The Role of Human Performance in Decision Making

Maritime Automated Systems Development: Implications of Autonomy in Naval and Maritime Command, Training and Assessment

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Outline

- Introduction
- Training and Systems Complexity
- Automation and Autonomous Systems
- The Modern Era of Maritime Automation
- Human Performance
- The Future
- Autonomous Ships and NexGen Command and Control


MM
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Orlando / UCF: The World Capital of Modeling, Simulation and Training (MS&T)
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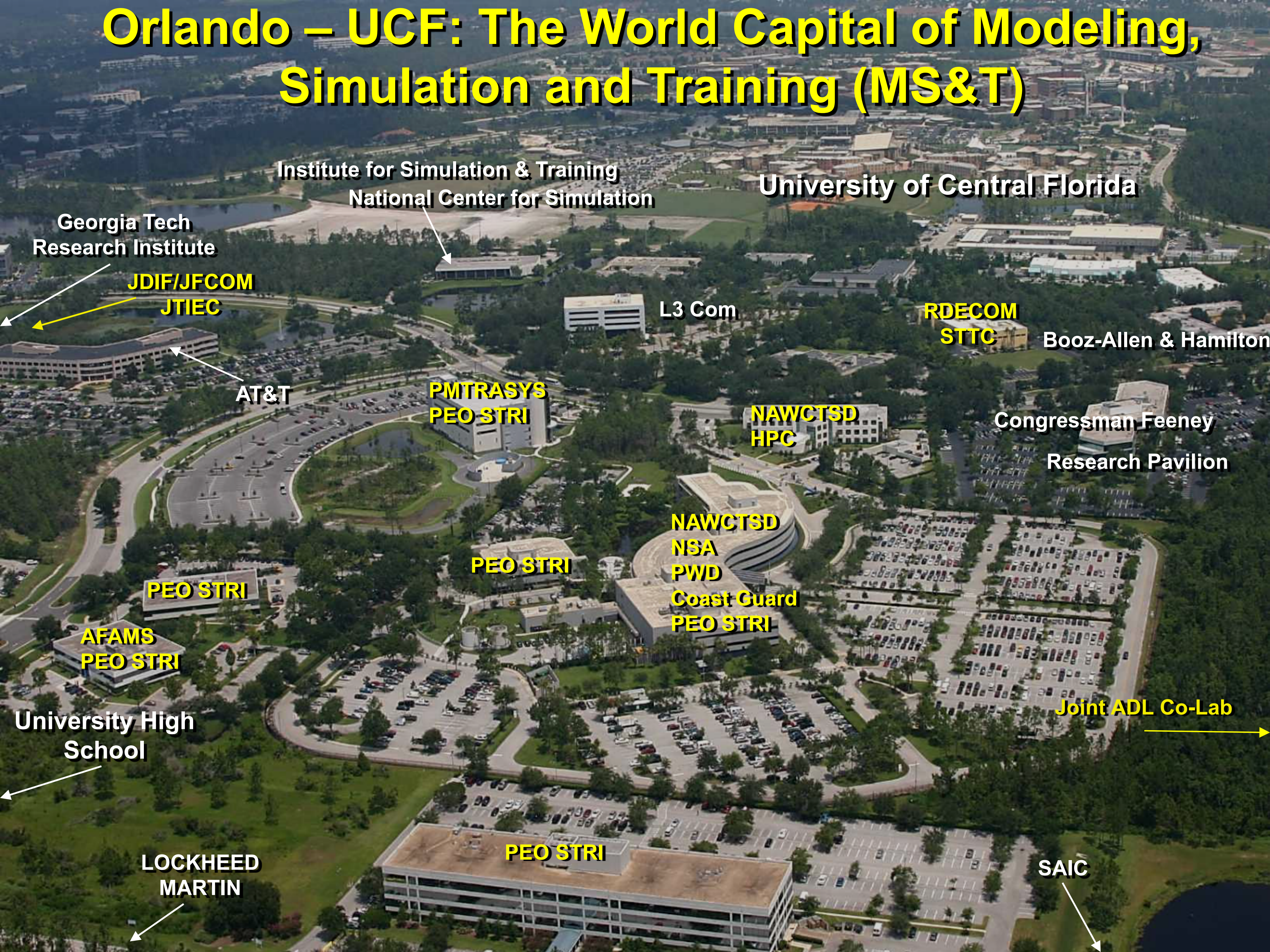

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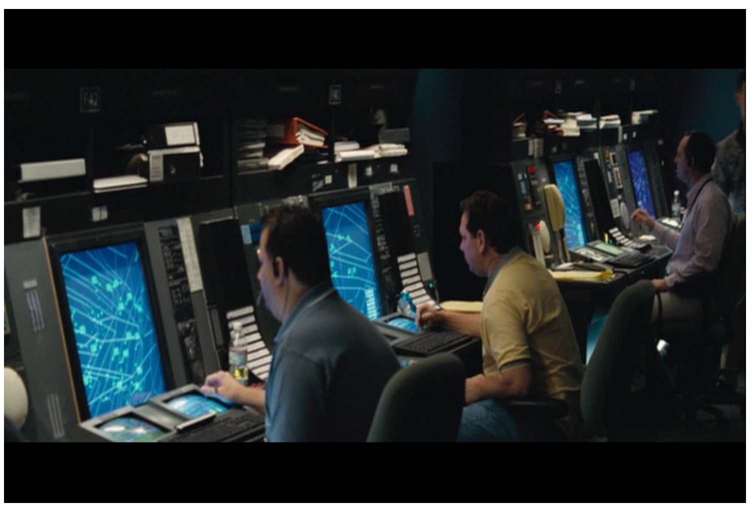
COMPLEXITY OF TECHNOLOGIES OF THE 21TH CENTURY

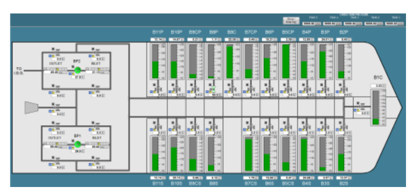
COMPLEXITY OF TECHNOLOGIES OF THE 21TH CENTURY

Training and Systems Complexity

Increased Cognitive Workload

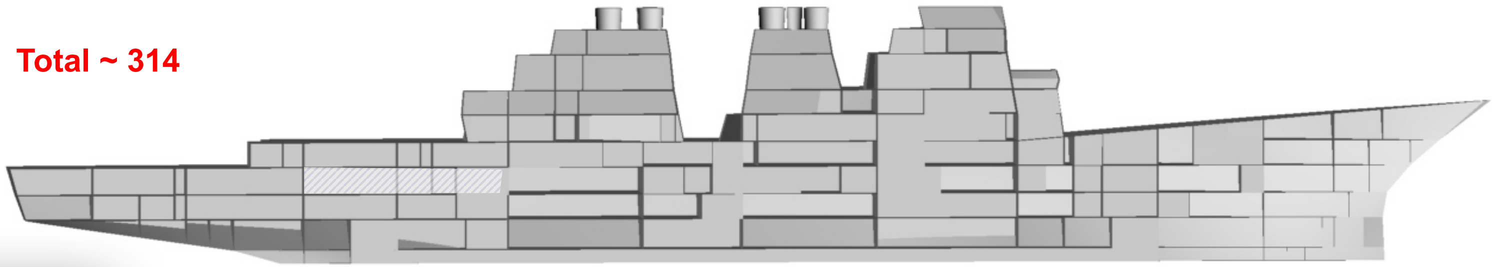


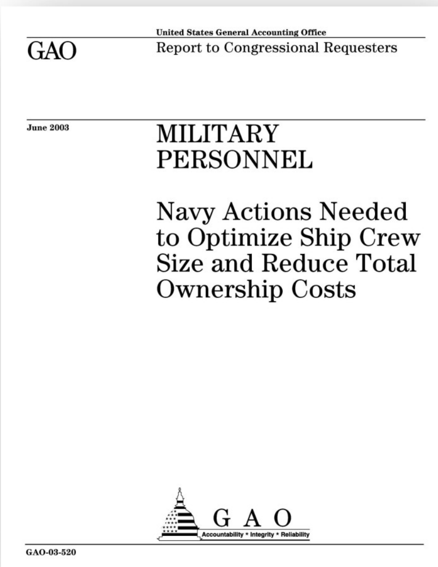
Poor system design as leading factor to safety risks with environmental impacts.



The Challenge: Crew Reduction

Total ~ 314





United States General Accounting Office

GAO Report to Congressional Requesters

June 2003

MILITARY PERSONNEL

Navy Actions Needed to Optimize Ship Crew Size and Reduce Total Ownership Costs

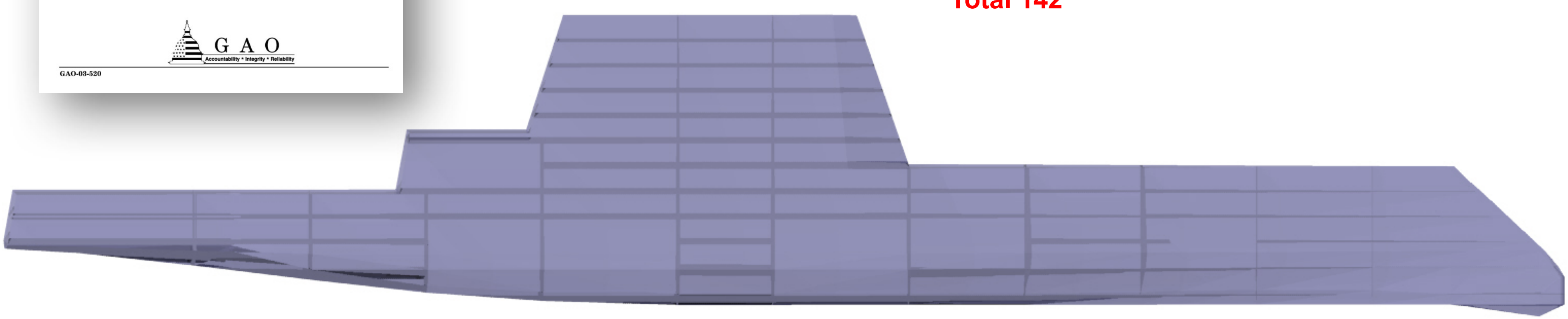
G A O

Accountability * Integrity * Reliability

GAO-03-520

The Challenge: Reducing the Crew Size more than 50% over legacy surface combatant in a larger and decidedly more complex platform

Total 142



Source: https://i.pinimg.com

Challenges

- Managing complexity

- Human-technology system adaptation of capacities and capabilities to mitigate risks and safety

- Resilience as emergent behavior of complex technological automated systems

Human Error in Maritime Industry

Human error contributes to the vast majority (75-96%) of marine casualties.

Studies have shown that human error contributes to:

- 84-88% of tanker accidents
- 79% of towing vessel groundings
- 89-96% of collisions
- 75% of fires

Source: McCallum M.C., Raby M., and Rothblum A.M. (1996) *Procedures for Investigating and Reporting Human Factors and Fatigue Contributions to Marine Casualties.* Washington, D.C.: U.S. Dept. of Transportation, U.S. Coast Guard Report No. CG-D-09-97. AD-A323392

Lessons Learned

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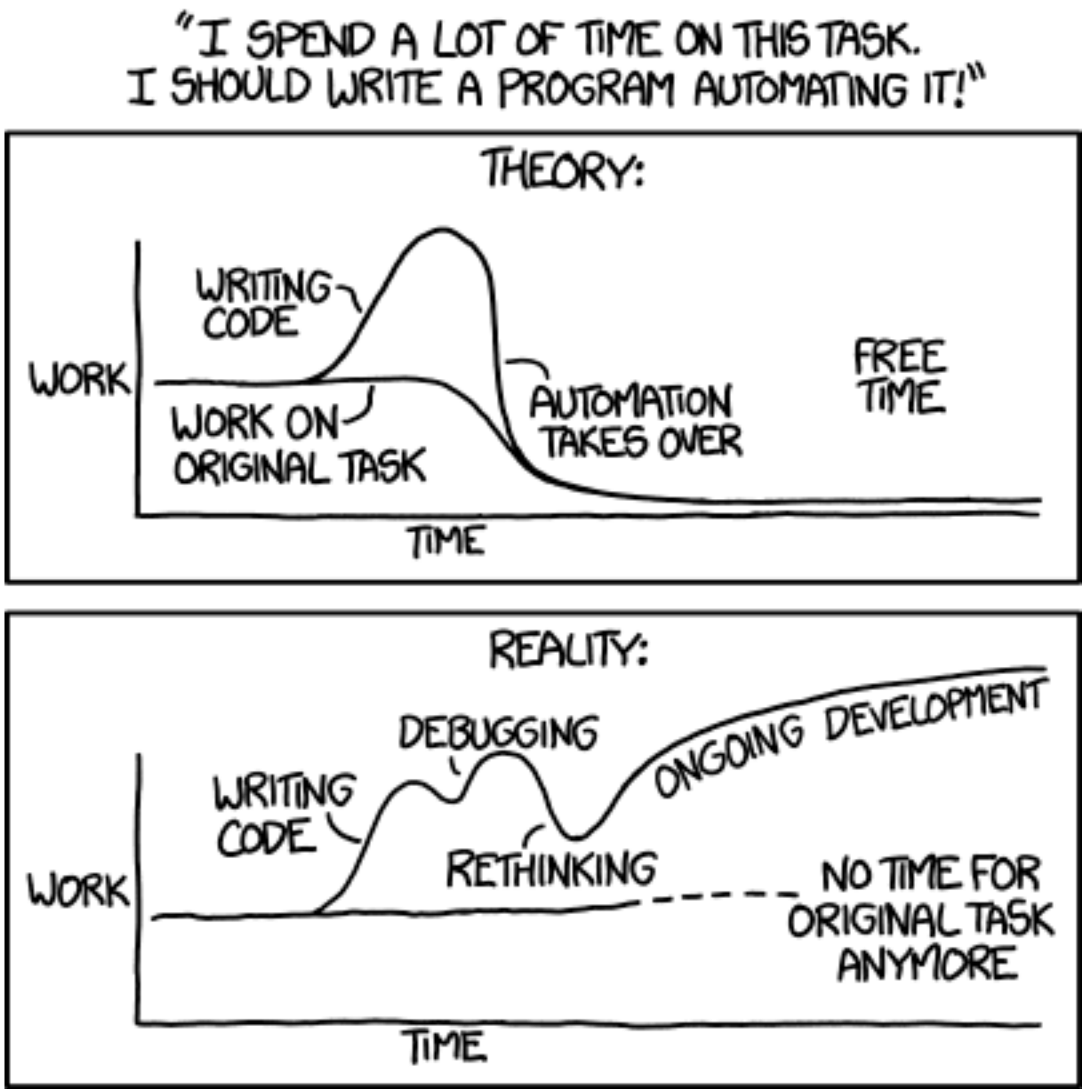
Lesson #1
Nothing Can Stop Automation

Lesson #2 Mistakes Happen! Automation help us avoid Them

Lesson #3 Automation is Not a Solution for All Problems!



