ROSS

GEMINI CENTRE

Risiko og pålitelighetsforskning i Trondheim

Jørn Vatn

jorn.vatn@ntnu.no

ESRA-seminar 7. februar 2023

Geminiordningen

- Geminiordningen er en modell for strategisk samhandling mellom faggrupper ved NTNU, SINTEF, Universitetet i Oslo, St. Olavs Hospital og NTNU Samfunnsforskning
- ROSS Geminisenter ble etablert i 2007 som et samarbeid mellom NTNUs Institutt for produksjons- og kvalitetsteknikk, RAMS-gruppen, NTNUs Institutt for industriell økonomi og teknologiledelse, HMS-gruppen, og SINTEF Teknologi og samfunn, SIPÅ
- Siden den gang har det vært flere omorganiseringer i SINTEF og NTNU, samt at det har vært en endring i hvilke enheter som har deltatt i senteret

Medlemmer

	Tom Ivar Pedersen	SINTEF Energi, Energisystemer	Oddbjørn Gjerde, Arnt Ove Eggen, Eivind Solvang, Erlend Sandø Kiel, Gerd Kjølle, Håkon Toftaker, Iver Bakken Sperstad, Maren Istad, Sigurd Hofsmo Jakobsen, Susanne Sandell, Tesfaye Amare Zerihun, Tom Ivar Pedersen	
	Mary Ann Lundteigen	NTNU, Institutt for teknisk kybernetikk (ITK)	Mary Ann Lundteigen, Børge Rokseth	6
	Martin Rasmussen Skogstad	NTNU Samfunnsforskning	André Karlsen, Asle Gauteplass, Evangelia Petridou, Gudveig Gjøsund, Jens Petter Johansen, Jörgen Sparf, Lucia Liste Munoz, Mads Dahl Gjefsen, Maja Joner Ognedal, Martin Inge Standal, Martin Rasmussen Skogstad, Naska Xas, Nataliia Korotkova, Per Morten Schiefloe, Stian Antonsen, Susanne Therese Hansen, Torgeir Kolstø Haavik, Ivonne Herrera, Marie Nilsen	2

	Kristine Vedal Størkersen	SINTEF Ocean, Havbruk	Trine Thorvaldsen, Andreas Midsund, Cecilie Salomonsen, Ingunn Holmen, Henning Braaten og Kristin Vedal Størkersen	
	Ingrid Bouwer Utne	NTNU, Institutt for marin teknikk (IMT)	Arne Ulrik Bindingsbø (prof II), Ali Mosleh (prof II/International chair)	7 PhD, 2 Post Doc, 1 gjeste - PhD
	Jørn Vatn	NTNU, Institutt for maskinteknikk og produksjon (MTP)	Yiliu Liu, Nicola Paltrinieri, Viggo Gabriel Borg Pedersen, Hyungju Kim, Jørn Vatn, Federico Ustolin, Shen Yin	13
	Stephen Dirk Bjørn Wolthusen	NTNU, Institutt for informasjonssikkerhet og kommunikasjonsteknologi (IIK)	Stephen Wolthusen, Sokratis Katsikas	

NTNU - Undervisning

- Flere 5-årige programmer hvor man kan spesialisere seg i risiko/sikkerhet og pålitelighet
- 2-årig internasjonal master i RAMS
- Etter- og videreutdanning, spesialisering i sikkerhet, pålitelighet og vedlikehold


2018-2023
Research projects at Department of Marine Technology
Project manager: Professor Ingrid Bouwer Utne
Email: Ingrid.b.utne@ntnu.no
Norwegian Centre of Excellence
AMOS

Research area in NTNU AMOS:

Supervisory risk control for autonomous systems and operations

Safer autonomous systems and operations: UNLOCK

This project aims to develop novel methods for supervisory risk control and integrate these with optimization-based control and predictive simulation to improve built-in decision-making abilities and intelligence of autonomous systems.

Safer autonomous ships: ORCAS

This project aims to develop competence, knowledge and enabling technology for the maritime industry to advance towards autonomous ships with high level of autonomy.

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

FRIPRO/FRINATEK - Forskningsrådet

RESEARCH PROJECT UNLOCK

Unlocking the potential of autonomous systems and operations through supervisory risk control (UNLOCK)

Fundamental and generic research focused on developing more intelligent and safe control systems for achieving higher level autonomy.

