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70 years

1950-2020

CORROSION AND CORROSION MONITORING OF STRUCTURAL STEEL IN OFFSHORE WIND TURBINES - THE WATEREYE PROJECT

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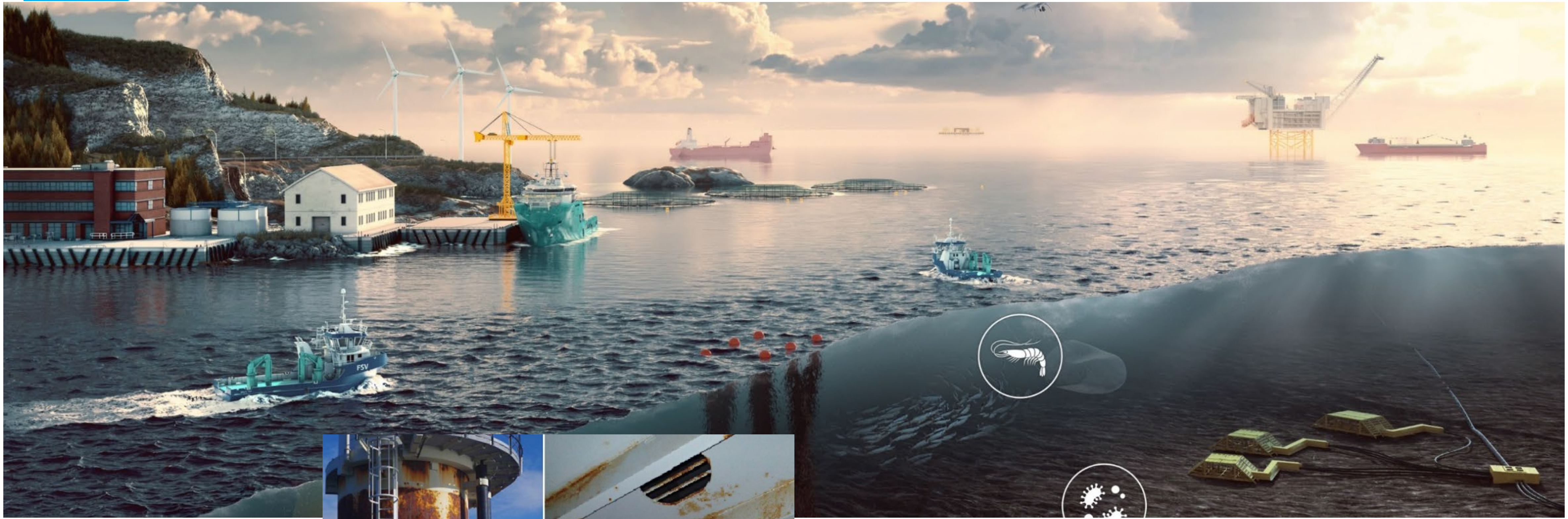
Outline

- Introduction:
  - Project Consortium
  - Background
  - Objectives
- Materials and methods
- Some results
- Summary

Project consortium for the Watereye project

Project consortium: Why Sintef



NONO!

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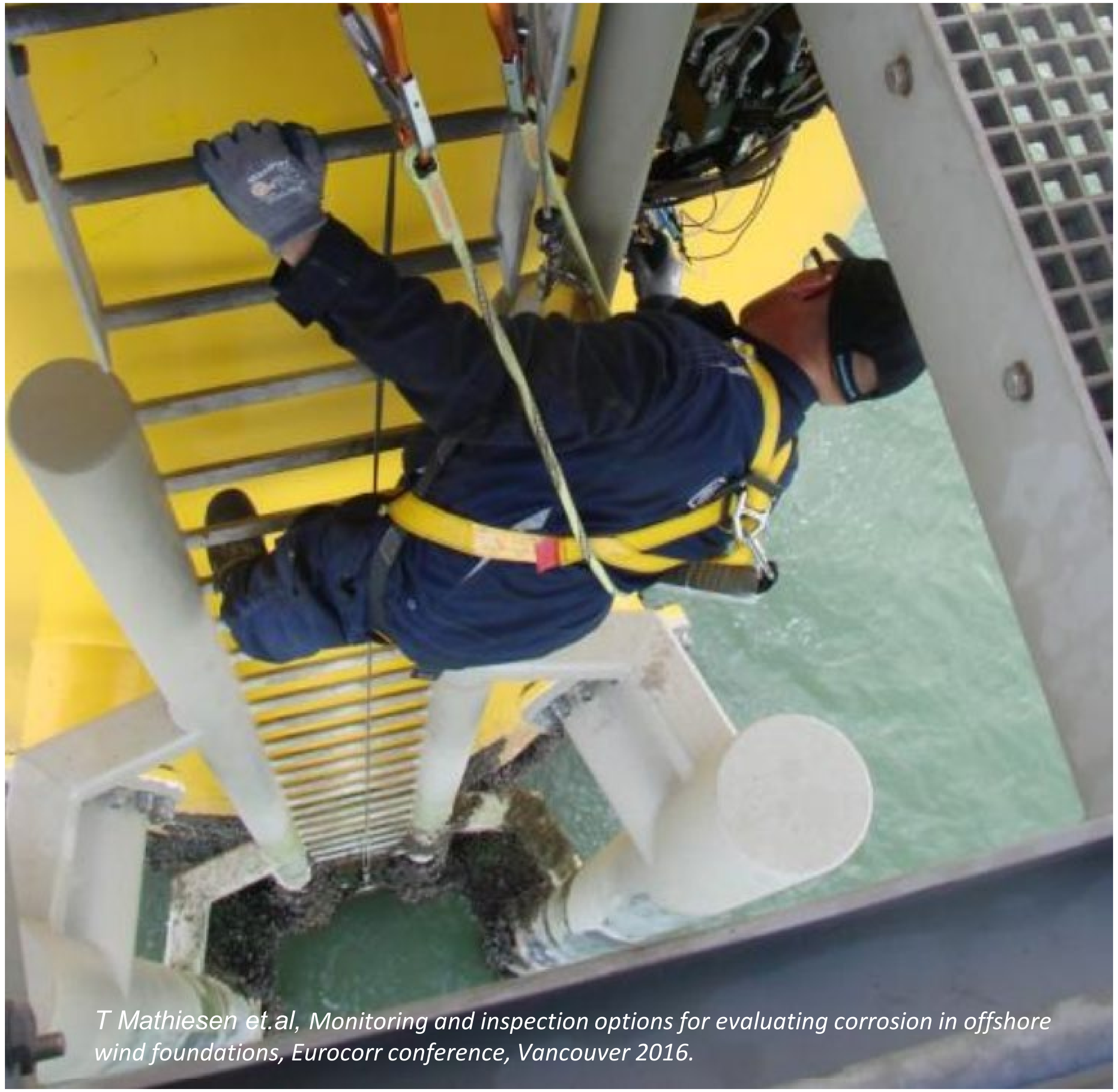
Background

