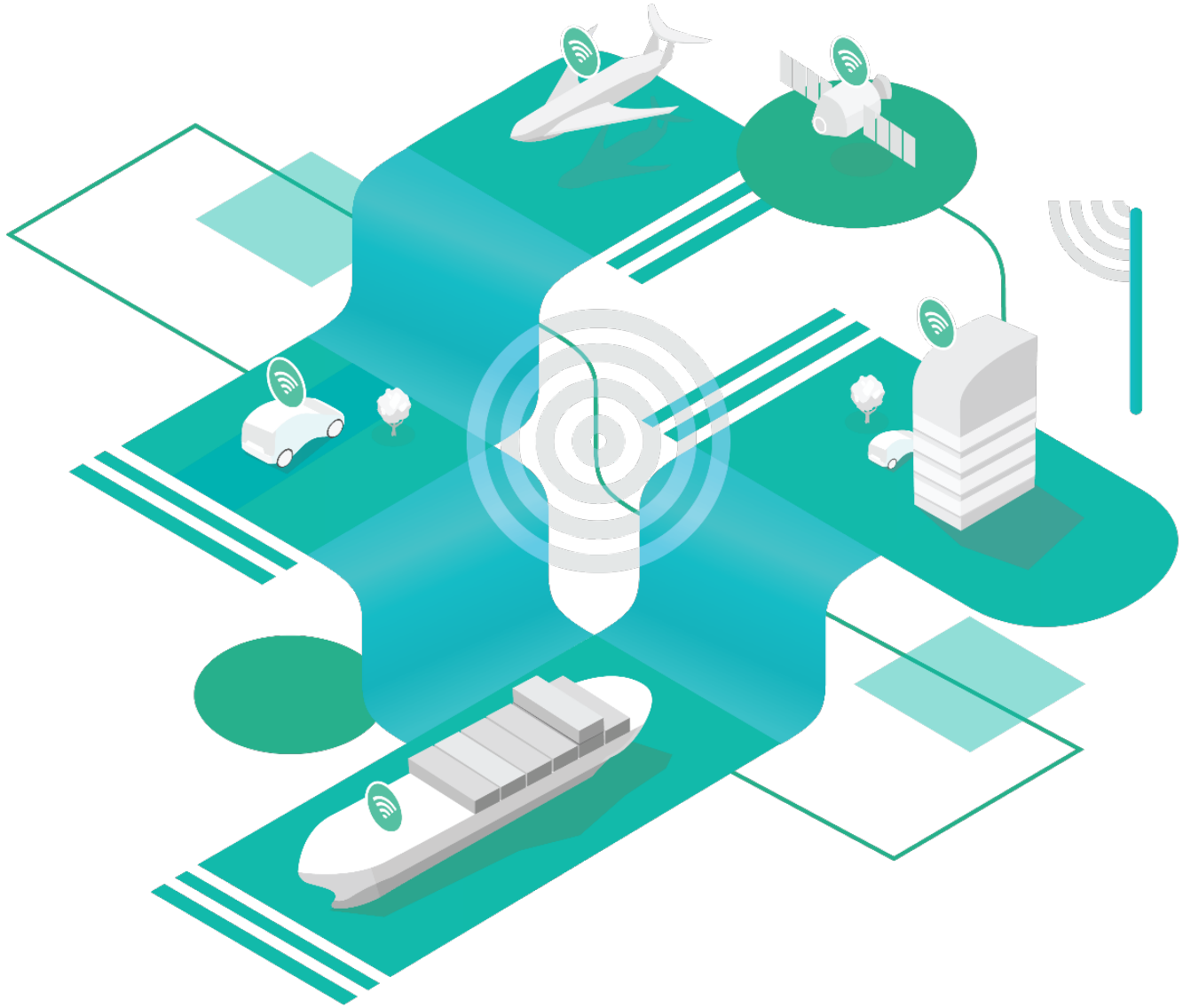

IWASS

First International Workshop on Autonomous Systems Safety

Trondheim, Norway
March 11th to 13th

Professor Ingrid Bouwer Utne
Departement of Marine Technology, NTNU

NTNU
Norwegian University of Science and Technology

The B. John Garrick Institute for the Risk Sciences
UCLA ENGINEERING

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The Research Council of Norway

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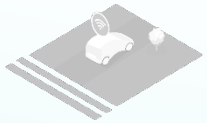
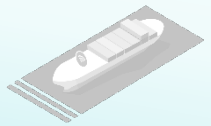
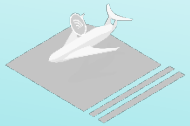

Welcome to IWASS

- Purpose:
  - Gather key experts in autonomous systems safety.
  - Aims to identify common challenges related to safety, reliability, and security (SRS) of autonomous systems.
  - Will discuss and propose possible solutions for the identified challenges.

