Autonomous Vessels: ABS' Classification Perspective

Discussion Issues in Technology, Safety and Security for the Marine Board

John Jorgensen
Director, Cyber and Software
ABS Technology
American Bureau of Shipping
JohnJorgensen@eagle.org

Agenda for Today's Discussion

- Definitions
- Autonomy and automation as growth areas
- Engineering autonomy
- Components of autonomy engineering
- ABS' View of Class for autonomy

Take-away Points:

1- Autonomy is another set of functional requirements to be engineered into systems where it makes sense.

2- Complex systems require integration and test of risk management, cybersecurity and software assurance for completeness.

3- Technical review for safety and regulatory compliance is vital to ensure automated systems meet expected standards.

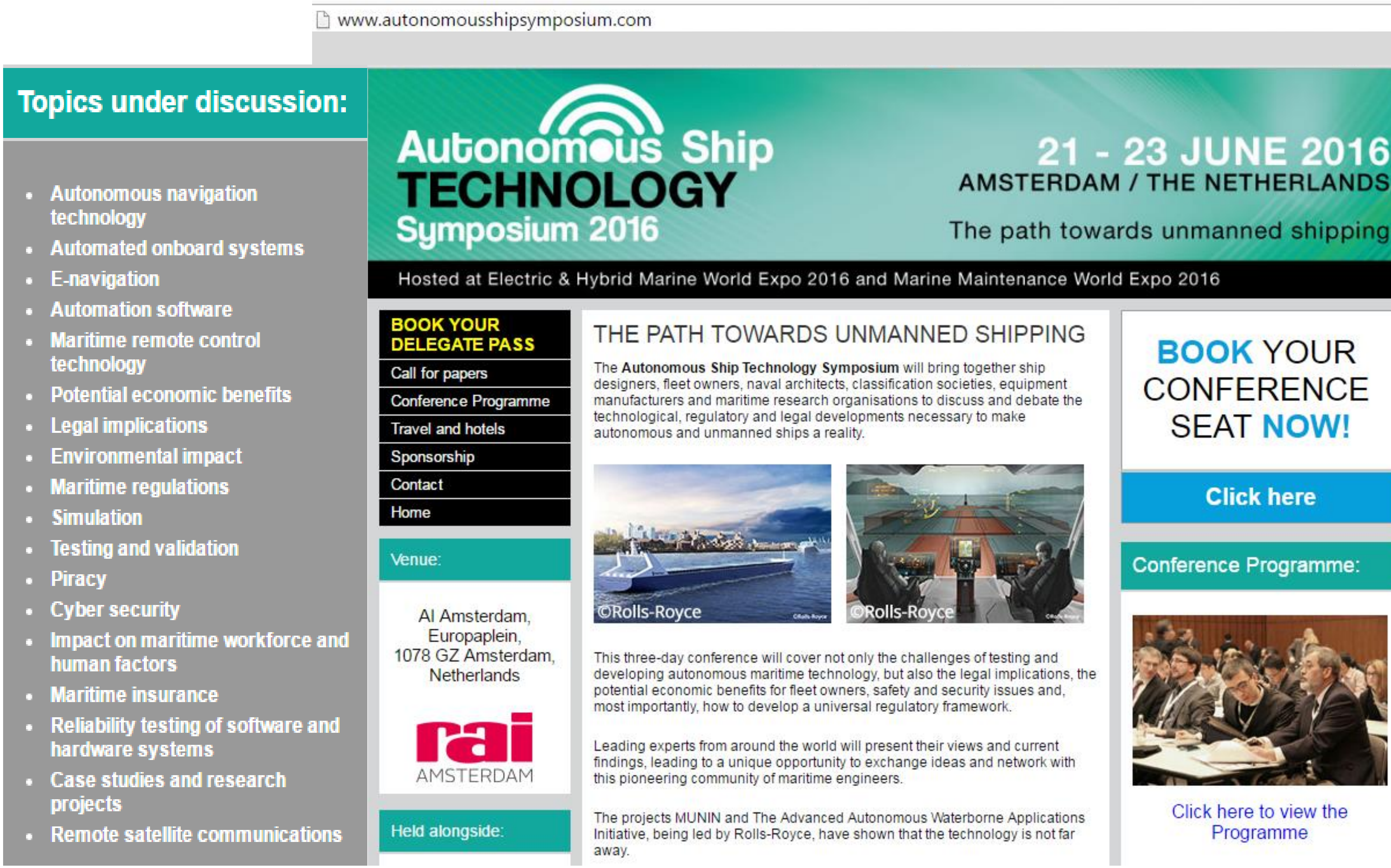
Definitions (1)