Manual inspection is complicated and presents logistical and safety challenges



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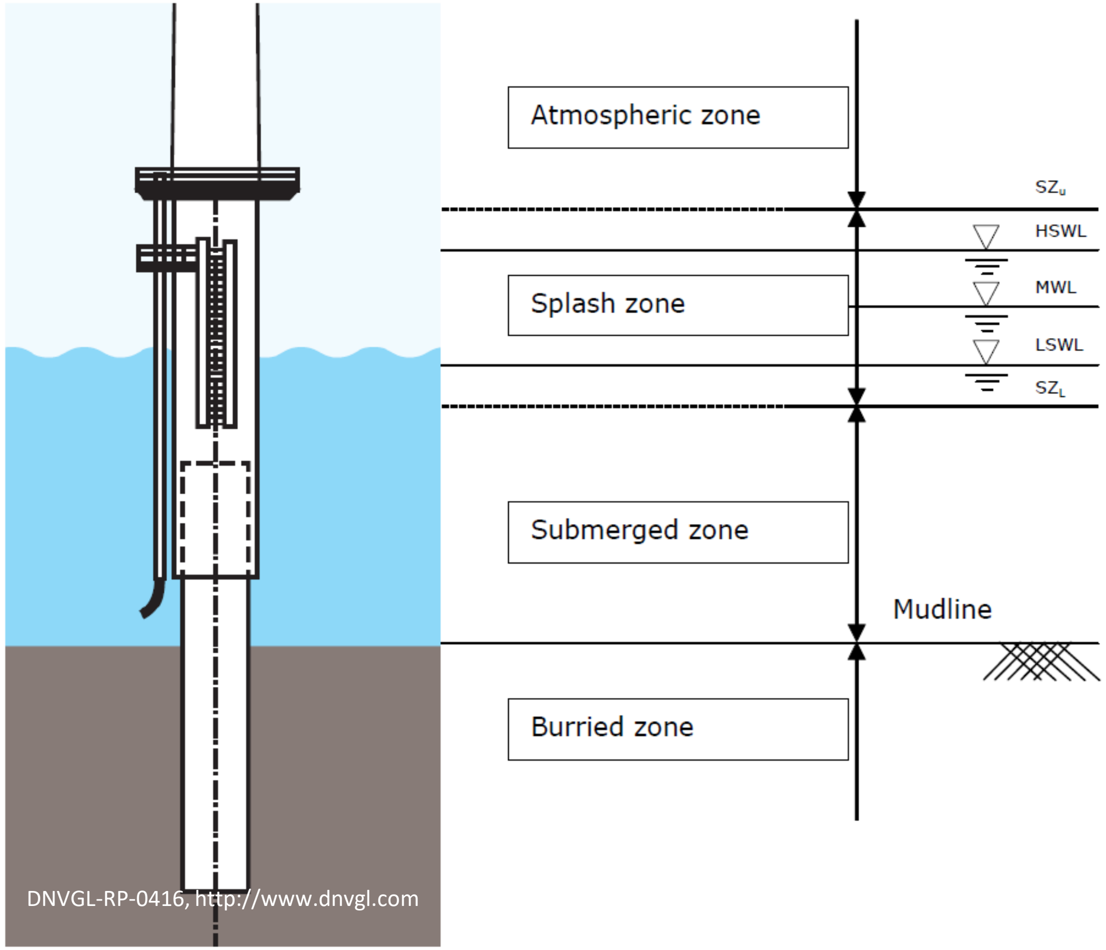
Design of wind turbines for long lifetime

- Environmental conditions on site
- Steel surfaces are different with respect to
  - Corrosivity
  - Corrosion protection methods
- External surfaces
  - Atmospheric zone
  - Splash zone
  - Submerged zone
  - Seabed sediments/Buried zone
- Internal surfaces

DNV-GL recommended practice "Corrosion protection for wind turbines" (DNVGL-RP-0416)