- Main sponsors:

The Research Council of Norway

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Why autonomy?

Unique (or cheaper) solution when no (or limited) communication is available (bandwidth, remoteness)

Unmanned systems may be smaller, lighter, cheaper and safer to deploy and operate

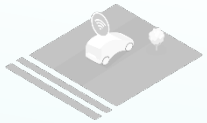
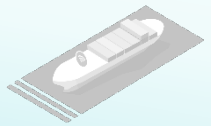
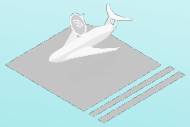
Qualified operators may be a shortage

Mandatory for new functions

Enables complex functionality; provides fault tolerance and robustness

Enables operations in complex, harsh and remote environment (Dull/Dirty/Dangerous Operations)

More intelligent systems that depend less on human operators

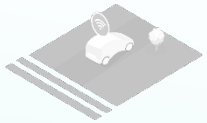
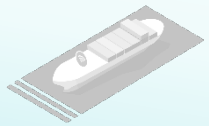
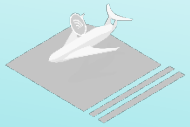




Definitions

- **Autonomy** can be defined as *a system's or sub-system's own ability of integrated sensing, perceiving, analyzing, communicating, planning, decision-making, and acting, to achieve its goals as assigned by its human operator(s) through designed human-machine interface (HMI).*
  - This definition is based on NIST (2008), but adjusted for autonomous systems and operations, both manned and unmanned.

Risk, reliability and safety

- Risk*: the consequences of the activities, with associated uncertainty (PSA Norway).*
- Safety: *Freedom from conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment (MIL-STD-882E)*
- Reliability:

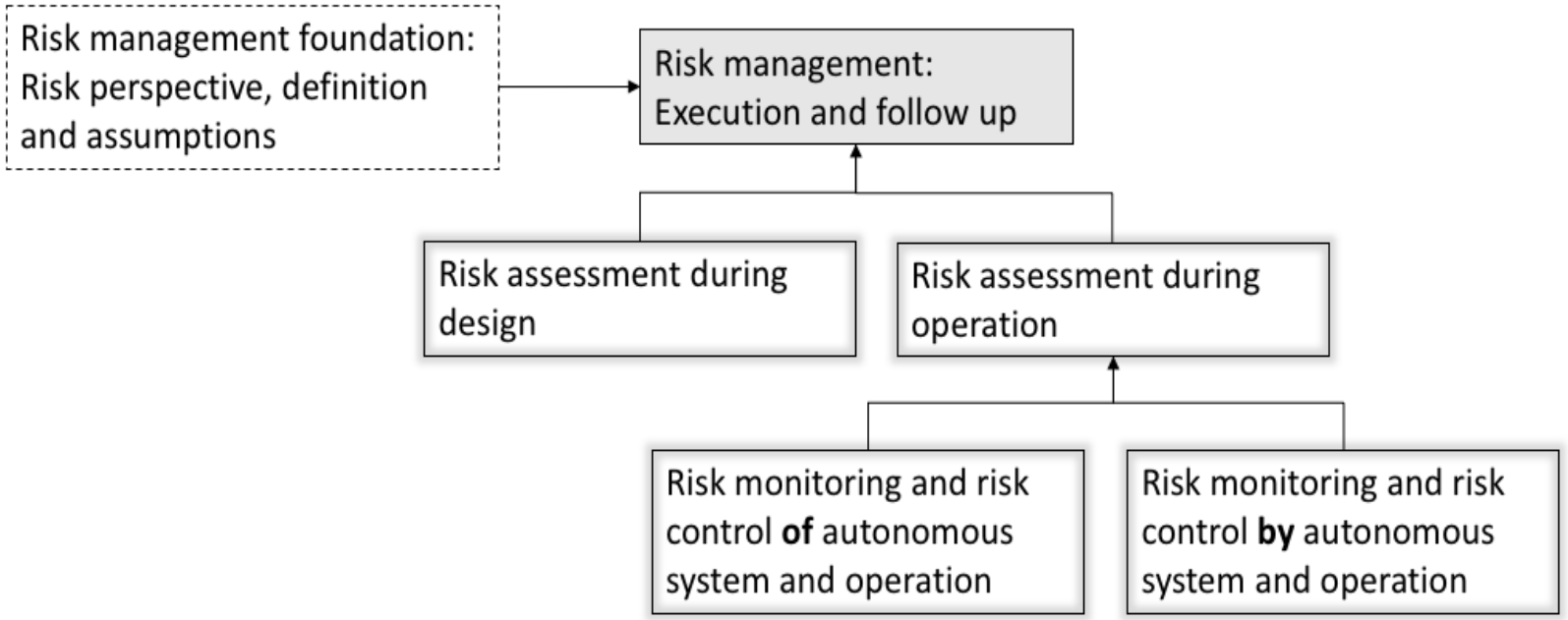




Levels of autonomy (LoA)

LoA	Title	Description	Examples
1	Automatic operation (Remote control)	System operates automatically. Human operator directs and controls all functions; some functions are preprogrammed (human-in-the-loop/human operated).	ROV/ subsea inspection and intervention.
2	Management by consent	System automatically makes recommendations for mission or process actions related to specific functions, where system prompts human operator at important points for information or decisions (human-delegated).	DP system, AUV inspection task with support by surface vessel.
3	Semi-autonomous operation or management by exception	System automatically executes mission-related functions when and where response times are too short for human intervention. Operator´s attention is only brought to exceptions for certain decisions (human-supervisory control).	DP system, energy management systems. AUVs in ocean monitoring and surveillance.
4	Highly autonomous operation	System automatically executes mission- or process-related functions in unstructured environment with capability to plan and re-plan mission or process. Human operator may be informed about progress, but the system is independent and “intelligent” (“human-out-of-the loop”).	AUV in ocean monitoring and surveillance, AUV inspecting subsea installations.

Utne et al., 2019

Autonomy and risk



Utne et al., 2017

30th September 2016:

Test site opened for autonomous vessels

The **Trondheims Fjord** in Norway is the world's first technological playground for pilotless vehicles that move under, on, and over the sea surface.

Norwegian authorities, industry, SINTEF and NTNU have taken this initiative.

milliAmpere/Autoferry

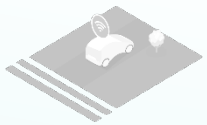
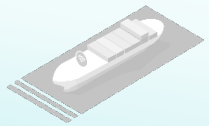
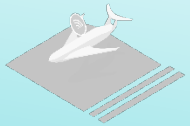
The world's first autonomous passenger ferry between Ravnkloa and Vestre Kanalhavn, Trondheim. Testing started in 2018, and from 2020 passenger transport will start, if permission is granted from the Maritime Authority.

SFF NTNU AMOS

Center of Excellence on Autonomous Marine Operations and Systems (2013-2022)

- World-leading research center which contributes with fundamental and interdisciplinary knowledge in marine hydrodynamics, ocean constructions and control theory.
- The research results contribute to intelligent ships and ocean structures, autonomous unmanned vehicles (under water, on the surface and in air) and robots for high-precision and safety-critical operations in extreme environments.
- Target: 100 PhDs
- Budget (10 years): 100M USD

Stenberg/NTNU AMOS

Research area in NTNU AMOS:

Supervisory risk control for autonomous systems and operations

Safer autonomous systems and operations: UNLOCK	Safer autonomous ships: ORCAS
Aims to develop novel methods for supervisory risk control to improve built-in decision-making abilities and intelligence of autonomous systems.	Aims to develop competence, knowledge and enabling technology for the maritime industry to advance towards autonomous ships.
Risk, safety, testing and verification	
Risk modeling, decision criteria and safety constraints	Identification of accident scenarios, modeling and categorization of risk
Analysis techniques for embedded and fast online consequence analysis	Formal and informal methods utilizing machine learning & the digital twin concept
Model predictive control (MPC), optimization, autonomy	
Scenario based MPC combined with artificial intelligence for safer mission planning	MPC based on digital twin concept utilizing machine learning for reduced operational risk

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