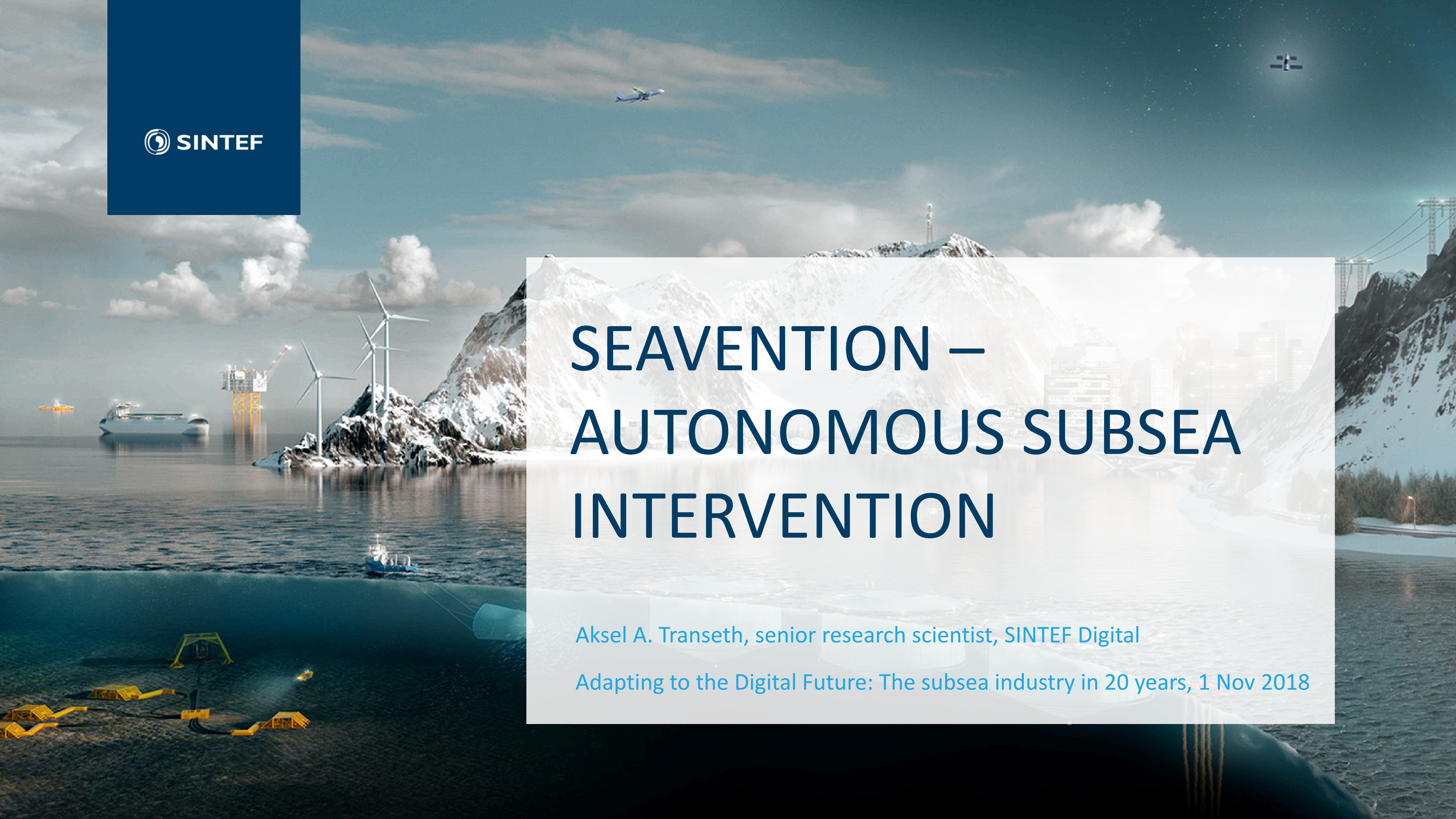


SINTEF

SEAVENTION – AUTONOMOUS SUBSEA INTERVENTION

Aksel A. Transeth, senior research scientist, SINTEF Digital

Adapting to the Digital Future: The subsea industry in 20 years, 1 Nov 2018

TECHNOLOGY FOR A BETTER SOCIETY

SINTEF

SINTEF

Why autonomy?