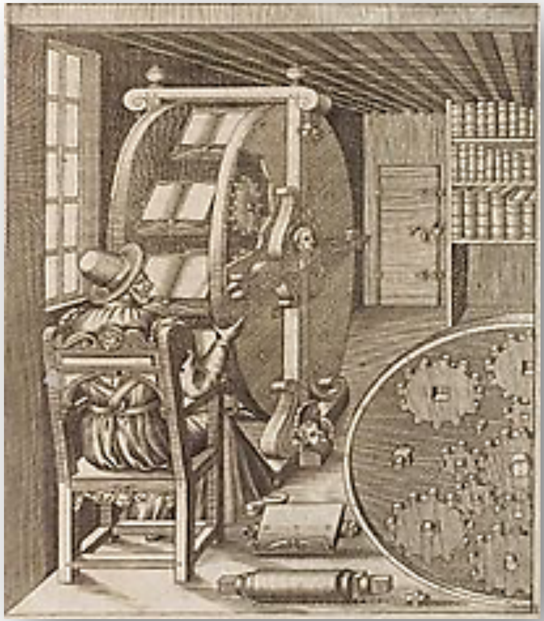
Lesson #4 Poor Implementation Can Cause Frustration!

"Your call is important to us. Please stay on the line until your call is no longer important to you."

Automation

What is Automation?

- ‘**Automatos**’ a word of Greek origin termed to be as Automation, means “self-movement”
- The dictionary defines *automation* as “**the technique of making an apparatus, a process, or a system operate automatically**.”
- Automation:“ the creation and application of technology to monitor and control the process/production and delivery of products/services.”
- **Automation** is the use of **machines**, **control systems** and **information technologies** to optimize productivity in the production of goods and delivery of services



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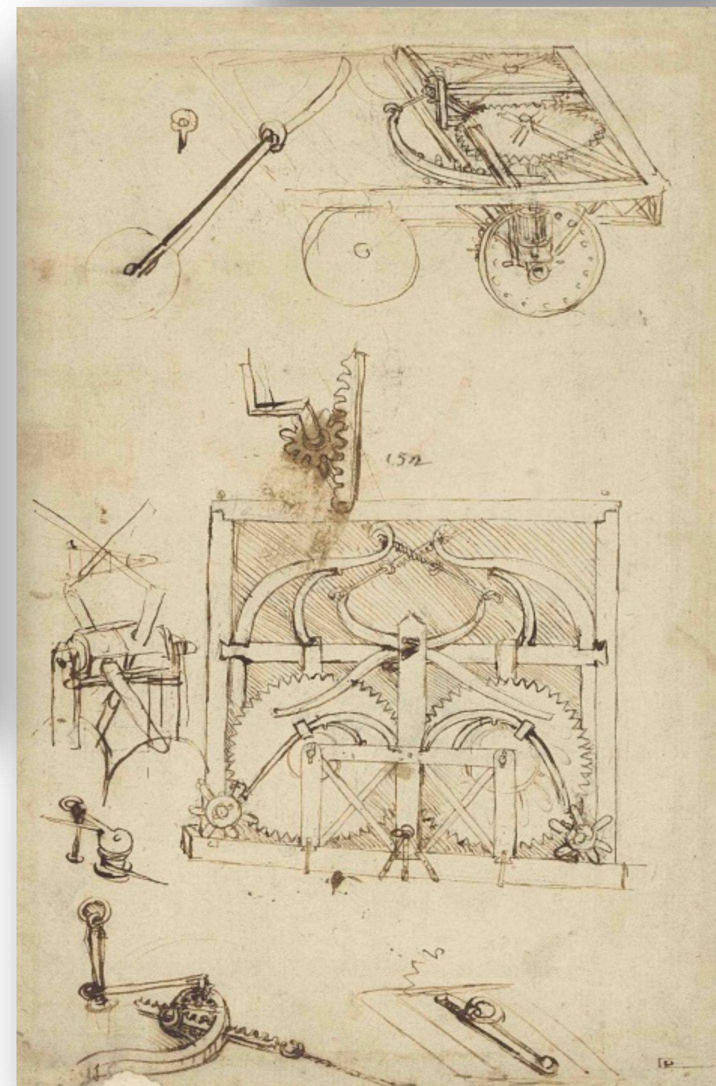
Where to? A History of Autonomous Vehicles

Drawing of a pre-programmed clockwork cart by Leonardo Da Vinci, circa 1478 Had it been built, this cart would have been powered by large coiled clockwork springs, propelling it over 130 feet. The clever control mechanism could have taken the vehicle through a predetermined course.

Source: Biblioteca Ambrosiana, Milan, Italy



History: 1920-50s

THE NEW YORK TIMES, SUNDAY, FEBRUARY 26, 1928. XX 3

MARCH OF THE MACHINE MAKES IDLE HANDS

Prevalence of Unemployment With Greatly Increased Industrial Output Points to the Influence of Labor-Saving Devices as an Underlying Cause

By EVANS CLARK.

A FEW days ago the General Motors Corporation reported the largest peace-time earnings ever made by a single concern in the history of America. Three days later Governor Smith made public a report from the New York Industrial Commissioner which called public attention to serious unemployment throughout the State: not since the depression of 1921, it was disclosed, have conditions been as bad.

The people of the United States—in the shadow of a Presidential election—are presented with a social

...

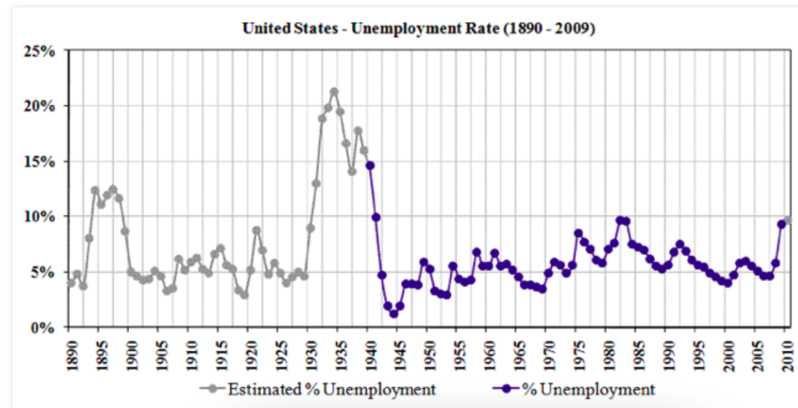
have gone far to make construction a machine industry instead of a collection of hand trades. One gasoline crane takes the place of ten or twelve laborers. The hod-carrier has disappeared before the invasion of the material hoist. In concrete construction building materials are mixed, like dough, in a machine and literally poured into place without the touch of a human hand. The Ohio figures record these results: with 15 per cent. fewer men employed, contractors put up 11 per cent. more square feet of finished buildings last year than in 1923.

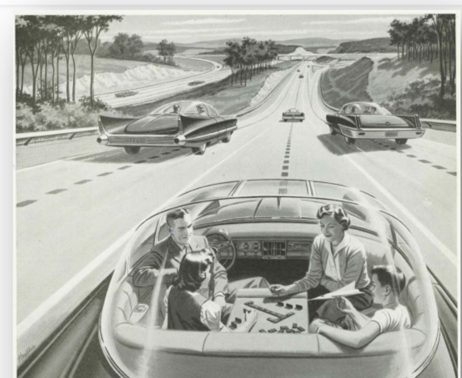
Coal Mined by Machines.

Robots have been about to take all the jobs for more than 200 years. Is it really different this time?

Technology has always triggered fears of mass unemployment. In 1811 it was the Luddites, who assumed they were done for.

In the 1930s, it was vaunted economist John Maynard Keynes, who implicated technology as one reason for the unemployment of the Great Depression.

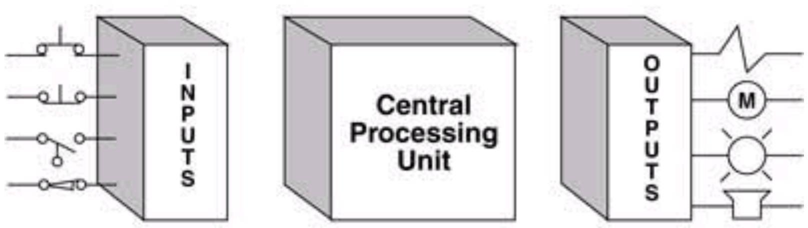


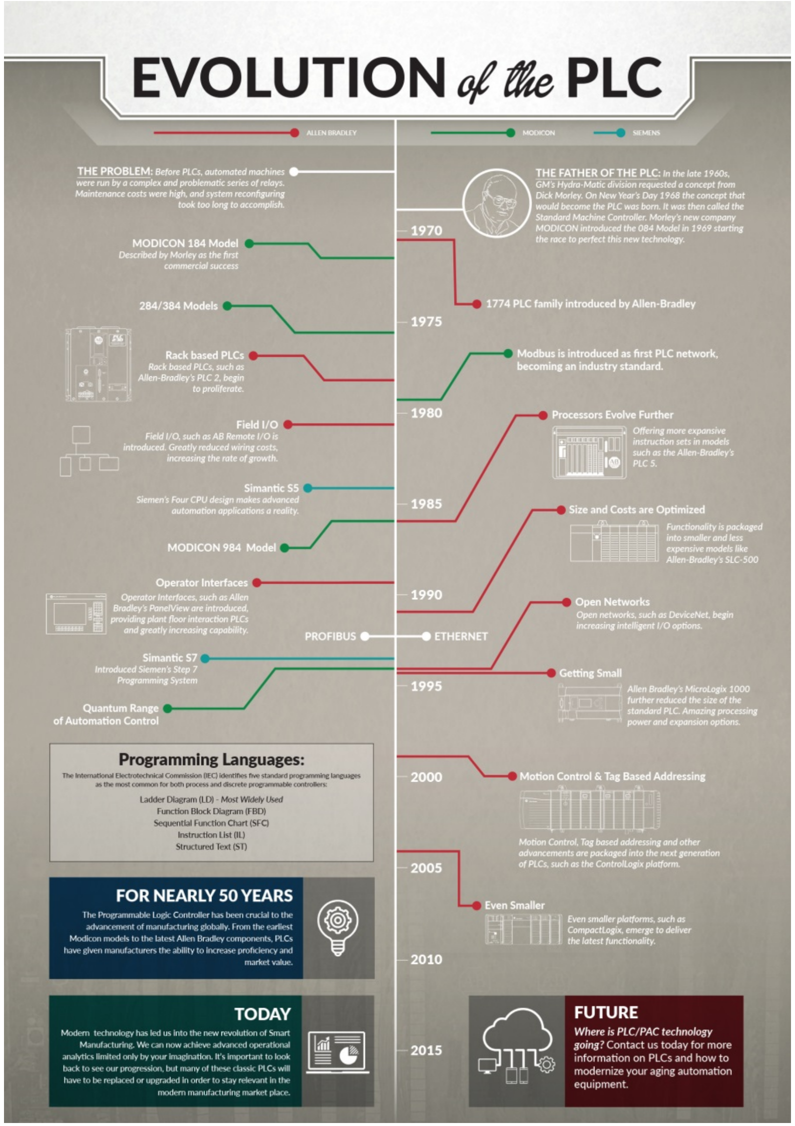


Beginnings of Autonomy with the Invention of PLC

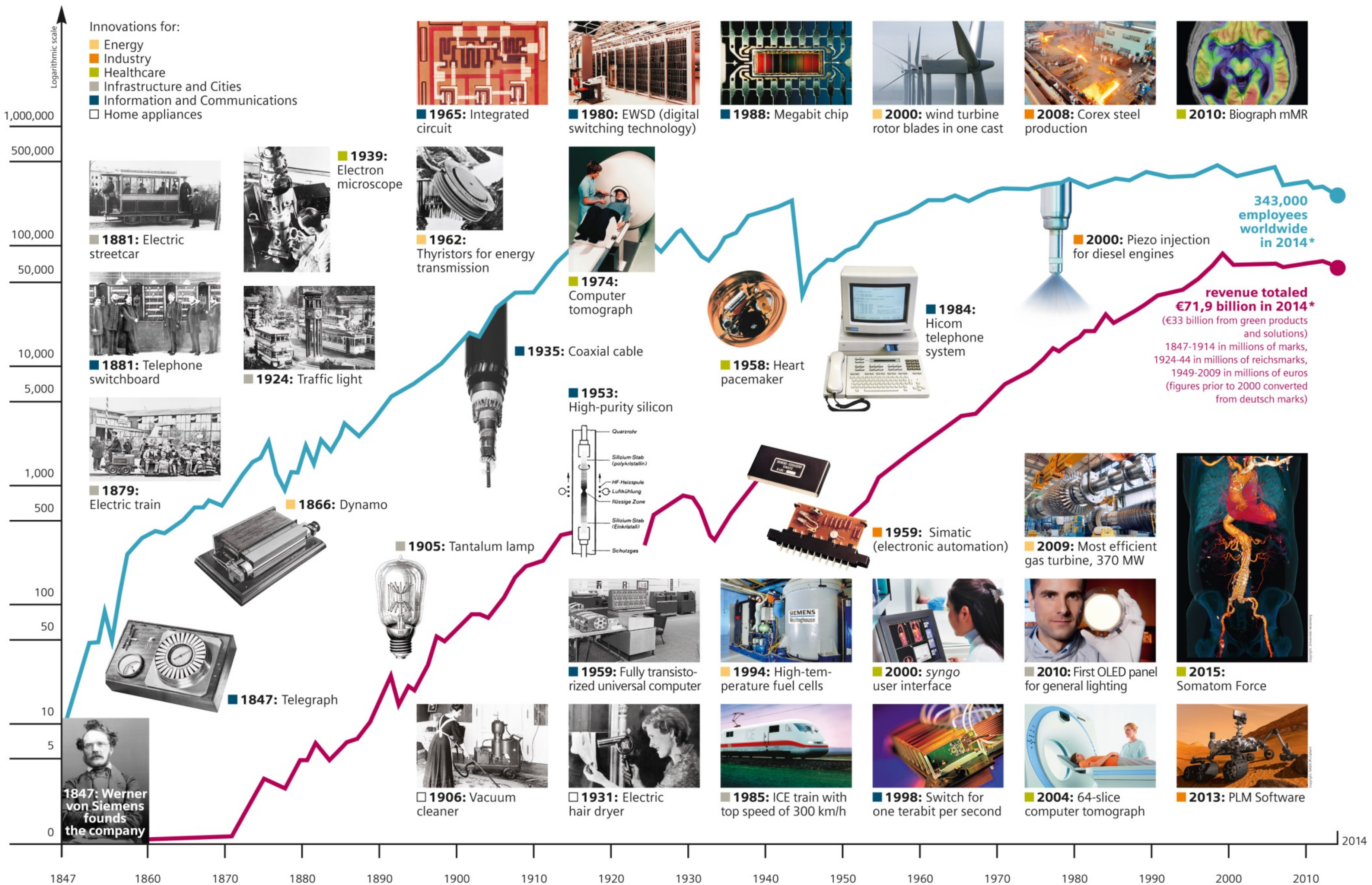
A **PROGRAMMABLE LOGIC CONTROLLER** (**PLC**) is an industrial computer control system that continuously monitors the state of input devices and makes decisions based upon a custom program to control the state of output devices.

