Autonomous Ships/Vehicles: Classification Society Perspective
Agenda

- Trends/Challenges
- Regulatory Development
- Autonomy Levels
  - New Technology Qualification
    - 5 Qualification Stages
- Smart to Autonomous Framework
  - Condition Based Class
  - Software notations
  - SMART notations
  - Goal Based Autonomous Vessel Certification
- Supporting the Journey
Trends in Autonomy for Marine application

• Improved
  - sensors and imaging technology,
  - connectivity within the vessel and from the vessel to shore
  - data management and analytics
  - machine learning and artificial intelligence tools

• Increasing application of technology to augment and replace personnel
  - Subsurface autonomous vehicles
  - Remote areas surface surveys and security monitoring
  - Government sponsored test surface vessels
  - Navigation and bridge level crew augmentation

• Dedicated routes/short shipping routes with remote operation centers
Challenges

- Technology
- Human factors
- Regulatory Framework

Autonomous functions which will perform tasks mandated by current regulations (for e.g. an autonomous navigation system performing the duties of a Lookout as required by COLREGS) would have to be shown to be equivalent to being carried out by humans, and an exemption would have to be granted by the flag state.
IMO Regulatory Scoping Exercises

Degrees of Autonomy

- Ship with automated processes and decision support
- Remotely controlled ship with seafarers on board
- Remotely controlled ship without seafarers on board
- Fully autonomous ship

Source: MSC 100
## ABS System Autonomy Levels

<table>
<thead>
<tr>
<th>ABS System Level of Autonomy</th>
<th>Integration and Application to Decision Loop</th>
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<tbody>
<tr>
<td></td>
<td>Monitoring</td>
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<tr>
<td>1  Smart</td>
<td>M</td>
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<tr>
<td>2  Semi-Autonomous</td>
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<tr>
<td>3  Autonomous</td>
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Notes: 1. H-Human, M-Machine

Smart systems augment human capabilities by assisting during the Monitoring and Analysis phases. A smart system may make recommendation, but the decision and final choice rests with the human operator.

Semi-Autonomous systems take a decision-making role and performs action selection. A human is in the loop for approval and possible override of system-selected actions.
Concepts within each Autonomy Level

- **Vessel Details**
  - Type
  - Size, capacity
  - Design envelope

- **Concept of Operations**
  - Intended Area of Operations
  - Autonomous System Application to Voyage Phases (seagoing, port operations, piloting, anchor/mooring, distress/emergency)
  - Operational Envelope (limitations and restrictions)

- **Modes of Control by Humans**
  - Where
  - How
  - Concept of Support Logistics
  - Maintenance
  - Emergency Response
ABS New Technology Qualification

- Five stage process compatible with API RP 17N/Q, ISO 16290 and US DoD
- Tailored for new/unproven vendor applications
  - System, Sub-system, Equipment, Component or materials
- Autonomous Review is aligned to a Goal Based Framework.
ABS Smart to Autonomous Framework

**Goals**

Designed, Constructed, Operated and Maintained for Planned Mission with Safety* and Reliability

<table>
<thead>
<tr>
<th>Level of Autonomy</th>
<th>Smart</th>
<th>Semi-Autonomous</th>
<th>Autonomous</th>
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<tbody>
<tr>
<td>Functional Requirements</td>
<td>Monitoring + Analysis</td>
<td>Decision + Action</td>
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<td>Verification of Conformity</td>
<td>Verification &amp; Validation</td>
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<tr>
<td>Foundational Requirements</td>
<td>ABS Smart Series</td>
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<td>ABS CyberSafety® Series</td>
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<td>ABS Software Series</td>
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<td>ABS Connected and Predictive Condition Based Survey Program</td>
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*Safe execution of mission has to consider the impact on/consequences to people, environment and the vessel.
Shift to ABS Condition-Based Class

From Scheduled-Based
- Vessel real-time condition
- Surveys based on condition assessments

To Condition-Based (Informed → Targeted → Predictive)
- Assessment model
- Personalized planning document

Customer Benefits
- Less intrusive survey
- Low customer downtime
- Tailored & comprehensive

Asset specific electronic survey planning document

Static checklist/surveyor planning document
ABS Software Quality and Integrity

- Integrated Software Quality Management (ISQM)
- ISQM Software Provider Quality Conformity Program
- Software System Verification
ABS CyberSafety® Type Approval Process

- **Component Level**
  - PDA Certification

- **Equipment/System Level**
  - SP Approval
  - PDA Certification

Equipment becomes increasingly complex
## Functions of a Smart Vessel

**Structure Health Mon.**
- Monitor structural loads, response, and health conditions
- Enhance safety and integrity
- Avoid damage and failures

**Machinery Health Mon.**
- Monitor health and conditions of onboard machinery
- Detect operational anomalies
- Prevent system failure and unplanned downtime

**Asset Eff. Monitoring**
- Assess system efficiency
- Optimize maintenance and tune-up activities

**Crew Asst. & Augmentation**
- Assist crew activities
- Augment crew’s ability, such as night vision, obstacle detection, collision avoidance, etc.

**Ops Performance Mgmt.**
- Monitor operational conditions
- Optimize operational parameters
Getting to a Smart Vessel or Asset

- PDA & SP Approval
- Installation/Commissioning
- Survey After Construction - CBC

**INTERIM**
- Vendors
  - SP/PDA Approval Engineering Review
  - SP/PDA Approval Audit At Vendor Site

**APPROVED**
- SP/PDA Approval Initial Service Validation

**INSTALLED**
- SHM/MHM Installation and Commissioning Survey
- CBC Implementation

**LIVE**
- SY and Owners/Operators
  - SHM/MHM Validation Period On Vessel
  - CBC Survey Execution
Smart in Context

- **Manual**: No system augmentation of human functions
- **Smart**: Passive decision support, System augmentation of human functions (i.e. Health Monitoring)
- **Semi-Autonomy**: Human augmentation of system functions, Human in the loop for supervisory/override
- **Full Autonomy**: No human augmentation of system functions, Human out of the loop (informed as requested)
Autonomous Operations

Beyond Ship Itself

Remote controlled from onshore control center

Satellite

Remote controlled from manned ship

Controlled from another unmanned ship

Port communicates to autonomous OSV via satellite

Autonomous OSV
Unmanned control

Sensor beams

Situational awareness and collision avoidance
ABS Supporting the Journey to Autonomy

- Data scientists and software engineering capability investment
- Industry collaboration via MASS projects
- Industry collaboration via Condition Based Class projects
- Refining foundational requirements: cyber, software, data collection and usage
- Defining autonomy requirements and pathways to safety equivalency
- Utilizing New Technology Qualification: risk assessment and engineering-based verification
- IMO Regulatory Scoping Exercise with MPA (Maritime & Port Authority of Singapore)
  - Assist with scoping exercise for SOLAS Chp. V and COLREGS.
- ISO 23860 MASS Terminology
- Widely accepted thought leadership
Considerations for Advancing Autonomy

- Joint development projects with government and industry
- Testing and evaluation of subsystem functionality and software reliability
- Algorithm testing and validation protocols and interoperability testing
- Standards development committees and peer review opportunities
- Regional surface vessel test sites and data collection centers
- Open source software and relaxed restrictions on technology transfer
- Line of sight remotely operated and optionally manned surface vessels
- Public outreach regarding safety and regulatory acceptance
- Demonstrated cost savings and risk reduction
Thank You

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