# Charting Regulatory Frameworks for Maritime Autonomous Surface Ship Testing, Pilots, and Commercial Deployments

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# Machine Learning in Autonomously Navigating Vessels

- Primary roles for Machine Learning (ML) in autonomous navigation systems are
  1. extracting semantic information from sensor data for situational awareness,
  2. predictive modeling of e.g. vessel trajectories for navigation.
- Typically ML models are not applied directly for navigational planning or vessel steering.
- Typically model training is not performed onboard the vessel, but as part of the overall software development and integration cycle. This requires collecting large data sets from vessels, setting demands on vessel connectivity.
- Specific characteristics of ML in maritime autonomous navigation include:
  1. large geographic scale in situational awareness and navigational planning, resulting in sensoring and computational challenges,
  2. special demands for semantic processing and prediction models arise from existing regulation and conventions, e.g. COLREGs.

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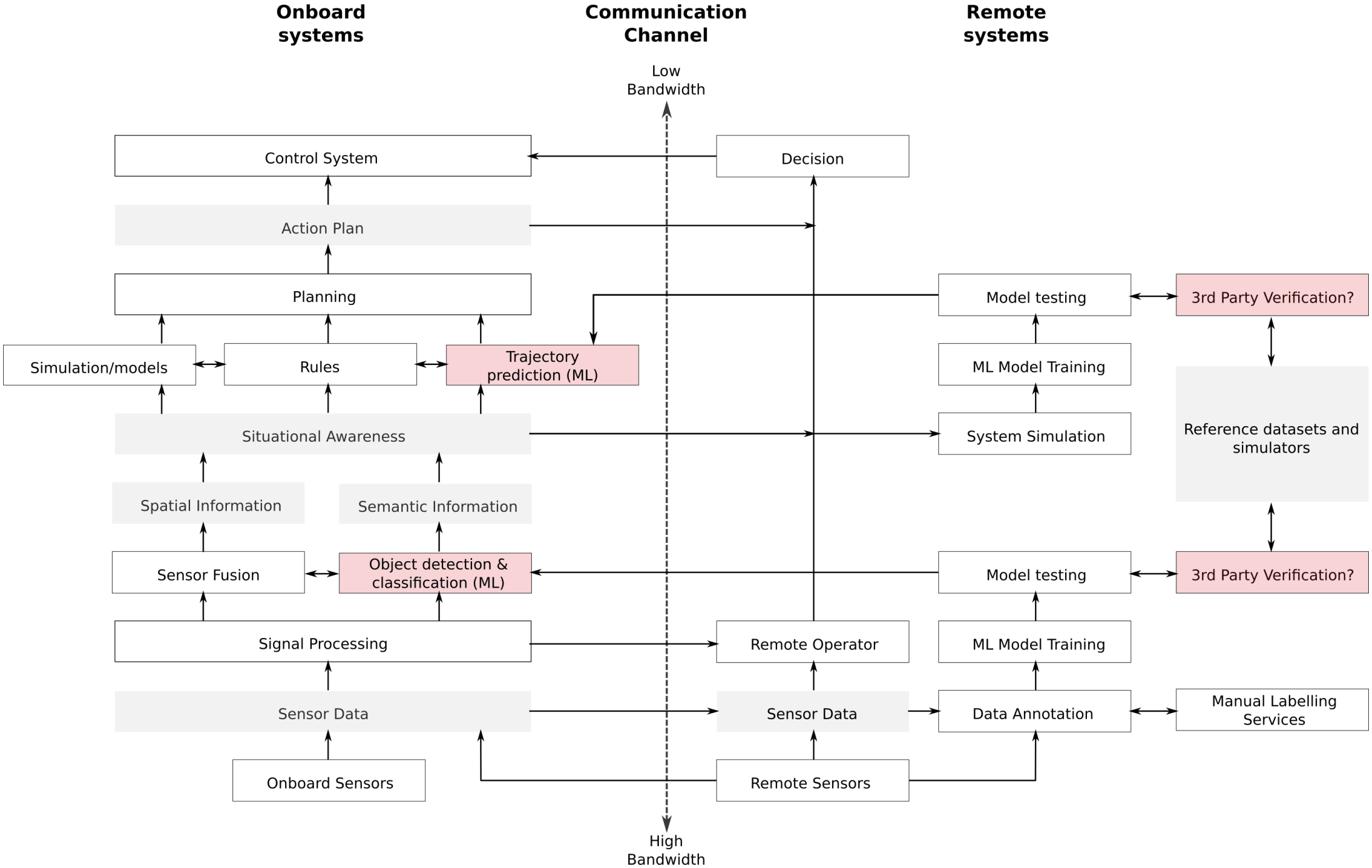
Onboard systems
Communication Channel
Remote systems
Low Bandwidth
High Bandwidth
Control System
Decision
Action Plan
Planning
Simulation/models
Rules
Trajectory prediction (ML)
Situational Awareness
Spatial Information
Semantic Information
Sensor Fusion
Object detection & classification (ML)
Signal Processing
Sensor Data
Onboard Sensors
Remote Operator
Sensor Data
Remote Sensors
Model testing
ML Model Training
System Simulation
Model testing
ML Model Training
Data Annotation
3rd Party Verification?
Reference datasets and simulators
3rd Party Verification?
Manual Labelling Services

# Preliminary conclusions on regulatory challenges for test areas and pilots

- Most legal challenges relate to international traffic.
- Most legal challenges relate to fully unmanned ships (whether remote operated or autonomous).
- The nature of the legal (and technical) challenges varies with the level of automation, but the difference between different unmanned (autonomous/remotely operated) ships is not enormous.
- A fair share of issues can be overcome in the international trial by leaving one or two crew members, including the master, on board. (This seems to be supported by the limited practice available today.)
- For permanent MASS operations, more robust solutions are needed, at national and international level.

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# Regulatory framework for commercial deployments

- To ensure safe navigation regulators should
  - articulate statistical simulation-based standards for minimum situational awareness and navigational system performance
  - build and maintain a third-party administered simulation platform to assess situational awareness and navigational system performance
  - Articulate minimun technical and redundancy standards for autonomy equipment

- Autonomous ship design processes are rife with ethics-sensitive trade-offs. Regulators should
  - require that all autonomy equipment manufacturers have a Chief Ethics Officer (CEO) and a permanent Ethics Review Committee
  - require that manufacturers conduct ethics assessments of all navigational system components and document the ethical assessments

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