Another advantage of a **PLC** system is that it is modular.

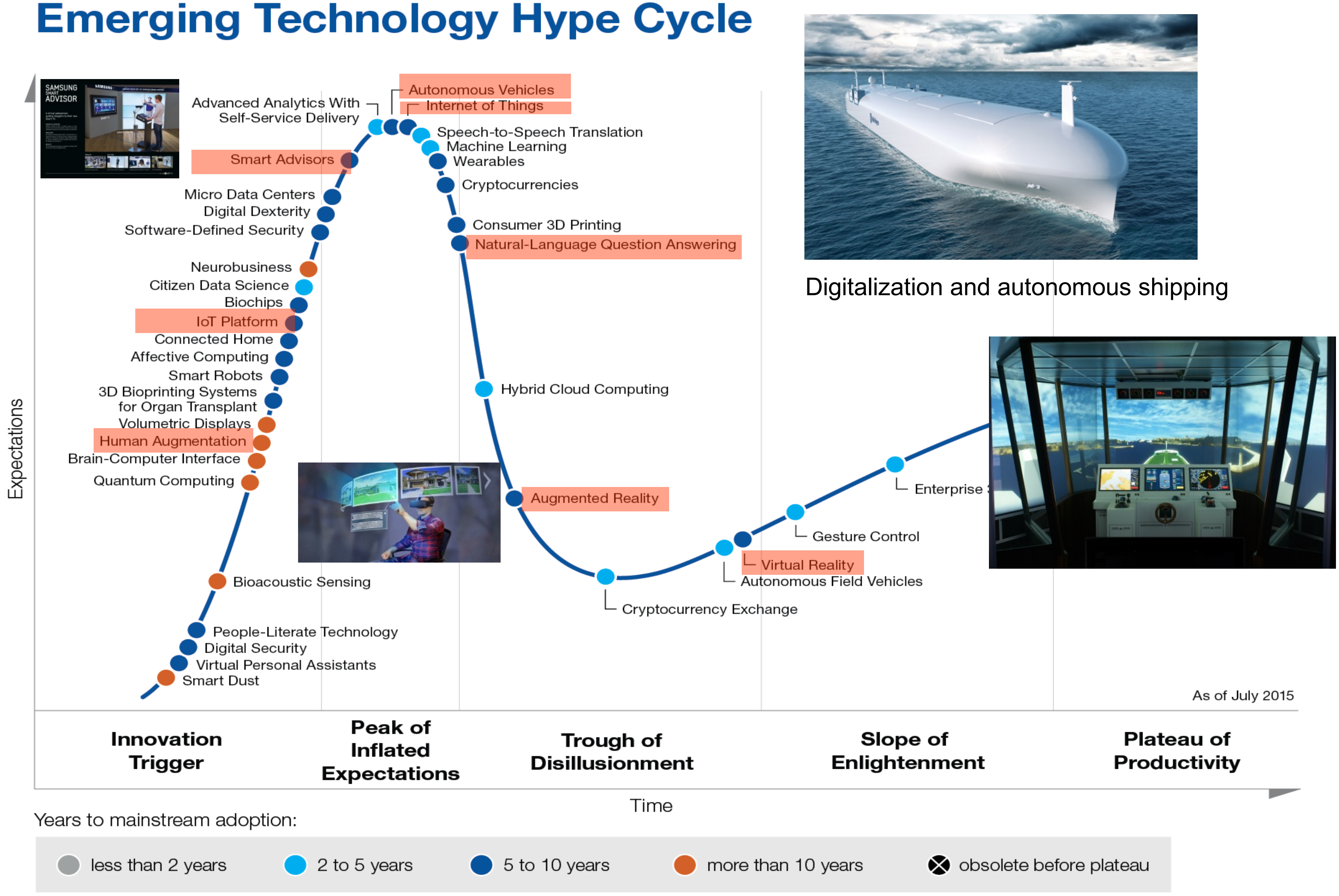




Timeline (1847-2016)



Emerging Technology Hype Cycle



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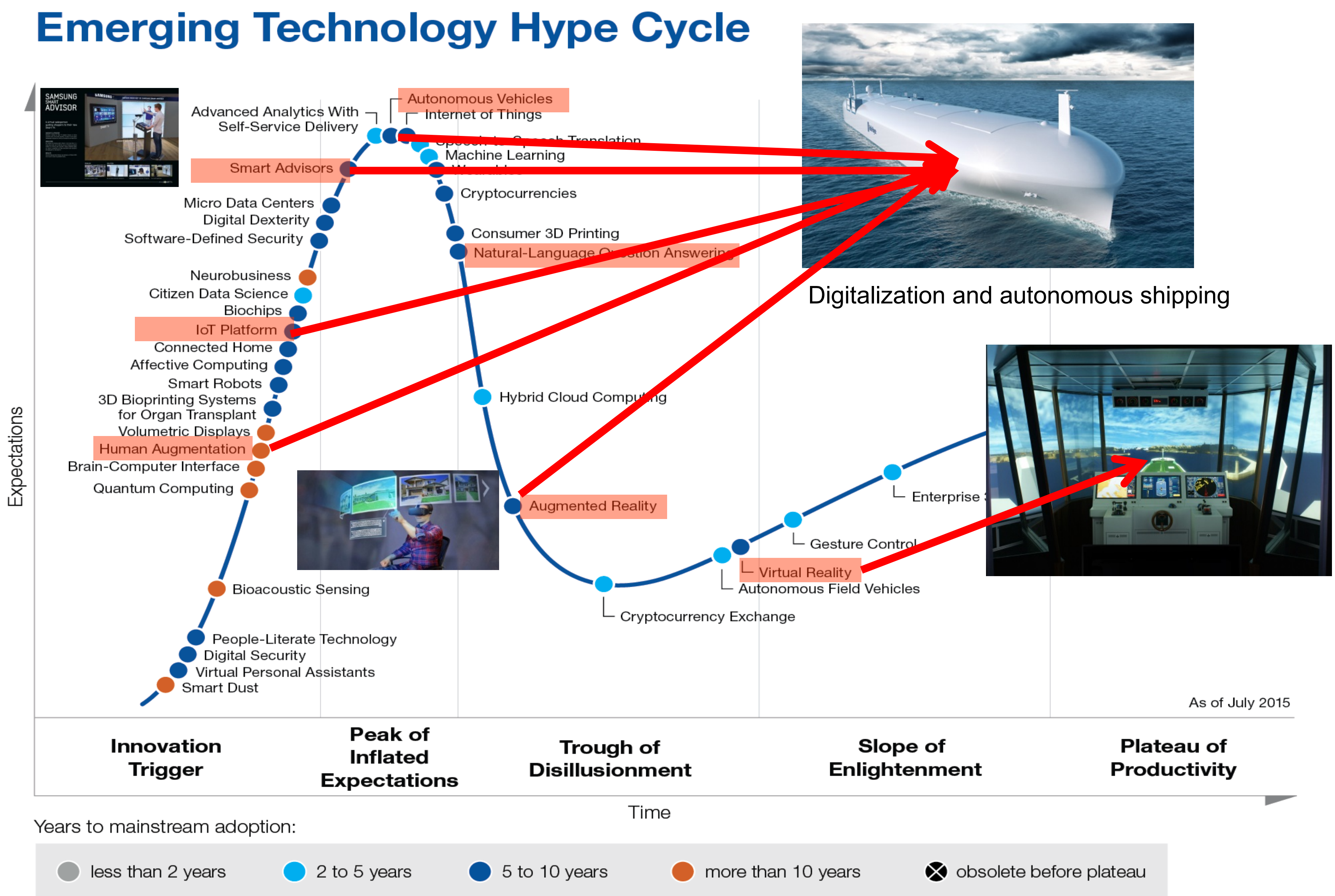

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Reasons for Automation

- Optimal Performance and operational cost
- Safety and Reliability.
- Crew Reduction, total Workforce Management, and increased productivity.
- High cost of labor.
- Labor shortages.
- Trend of labor towards service sector.
- High cost of raw materials.
- Improved quality.
- Reduced lead-time.
- Reduction of inventory.

High cost of not automating!

Levels of Automation

Levels	Description	Attributes
Level 0	Labor	Mechanization
Level 1	Scripts	Automation
Level 2	Orchestration	Level 1 + Adaptability
Level 3	Autonomics	Level 2 + Awareness
Level 4	Pre-cognitive	Level 3 + Analytics
Level 5	Cognitive	Level 4 + Alive

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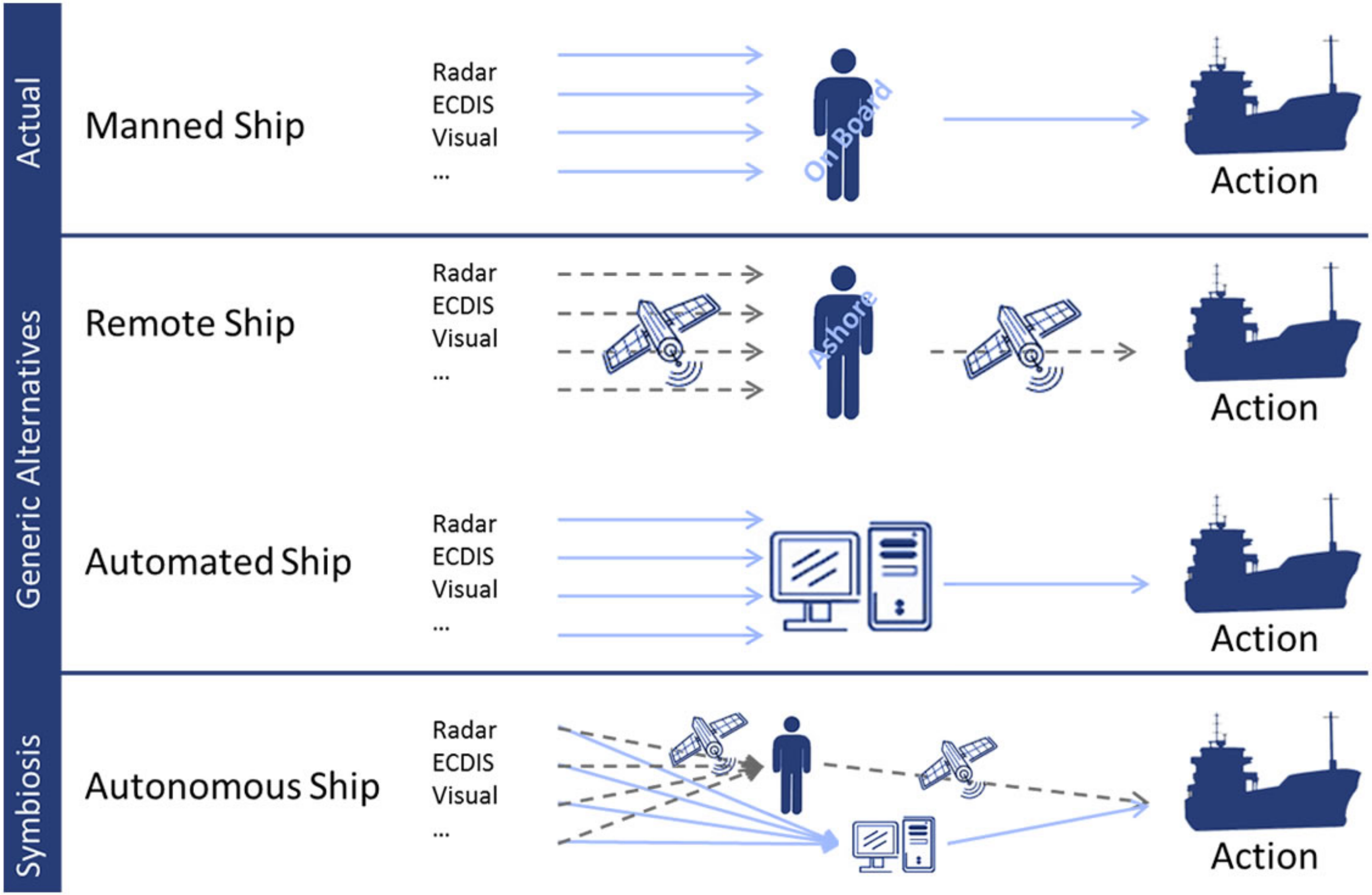
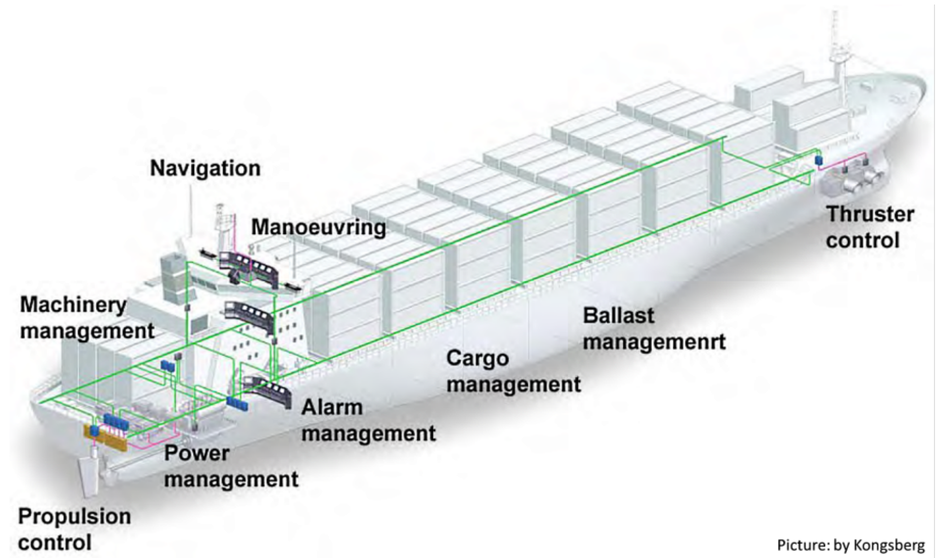
Level of Automation



