



8 years with RAMS research in SUBPRO

Mary Ann Lundteigen and Jørn Vatn, Nov 27h 2023

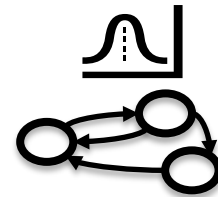
RAMS in SUBPRO

“Cost efficient solutions without compromising safety and environment”

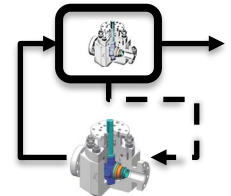
- How can we **demonstrate** (adequate) safety of novel technologies?
- How can we build **confidence about reliability** performance in design?
- How can we **reduce the costs** of maintenance by better prognosis of technical health?
- How can we **benefit** from using **machine learning** and **digital twins** for those purposes?



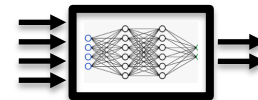
Regulations and standards



Systems reliability



Digital twins



AI /Machine learning

PhDs and postdocs involved



POSTDOCTORAL FELLOW
HYUNGIU KIM
PROJECT MANAGER:
PROFESSOR MARY ANN LUNDTVEIGEN
CO-SUPERVISOR:
ASSOCIATE PROFESSOR CHRISTIAN HOLDEN

2015-2018

2018-2022

Safety4.0

DNV



PhD student:
Manda Anugrah
Dharmasari
Main Supervisor:
Professor Mary Ann
Lundtveigen
Co-Supervisor:
Hyungiu Kim
Mikaela Nyberg
Dhruv Chak



PhD student: **Jie Liu**
Start date: 01.09.2021
Planned end date: 31.08.2024
Project manager and supervisor: Professor Shen Yin
Co-supervisor: Prof. Jørn Vatn
Department of Mechanical and Industrial Engineering

2021-2024

wood.



PHD STUDENT: JUNTAO ZHANG
PROJECT MANAGER AND
MAIN SUPERVISOR:
PROFESSOR MARY ANN LUNDTVEIGEN
CO-SUPERVISOR:
ASSOCIATE PROFESSOR YILIU LIU

2015-2018

equinor



PhD student: **Muhammad Gibran Alfarizi**
Start date: 16.08.2020
Planned end date: 31.07.2023
Project manager and main supervisor: Professor Shen Yin
Co-Supervisor: Professor Jørn Vatn
Department of Mechanical and Industrial Engineering

2020-2023

HMM



PHD STUDENT: YUN ZHANG
PROJECT MANAGER AND
MAIN SUPERVISOR:
PROFESSOR ANNE BARRIOS
CO-SUPERVISOR:
ASSOCIATE PROFESSOR ANTOINE BAUZY



Researcher: **Xingheng Liu**
Start date: 01.10.2022
Planned end date: 30.09.2023
Supervisor/Co-supervisor: Prof. Jørn Vatn and Prof. Shen Yin
Department of Mechanical and Industrial Engineering

2022-2022 (PD)

2022-2023



PHD student: **Ludvig Bjørklund**
Start date: 28.08.2020
Planned end date: 31.03.2024
Project manager: Professor Mary Ann Lundtveigen
Supervisors: Prof. Mary Ann Lundtveigen, Prof. Markus Glaser (Aalen University) and Prof. Gunlev Skoftefjord (Equinor)
Department of Engineering Cybernetics

2020-2024

SUBPRO ZERO



2023-2026



PHD STUDENT: HIMANSHU SRIVASTAV
PROJECT MANAGER AND
MAIN SUPERVISOR:
PROFESSOR ANNE BARRIOS

2017-2021



PHD student: **Tae Hwan Lee**
Start date: 28.10.2019
Planned end date: 11.02.2023
Project manager and main supervisor: Professor Mary Ann Lundtveigen
Co-Supervisor: Adjunct professor Gunlev Skoftefjord (Equinor), Adjunct professor Frank Ove Westad
Department of Engineering Cybernetics

2019-2023

Ongoing projects (I) – 2023

Using digital twin for safety demonstration all electric subsea safety valves

Research update:

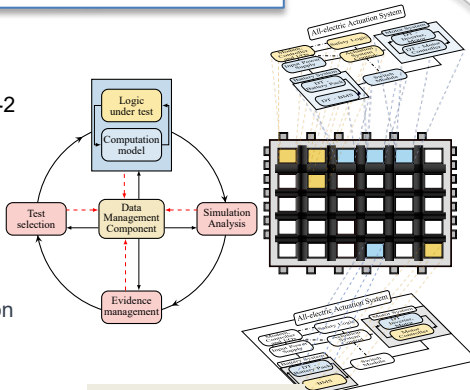
- 1 journal paper just published; 1-2 others ongoing
- 1 conference paper

Examples of ongoing research:

- Interface logic with FPGA-based DT for accelerating testing
- Falsification-guided DT simulation framework for safety-critical scenarios
- Data management in development of DT & in safety demonstration

Other:

- Visit to Aalen University with supervisors



Just published!



PhD student: **Ludvig Björklund**
 Start date: 28.08.2020
 Planned end date: 31.03.2024
 Project manager: Professor Mary Ann Lundteigen
 Supervisors: Prof. Mary Ann Lundteigen, Prof. Markus Glaser (Aalen University) and Prof. Gunleiv Skoftealand (Equinor)
 Department of Engineering Cybernetics

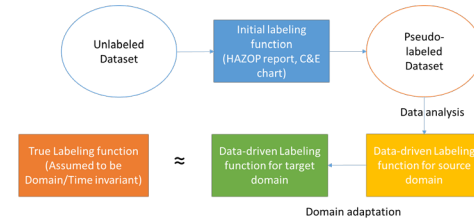
Advanced Process Safety Diagnostic Tool (SIS Advisor) Using Dynamic Process Simulation Data

Research update:

- 2 journals ongoing
- 1 conference paper
- Submission of thesis in 2024
- Innovation project

Example of ongoing research:

- Utilize dynamic simulation technology and machine learning to build an advanced process safety diagnostic tool
- Reduce the effect of class imbalance and sample selection bias
- Reduce the effect of data shift using domain adaptive ML



PhD student: **Tae Hwan Lee**
 Start date: 28.10.2019
 Planned end date: 11.02.2023
 Project manager and main supervisor: Professor Mary Ann Lundteigen
 Co-Supervisor: Adjunct professor Gunleiv Skoftealand (Equinor), Adjunct professor Frank Ove Westad
 Department of Engineering Cybernetics

Ongoing projects (II)

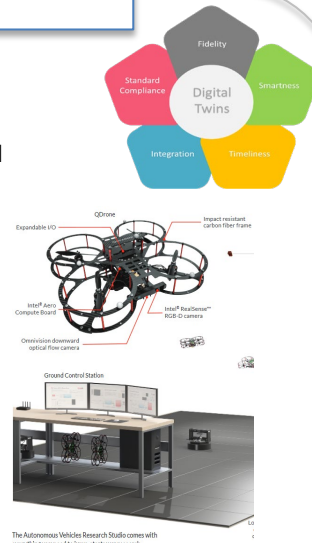
Digital twin qualification for maintenance

Research update:

- Two journal papers published; 1 other ongoing
- 3 conference papers published.

Examples of ongoing research:

- Demonstrate the proposed framework for digital twin qualification
- Case study with maintenance activities for autonomous vehicles research studio



PhD student: **Jie Liu**
 Start date: 01.09.2021
 Planned end date: 31.08.2024
 Project manager and supervisor: Professor Shen Yin
 Co-supervisor: Prof. Jørn Vatn
 Department of Mechanical and Industrial Engineering

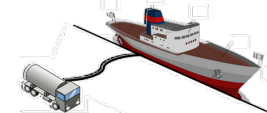
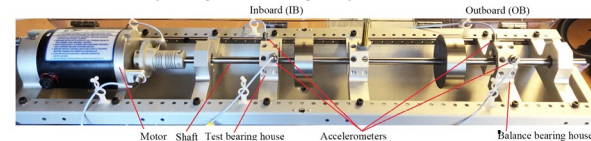
Data-driven design for fault prognosis: Application to industrial components, subsystems, and systems

Research update:

- 3 journals published, 1 conference paper
- Thesis submitted, preparing for defense

Research results:

- Developed fault prognosis design for roller bearings (component), manufacturing line (subsystem), and liquid hydrogen storage system.