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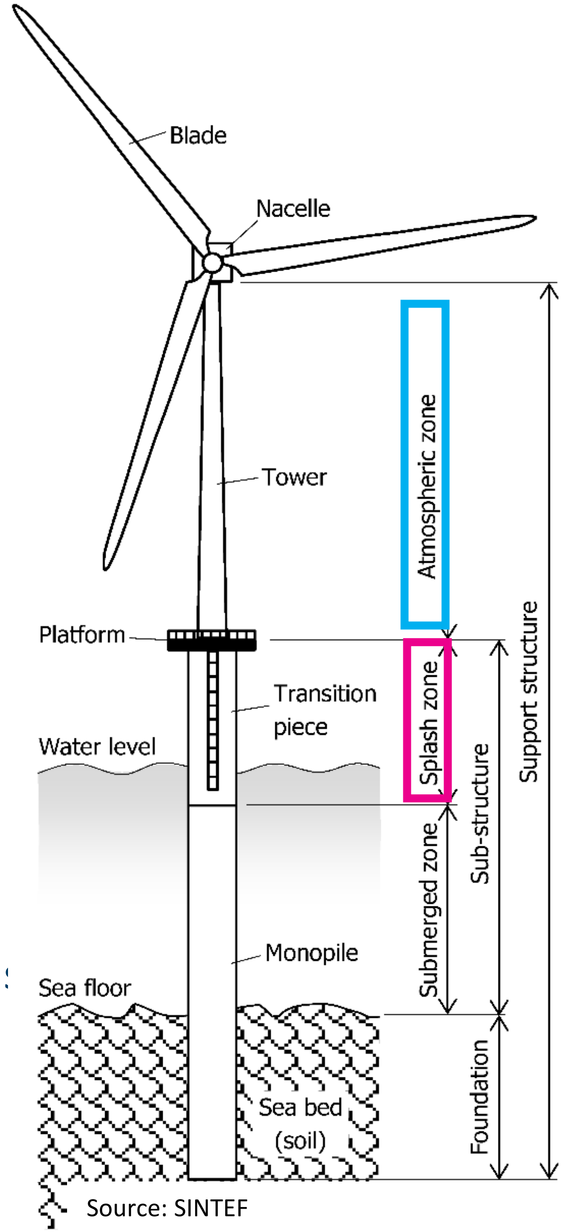
Corrosion protection systems –
DNVGL-RP-0416

- Atmospheric zone
  - Protective coating systems is mandatory in external and internal surfaces
- Splash zone
  - Protective coating systems is mandatory for external surfaces but optional for internal surfaces
  - Coatings are combined with corrosion allowance
- Standards for selecting protective coating systems
  - DNVGL-RP-0416
  - ISO 12944: Corrosion protection of steel structures by protective paint systems
  - ISO 12944-9: Performance requirements for protective paint systems for offshore and related structures
  - NORSOK M-501: Surface preparation and protective coating



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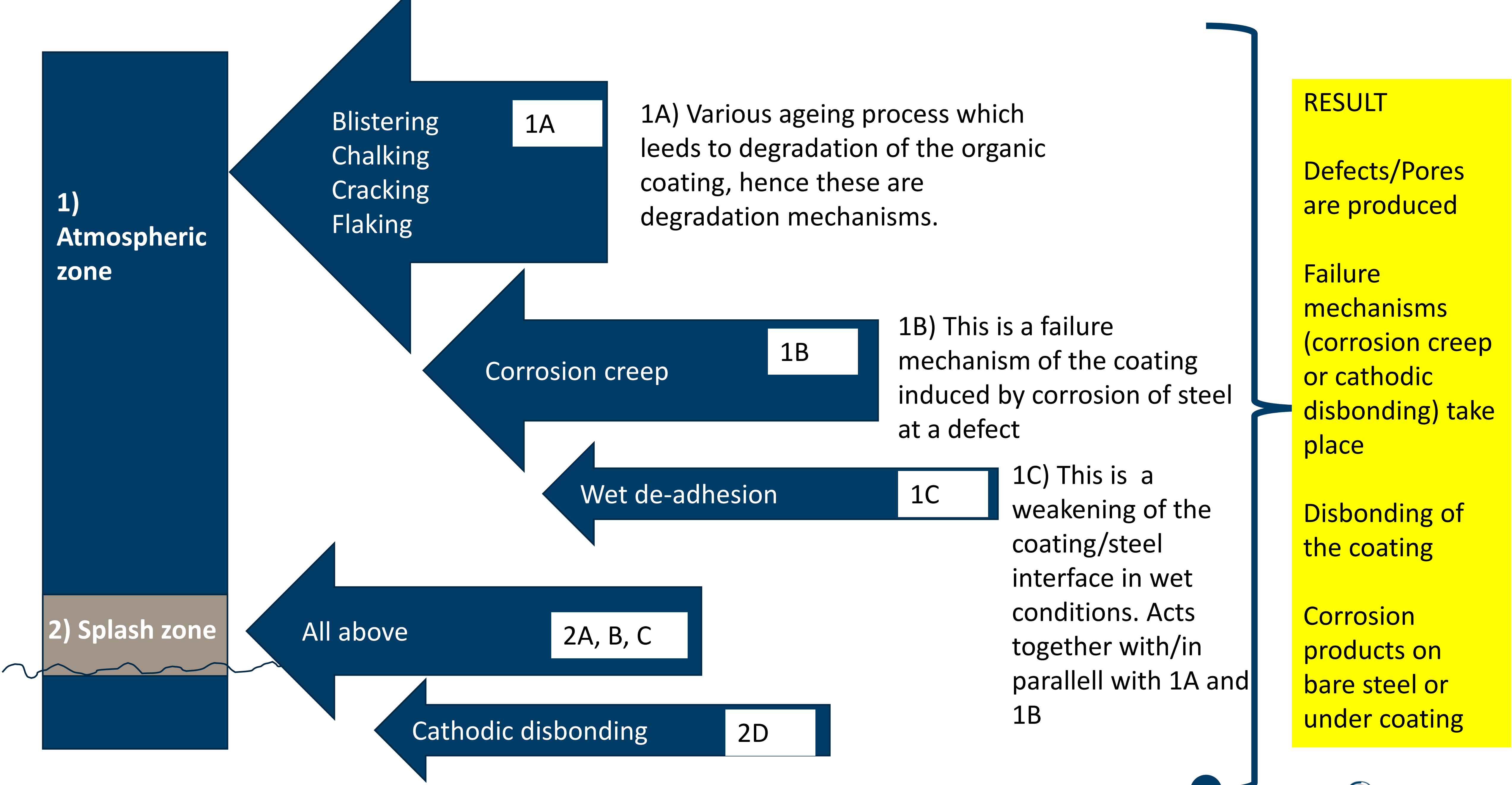
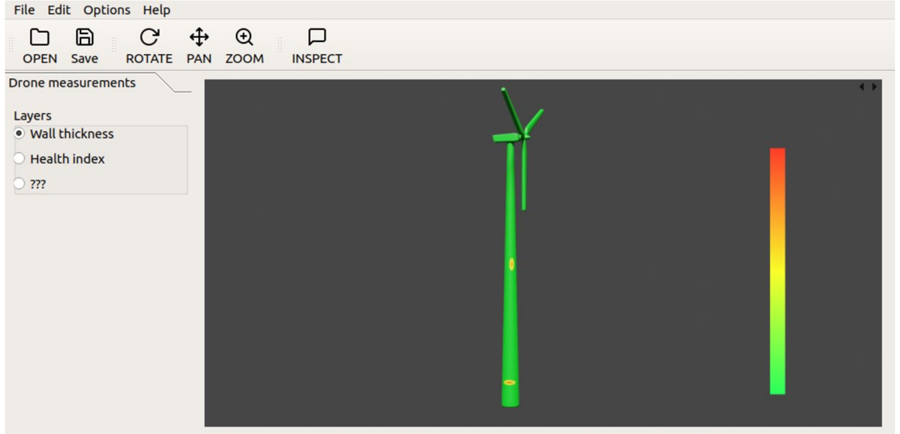

