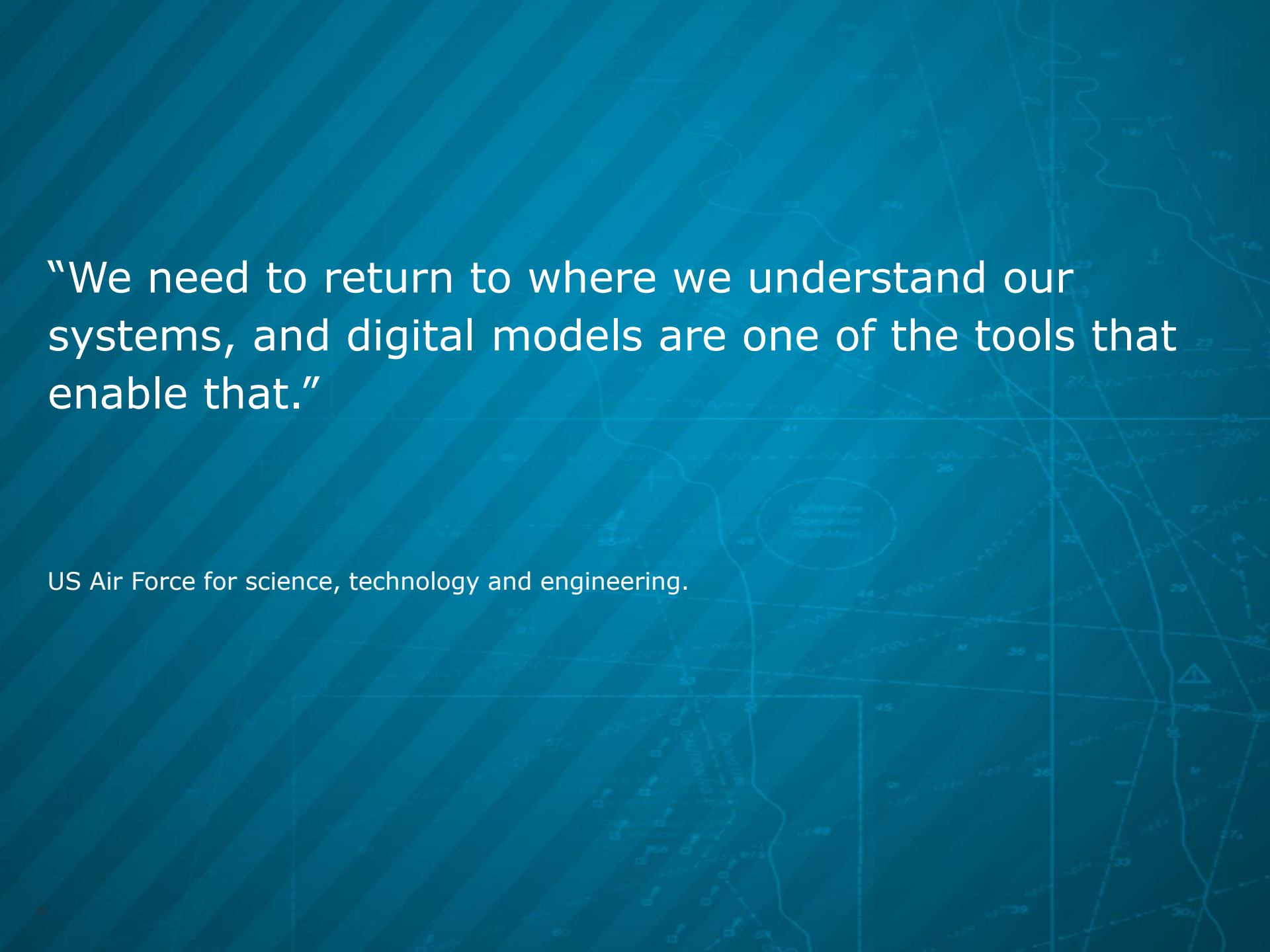
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Digital Twins

