8 years with RAMS research in SUBPRO

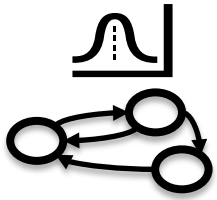
Mary Ann Lundteigen and Jørn Vatn, Nov 27h 2023

RAMS in SUBPRO

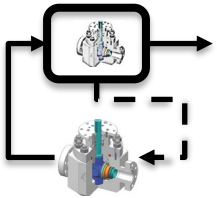
"Cost efficient solutions without compromising safety and environment"

- 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?

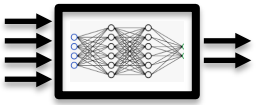
Regulations and standards



Systems reliability



Digital twins



AI /Machine learning

PhDs and postdocs involved

NTNU

SUBPRO

NTNU

POSTDOCTORAL FELLOW:
HYUNGJU KIM

PROJECT MANAGER:
PROFESSOR MARY ANN LUNDTEIGEN

CO-SUPERVISOR:
ASSOCIATE PROFESSOR CHRISTIAN HOLDEN

2015-2018

2018-2022

Safety4.0

DNV

PhD student:
Nanda Anugrah Zikrullah
Main Supervisor:
Professor Mary Ann Lundteigen
Co-Supervisor:
Associate Professor Hyungju Kim (Uni Weine J.g. Van Der Meulen (Dnv Gl)

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 Engineerin

2021-2024

wood.

PHD STUDENT: JUNTAO ZHANG

PROJECT MANAGER AND
MAIN SUPERVISOR:
PROFESSOR MARY ANN LUNDTEIGEN

CO-SUPERVISOR:
ASSOCIATE PROFESSOR YILIU LIU

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

HVH

PHD STUDENT: YUN ZHANG

PROJECT MANAGER AND
MAIN SUPERVISOR:
PROFESSOR ANNE BARROS

CO-SUPERVISOR:
ASSOCIATE PROFESSOR ANTOINE RAUZY

2015-2018

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

SUBPRO ZERO

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 Univers-ty) and Prof. Gunlelv Skofteland (Equinor)
Department of Engineering Cybernetics

2020-2024

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 Gunlelv Skofteland (Equinor), Adjunct pro-fessor Frank Ove Westad
Department of Engineering Cybernetics

2019-2023

2023-2026

Vysus Group

PHD STUDENT: HIMANSHU SRIVASTAV

PROJECT MANAGER AND
MAIN SUPERVISOR:
PROFESSOR ANNE BARROS

2017-2021

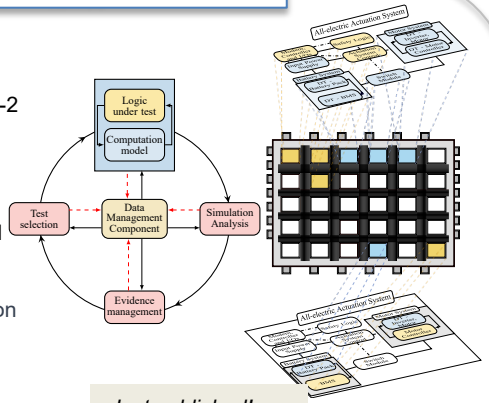
Ongoing projects (I) – 2023

Using digital twin for safety demonstration all electric subsea safety valves

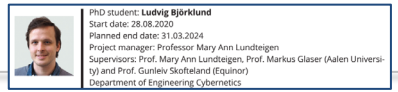
Research update:
- 1 journal paper just published; 1-2 others ongoing
- 1 conference paper

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!

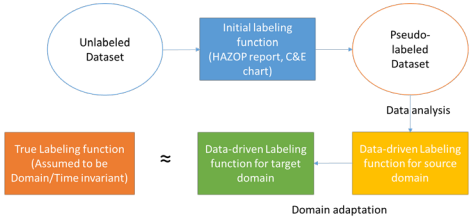


PhD student: **Ludvig Björklund**
Start date: 28.08.2020
Planned end date: 31.03.2024
Project manager: Professor Mary Ann Lundteigen
Supervisors: Prof. Mary Ann Lundteigen, Prof. Markus Glaser (Aalen University) and Prof. Gunleiv Skofteland (Equinor)
Department of Engineering Cybernetics

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

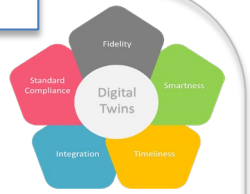
Example of ongoing research:
- Utilize dynamic simulation technology and machine learning to build an advanced process safety diagnostic tool
- Reduce the effect of class imbalance and sample selection bias
- Reduce the effect of data shift using domain adaptive ML



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 Skofteland (Equinor), Adjunct professor Frank Ove Westad
Department of Engineering Cybernetics

Ongoing projects (II)

Digital twin qualification for maintenance

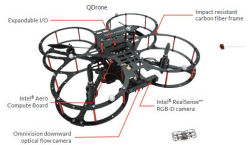


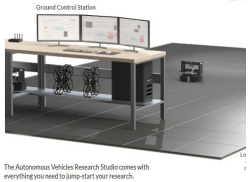
Research update:

- 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

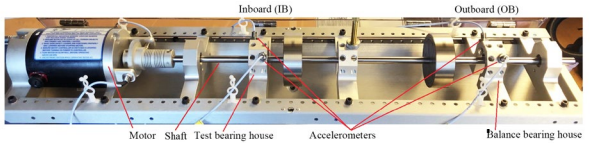
Data-driven design for fault prognosis: Application to industrial components, subsystems, and systems

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.