1) Atmospheric zone
2) Splash zone
Blistering
Chalking
Cracking
Flaking
1A
1A) Various ageing process which leeds to degradation of the organic coating, hence these are degradation mechanisms.
Corrosion creep
1B
1B) This is a failure mechanism of the coating induced by corrosion of steel at a defect
Wet de-adhesion
1C
1C) This is a weakening of the coating/steel interface in wet conditions. Acts together with/in parallell with 1A and 1B
All above
2A, B, C
Cathodic disbonding
2D
RESULT
Defects/Pores are produced
Failure mechanisms (corrosion creep or cathodic disbonding) take place
Disbonding of the coating
Corrosion products on bare steel or under coating

Objectives: Structural health monitoring (SHM)

Fixed sensors will deliver data regarding the wall thickness at that specific sensor



Digital twin of a wind turbine tower

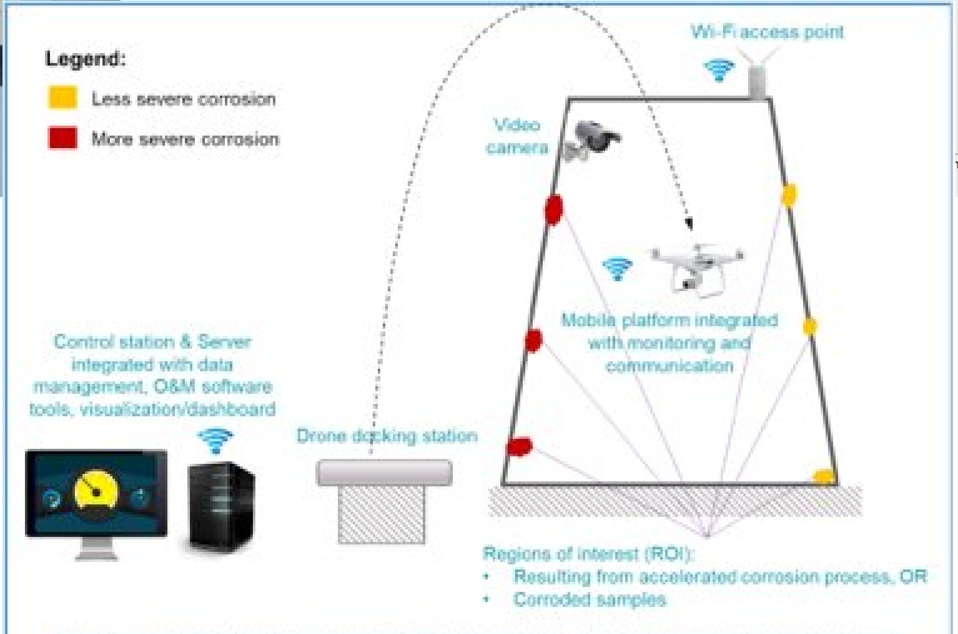
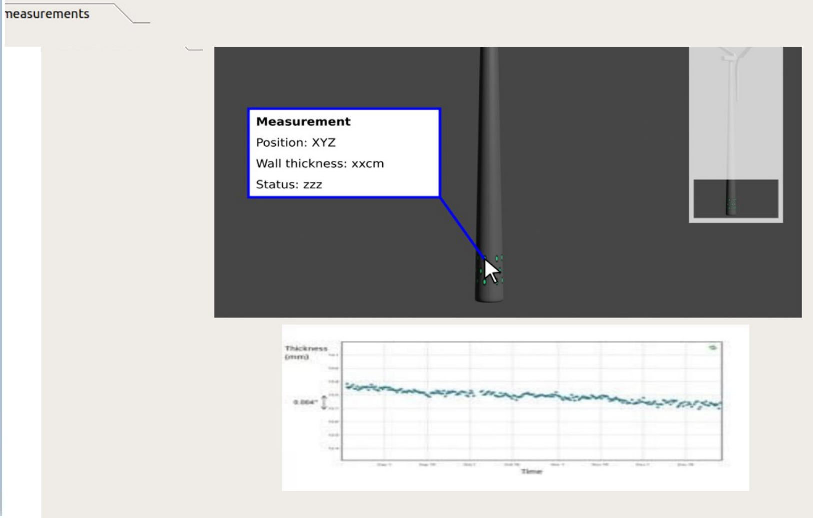