PhD student: **Muhammad Gibran Alfariz**
 Start date: 16.08.2020
 Planned end date: 31.07.2023
 Project manager and main supervisor: Professor Shen Yin
 Co-Supervisor: Professor Jørn Vatn
 Department of Mechanical and Industrial Engineering

Ongoing projects (III)

Towards safety and security of autonomous systems against cyber-physical attacks
(Postdoc/1 year researcher project)

Research update (ended 2023):

- Completed a PD in estimation and optimization of remaining useful life (2021-2022)
- One year postdoc/researcher from 2022 till sept 2023.

Focus of researcher project:

- Use of autonomous systems in RAMS lab to research resilient operation during cyber-attacks



Researcher: **Xingheng Liu**
 Start date: 01.10.2022
 Planned end date: 30.09.2023
 Supervisor/Co-supervisor: Prof. Jørn Vatn and Prof. Shen Yin
 Department of Mechanical and Industrial Engineering

Topic: AI in safety-critical systems – related to CO2 capture, injection, and storage

Funded by SUBPRO Zero

Research update:

- **Just started** (1.1.2023)
- Preparation of research plan and selection of PhD courses

Planned tasks:

- Define safety-critical systems in CCS and analyze the current state.
- Investigate regulations and limitations for AI in safety-critical systems.
- Examine opportunities and challenges for AI in those systems and evaluate potential AI models to enhance the current state.



Researcher: **Niclas Flehmig**
 Start date: 1.11.2023
 Planned end date: 31.10.2026
 Supervisor/Co-supervisors: Prof. Shen Yin and Prof. Mary Ann Lundteigen
 Department of Mechanical and Industrial Engineering

RAMS workshops

RAMS workshop 17.2.2016 @ ABB

Participants

Name	Company	E-mail
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Espen Hovde	ABB	espen.hovde@abb.com



SUBPRO RAMS Workshop
Functional safety and control of industrial systems, achieving high-reliability of control functions

Power and productivity for a better world **ABB**

Power and productivity for a better world

RAMS workshop 29.10.2019 @ DNV

Agenda

Time	Topic
08:30-09:00	Registration and coffee
09:00-09:15	Session 1: Introductory perspectives
09:15-09:30	Welcome with information about the work of the seminar (9:15-9:30) (only Mary Ann Lundteigen, NTNU)
09:30-09:35	Opportunities/spaces of introducing unmanned facilities as seen from industry v/ Gunner H. Lille, OSL21 (20 min)
09:35-10:00	Safety philosophy for introducing facilities (Industry experts and perspectives in connection with the presentation of the paper)
10:00-10:15	Break time
10:15-10:30	Session 2: Safety
10:30-10:35	Experiences
10:35-10:50	Operations
10:50-11:00	Design of Unmanned Facilities - Safety aspects (Ulfrik Pattison, Aker Solutions) (20 min)
11:00-11:30	Techniques and training for Redundant systems onboard unmanned facilities v/ Kamen Vangelj (Justus-Liebig-Fakultät) (20 min)
11:30-11:45	Break (Interim meeting)
11:45-12:30	Session 3: Group work
12:30-12:35	Short introduction to group work (presentation of pre-prepared questions) (10 min) v/ Mary Ann Lundteigen, NTNU
12:35-13:15	Group work (part 1)
13:15-14:00	Plenary discussion (2 minutes per group)
14:00-14:45	Group work (part 2)
14:45-14:55	Summary of group work in plenary (3 minutes per group) conclusions and closure of seminar, including a short feedback on the organization of this seminar

The seminar ends no later than 15:30.

Local contact person:
Frank Berre Pedersen (DNV-GL)
Mobile: 905 52 666

Other contact:
Mary Ann Lundteigen (NTNU)
Mobile: 930 59 365

Place:
Store møterom, Veritas 1 bygging, DNV-GL (Havik)

What new requirements are placed on safety-instrumented systems for unmanned facilities?

System control & RAMS workshop 11.11.2020 @ DNV

SUBPRO Digital twin seminar November 11th 2020

A digital twin is a digital representation of a real-world entity or system. In many data-intensive industries including the O&G industry we see huge effort on implementing digital twins.

In this seminar the ambition is to elaborate on what is needed to develop model-based and data-driven digital twins that provide "what-if" scenario analysis supporting important decisions.