The Modern Era of Ship Automation

Propulsion (Main Engine) and
Power (Auxiliary Engines)
Monitoring & Control

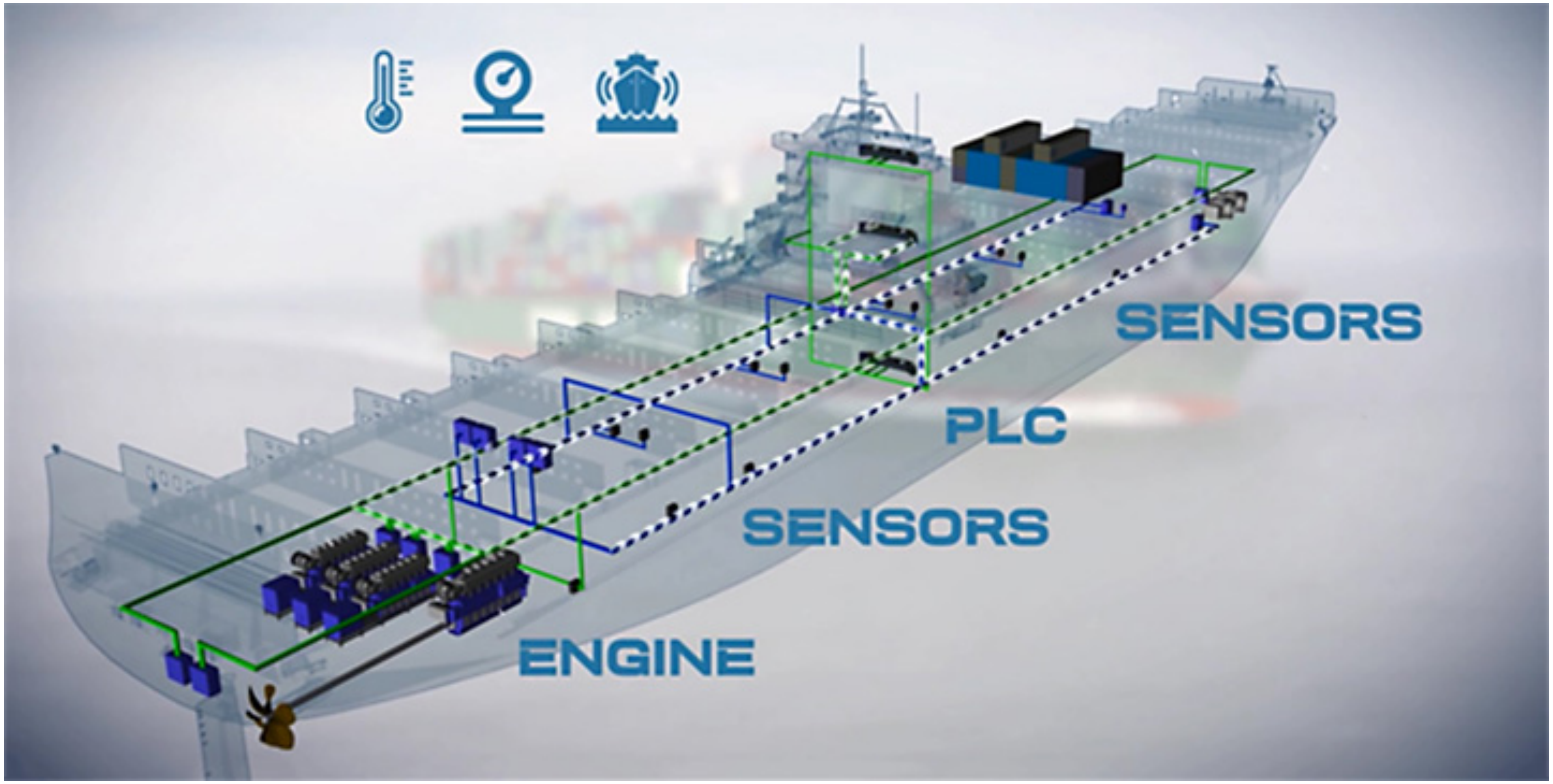


Auxiliary Machinery Monitoring and Control
covers several systems like: main sea & fresh water cooling system – pumps, system pressure, temp. etc.,

Cargo & Ballast Monitoring & Control For safe on and off loading of cargo, especially on tankers, this process is closely monitored and many times incorporates functions like: Level gauging, Control of cargo pumps, Valve control, Ballast & ballast pump control, Heeling control, Remote monitoring of temperature, pressure, and flow.

Condition based monitoring In order to further improve the ships efficiency many equipment manufacturers are looking into feeding the main control and monitoring system with opportunities for condition based monitoring.

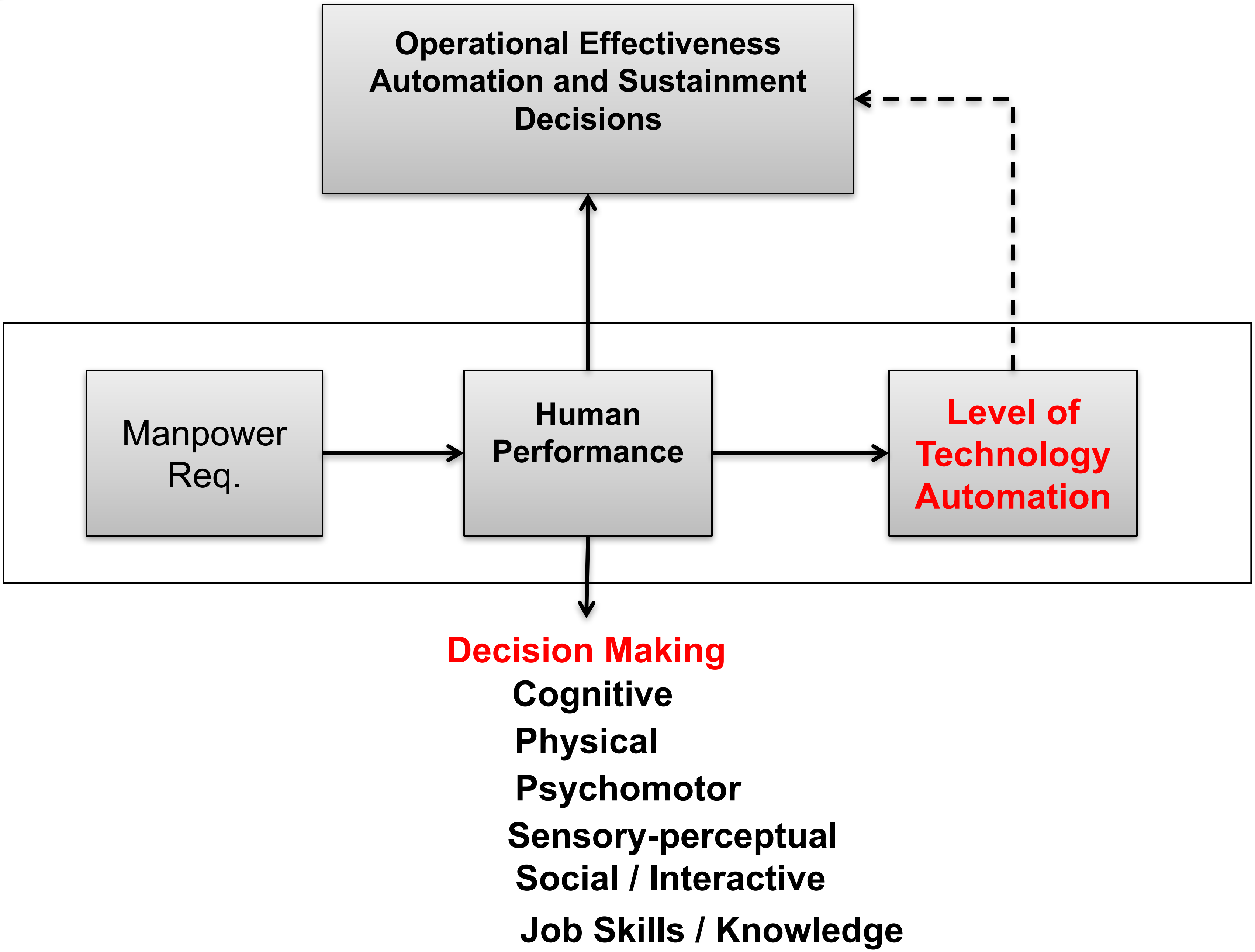
Digitalization and Autonomous Shipping



Ships are becoming sophisticated sensor hubs and data generators. This make our challenges more complex and dynamic

The fleet of the future will continually communicate with its managers and perhaps even with a "traffic control" system that is monitoring vessel positions, maneuvers and speed.

The Role of Human Performance and Decision Making


Operational Effectiveness
Automation and Sustainment
Decisions
Manpower
Req.
Human
Performance
Level of
Technology
Automation
Decision Making
Cognitive
Physical
Psychomotor
Sensory-perceptual
Social / Interactive
Job Skills / Knowledge

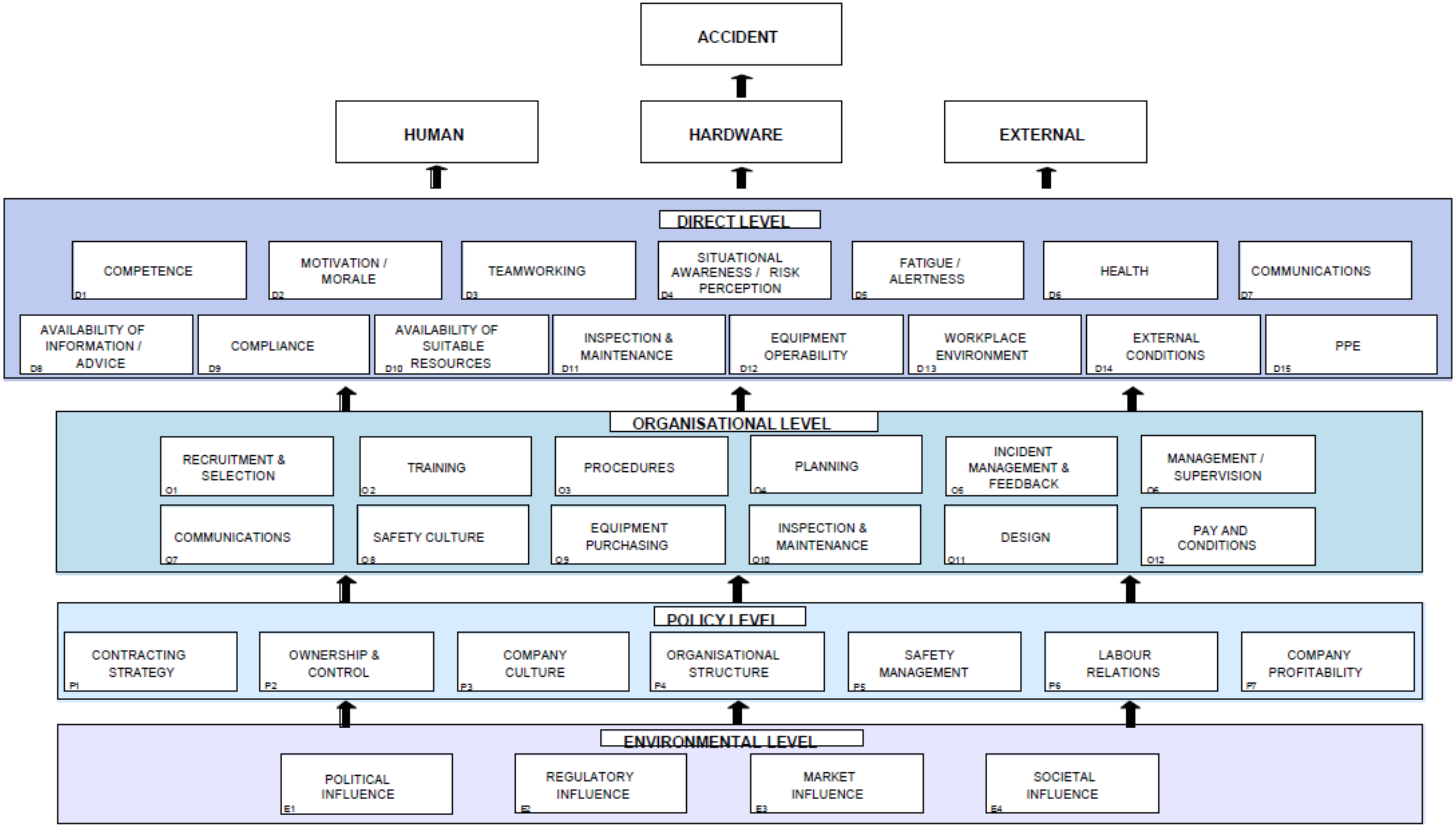
Role of Human Decision in Accidents

“Direct Factors”

“Indirect Factors”