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Digital Twin

A model of an asset, specific to its physical counterpart

Mathematical model - information model - visual models
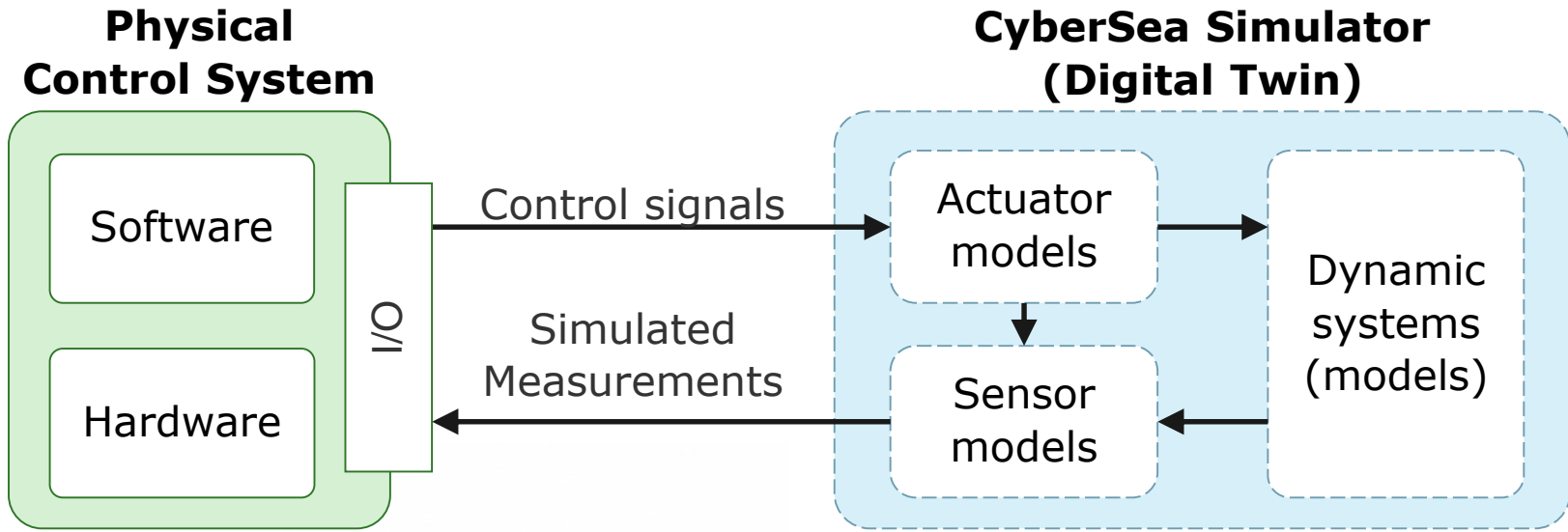

Image credit: GE Power & gorex

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"We need to return to where we understand our systems, and digital models are one of the tools that enable that."

US Air Force for science, technology and engineering.

Hardware-in-the-loop

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Hardware-In-the-Loop Setup

Physical Control System

CyberSea Simulator (Digital Twin)

Software

Hardware

I/O

Control signals

Simulated Measurements

Actuator models

Sensor models

Dynamic systems (models)

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Software-in-the-loop

(Model-in-the-loop Processor-in-the-loop)

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Software-In-the-Loop Setup

Virtualized Control Systems

- Software
- Virtualized Hardware
- I/O
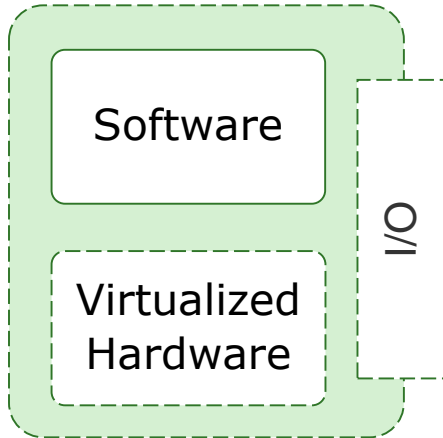
Control signals →

← Simulated Measurements

CyberSea Simulator (Digital Twin)