- Autonomy: quality of self-governance and freedom from external control or influence; independence (Merriam-Webster)
- Autonomous vehicle: "…a motor **vehicle** that uses artificial intelligence, sensors and global positioning system coordinates to drive itself without the active intervention of a human operator." (Nevada law definition for autonomous car)
- Autonomous ship: marine vessel with sensors, automated navigation, propulsion and auxiliary systems, with the decision logic to follow mission plans, sense the environment, adjust mission execution for the environment, and operate without human intervention. (ABS)

Definitions (2)

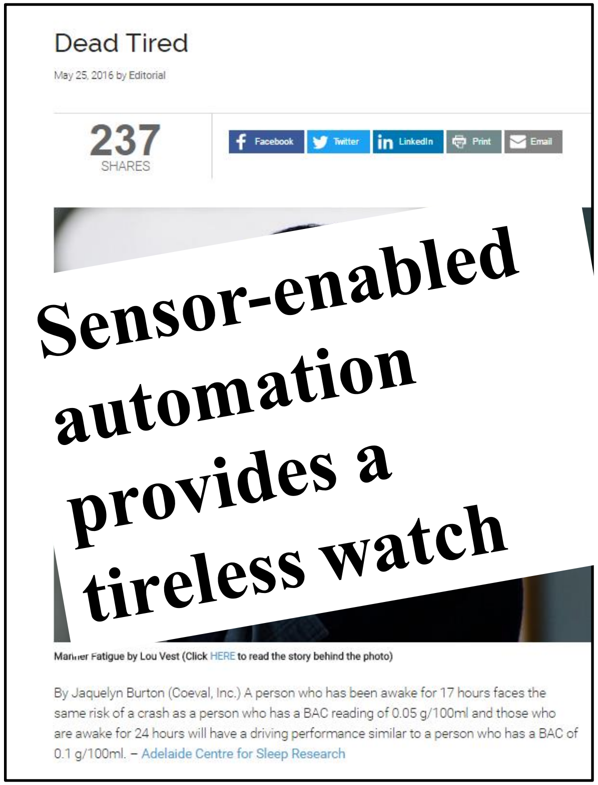
- Levels of autonomy
  - 0: human control
  - 1: some functions automated
  - 2: normal operations automated; human ready to take over
  - 3: safety-critical functions automated; human present
  - 4: full autonomy of safety-critical functions and environmental monitoring for duration of trip
  - 5: full autonomy with no human-available control interfaces (NHTSA)
- ‘Smart Ship’: Marine asset built with significant degrees of automation in systems, system monitoring and management, and data communications. Automation provides labor-saving methods; human augmentation and error-checking; multiple simultaneous system control and management; and data reporting to enable better and faster decisions. A Smart Ship may have entirely automated, or even autonomous, processes that operate without human intervention. (ABS)

Marine Autonomy is a Growth Area



Reasons for Maritime Autonomy

- Maritime Autonomous Systems (MAS) are in development because they may provide:
  - Reduced crew across a continuum of concepts: low-end task automation through high-end unmanned, hands-off operations
  - Potential for streamlined operations: faster port turnarounds, little / no crew rest considerations
  - More efficient designs: Human-free ships may be 5% lighter (no HVAC, crew quarters, water, etc.) and potentially may use less fuel
  - More effective operations: remote monitoring and control can accommodate unexpected conditions
  - Completely new designs possible



Dead Tired

May 25, 2016 by Editorial

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Mariner Fatigue by Lou Vest (Click HERE to read the story behind the photo)

By Jaquelyn Burton (Coeval, Inc.) A person who has been awake for 17 hours faces the same risk of a crash as a person who has a BAC reading of 0.05 g/100ml and those who are awake for 24 hours will have a driving performance similar to a person who has a BAC of 0.1 g/100ml. – Adelaide Centre for Sleep Research