- **Health, Environment, Safety**: E.g., avoid (or reduce the need for) having to mobilize support vessels and human personnel, possibly to inaccessible and/or dangerous areas.
- **Reduce need for support vessels**: E.g. subsea inhabitants, or more multi ROV/AUV operations in order to reduce the time needed for operations involving support vessels.
- **Reduce cost and duration of operations** for high-frequency operations: See the two above bullet points.
- **Increase uptime**: Improved condition monitoring and possibly faster response time for certain intervention operations may lead to increased uptime. Reduced dependence on weather conditions.

Autonomous Job Analysis (AJA) – a tool for cooperating on designing autonomous operations

Purpose:

- Analysis and break-down of operations.
- Uncover operational modes, design challenges, and limitations regarding autonomous behaviours.
- Facilitate a common understanding for all stakeholders.

Also,

- Input to pre-mission meetings
- Identify common challenges between sub-operations.

Autonomous Job Analysis Canvas

Communication

What key information needs to be communicated?

What are the communication restrictions and limitations?

What communication infrastructure can be used?

Bandwidth
Delay
Availability
Sensor data
Control data
Video/audio feeds
Emergency stop signal

Human Machine Interaction (HMI)

What type of user interface is needed?
What information does the operator need?
What is the role of the human?

UI: Touch panel, joystick, console, etc
Error handling responsibility
Mental workload/human performance
Situational awareness
Operator skills vs autonomous skills

Perception

Which information about the environment and the system itself must be available?

Ex:
Object detection
Self-localization
Environment sensing
3D, Tactile, Vision sensors
Spatial information
Self-sensing
Task-specific sensor
Refresh rate

Sub-Operation Description

What are we trying to accomplish?

What is the relationship to other suboperations?

Overall objective
Qualitative description
Backup plan
Sketch/illustration of sub-operation
Sub-operation:
- Move tool to position A

Preconditions;
- Have tool
- Position A is unoccupied

Success Criteria

What are the criteria for sucessfully executing the sub-operation?

How do you quantify/measure each criteria?

Quantitative description
Efficiency
Thoroughness
Constraints
Time bound

Operational Safe State

What should the system do in case of failure/danger?

Are there several safe states?

Power shutdown
Go to a safe area
Try to communicate
Do not move

What can go wrong

Which external and internal events should be planned for?

What should the system do in case of undesirable events?

Goal cannot be reached
Human error
Sensor failure
Obstacles
Communication loss
Emergency alert
Hardware failure
Bad weather

Other possible inputs

Useful infrastructure / human operators
Changes to the system, e.g. new sensor.
Changes to the environment, e.g. Lighting / optical markers