FIGURE 3-3: INTEGRATION AND VALIDATION OF WATEREYE MONITORING SOLUTION AT WT LEVEL



Drone measurements from mobile drones will collect data about wall thickness and be used to generate a wall thickness condition map in colours

Materials and methods

Case study in the project

- Gran Canaria: based on end-user offshore WT plans
- Atmopsheric zone
- Splash zone
- Structural carbon steel
- Various coatings systems: 3, see next slide

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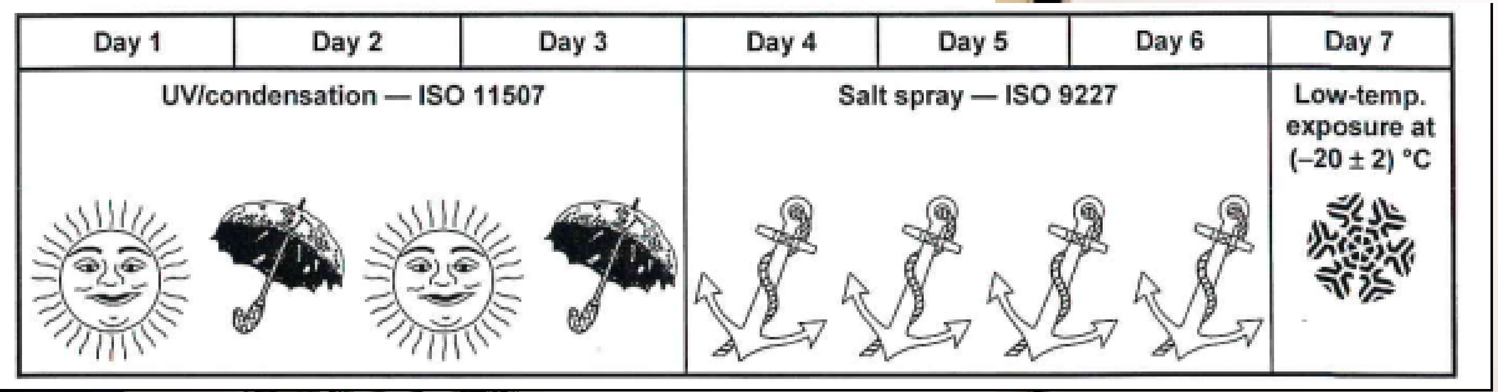
Coatings employed in the project

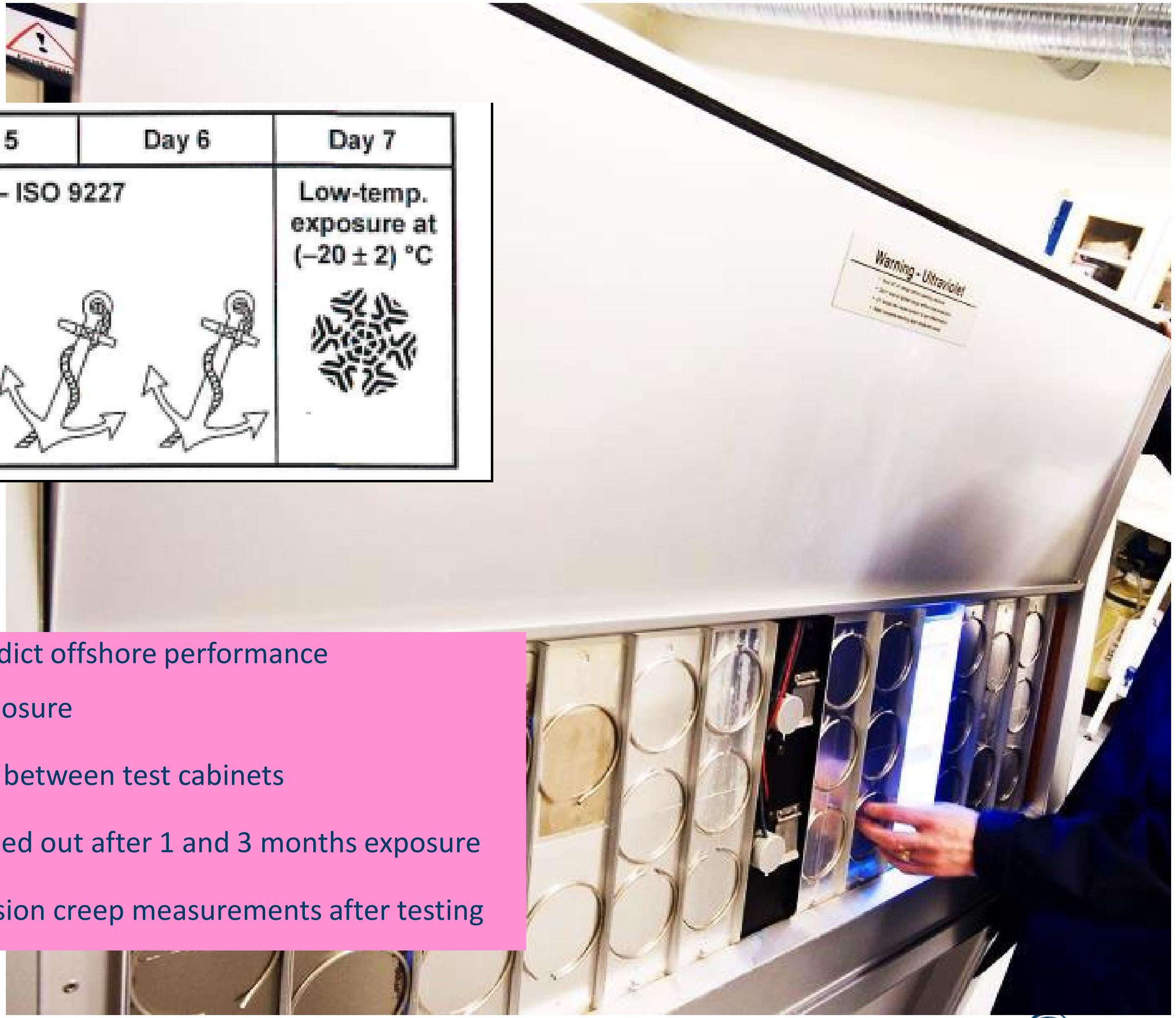
Ultrasound is expected to handle different coatings…..