Source: https://gcaptain.com/dead-tired/

Current Efforts in Autonomous Vessel Research

- Maritime Unmanned Navigation through Intelligent Networks (MUNIN)
- Rolls Royce – TEKES “Advanced Autonomous Waterborne Applications Initiative”
- ABS ‘Smart Ship’ development effort
- DARPA ASW Continuous Trail Unmanned Vessel (ACTUV)

Engineering for Autonomy

- System engineering will emphasize ***integrative activities***
  - Cybersecurity: maintaining resilient, continuous positive control
  - Software assurance and software quality: deterministic, understandable behavior at all times
  - Data integrity: generation, monitoring and measurement of data veracity
  - Decision system testing, certification and accreditation: standards and confidence in systems' capabilities to operate unsupervised
  - Risk management: operating and maneuvering in the environment
- Autonomous systems of systems (ships or platforms) increase functions while decreasing numbers of personnel
  - *May* provide remote access for emergent conditions
  - *Must* provide fault tolerance and incident response methods and mechanisms
  - *Must* provide safety systems for personnel aboard

"Dave, I can't let you do that."

Some Requirements for Autonomy

Technical Requirements

- Internal operational monitoring and control
- Sensors and sensor management on ship / platform
- Fault tolerance requirements
- Cyber and physical safeguard mechanisms against unexpected events (cargo handling / offload)
- External sensors and systems (navigation aids or networks)
- Decision capabilities for recognition of / reaction to anomalous conditions
- Mission planning, with security for mission execution
- Communications assurance on multiple channels

Process Requirements

- Remote operations methods and system monitoring standards
- Legal framework for operations and incident response
- Secure software development methods *and* Software Management of Change (SMoC)
- Comprehensive test regimes for systems (prevent intrusion, faults, exception generation)
- Systems of systems test, integration and holistic operations
  - Testing for system integration, data exchanges
  - Emphasis will develop on data integrity

Potential Areas to Support Autonomy Research

- Decision making processes
- Testing methodologies that prove deterministic behavior
- Fault tolerance and testable resilience in critical systems
- Communications links
- Secure, hard real-time remote control / access
- Navigation / positional assurance (potential coastal nav aid networks)
- Traffic management system (Maritime / Coastal Traffic Control)
- Mission planning and execution following
- Shore infrastructure needed to support autonomy and automation
- Ship condition management at port visits
- Machinery monitoring
- Automated data analysis
- Workforce and skills
- Human factors aboard automated platforms
- Legal considerations: responsibility for operations and potential incidents
- Rules for working with autonomous systems