Notes/Comments

Relevant comments that are not captured by the previous questions

subgoal nr

SEAVENTION

Autonomous subsea intervention – empowered by people and AI

2018-2021

The Research Council of Norway

equinor

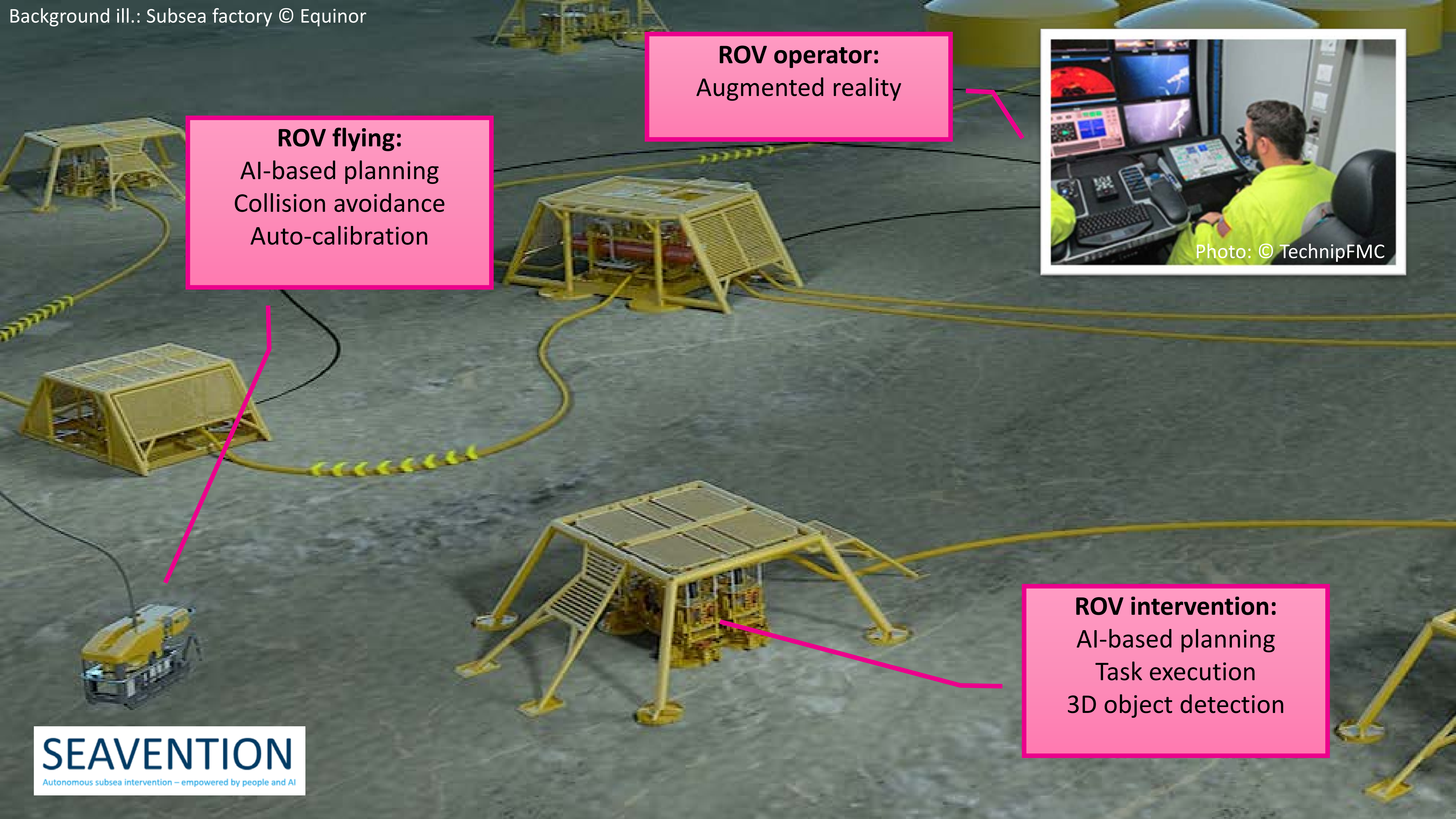
TechnipFMC

I·K·M

OCEANEERING®

SINTEF

NTNU


Background ill.: Subsea factory © Equinor
ROV operator:
Augmented reality
ROV flying:
AI-based planning
Collision avoidance
Auto-calibration
Photo: © TechnipFMC
ROV intervention:
AI-based planning
Task execution
3D object detection
SEAVENTION
Autonomous subsea intervention – empowered by people and AI

Need subsea situational awareness – current recommended regulation

- Recommended Standard DNV GL (2016) – Rules for Classification – Underwater Technology suggests:

"Systems for locating of obstacles, like rocks, wrecks, pipelines, offshore structures, etc. are to be provided to avoid collisions safely."