Develop novel methods for supervisory risk control and integrate these with optimization-based control and predictive simulation to improve built-in decision-making abilities and intelligence of autonomous systems.

Fundamental research challenges

- To reduce risks related to autonomous systems, **improved intelligence, situation awareness, and decision-making capabilitie**s are needed.

- Existing control theoretic approaches, such as model predictive control (MPC), are not explicitly connected to risk assessment and modelling. Hence, *research is needed to determine how parameters, constraints and cost functions should be set up in MPC to minimize operational risk of autonomous systems*.

- ***Verification of software intensive systems*** *and control systems for autonomous systems is highly challenging*, both with respect to test regime and supervisory risk control.

Specific sub objectives

Educate **2 Doctoral candidates and 1 Post Doc.**

Publish and disseminate the **main results in top ranked scientific journals and conferences** in the fields of research.

Develop **demonstrators** for industrial inspection using unmanned aerial vehicles (UAVs) and ocean mapping and monitoring using autonomous underwater vehicles (AUVs), based on objectives 1-3.

Utilize synergies and interact with researchers in the **Centre of Excellence NTNU AMOS**.

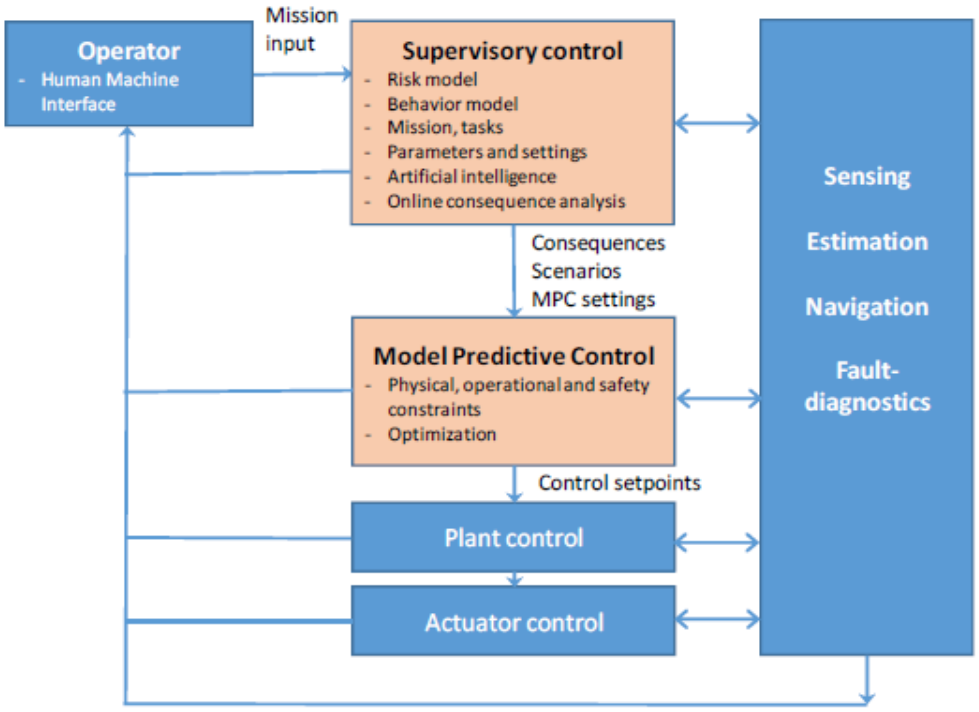
Project partners

- NTNU: Department of Marine Technology
  - Professor Ingrid B. Utne (Project Manager& Principal Scientist), Professor Asgeir J. Sørensen (Principal scientist)
- NTNU: Department of Engineering Cybernetics
  - Professor Tor Arne Johansen (Principal Scientist)

- International partners:
  - Professor Ali Mosleh, University of California, Los Angeles (UCLA)
  - Professor Tristan Perez, Queensland University of Technology (QUT)
  - Professor Murat Arcak University of California, Berkeley (UCB)

Research content

- Control system architecture with main focus research areas (orange).



More information: https://www.ntnu.edu/imt/unlock

MAROFF KPN - Forskningsrådet

RESEARCH PROJECT ORCAS

Vision:
To strengthen the competiveness of the Norwegian maritime industry to attain world leading competence and knowledge in the design, verification and operation of control systems for safe autonomous ships.