Class Perspective on Marine Autonomy

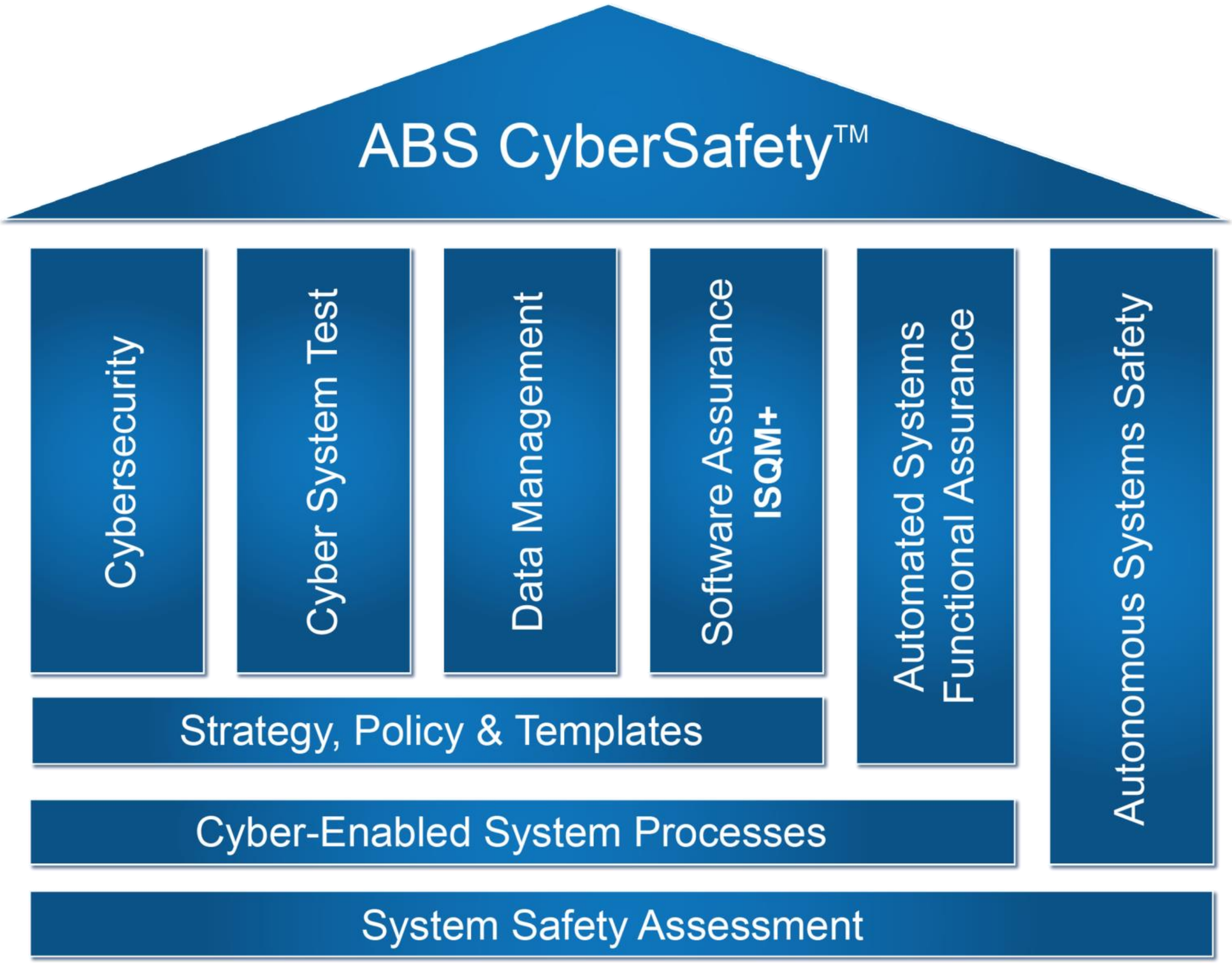
- **Safety and risk interrelate**
  - Human safety is more than safety aboard the ship
  - Risk includes safety of the maritime community in the presence of machines
- **Autonomy requires more rigorous and thoughtful engineering**
  - Appropriate autonomy levels will differ based on use cases
  - ***Critical systems must be <u>allocated fault tolerant capabilities</u>***
  - Decision and execution logic in mission processor set must be probabilistically testable and built with operational tell-tales
  - Developmental engineering processes require software assurance, data integrity, cybersecurity
  - Operational capability depends heavily on risk management
- Testing: Classification will **<u>verify that integrated safety is not compromised by automated systems</u>**

Classification of Autonomous Vessels

- Conventional requirements for autonomous systems may include
  - Material condition
  - Equipment and machinery operational conditions and dynamic demonstrations
  - Onboard safety equipment (for crew or maintenance personnel)
  - Safety systems for automation support and safety of SHIP
- Additional requirements specific to autonomous systems may include
  - Decision core testing and diagnostics
  - Data flow verification
  - Remote access, monitoring modes and authentication methods verification
  - Network operational monitoring
  - System of systems penetration testing

Automation methods in testing and code generation have potential to remove risks – if engineered and reviewed rigorously.

CyberSafety™ Family of Documents



Roadmap to Autonomy

- System engineering can provide capabilities for all levels of autonomy, if and only if
  - Both process (use) and technical requirements are understood for individual systems and for categories of vehicles;
  - Regulatory guidance is provided to determine how autonomy is used, and at what level of implementation; and
  - Technical review continues to be required to satisfy needs for safety of personnel, of system, of vehicle/platform/asset, and of environment or community.
- Automation and autonomy are an opportunity if developed and fielded as developing sets of capabilities, with emphases on deterministic behavior and functional assurance

The Roadmap to Autonomy requires research and development, collaboration with academia, industry and Class: ABS CyberSafety™ provides a framework for the roadmap.

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