Slide content from Jeevith Hedge, NTNU

The 3D Sensor Revolution

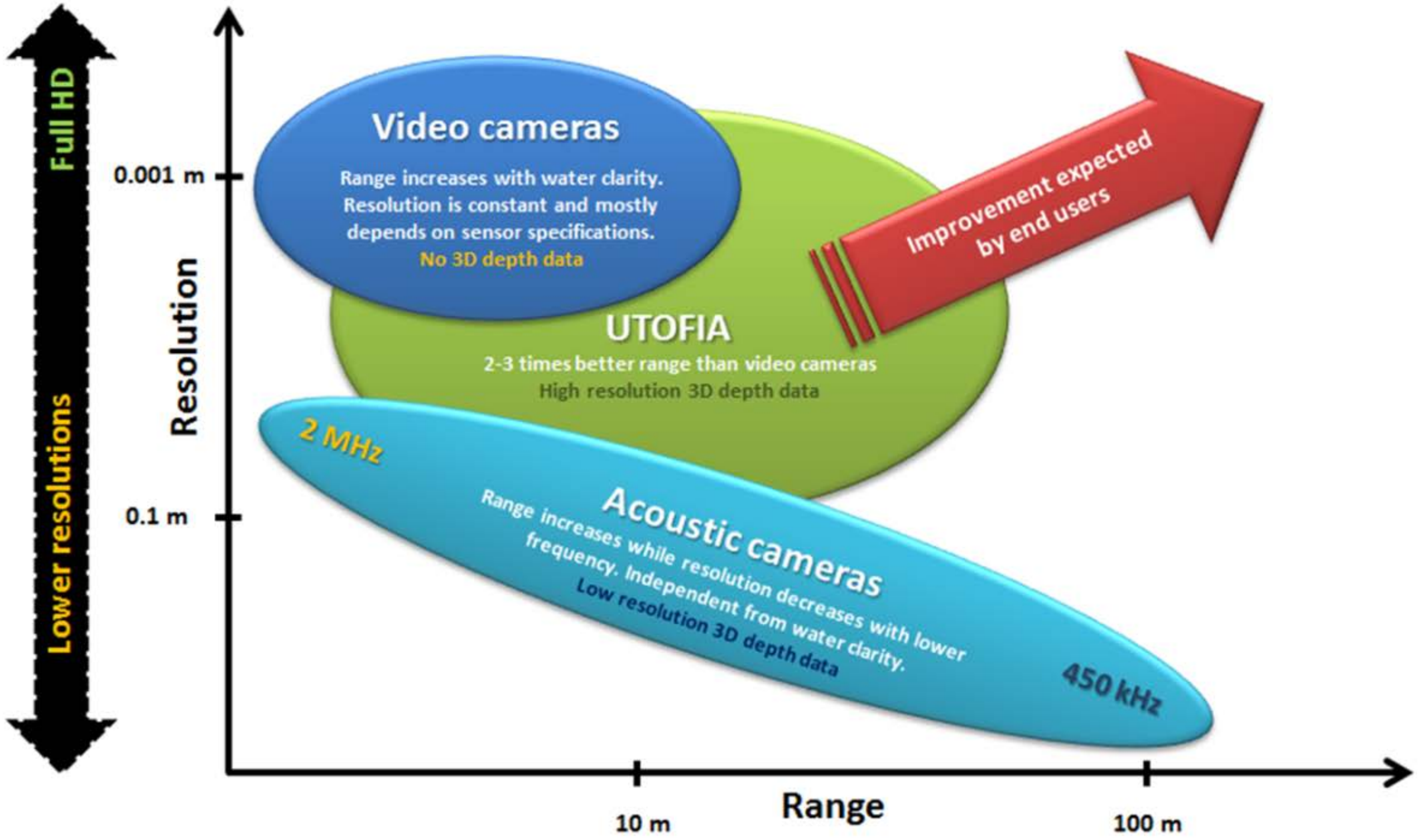
- Gestures and natural user interfaces
- Augmented/Virtual-Reality
- Robotics
- Industrial automation
- Autonomous cars

"see further, faster, with higher accuracy"

Slide content from Petter Risholm, SINTEF

Underwater 3D – the state of the art

- **Acoustic cameras**
  - Low resolution
  - Long range
- **Optical cameras**
  - High resolution
  - Short range due to attenuation and backscatter
  - Generally no 3D