Watereye system no.	NORSOK system no.	Zone	External surfaces			Internal surfaces
			Coating description		Dry film thickness - DFT [µm]	
0	Bare steel	Atmospheric zone	Reference		-	Bare steel
1	1	Atmospheric zone	3-coat system	Zn-rich primer + epoxy intermediate coat + PU topcoat	280	1-2 coats epoxy
2	2B	Atmospheric zone	Duplex coating	TSZ + tie coat + epoxy intermediate coat+ PU topcoat	100 + 200	1-2 coats epoxy
3	7A	Splash zone	Epoxy coating system	2 epoxy coats	660	1-2 coats epoxy

Cyclic corrosion test – ISO 12944-9 and CD test ISO 15711 – Method A



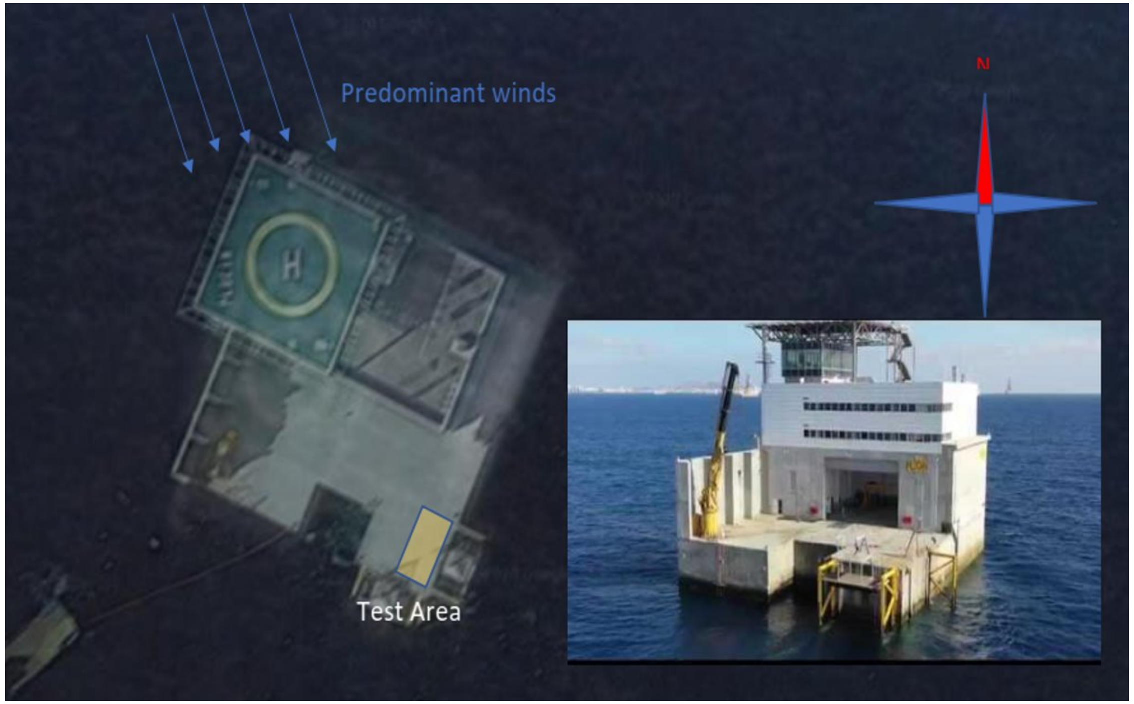
Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
UV/condensation — ISO 11507			Salt spray — ISO 9227			Low-temp. exposure at (−20 ± 2) °C



- Test method known to predict offshore performance
- 25 cycles – 4200 hours exposure
- Samples are moved manually between test cabinets
- Visual examination to be carried out after 1 and 3 months exposure
- Visual examination and corrosion creep measurements after testing

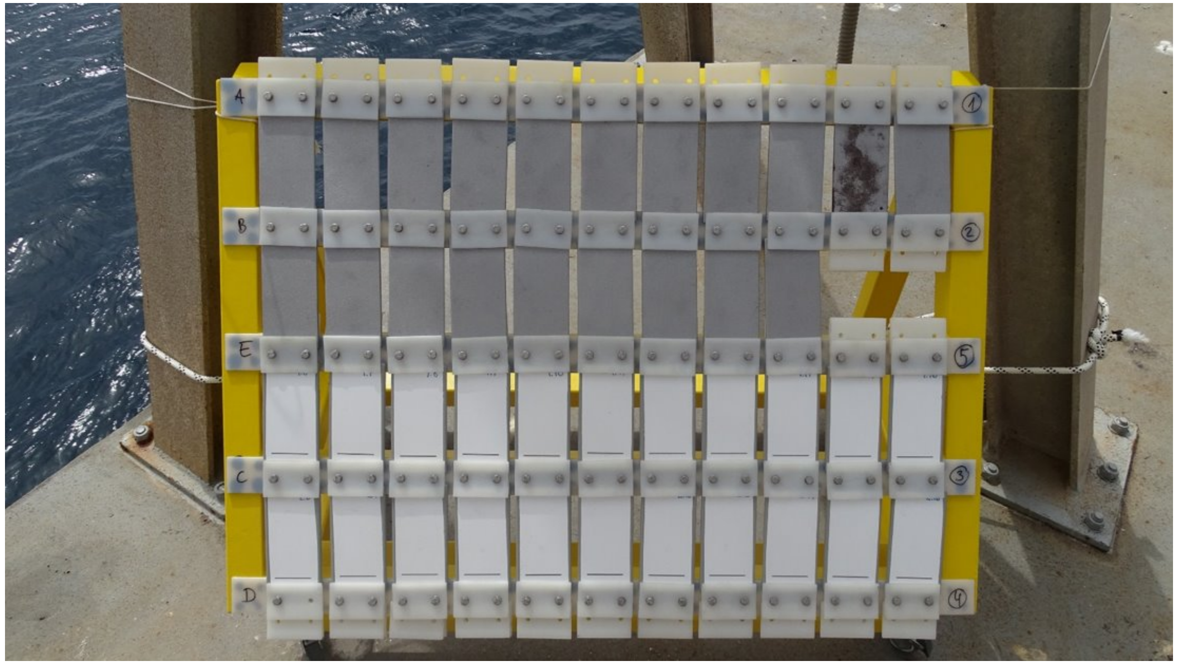
Field exposure of test samples at PLOCAN