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

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

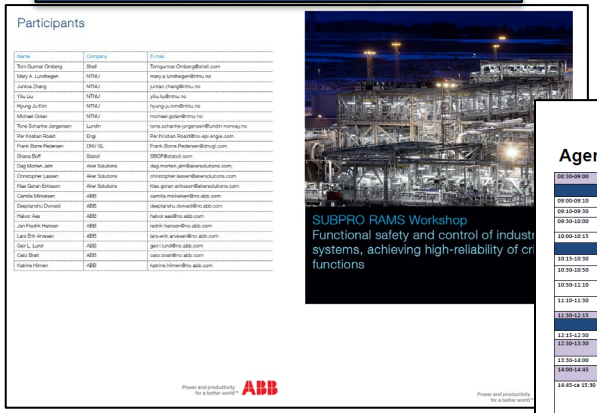
Research update:
- **Just started** (1.1.2023)
- Preparation of research plan and selection of PhD courses

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.

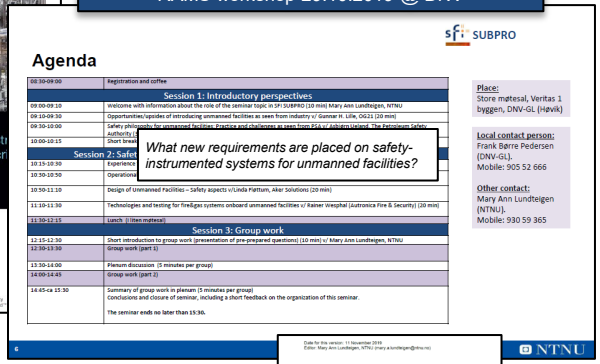
Researcher: Niclas Flehmig
Start date: 1.11.2023
Planned end date: 31.10.2026
Supervisor/Co-supervisors: Prof. Shen Yin and Prof. Mary Ann Lundteigen
Department of Mechanical and Industrial Engineering

RAMS workshops

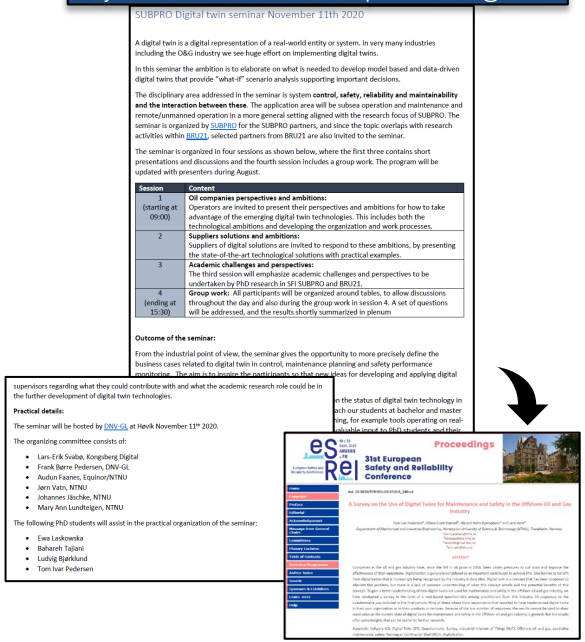
RAMS workshop 17.2.2016 @ ABB



RAMS workshop 29.10.2019 @ DNV



System control & RAMS workshop 11.11.2020 @ DNV



Staff and industry contacts involved

NTNU

Gunleiv Skofteland (Equinor &NTNU)

Industry (some of)

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

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

Importance of international standards

Existing standards

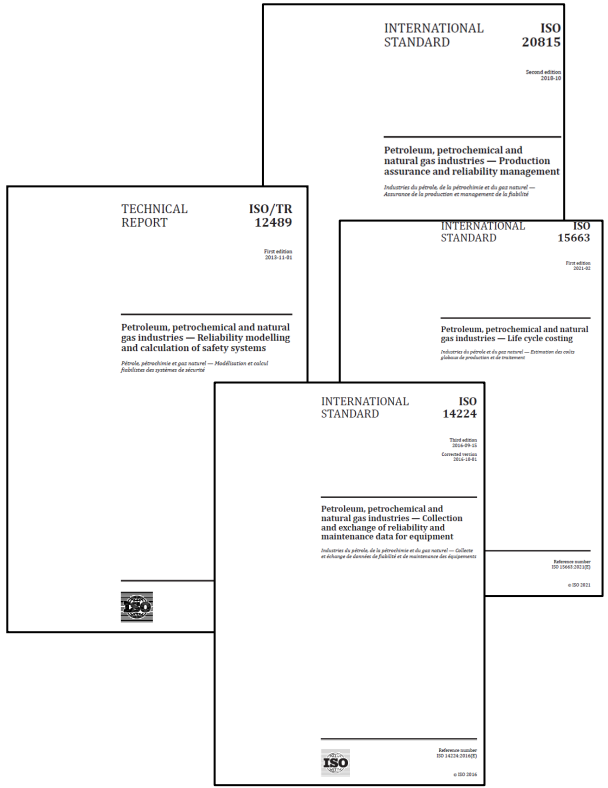
Practice of standards amongst students increase their skillset and add value for SUBPRO partners

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

Photo: Edited from LinkedIn, ONS2022

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:

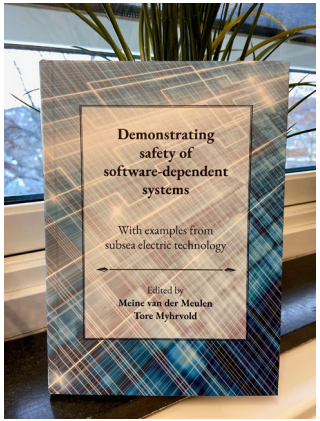
Tore Myhrvold

Senior Principal Researcher

PhD student:
Nanda Anugrah Zikrullah

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

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



Link: https://www.dnv.com/research/energy/safety-40.html