Need high-resolution 3D cameras with long range to support autonomy

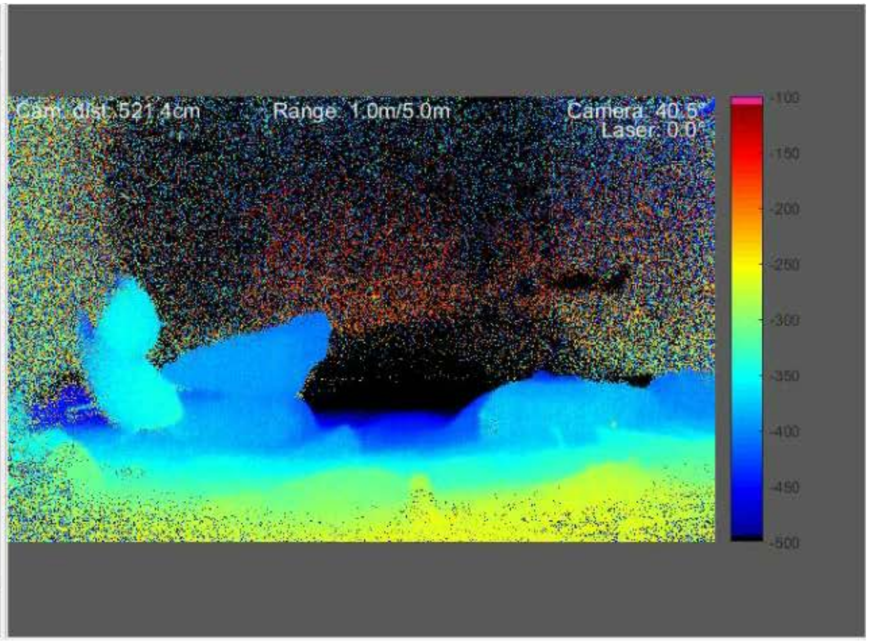
SINTEF

Slide content from Petter Risholm, SINTEF

3D – key enabler for underwater autonomy

Intensity image

Depth image



- Housing, 7 L, 24V
- 300m depth
- 10-20 Hz image rate
- 3rd gen system

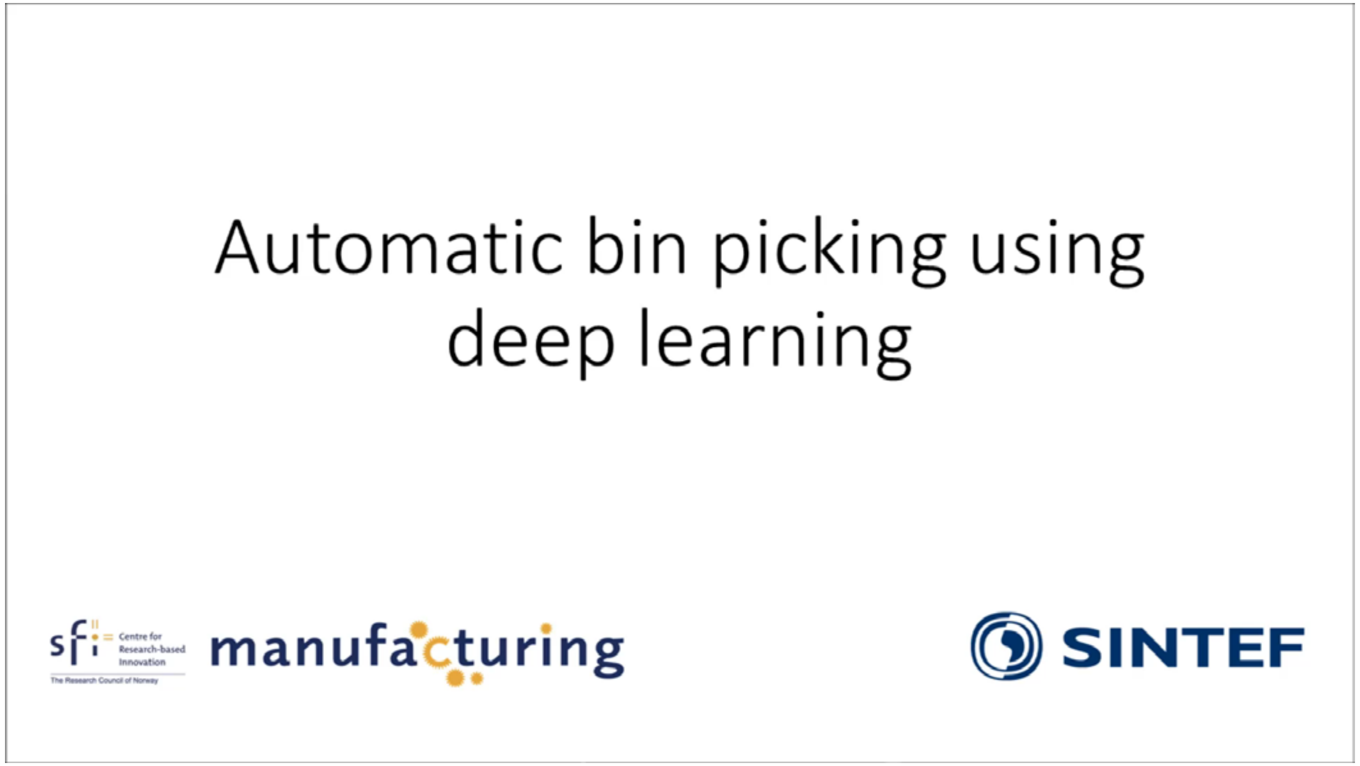
Gives live 3D, backscatter-free images at video-rate