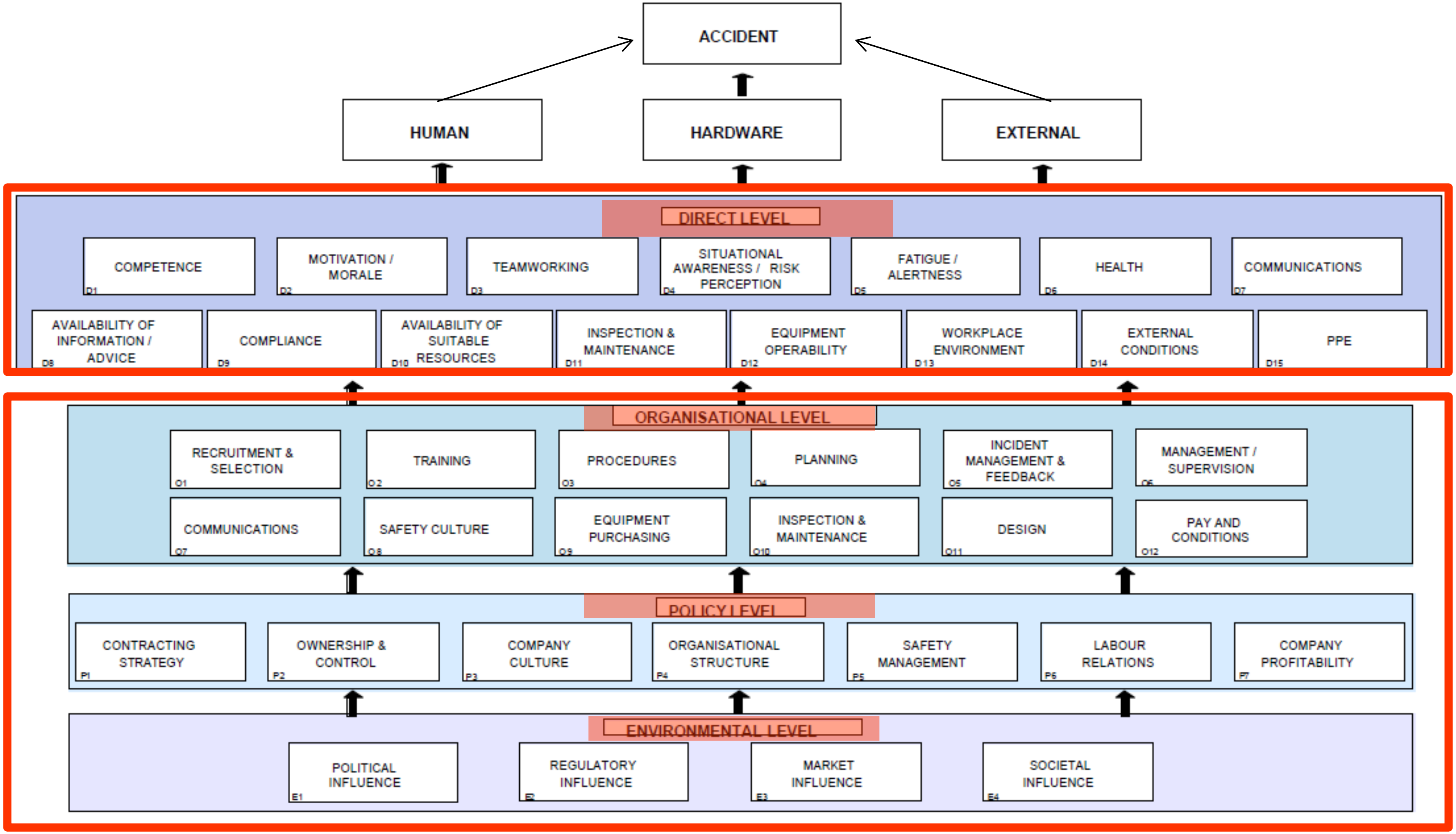
Regulatory, Policy, Social, Environmental and Organizational Factors

Accidents Root Cause



Source: Jeffrey Thomas (2002) Application Of Human Factors Engineering In Reducing Human Error In Existing Offshore Systems.

Accidents Root Causes are Complex



Source: Jeffrey Thomas (2002) Application Of Human Factors Engineering In Reducing Human Error In Existing Offshore Systems.

Accidents Root Causes

- *Fatigue (*16% of vessel casualties,33% of injuries*)*
- *Inadequate Communications (*70% of major marine collisions)
- *Inadequate General Technical Knowledge (*35% of casualties)
- *Inadequate Knowledge of Own Ship Systems (*78% of accidents)
- *Poor Design of Automation*
- *Decisions Based on Inadequate Information*.
- *Faulty standards, policies, or practices*
- *Poor maintenance*
- *Hazardous natural environment.*

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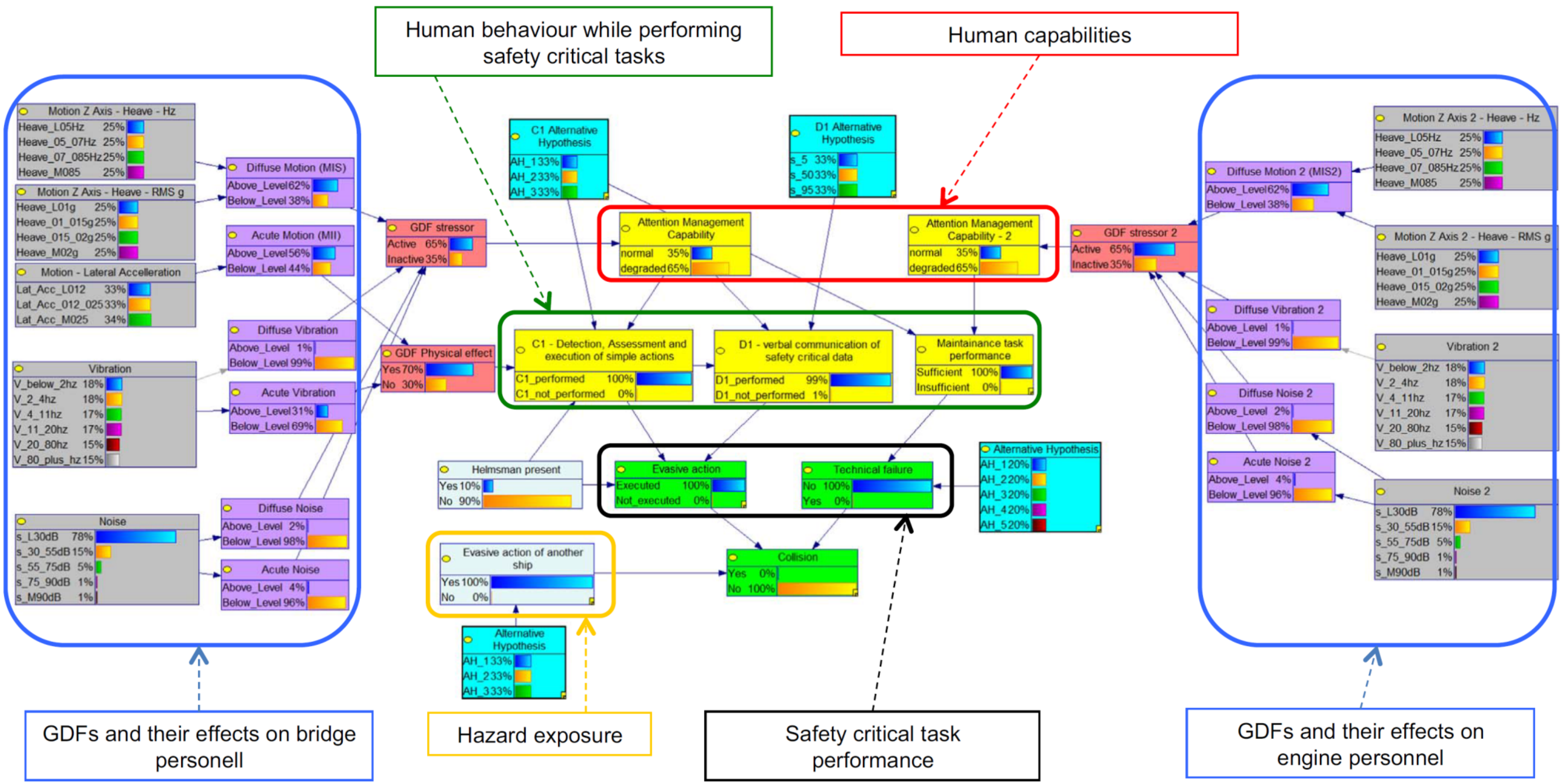
Example



Source: Enhancing human performance in ship operations by modifying global design factors at the design stage Reliability Engineering and System Safety 159 (2017) 283–300

Human Performance and Training Assessment

- Training planning and Automation decisions should be made based on manpower and performance considerations in order to:

    1) Assess team readiness
    2) Determine training needs
    3) Evaluate the impact of an intervention
    4) Conduct capability and reliability analysis
    5) Assess level of Automation needed

- Human performance measures studied and developed to quantify and maximize crew performance with respect to technology readiness and total ownership cost.

Human Performance and Decision Making

An insufficiency of human factors research is an issue in many areas however, the problem is particularly severe in the maritime sector, likely due to a combination of reasons including:

1. A lack of movement away from traditional practices particularly compared to other transport domains, which can, for example, lead to relatively slow adoption of technology in maritime industry.
2. A lack of awareness for many people about the maritime industry in general, as maritime shipping does not appear to be a part of our everyday lives, compared to road, rail and air.
3. Acute and increasing competition in the industry, resulting in time and cost pressures, with human factors considered by many to be an unnecessary expense.
4. A lack of crew involvement in vessel and task design, resulting in poorly adapted equipment.
5. The multinational nature of shipping, leading to disparity between operating procedures, safety management and skill levels of crew and a lack of coherent research on these topics.

Source: http://www.ergonomics.org.uk/safety-at-sea-human-factors-aboard-ship/

Human Performance and Decision Making

Physical, psychological, medical, social, workplace and environmental factors have all been listed as potential contributors to maritime accidents.

All influence the performance of the human element of the system, potentially leading to unsafe actions by crew members.

Ships operate with large inertia often combined with close proximity to other vessels. Furthermore, the cues for decision making are not always directly observable, for example the sea-ship interaction and the effects of currents and meteorological conditions are often ‘felt’ rather than measured.

These factors create challenges for seafarers and increase the risks of working on ships.

Source: http://www.ergonomics.org.uk/safety-at-sea-human-factors-aboard-ship/

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Human Performance/Manpower Automation Programs

Provide Total Workforce Management

- Continue development of Simulation Toolset for Analysis of Mission, Personnel, and Systems (STAMPS)
- Define framework for Position Management Line of Business
- Expand development of Navy Manpower Methodologies and Tools
  - Prototype Interim Staffing Standards Development Methodology
  - Uniform Manpower Requirements Determination Capability
- Expand manpower analytics capabilities
  - e.g. CNA, WCM, NPS-Thesis, etc.
- Continue assessment of manpower requirements determination processes, allowances & factors
  - e.g., Make Ready/Put Away (MRPA) Phase II
- Complete design of new manpower requirements determination process for unmanned aerial vehicles (UAV) – NAVSEA collaboration
- Continue integrating Manpower into Supply Chain initiatives
- Ensure accuracy & alignment of manpower data & systems to Navy policy
  - Manpower data – FIT focus
  - Increase Policy Effectiveness - OPNAVINST 1000.16