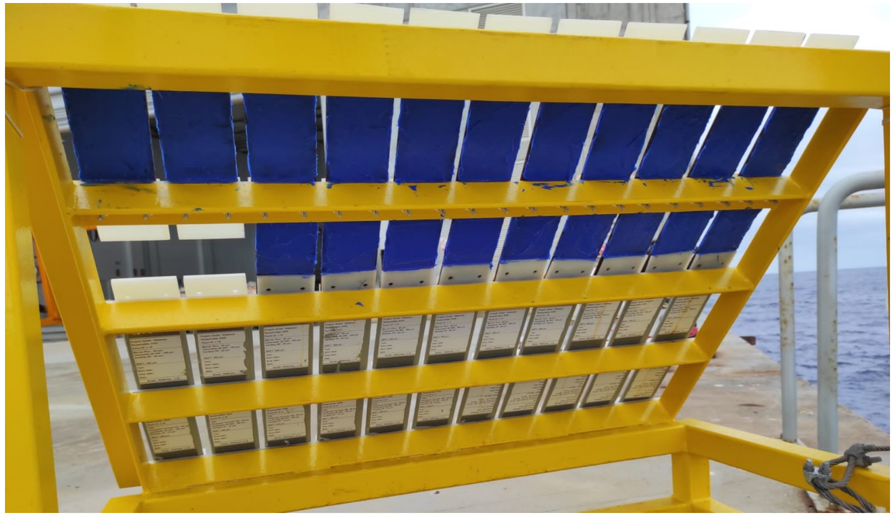
- Samples to be exposed
  - 4 months
  - 8 months
  - 12 months
  - 24 months



- Corrosion examination of exposed samples
  - **CEIT** by US measurements
  - **SINTEF** in agreement with the ISO 12944-9 by SINTEF

Field exposure of test samples at Plocan





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Some results: Bare steel corrosion

As exposed

1 month

3 months

As stripped – corrosion products removed

Field exposure, 1 month

Accelerated laboratory test

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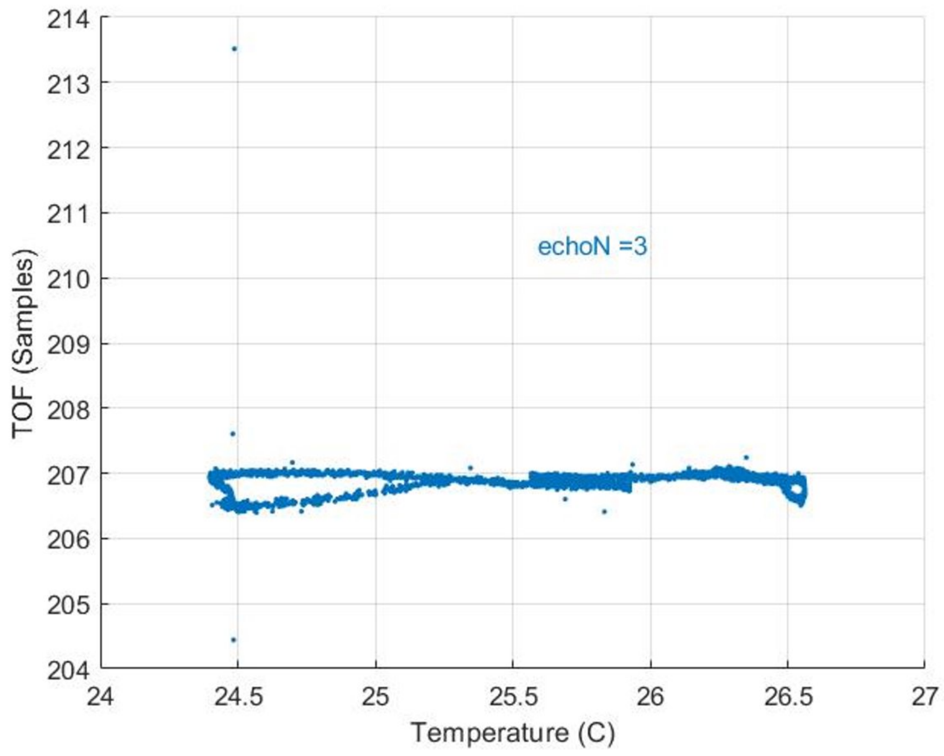
Some results: US measurements on bare steel – after corrosion products are removed