The disciplinary areas addressed in the seminar is system control, safety, reliability and maintainability and the interaction between these. The application area will be subsea operation and maintenance and remote/semi-remote operation in a more general setting aligned with the research focus of SUBPRO. The seminar is organized by SUBPRO for the SUBPRO partners, and since the topic overlaps with research activities within [SUBPRO](#), selected partners from BRU21 are also invited to the seminar.

The seminar is organized in four sessions as shown below, where the first three contain short presentations and discussions and the fourth session includes a group work. The program will be updated with presenters during August.

Session	Content
1 (starting at 09:00)	Oil companies perspectives and ambitions: Operators are invited to present their perspectives and ambitions for how to take advantage of the emerging digital twin technologies. This includes both the technological ambitions and developing the organization and work processes.
2	Suppliers solutions and ambitions: Suppliers of digital solutions are invited to respond to these ambitions, by presenting the state-of-the-art technology solutions with practical examples.
3	Academic challenges and perspectives: The third session will emphasize academic challenges and perspectives to be undertaken by PhD research in SUBPRO and BRU21.
4 (ending at 15:30)	Group work: All participants will be organized around tables, to allow discussions throughout the day and also during the group work in session 4. A list of questions will be addressed, and the results shortly summarized in plenary.

Outcome of the seminar:
From the industrial point of view, the seminar gives the opportunity to more precisely define the business cases related to digital twin in control, maintenance planning and safety performance management. This aims to provide the participants with the necessary tools for developing and applying digital twins.

At the status of digital twin technology in both our students at bachelor and master level, for example tools operating on real-time data, and how to use them in the industry.

Practical details:
The seminar will be hosted by [DNV-GL](#) at Havik November 11th 2020.

The organizing committee consists of:

- Lars Erik Svabø, Kongsberg Digital
- Frank Berre Pedersen, DNV-GL
- Audun Faaes, Equinor/NTNU
- Jens Vabø, NTNU
- Sabina Jeschke, NTNU
- Mary Ann Lundteigen, NTNU

The following PhD students will assist in the practical organization of the seminar:

- Ewa Leskowska
- Babareh Tajani
- Ludvik Bjerkland
- Tom Ivar Pedersen

Date for this seminar: 11. November 2020
E-mail: Mary Ann Lundteigen, NTNU (mary.a.lundteigen@ntnu.no)

SUMMARY OF SEMINAR 29.10.2019

Safety instrumented systems for unmanned facilities with wireless networks

ABSTRACT:
This document summarizes the results of the seminar in which participants presented their research and industry related papers. The seminar was held on 29.10.2019, at DNV-GL, Havik. The seminar was organized by SUBPRO, and since the topic overlaps with research activities within SUBPRO, selected partners from BRU21 are also invited to the seminar. The seminar is organized by SUBPRO for the SUBPRO partners, and since the topic overlaps with research activities within SUBPRO, selected partners from BRU21 are also invited to the seminar.

Staff and industry contacts involved

NTNU

Professor Jørn Vatn



Professor Mary Ann Lundteigen

Assoc. Professor HyungJu Kim (previous postdoc in SUBPRO)

Professor Mary Ann Lundteigen



Professor Anne Barros (DNV professorship, 2014-2019). Now, Professor and head of safety & risk research group, Centrale Supélec, Paris

Professor Antoine Rauzy

Professor Yiliu Liu

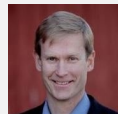
Shen Yin (DNV professorship 2020-2025)



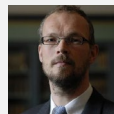
Gunleiv Skoftealand (Equinor & NTNU)



Erling Lunde (Equinor)



Frank Børre Pedersen (DNV)



Meine van der Meulen (DNV)



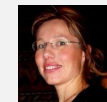
Odd Ivar Haugen (DNV)



Lars Erik Svabø (Kongsberg Digital, K-spice)



Christoffer Lassen, now Equinor, previously AkerSolutions



Katrine Hilmen, ABB

Industry (some of)

International collaboration

- Professor **Annes Barros**, Centrale Supelec, safety and risk research, Paris.
 - Previous professor and main supervisor in SUBPRO.
- Professor **Markus Glaser**, head of institute for high-integrity mechatronic systems at Aalen University in Germany:
 - Mobility visit (one year) in SUBPRO, hosting and co-supervising one PhD student
- Professor **Antoine Grall** (Reliability & maintenance, University of Troyes, France).
 - Participating in the scientific advisory committee