Automation possibilities and Performance Architecture

<table>
<tr><th>Performance Function</th><th>Description</th><th>Value</th></tr>
<tr><td>Cognitive</td><td rowspan="7">AUTOMATION AREA
Human Performance TOC Translation
(Economical Value Assessment Modeling
e.g. CBA, HPV, RCA, MAUTI..etc.)</td><td></td></tr>
<tr><td>Physical</td><td></td></tr>
<tr><td>Sensory-perceptual</td><td></td></tr>
<tr><td>Knowledge</td><td></td></tr>
<tr><td>Social</td><td></td></tr>
<tr><td>Interactive</td><td></td></tr>
<tr><td>Skills</td><td></td></tr>
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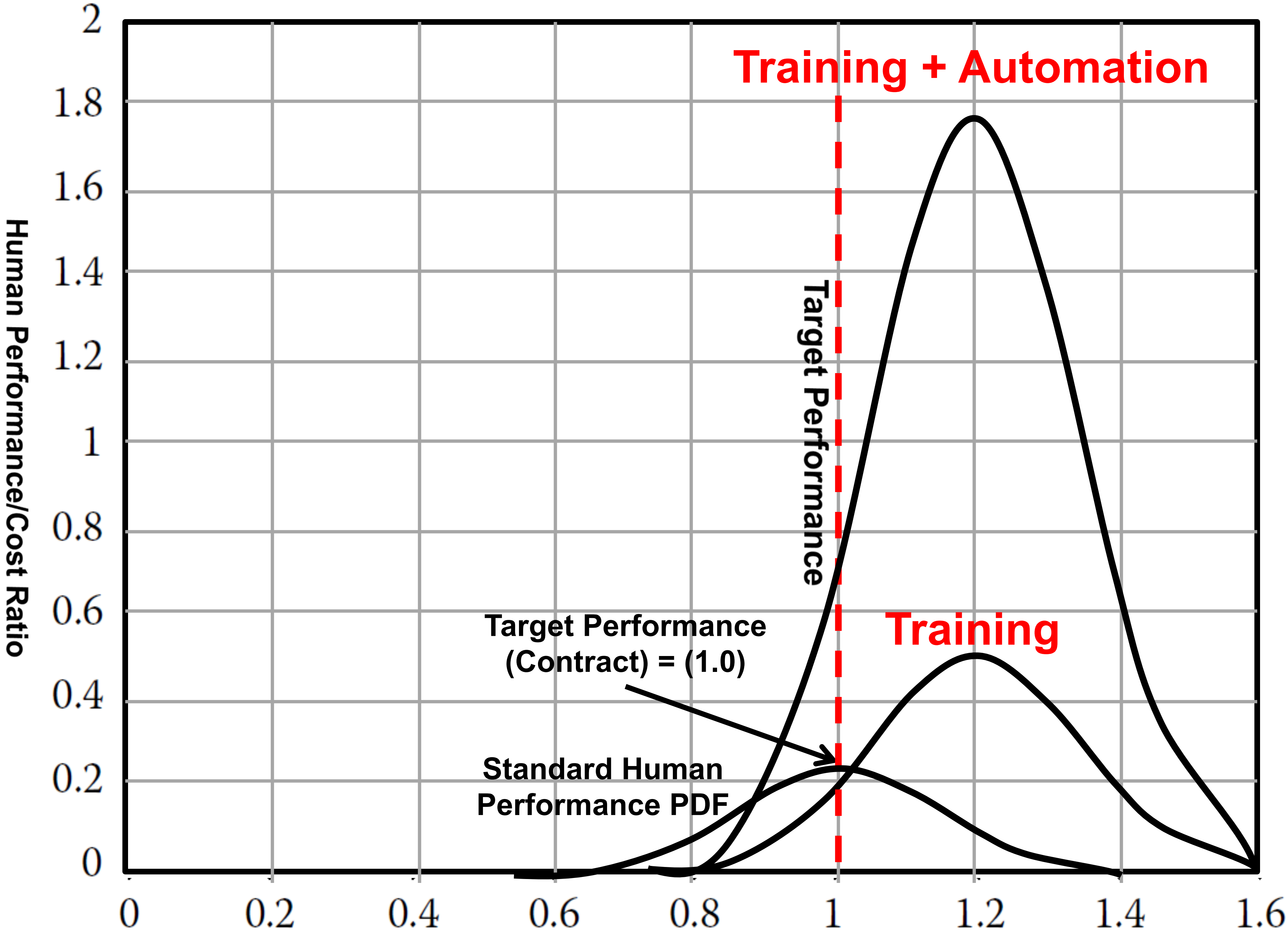
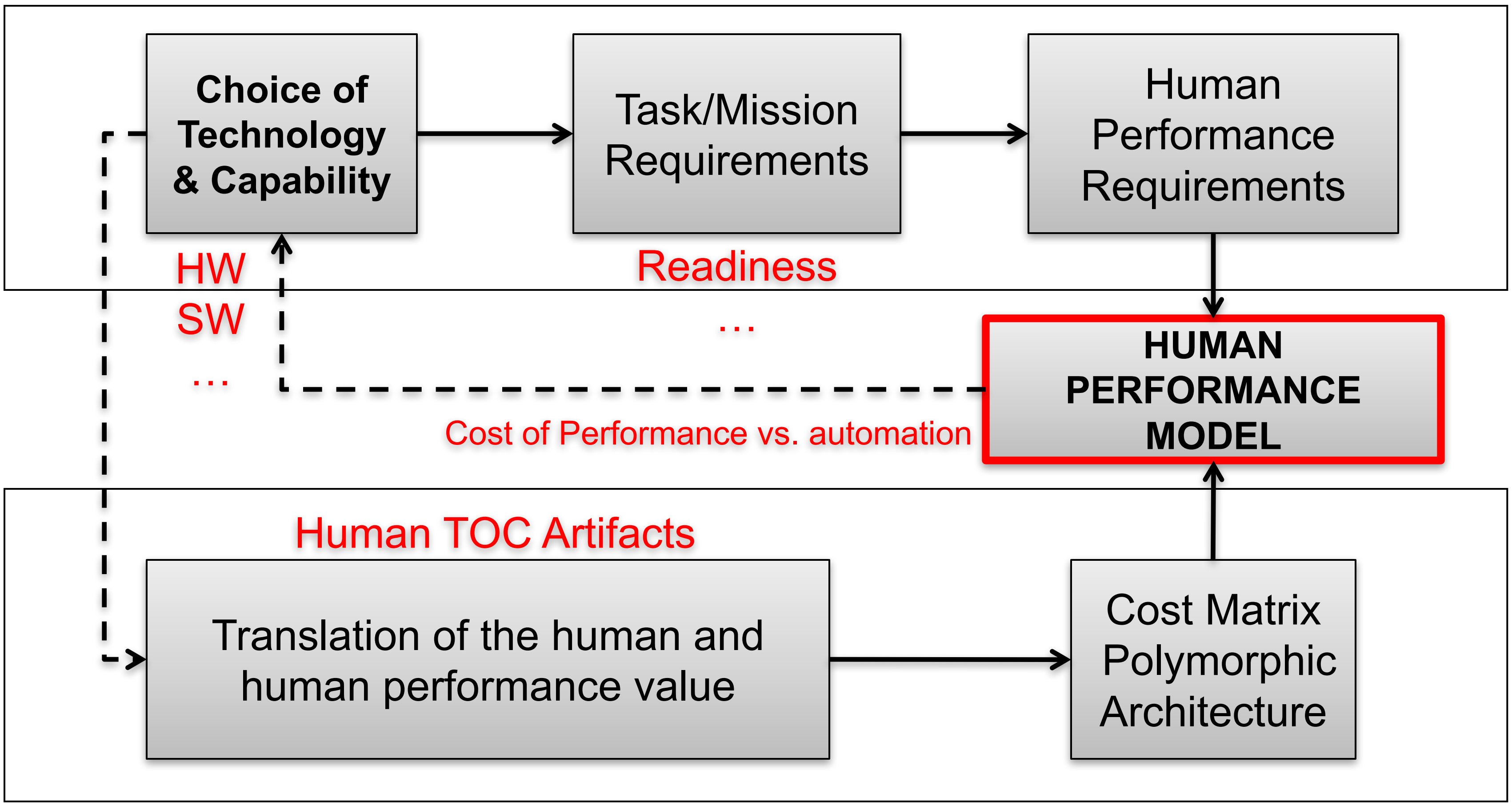
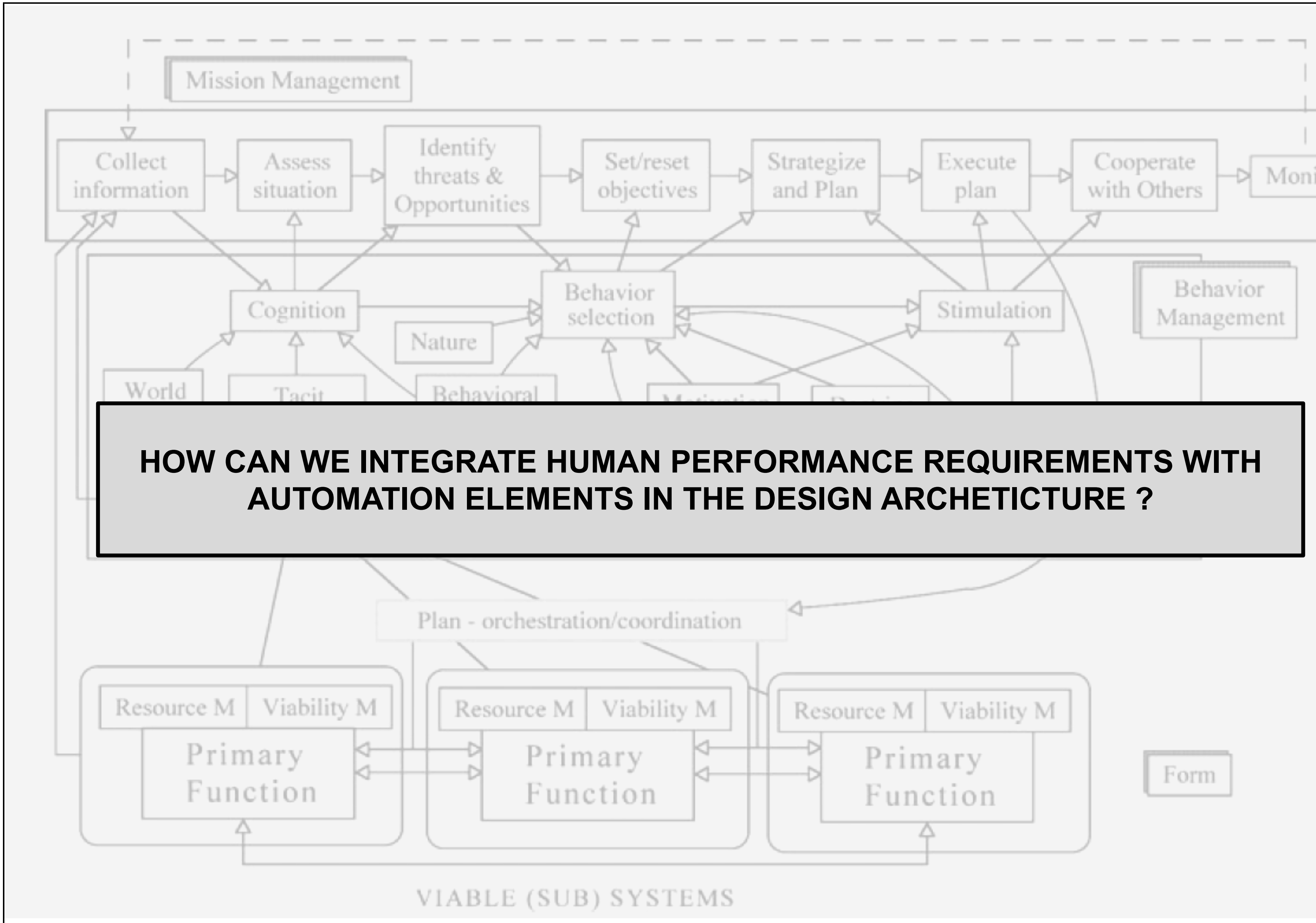

Training + Automation
Target Performance
Training
Target Performance
(Contract) = (1.0)
Standard Human
Performance PDF
Human Performance/Cost Ratio
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6

Human Performance Quantification and Evaluation of Task Automation Level



HOW CAN WE INTEGRATE HUMAN PERFORMANCE REQUIREMENTS WITH AUTOMATION ELEMENTS IN THE DESIGN ARCHETICTURE ?



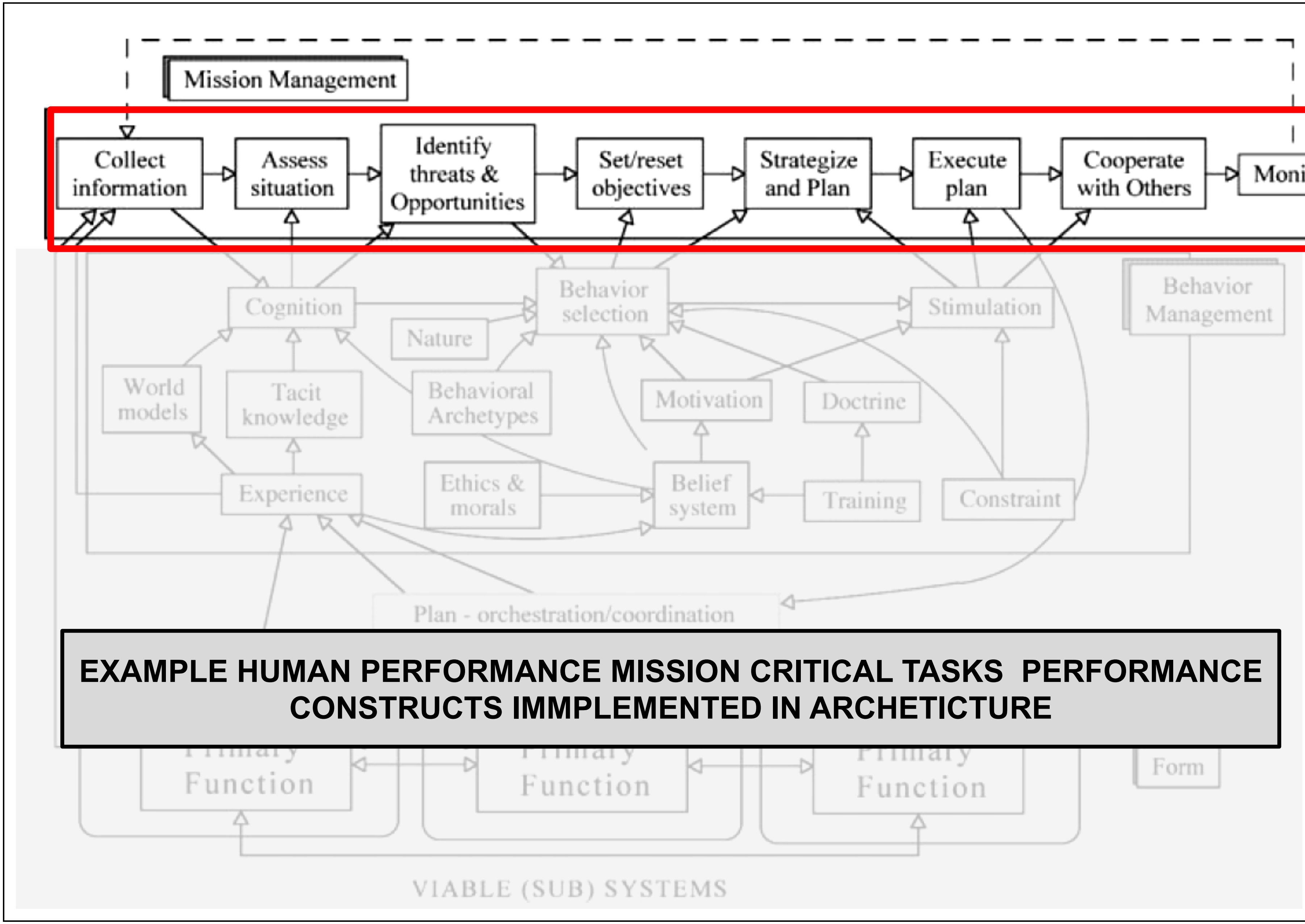
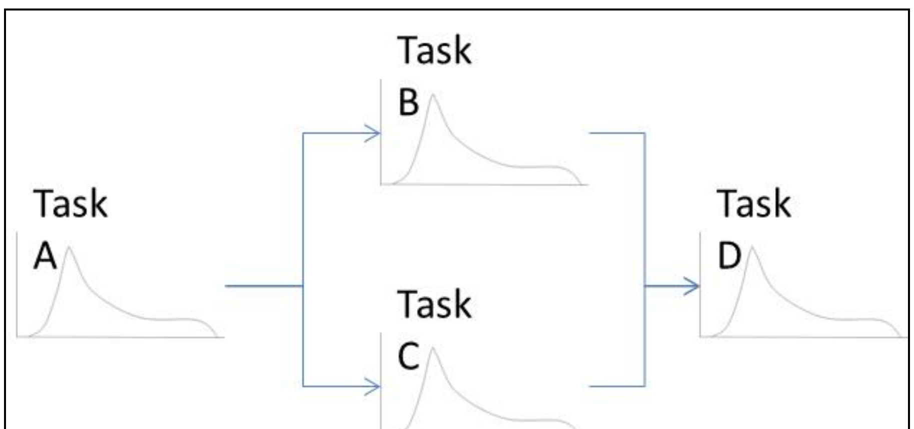


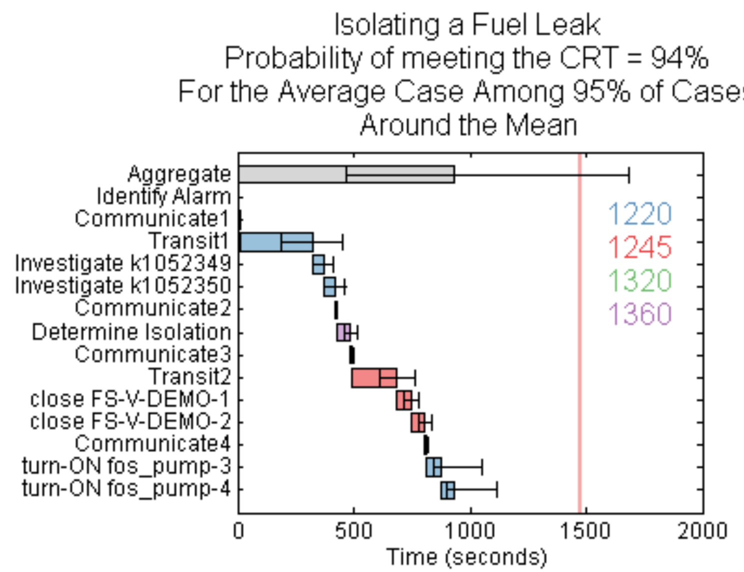
Figure . Layered generic reference model for a Human performance system of systems (modified from original by Hitchins, 2007)

Event Driven Model Component

Objective: Estimate crew response time on tasks

1. Receive, augment, & prioritize tasks
2. Retrieve task durations (A, B)
3. Assign crew given availability, qualifications, state, task precedence, management rules
4. Estimate crew response confounded (C: slowed, D: repeated)
6. Combine distributions for (sub)tasks across time using mixture model for single-pass computation
7. Compute Cumulative Distribution Function
8. Output p(CRT), Diagnostics, Confidence





Example

1980’s

Modern human machine interface

Removable programming unit on the left side of the photo in a modern ship.