ONLINE RISK MANAGEMENT AND RISK CONTROL FOR AUTONOMOUS SHIPS (ORCAS)

To develop competence, knowledge and enabling technology for the maritime industry to advance towards autonomous ships with high level of autonomy (LoA).

Applied research on risk management of autonomous ships. Particular focus is planned for automatic sailing and power and propulsion systems.

Objectives

Develop **new methods and technology for risk modeling of control systems** with high LoA that determine and manage the real-time risk of autonomous ship operations. Machine learning techniques using recorded ship data combined with models of ship systems will be studied.

Develop **new methods and technology supporting higher LoA based on online verification** that exploits risk modeling, consequence analysis, and health monitoring.

Develop n**ew methods and technology for autonomous online decision making under uncertainty**, considering risk subject to the different modes of ship operations, potential failures, and changing environmental conditions.

Use cases and demonstrations: **Particular attention will be given to automatic sailing systems and power and propulsion control systems**.

Project partners

- NTNU: Department of Marine Technology
  - Professor Ingrid B. Utne (Project Manager& Principal Scientist), Professor Asgeir J. Sørensen (Principal scientist)
- NTNU: Department of Engineering Cybernetics
  - Professor Tor Arne Johansen (Principal Scientist)
- DNV
- Kongsberg Maritime

- International partners:
  - Professor Ali Mosleh, University of California, Los Angeles (UCLA)
  - Professor Tristan Perez, Queensland University of Technology (QUT)
  - Professor Murat Arcak University of California, Berkeley (UCB)

+ 3 Doctoral candidates and 1 Post Doc.

Research content

Q1: How can online consequence analysis motivated by the DP consequence analysis be extended into an online and dynamic operational risk analysis tool that provides a foundation for optimal decision-making and control, assessment and verification of automatic sailing systems and power and propulsion control systems?

Q2: How to develop machine learning methods combined with models of risk, vessel, sensors, power and propulsion systems supporting higher LoA and online verification of autonomous systems undertaking an adaptive behavior?

Q3: How to develop formal and informal testing and verification methods that scale up and are relevant for autonomous ships?

Q4: How can risk modeling of hazardous scenarios for automatic sailing systems, power and propulsion systems be used for autonomous optimization-based decision-making and control under uncertainty?

More information: https://www.ntnu.edu/imt/orcas

International cooperation

IWASS

Navigation

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IWASS 2022 International Workshop on Autonomous Systems Safety

August 27 - Dublin, Ireland

The International Workshop for Autonomous System Safety (IWASS) is a joint effort by the B. John Garrick Institute for the Risk Sciences at the University of California Los Angeles (UCLA) and the Norwegian University of Science and Technology (NTNU).

IWASS 2022 will be held on August 27, 2022, in Dublin, Ireland.

IWASS 4 will be arranged at ESREL 2023

IWASS is a by-invitation-only event

ESREL 2022 Panel / Special Session

The European Safety and Reliability Conference (**ESREL**) will have a Special Session and a Panel dedicated to IWASS.

QUESTIONS or COMMENTS?

PLEASE CONTACT:
PROFESSOR INGRID BOUWER UTNE
DEPARTMENT OF MARINE TECHNOLOGY, NTNU
EMAIL: INGRID.B.UTNE@NTNU.NO

SFI AUTOSHIP
Autonomous ships

Knowledge for a better wolrd

Research within Safety and Assurance in SFI AutoShip

Professor Mary Ann Lundteigen & Professor Ingrid B. Utne

SFI AutoShip

- Research-based innovation centre
- Headed by NTNU
- 8 years (2020-2028)
- Aim: Increase the adaption of autonomous systems and technologies within Maritime sectors
- 24 partners
- Educating > 20 PhDs, > 5 Postdocs, 50-100 master students

Safety and assurance research – started up in 2020

DNV

IFE

Sjøfartsdirektoratet
Norwegian Maritime Authority

KYSTVERKET

gard

Legal deployment

Motivation:
Autonomous vessels a unique opportunity of exploring topics which delve deeper into the relationship between Law and technology

Tasks:
- Legal analysis and application in court
- Develop legally-substaintiated explanation of rules to deploy in autonomous systems

Use case:

UNIVERSITAS OSLOENSIS MDCCCXI

Risk related to software

Motivation:
Software risk in the maritime environment in early stage of development and understanding. Existing practices from the automotive and railway industries. Are restrictive in terms of high-level autonomous functions.