- Actuator models
- Sensor models
- Dynamic systems (models)
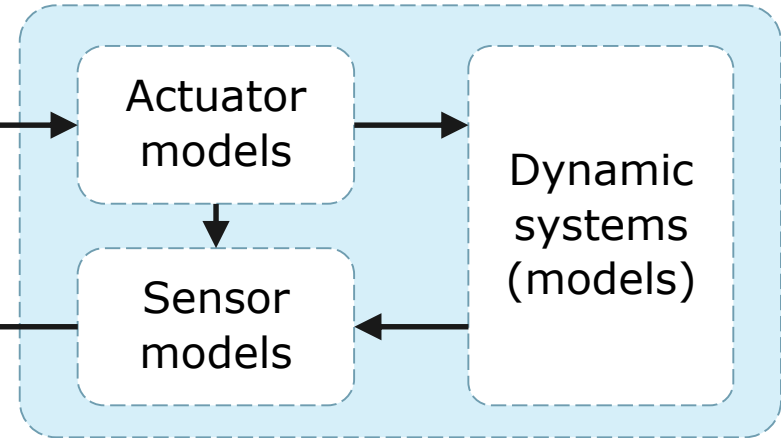
- No real time requirements
- "just files"→ Easy duplication
- Suitable for scaling in the cloud
- Exact same SW as in normal operation

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The ReVolt Project

- **Concept developed by DNV GL**
  - Released 2014
  - Unmanned container vessel
  - Zero emission
  - Battery powered
- **ReVolt Student project**
  - 1:20 Scale model
  - Fully capable with 3 azimuth thrusters
  - Two summer students and MSc's 2016/2017
  - Five summer students and MSc's 2017/2018

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Ongoing public funded R&D projects

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The SIMAROS project
Safe Implementation of Autonomous and Remote Operation of Ships

- **Unmanned offshore vessel**
  - Technology development
  - Development of risk assessment tools and standards
  - Ambition: Enable national regulations and class to allow for commercial unmanned operation
  - Building starts 2017, test operation 2018

- **Partners:**

Press Release

KONGSBERG

Automated Ships Ltd and KONGSBERG to build first unmanned and fully-automated vessel for offshore operations

- First full size unmanned ship to be built through UK and Norwegian co-operation
- Offshore vessel 'Hrönn', to be contracted January 2017 and in operation in 2018

Artists impression of the 'Hrönn'

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The AAWA project
Advanced Autonomous Waterborne Applications

- **Areas of focus:**
  - Technology
  - Safety and security
  - Societal & legal acceptance
  - Economy and business models

- **DNV GL focus:**
  - Class requirements and assurance of safety and performance

- **Partners:**

Rolls-Royce DNV·GL DELTAMARIN NAPA inmarsat

Turun yliopisto University of Turku Åbo Akademi TAMPERE UNIVERSITY OF TECHNOLOGY A? Aalto University VTT

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The Autosea project

AUTOSEA

- **Areas of focus:**
  - Sensor fusion
  - Collision avoidance
  - System architecture

- **DNV GL focus:**
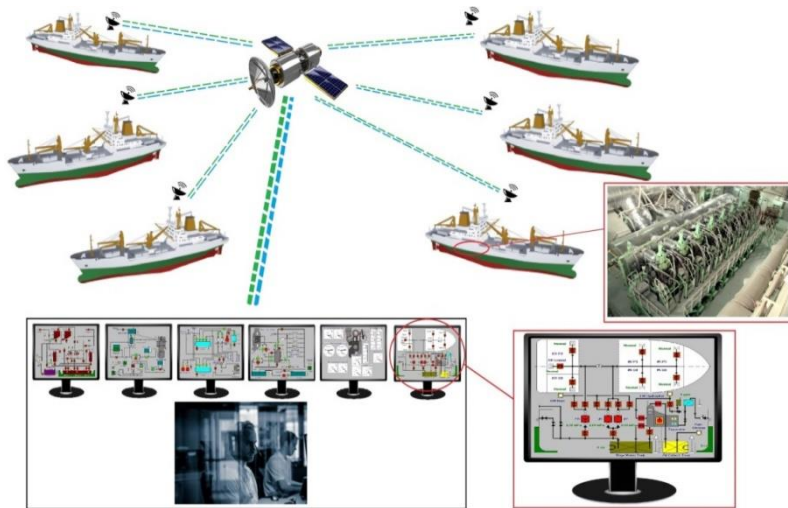 - Competence on core technologies

- **Partners:**

NTNU

DNV·GL

KONGSBERG

MARITIME ROBOTICS

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The ROMAS project (On Shore ECR)
Remote Operations of Machinery and Automation Systems

Thank you!

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SAFER, SMARTER, GREENER

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