Touch screen to the right replaces a wall of annunciators and ten-turn potentiometers.

Source: Marine Automation: Technological Possibilities and Human Limitations Stephen Wright, 2015

Ship-automation Limitations

Many limitations on autonomous vessels are not technical; they are social.

Anticipated skeptics include labor unions and environmental organizations.

We can build and operate a remote-controlled or autonomous vessel today. But our neighbors may not let us!

- Only scientific risk-analysis can determine actual risk
- We compare an autonomous vessel to a crewed vessel and compare the cargo risk and vessel risk.
- The actual risks include equipment failure and malicious interference – hackers on line or pirates on speedboats.

Source: Marine Automation: Technological Possibilities and Human Limitations Stephen Wright, 2015

Benefits

- An automation system can apply simultaneous analysis and comparisons in real time, learning from system history to better anticipate responses providing more appropriate system corrections with each iteration of its ever-improving response curves.
- In an autonomous ship, the system learns the ship just as a crew would, but all system information is shared, not subjectively compartmentalized, as with a human crew.
- The engineering challenge is to parse and save the data while gleaning all that can be learned from it. A complex system has large data needs. There is no data center at sea.
- What is done at sea and what is done on land is part of the developing methods of control.

The Future
Autonomous Ships and NexGen Command and Control

"Autonomous shipping is the future of the maritime industry. As disruptive as the smartphone, the smart ship will revolutionise the landscape of ship design and operations"

Mikael Mäkinen, President, Marine

Rolls-Royce

Revolution

For the smart ship revolution to become a reality a number of critical questions need to be answered

Technology

What technology is needed and how can it be best combined to allow a vessel to operate autonomously, miles from shore?

Safety

How can an autonomous vessel be made at least as safe as existing ships, what new risks will it face and how can they be mitigated?

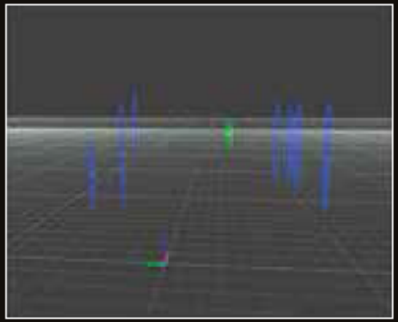
Regulatory Liability

What will be the incentive for owners and operators to invest in autonomous vessels? Are autonomous ships legal and who is liable in the event of an accident?

Source: Marine, Ship Intelligence - Rolls-Royce Advanced Autonomous Waterborne Applications Initiative (AAWA), August2017

Technology.

A ship's ability to monitor its own health, establish and communicate what is around it and make decisions based on that information is vital to the development of autonomous operations




1. Sensors that inform an electronic brain and allow the vessel to navigate safely and avoid collisions

2. Control algorithms Navigation and collision avoidance will be particularly important for remote and autonomous ships, allowing them to decide what action to take in the light of sensory information received.

3. Communication
Autonomous vessels will still need human input from land, making connectivity between the ship and the crew crucial.

Safety and Security.

The operation of remote and autonomous ships will need to be at least as safe as existing vessels if they are to secure regulatory approval, the support of ship owners, operators, seafarers and wider public acceptance.

Remote and autonomous ships have potential to reduce human-based errors, but at the same time may modify some existing risks as well as create new types of risk. These circumstances and possible remedies will need to be explored.

The marine industry has some experience on systematic and comprehensive risk assessments. However, when new, emerging technology is involved, new knowledge, wider and deeper understanding of new and changed risk (with a variety of known and unknown hazards) is needed; guided by research to lead us to new approaches the project is exploring.

Cybersecurity will be critical to the safe and successful operation of remote and autonomous vessels. The project will identify and adapt current best practice from a range of industries for application in the marine environment.

The results will be used to make recommendations to regulators and to classification society and other AAWA Partners to support development work for creating the first set of standards for remote and unmanned vessel operation.

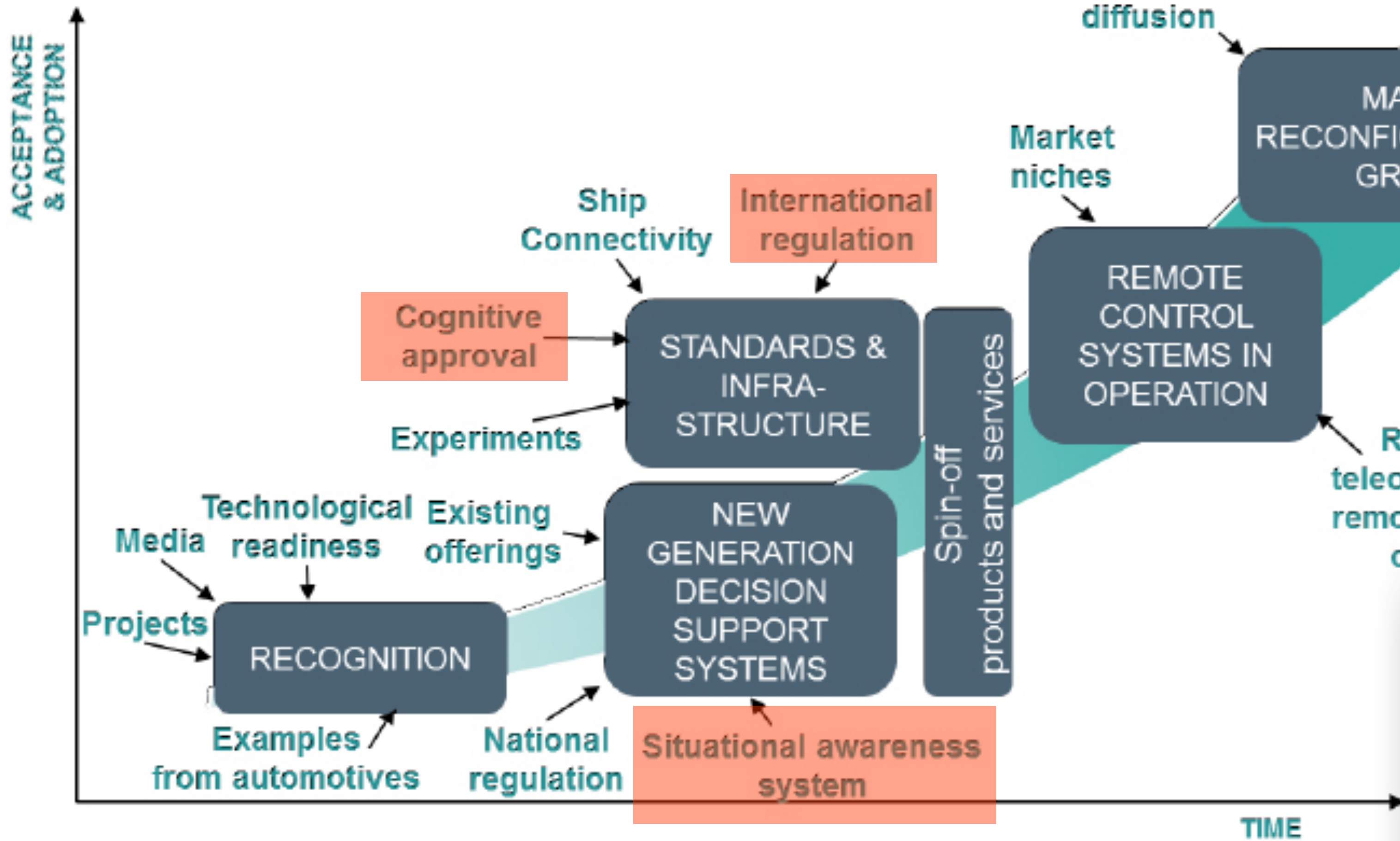
“Cyber Security”

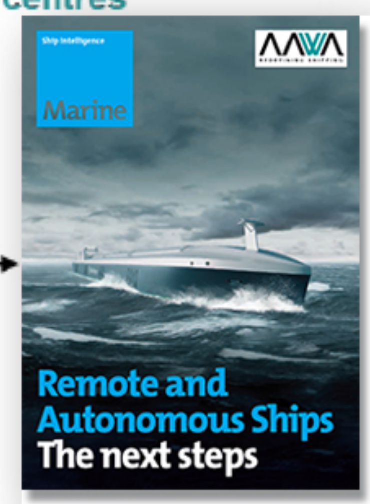
Source: Marine, Ship Intelligence - Rolls-Royce Advanced Autonomous Waterborne Applications Initiative (AAWA), August2017

Regulatory Liability

NexGen Command and Control

Transition Roadmap to Autonomous Shipping





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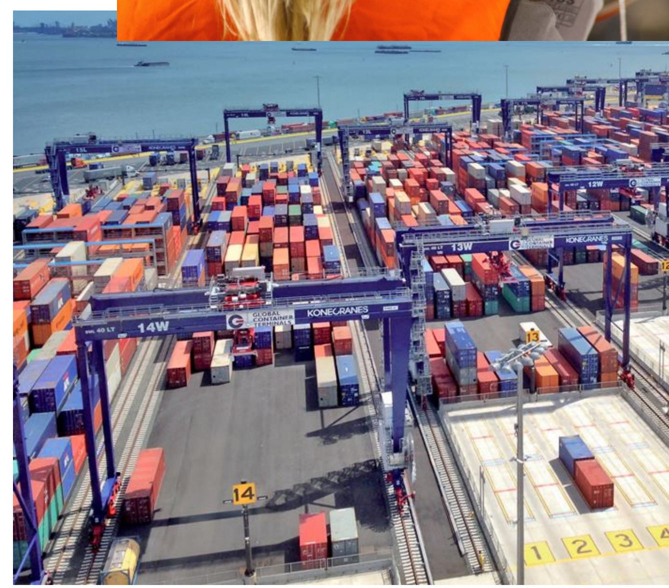
Port Automation: Smart, Smarter, Smartest!

- The global container handing equipment fleet is getting smarter as port operators apply more sophisticated IT in their operations.



- The amount of intelligence on both manned cranes as well as unmanned equipment is increasing in a quest for improved safety, productivity and eco-efficiency.
- As part of the evolution, equipment is becoming more and more unmanned.

Next steps...

Reduced crew with remote support and operation of certain functions	Remotely operated local vessel Remote controlled unmanned coastal vessel	Remote controlled unmanned ocean-going ship	Autonomous unmanned ocean-going ship
2020	2025	2030	2035

Unmanned ships will most likely start with local applications

Source: Marine, Ship Intelligence - Rolls-Royce Advanced Autonomous Waterborne Applications Initiative (AAWA), August2017

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Conclusions:

- Ships already have centralized lineups of switchgear actuated remotely.
- Each of these motor controllers has a “Hand/Off/Auto” or “Hand/Off/Remote” switch.
- It is only a question of how remote or how automatic.

- Complete remote operation is possible. Transas and Kongsberg training simulators resolved many issues
- Remotely operated underwater vehicle ROV/autonomous underwater vehicle AUV developments are largely scalable to commercial vessels
- Department of Defense drone deployments are more challenging than operating a ship at 12 knots.
- Remote operation is limited by telecommunications reliability and bandwidth. In short –weather.

Emerging technologies in Maritime

1. Big Data Analytics

Machine learning can find meaningful patterns buried in the noise

2. IoT for Automation (Connected Web of Sensors)

All of this IoT data can be fed into the big data analytics platform and visualized in a way that helps command centers make better decisions.

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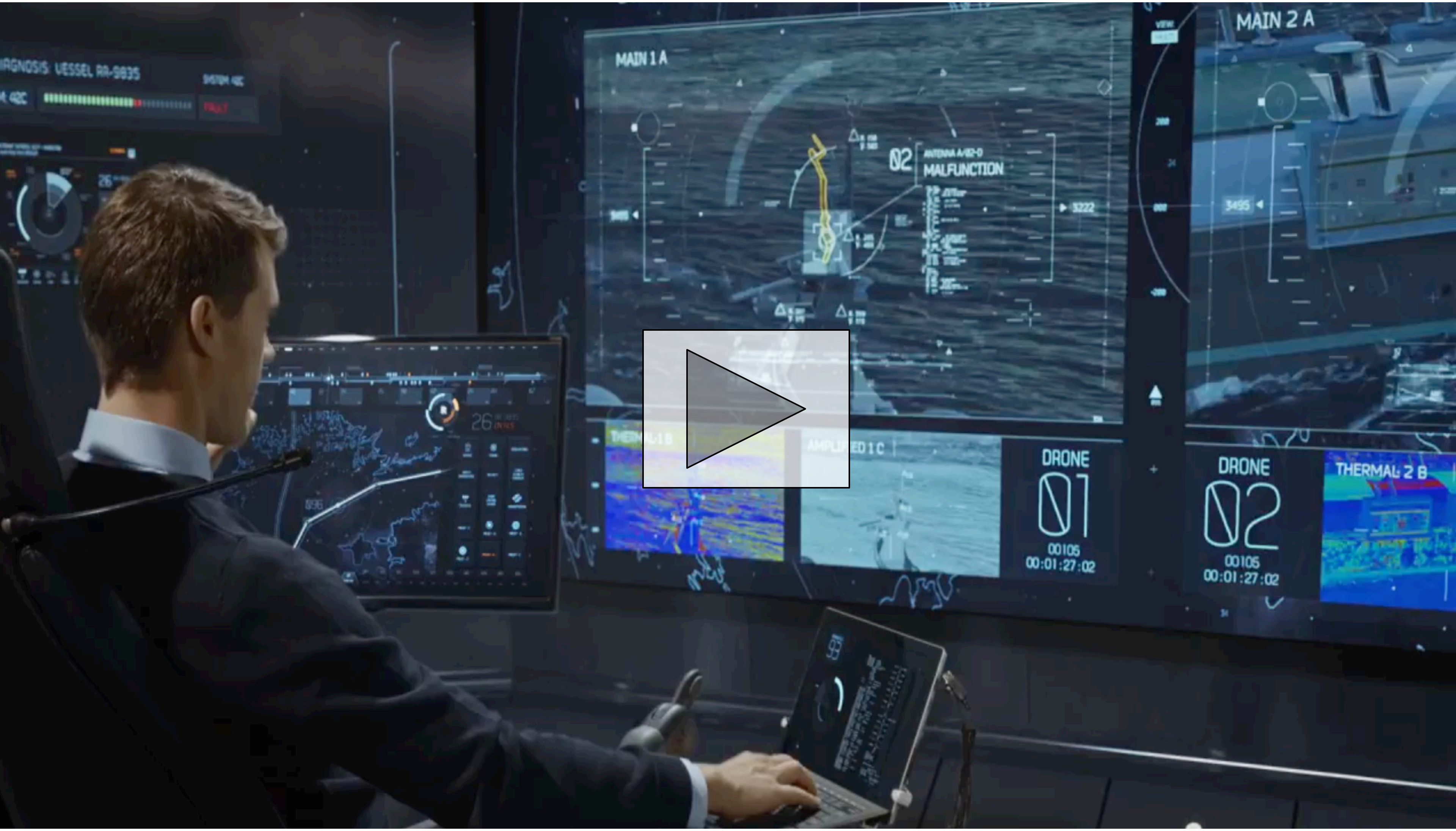
Futuristic Demo: NexGen Command and Control



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1th International Conference on

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Integrating People with Intelligent Systems

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Dubai, UAE

Call for Papers

7-9 January, 2018

Thank you!