Tasks:
- Development of software risk and failure taxonomy
- Integration of software risk into risk methods
- Suggest countermeasures

Use case:

NTNU

Use of DT for safety demostr

Motivation:
Digital twins have been used in different domains for several years now but approaches to represent autonomous systems with digital twins started recently.

Tasks:
- Identify requirements to digital twin and environment for safety demonstration
- Build a prototype to test with applicable use cases

Use case:

NTNU

Reliable Design & Operation

Motivation:
Electric propulsion plants may suffer from complex failure modes and require careful and predictive maintenance. Critical failures may create unsafe situations.

Tasks:
- Investigate the reliability and safety combining qualitative and quantitative methods
- Incorporating hydrodynamics for stability analysis and prediction of grounding.

Use case:

NTNU

Online risk monitoring

Motivation:
Autonomous ships will be subjected to dynamic factors, such as equipment degrading and changing environmental factors, affecting risks., Must be considered in the autonomous system and tools for decision-making.

Tasks:
- Develop online risk models, developed on the basis of identifying hazards related to safety and security
- Test the risk models and their use for decision-making

Use case:

NTNU

equinor

FUGRO

REACH SUBSEA

TORGHATTEN

SINTEF

MARITIME ROBOTICS

KONGSBERG

One new PhD project (not shown above) started up in fall 2022

Want to learn more about SFI AutoShip?

@NTNU homepage:

www.ntnu.edu/sfi-autoship

@LinkedIn:

https://www.linkedin.com/company/sfi-autoship/

Contact us

Ingeborg Guldal
Administrative Coordinator

Anastasios Lekkas
Center Director

Look inside

BRU21 og SUBPRO

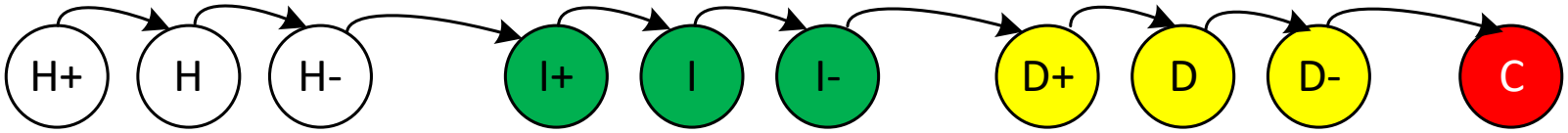
- SFI SUBPRO er i avslutningsfasen
- NTNU jobber for en videreføring: SUBPRO-Zero
- BRU21 er et «Prosjekthotell» hvor industrien finansierer egne PhD «usecases»
- Begge prosjektene har arbeidspakker på RAMS, hvor vi har et formalisert samarbeid, f eks gjennom felles PhD samlinger (Oppdal, Røros, Orkanger osv)
- SUBPRO er støttet av NFR + industribedrifter, BRU21 kun av industribedrifter