Slide content from Petter Risholm, SINTEF

SINTEF

A 6DOF object detection for subsea intervention tasks

- SEAVENTION will investigate perception based on 2D and 3D sensor data
- Methods based on, e.g., Deep Learning, will be used as basis
- Training simulators for machine learning are important



Autocalibration increases precision and flexibility in operations

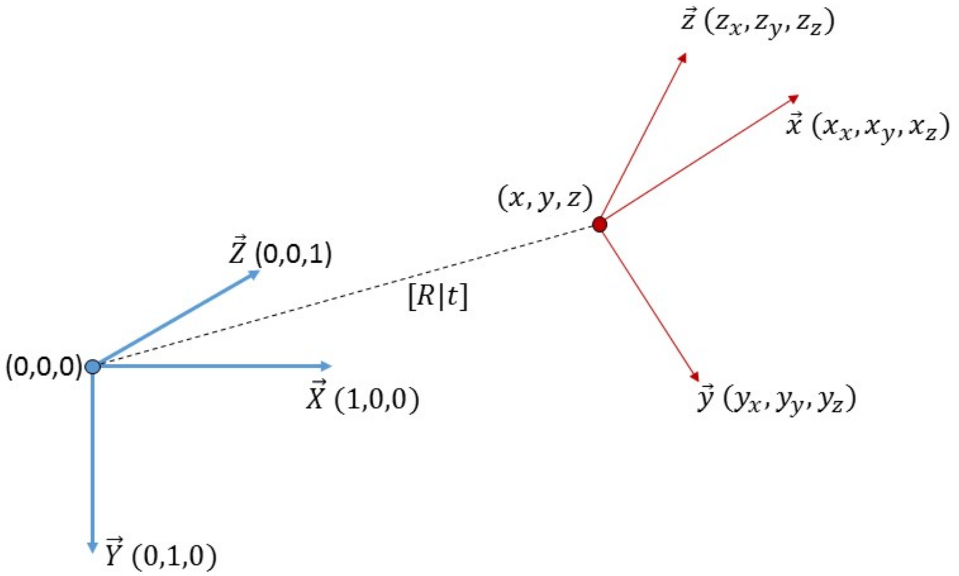