TOF= 207 x 8ns = 1'656µs

Vs (steel) = 5900m/s

Thickness = 1'68µs x 5900 / 2 = 4'8852mm

Loss of thickness = 4'956 – 4'8852 = 70'8µm

!! Loss of thickness confirmed by other methods

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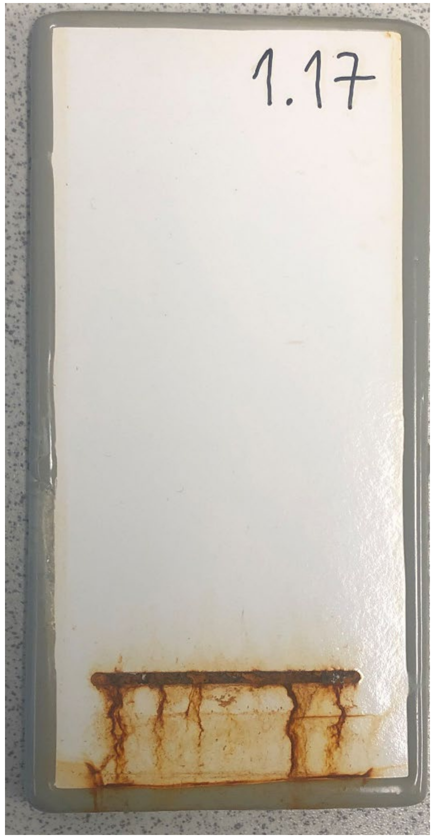
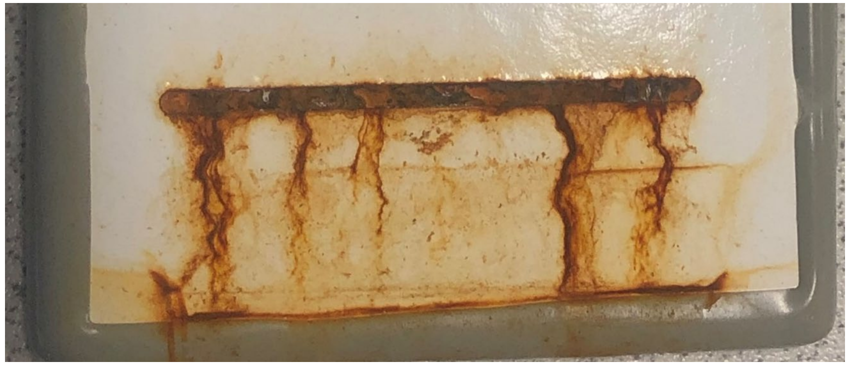
Some results: Corrosion on steel from damaged coating

1 month



3 months

- Effect of exposure time
  - Blisters due to corrosion from scribe
  - Increased blister sizes



NORSOK system 1: 3-coat system for atmospheric zone

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Some results: Corrosion on steel from damaged coating

NORSOK system 2B: duplex coating system for atmospheric zone

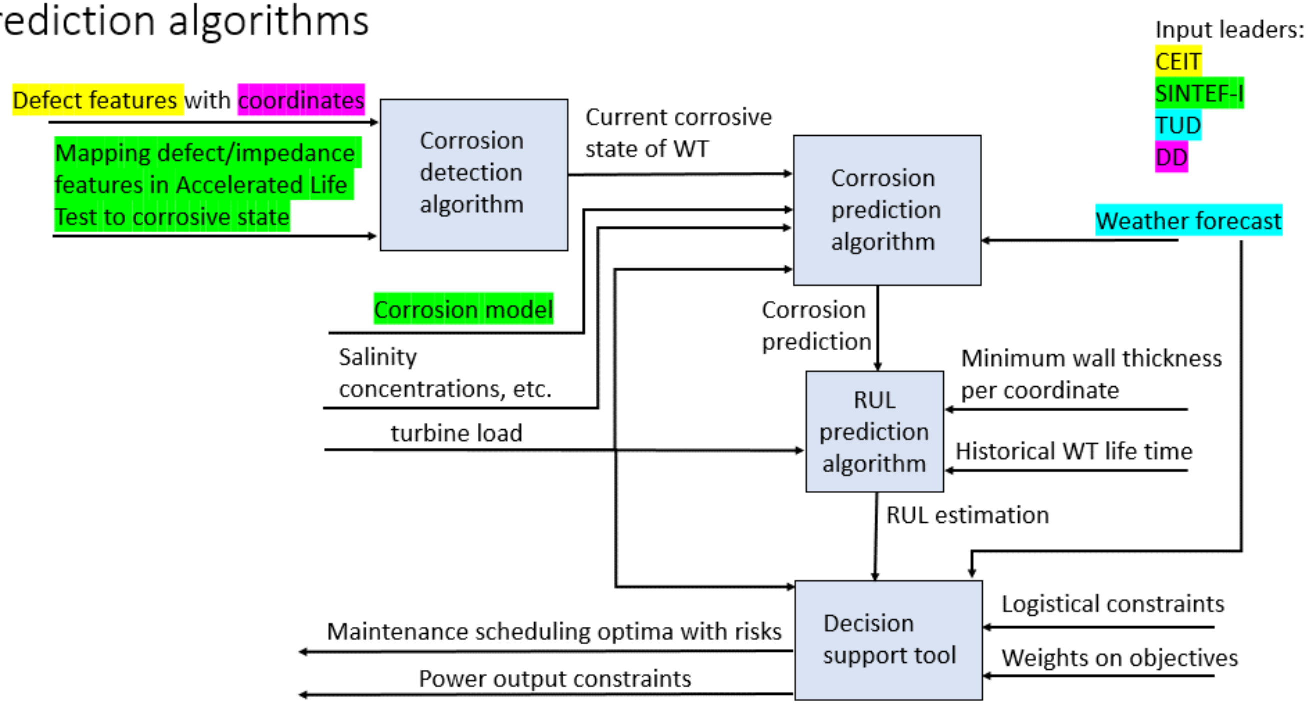
1 month

3 months

- Effect of exposure time
  - Minor coating lift
  - Small blisters from scribe

Summary: The Watereye project

Overview of envisioned decision support tool and detection & prediction algorithms



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