BRU21 og SUBPRO

Maintenance modelling and optimization

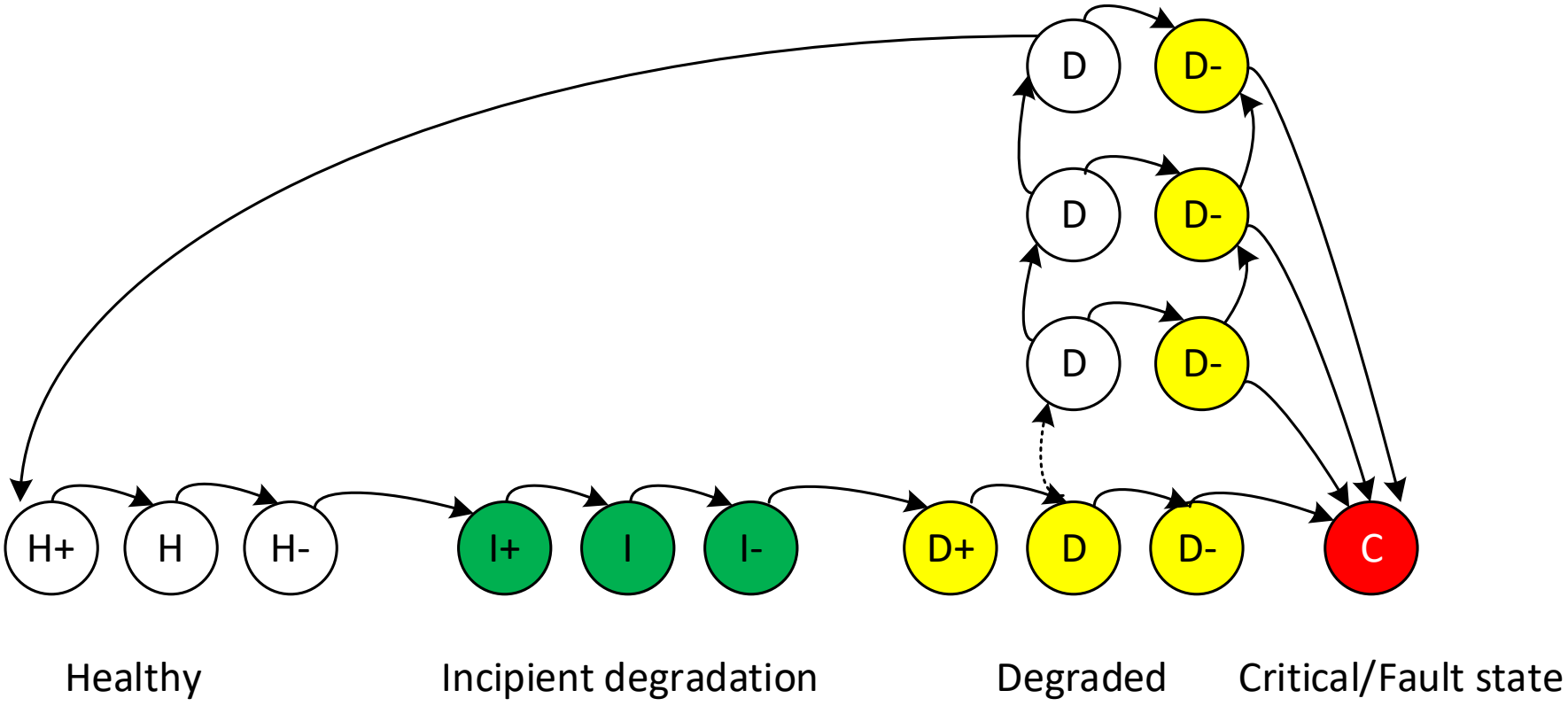
- Degradation modelling
  - Wiener process / Geometric Brownian Motion
  - Gamma process / Gamma process with noice
  - Markov state modelling/ Markov state model with phase type distributions
- Optimization
  - Inspection regimes, i.e., for safety instrumented systems
  - Optimal renewal and imprefect repair strategeis
- Data analysis for estimating model parameters
- Machine learning
- Qualificaiton of digital twins for maintenace

Markov modelling (ISO14224)