- Autonomy requires several sensors

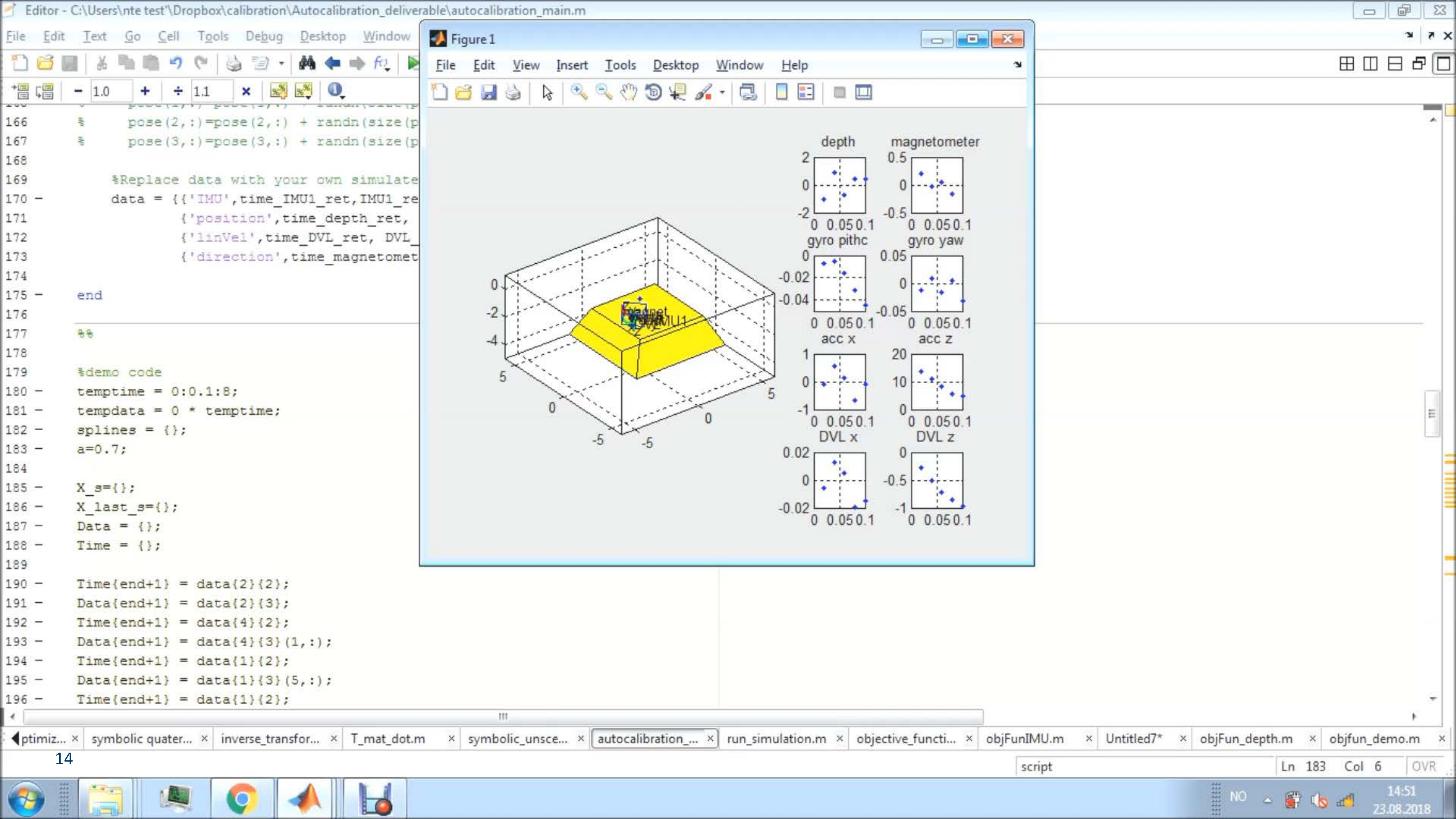
Scenarios

- New sensor was added in a "clever position"
- A crash has pushed the sensors out of alignment
- Custom ROV solutions

Calibration quality directly affects performance

- Traveling 1 m/s and 1 degree misalignment gives
  - 11 m error on DVL after 15 min
  - 200 m error on IMU after 1 min