SAFETY AND RISKS RESEARCH GROUP LGI

MEMBERS PUBLICATIONS DEFENSES HISTORY

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Our team is developing research activities for safety and risk analysis of complex engineering systems. Our models are mainly based on stochastic processes and data driven approaches with a strong focus on optimization and quantitative quantification for decision making in design and operation. We are strongly connected to several industry partners with the chair Risk and Resilience of Complex Systems (CR2). This chair is supported by EDF, Safran, Orange and Fraunhofer. This is an avenue to derive state-of-the-art from knowledge, data and experiences, develop methods, engagement benchmark and prototypes of tools. This chair is taking over the previous chair on Systems Sciences and Energy Challenges supported by EDF.

Our research is organized around 3 main studied objects:




M. Antoine GRALL

Full professor / Professeur des Universités Director of doctoral school 361 "Science for Engineers"

Contact details

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Importance of international standards

Existing standards

Practice of standards amongst students increase their skillset and add value for SUBPRO partners

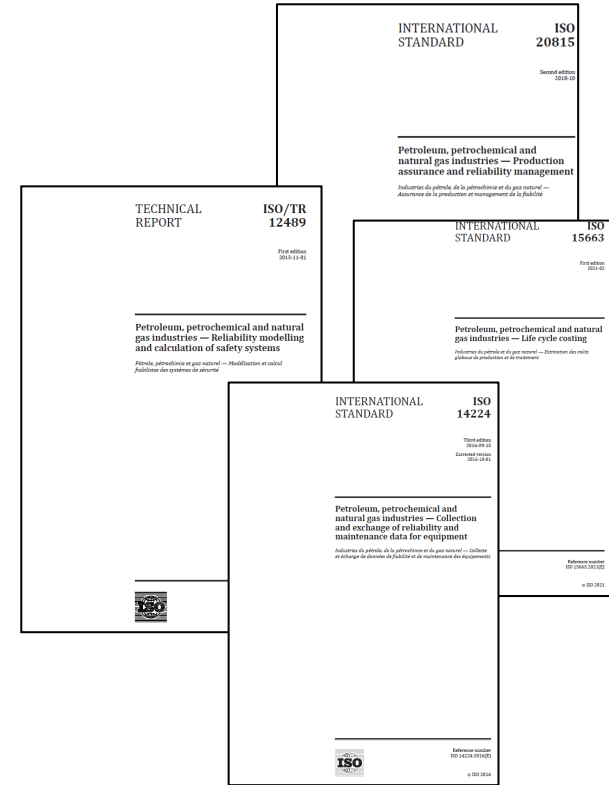
Research activities
(PhD, PD, master)

People with new skills can join ISO/IEC standardization groups

Published methods and tools can provide input to standardization development organizations

New and revised standards

Special thanks from SUBPRO to Runar Østebø (Equinor) for promoting the use of standards to build on best practices and ease adaption in industry



Way forward

- **SUBPRO Zero:**
 - PhD project in the use of AI for safety-critical systems – use cases within CO2 capture, injection, and storage
- **PRO-Energy (FME application submitted Nov 2023):**
 - Boost applications of digital twins and AI for decision-support (safety and maintenance)
 - Low-emission maintenance
 - Adaption of digital interoperable platforms for efficient data usage
 - Applications of autonomous systems

Thank you for the attention

- Questions and comments?



Group Research and Development Safety 4.0 project 2018-2022

The main objective of the Safety 4.0 project, a consortium consisting of operators, suppliers, academia and the Petroleum Safety Authority (as an observer), is to enable and accelerate the up-take of novel subsea solutions by developing a framework for standardized demonstration of safety.

CONTACT US:



Tore Myhrvold
Senior Principal Researcher



PHD student:
**Nanda Anugrah
Zikrullah**

Main Supervisor:
Professor Mary Ann
Lundteigen
Co-Supervisor:
Associate Professor
Hyungju Kim (Ulsan)
Meine J.p. Van Der Meulen
(Dnv GI)



Developing approaches to support safety demonstration of **all-electric actuators** for subsea safety valves.