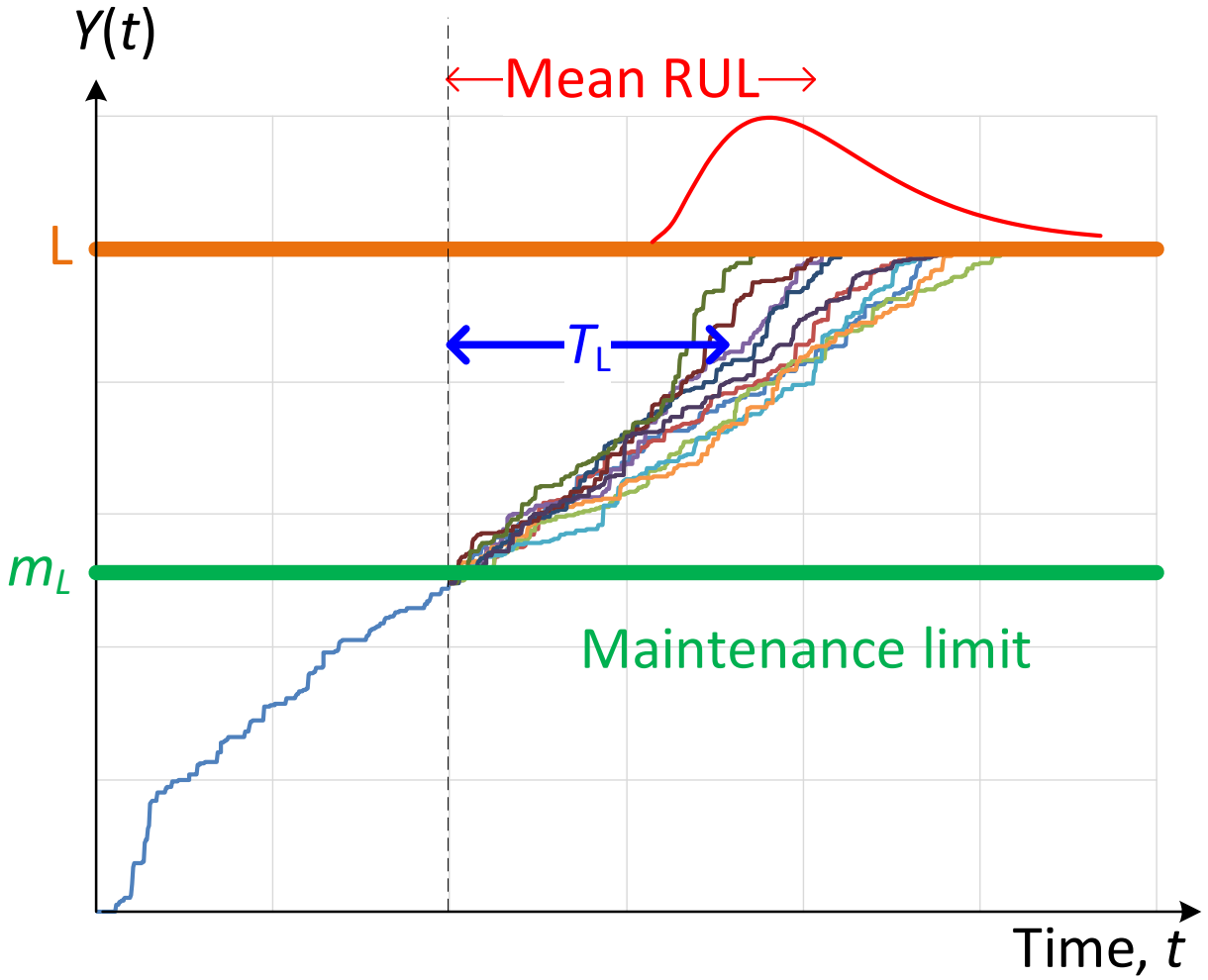


Healthy Incipient degradation Degraded Critical/Fault state

Markov model with repair

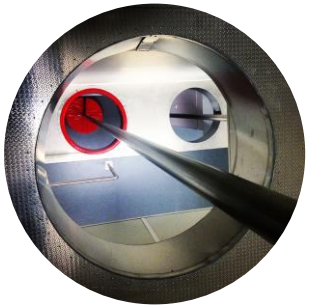


Continious degradatoin



Nordic Fire and Rescue Services in the Twenty First Century – FIRE21

- Finansiert av Nordforsk
  - Program: Nordic societal security in light of the emerging global and regional trends.
  - Totalt 11,6 mill. SEK.
- Partnere:
  - Lund Universitet, School of Engineering (prosjektledelse) + RISE Sverige
  - NTNU Samfunnsforskning + NTNU, ISS og RISE Norge
  - Danmarks Tekniske Universitet (DTU)
- 4-årig (August 2020 – Juli 2024)
- Prosjektmål: Forbedre problemløsing i hele beredskapskjeden gjennom å :
  - Forstå de nettverkene som beredskapskjeden består av og måten de jobber på.
  - Etablere strategier for hvordan disse nettverkene kan omstille seg i takt med samfunnsendringer og nye utfordringer.
- Dette studeres i lys av ulike rammebetingelser brann- og redningsvesen må forholde seg til innad i hvert land og på tvers av land
  - Rurale vs urbane
  - Fulltidsmannskap vs deltidsmannskap
  - Profesjonaliserte vs uformelle aktører
  - Sentralisering vs desentralisering
  - Betalt arbeid vs ubetalt arbeid



RI8KY Consequences of fundamental changes in risk regulation

- Finansiert av PETROMAKS, NFR
- 12M NOK, 3 år
- Ledes av NTNU Samfunnsforskning, og forskningspartnere er Universitetet i Stavanger, NTNU, SINTEF Digital, SINTEF Ocean og det australske universitetet RMIT
- PTIL har endret sin risikodefinisjon til:

Med risiko menes konsekvensene av virksomheten med tilhørende usikkerhet

- Vi undersøker:
  - Hvordan den generelle risikoforståelsen har utviklet seg, og hvordan det har ført til den fundamentale endringen i risikobegrepet
  - Hvordan risikokonseptet har blitt implementert i olje- og gasselskap, regulering, kontroller og granskning i Norge
  - Hvordan skiftet i risikodefinisjonen, tolkningen og implementeringen av denne i norsk olje og gass er i forhold til andre land og bransjer

NTNU Samfunnsforskning

Universitetet i Stavanger

SINTEF

NTNU Kunnskap for en bedre verden

RMIT UNIVERSITY

Prosjekter - Autonomi

Endure - Detection, prediction, and solutions for safe operations of MASS	Endure	Ingrid Bouwer Utne	NTNU + partnere	EU
Risikokontroll i autonome marine systemer	UNLOCK	Ingrid Bouwer Utne	NTNU marin + NTNU kyb	NFR (Fripro)
Autonomous all-electric passenger ferries for urban water transport	Autoferry	Ingrid Bouwer Utne	NTNU marin + NTNU kyb + flere NTNU institutt	NTNU
SFI AutoShip - Safety assurance work package	sfi-autoship	Mary Ann Lundteigen	NTNU marin + NTNU kyb + industry partners	NFR+ partnere
Online risikovurdering i autonome skip	ORCAS	Ingrid Bouwer Utne	NTNU marin + NTNU kyb + industry partners	NFR+ partners
Seamless - autonomous maritime systems	TBA	Ingrid Bouwer Utne	NTNU marin + NTNU kyb + partnere	EU
HMS, beredskap, sikkerhet og risikostyring, i kombinasjon med bl.a. fartøyoperasjoner, autonomi, beslutningsstøtte og fiskevelferd	SFI Exposed aquaculture operations	Kristine Vedal Størkersen	SINTEF Ocean, S Digital, NTNU (flere inst)	NFR+ partnere

Prosjekter - Cybersikkerhet

NORCICS WP4: Demonstration of cyber security solutions developed in NORCIC in laboratory and realistic environments at the user partners	SFI NORCICS	Gerd Kjølle	SINTEF Energi Energisystemer, SINTEF Digital, NTNU	NFR+partnere
Turning wind R&D into a sustainable industry (Prediktivt vedlikehold for offshore wind)	FME Northwind	Jørn Vatn	NTNU Maskin&prod	NFR+partnere

Prosjekter - Fornybar

Turning wind R&D into a sustainable industry (Prediktivt vedlikehold for offshore wind)	FME Northwind	Jørn Vatn	NTNU Maskin&prod	NFR+partnere
SUSHy - SUStainability and cost-reduction of Hydrogen stations through risk-based, multidisciplinary approaches	SUSHy Project	Nicola Paltrinieri	NTNU Maskin&prod	European Interest Group
HyInHeat - Hydrogen technologies for decarbonization of industrial heating processes	HyInHeat	Nicola Paltrinieri	NTNU Maskin&prod	EU
H2GLASS: Advancing Hydrogen (H2) technologies and smart production systems to decarbonise the glass and aluminium sectors	H2GLASS	Yiliu Liu	NTNU Maskin&prod	Horizon Europe
Norwegian research and innovation centre for hydrogen and ammonia (Sikkerhet og vedlikehold)	FME-HYDROGENi	Nicola Paltrinieri	NTNU Maskin&prod, SINTEF Energiforskning, SINTEF Digital	NFR+partnere

Prosjekter - Fornybar

Safe Hydrogen Fuel Handling and Use for Efficient Implementation	SH2IFT	Nicola Paltrinieri	NTNU Maskin&prod - SINTEF Energiforskning	NFR
H2 CoopStorage	h2coopstorage	Nicola Paltrinieri	NTNU Maskin&prod - SINTEF Energiforskning	EU
Safe hydrogen fuel handling and use for efficient implementation	SH2IFT-2	Nicola Paltrinieri	NTNU Maskin&prod - SINTEF Energiforskning	NFR
Sikker transport og lagring i verdikjeden for grønn hydrogen	Verdikjede hydrogen	Maria Vatshaug Ottermo	SINTEF Digital	RFF
Enhancing safety of liquid and vaporised hydrogen transfer technologies in public areas for mobile applications	ELVHYS	Federico Ustolin	NTNU Maskin&prod	EU
HyScool - Norwegian Research School on Hydrogen and Hydrogen-Based Fuels	HySchool	Nicola Paltrinieri	NTNU Maskin&prod	NFR
HySET - Hydrogen systems and enabling technologies	HySET	Nicola Paltrinieri	NTNU Maskin&prod	Erasmus modus