Dr. Tareq Ahram

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"Design is the first signal of human intention"

William McDonough, 2013

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Thank you!

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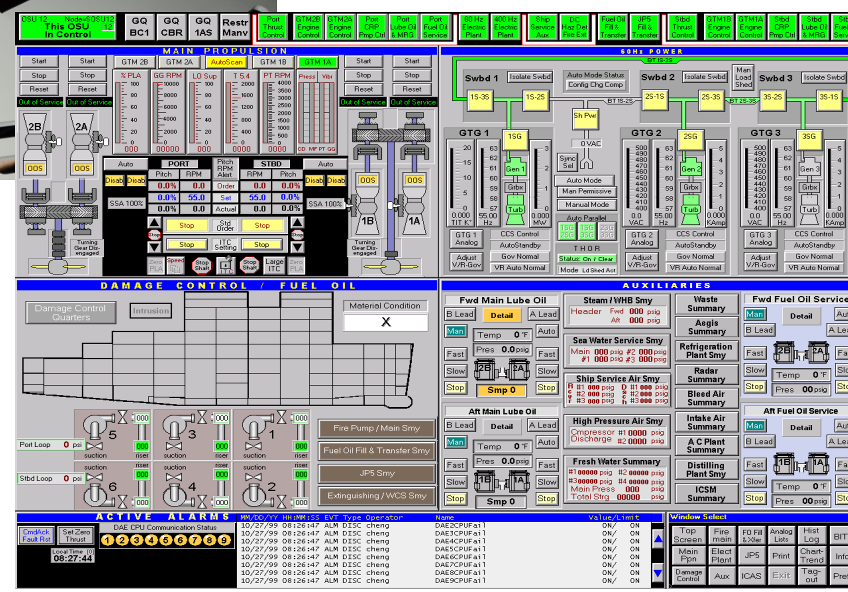
Backup Slides

Littoral combat ship simulator at the Littoral Combat Ship Shore Based Training Facility, Naval Base San Diego, Calif., Feb. 9, 2011.

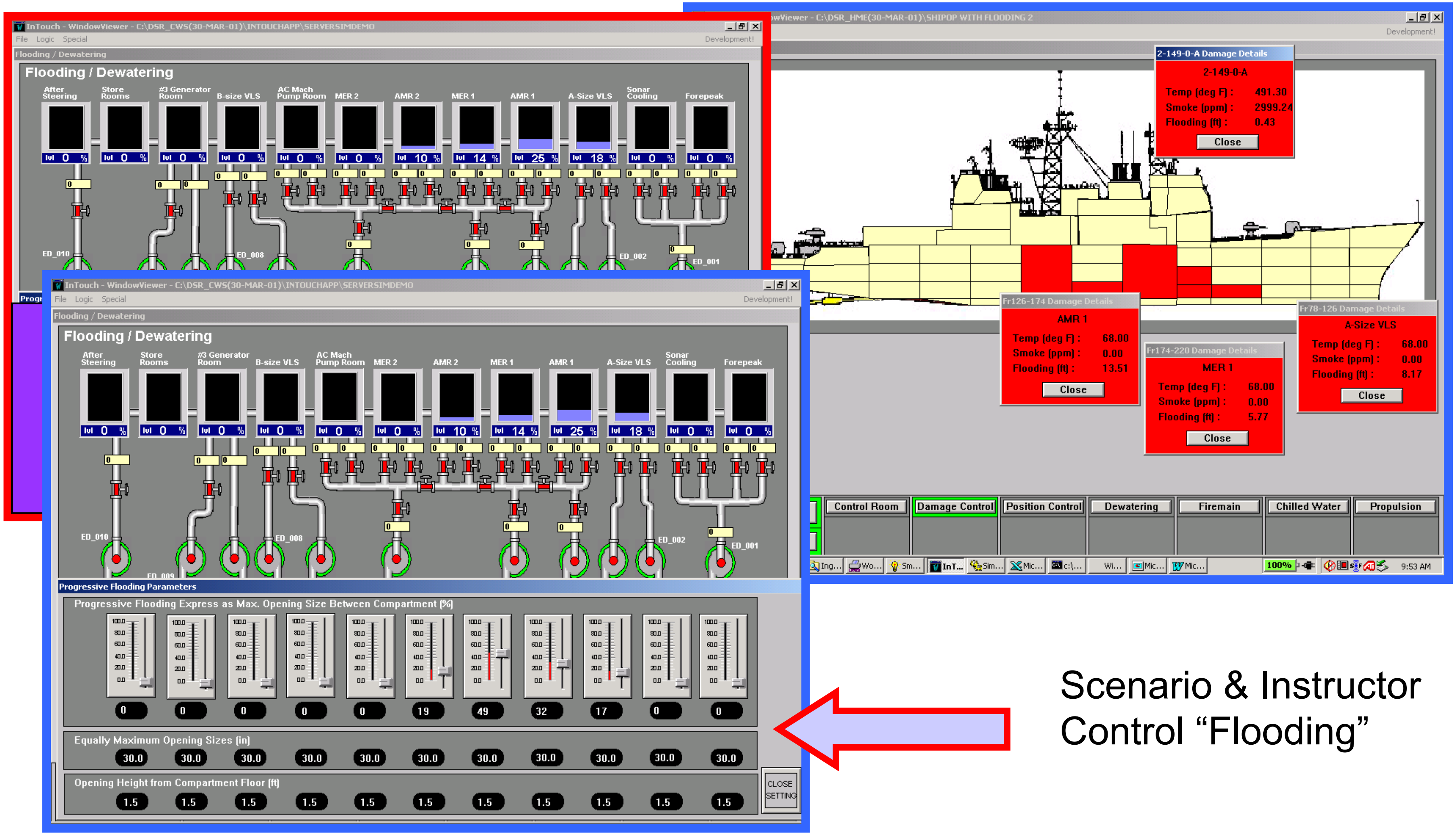
Public domain photograph from defenseimagery.mil



Source: A Total Ship-Crew Model to Achieve Human Systems Integration, Dr. Loretta DiDonato CDR Joseph B. Famme USN (ret.),LCDR Alan Nordholm USN, Senior Chief Alan Lemon

Case Study 2

Operator

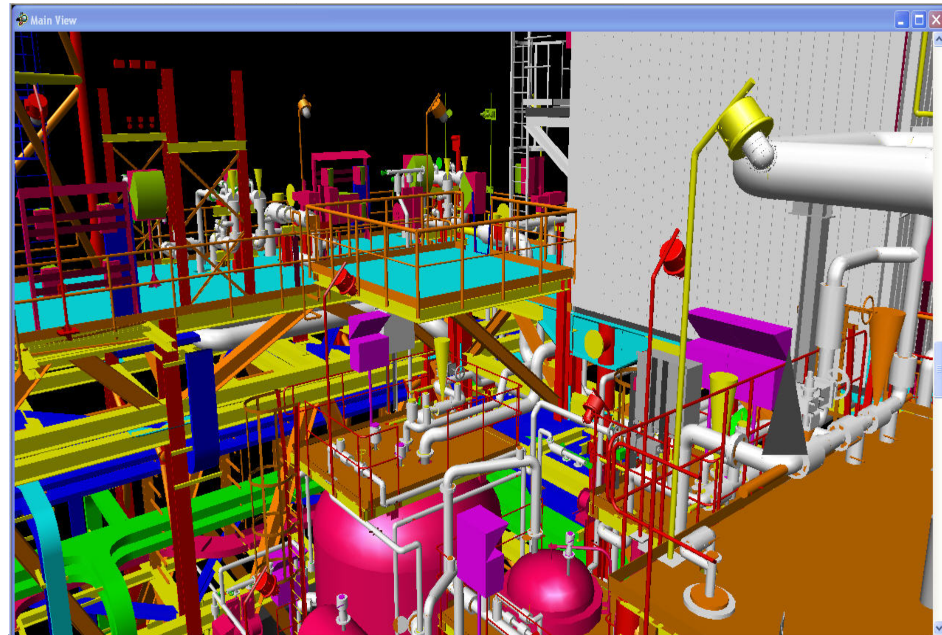


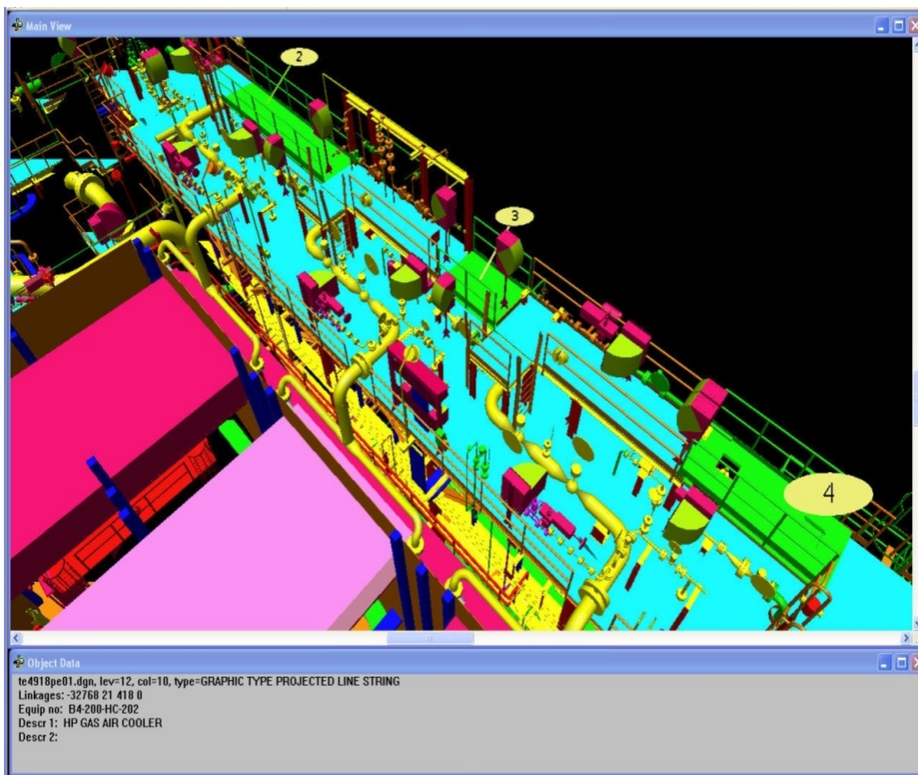
Scenario & Instructor Control "Flooding"

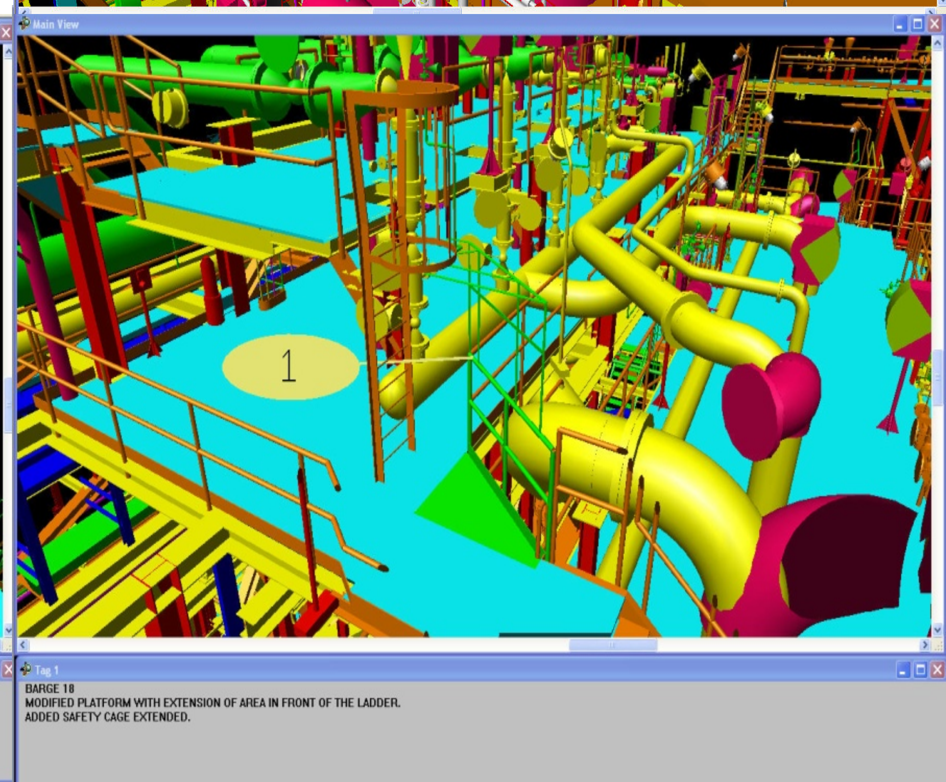
Source: A Total Ship-Crew Model to Achieve Human Systems Integration, Dr. Loretta DiDonato CDR Joseph B. Famme USN (ret.),LCDR Alan Nordholm USN, Senior Chief Alan Lemon

ACCESS, EGRESS AND EVACUATION PLANS

- Carbon Filter Maintenance
- Ladder design
- Ladder length
- Ladder guard gates and barriers
- Location information
- Route choices/ alternative means of escape







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