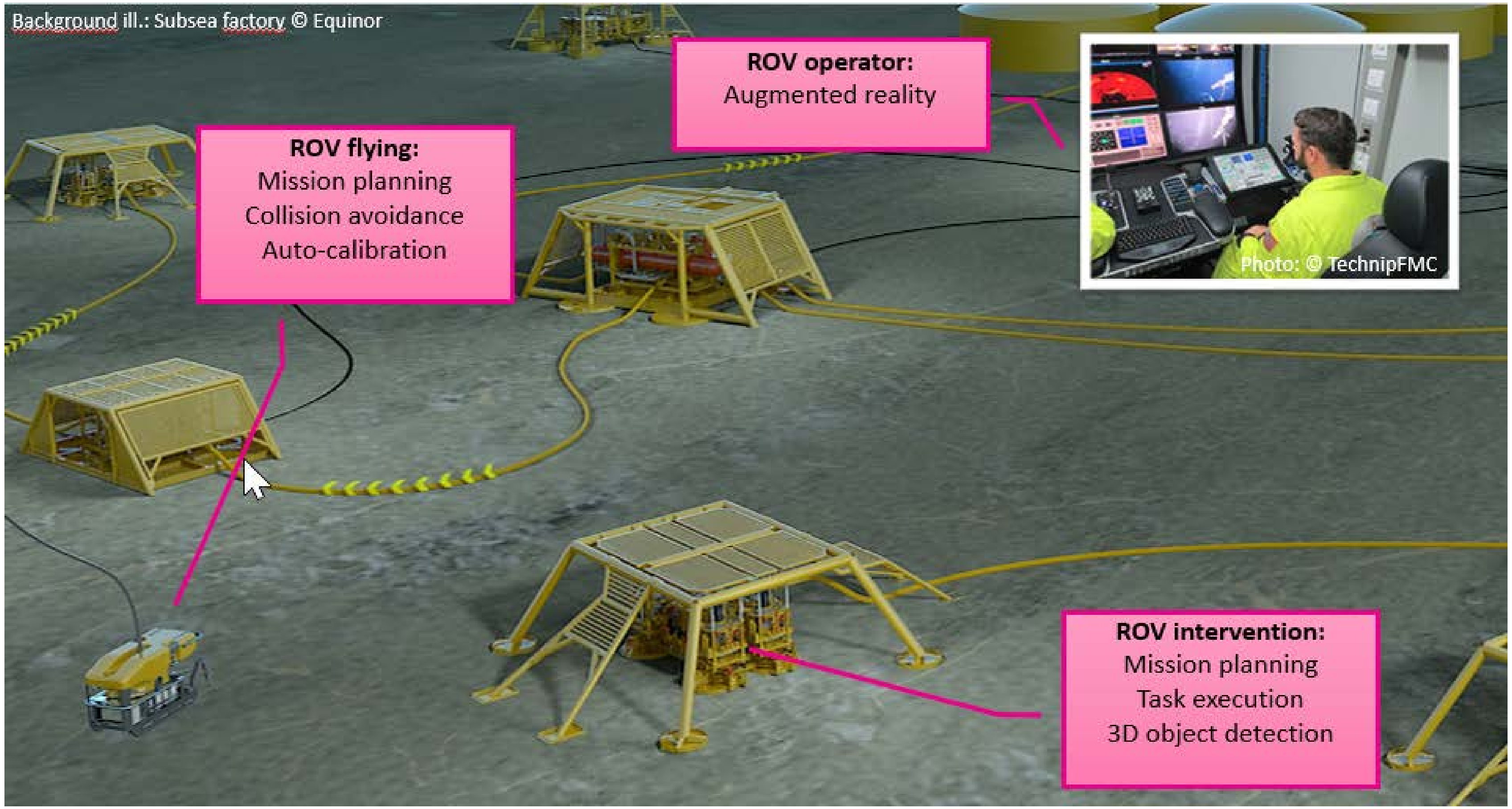

Editor - C:\Users\nte test'\Dropbox\calibration\Autocalibration_deliverable\autocalibration_main.m
File Edit Text Go Cell Tools Debug Desktop Window
%   pose(2,:)=pose(2,:) + randn(size(p
%   pose(3,:)=pose(3,:) + randn(size(p
%Replace data with your own simulate
data = {{'IMU',time_IMU1_ret,IMU1_re
{'position',time_depth_ret,
{'linVel',time_DVL_ret, DVL_
{'direction',time_magnetomet
end
%%
%demo code
temptime = 0:0.1:8;
tempdata = 0 * temptime;
splines = {};
a=0.7;
X_s={};
X_last_s={};
Data = {};
Time = {};
Time{end+1} = data{2}{2};
Data{end+1} = data{2}{3};
Time{end+1} = data{4}{2};
Data{end+1} = data{4}{3}(1,:);
Time{end+1} = data{1}{2};
Data{end+1} = data{1}{3}(5,:);
Time{end+1} = data{1}{2};
Figure 1
File Edit View Insert Tools Desktop Window Help
depth
magnetometer
gyro pithc
gyro yaw
acc x
acc z
DVL x
DVL z
symbolic quater...
inverse_transfor...
T_mat_dot.m
symbolic_unsce...
autocalibration_...
run_simulation.m
objective_functi...
objFunIMU.m
Untitled7*
objFun_depth.m
objfun_demo.m
script
Ln 183 Col 6 OVR
14:51
23.08.2018

"Take-aways" to roadmap

- Increasing levels of autonomy gives challenges in keeping the operator in the loop.
- Resident UUVs will push the state of the art on underwater autonomy.
- Sensor fusion and improved sensors will increase perception robustness. E.g., acoustic and optical.
- UUVs will understand their environment more like humans do to enable full autonomy.
  - Need generalization: the UUVs need to recognize something that is not completely similar to the training set they have been provided.
  - Improved transition from simulators to real-life training.

SEAVENTION

Autonomous subsea intervention – empowered by people and AI



The Research Council of Norway

equinor

TechnipFMC

OCEANEERING

IKM

NTNU

SINTEF

SINTEF

Technology for a better society