Prosjekter - Havbruk

Zerokyst - avkarbonisering av sjømatnæringen	Zerokyst	Ingrid Bouwer Utne	NTNU + SINTEF + partnere	NFR
Sikkerhet og risikostyring i fiskeri	Nytt prosjekt	Kristine Vedal Størkersen	SINTEF Ocean	FHF
HMS i forskjellige operasjonssystemer i havbruk	HMS i havbruk	Kristine Vedal Størkersen	SINTEF Ocean og NTNU IØT	FHF
HMS og risikostyring i havbruk, regulering og utvikling	Develop	Kristine Vedal Størkersen	SINTEF Ocean, NTNU SU, NTNU Samfunnsforskning	NFR

Havrom

Arven etter Nansen	AeN	Ingrid Bouwer Utne	NTNU + universiteter + forskningsinsitutt	NFR + KD
Sikkerhet i polare strøk	ArctRisk	Trond Kongsvik	NTNU IØT, NTNU Samfunnsforskning	NFR
Sikkerhet i polare strøk, regulering av polarsikkerhet, sjøfart, lokalsamfunn og turisme	Polarkodenettverket	Kristine Vedal Størkersen	NTNU IØT, NTNU Samfunnsforskning	Dansk forskningsråd
Konfliktløsing i sjøfart	Medimare	Kristine Vedal Størkersen	NTNU Samfunnsforskning	EØS-finansiert
Kystnær beredskap	Kystnær beredskap	Eivind Halvard Okstad	SINTEF Ocean og SINTEF Digital	NFR

Kritisk infrastruktur

Risikobasert fornyelsesplanlegging av kraftledninger	Rifok	Håkon Toftaker	SINTEF Energi Energisystemer	NFR+ partnere
Engineering and Condition monitoring in Digital Substations	ECoDiS	Maren Istad	SINTEF Energi Energisystemer	NFR+ partnere
Accelerated electrification through conditional grid connection and reliability of supply adapted to different grid users	FORSEL	Iver Bakken Sperstad	SINTEF Energi Energisystemer	NFR+ partnere

Kritisk infrastruktur

Sikker utkobling ved kortslutninger i svake lavspenningsnett og lavspenningsinstallasjoner	OptiNett	Eivind Solvang	SINTEF Energi Energisystemer	NFR+ partnere
CINELDI WP1: Smart grid development and asset management	FME CINELDI	Oddbjørn Gjerde	SINTEF Energi Energisystemer	NFR+ partnere
Resilient and Probabilistic reliability management of the transmission grid	RaPid	Oddbjørn Gjerde	SINTEF Energi Energisystemer, SINTEF Digital, NTNU	NFR+ partnere
Forsyningssikkerhet i smarte nett med samhandlende digitale systemer	InterSecure	Maren Istad	SINTEF Energi Energisystemer, SINTEF Digital, NTNU IIK	NFR+ partnere

Olje og gass

SUBPRO - Subsea Production and Processing (RAMS arbeidspakke)	SFI-SUBPRO	Jørn Vatn	NTNU Maskin&prod + Kyb	NFR+ partnere
Risikodefinisjonens vandring og forandring, særlig i petroleum	RISKY	Martin Rasmussen Skogstad	NTNU Samfunnsforskning, Sintef Dig + Ocean, NTNU	NFR
Automatisert prosess for oppfølging av instrumenterte sikkerhetssystemer (APOS) (2019-2023)	APOS	Mary Ann Lundteigen	SINTEF Digital + NTNU kyb	NFR+ partnere
Digital life cycle management of interoperable safety system	DILMIS	Mary Ann Lundteigen	SINTEF Digital + NTNU kyb.	NFR+ partnere
BRU21 - Program in Digital and Automation Solutions for the Oil and Gas Industry (RAMS Arbeidspakke)	BRU21	Jørn Vatn	NTNU Maskin&prod + Kyb + IIK	JIP