

Real-time hybrid testing of a braceless semi-submersible wind turbine

Erin Bachynski, MARINTEK

Valentin Chabaud, NTNU

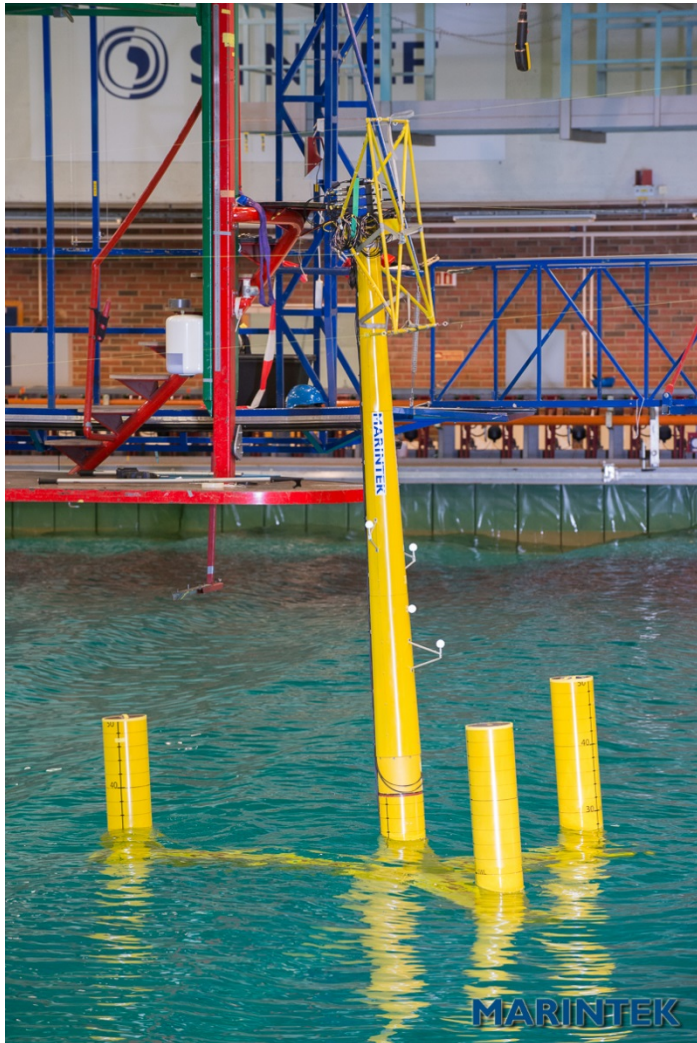
Maxime Thys, MARINTEK

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Norsk Marinteknisk Forskningsinstitutt

 **SINTEF**

Outline



- How to Perform Model Test with a Floating Wind Turbine (FWT)
- Objectives of the Model Tests
- The Experimental Setup
- The Hybrid System
- Results of the Model Tests
- Conclusions about the Hybrid Model Tests

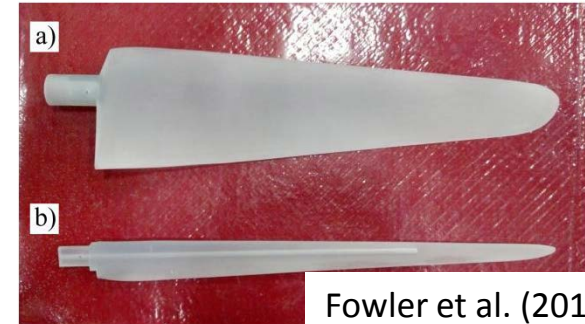
How to Perform Model Tests with a FWT?

Approach 1: Install a wind tunnel in the basin

Use Froude scaling for waves, current, and floater.

What about wind and rotor scaling?

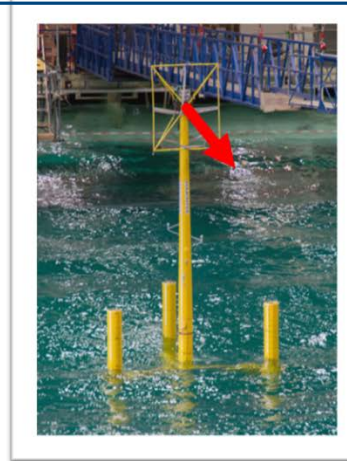
- Geometrical or performance-based scaling.



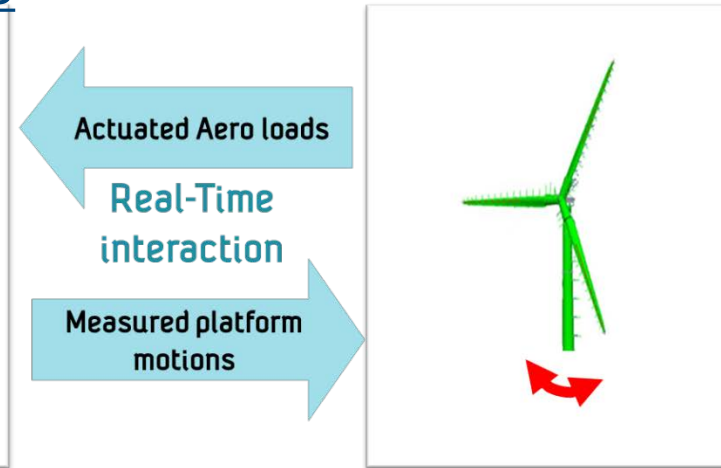
Fowler et al. (2013)

Approach 2: Real-Time Hybrid Model Tests

Use Froude scaling for waves, current, and floater and aerodynamic loads!



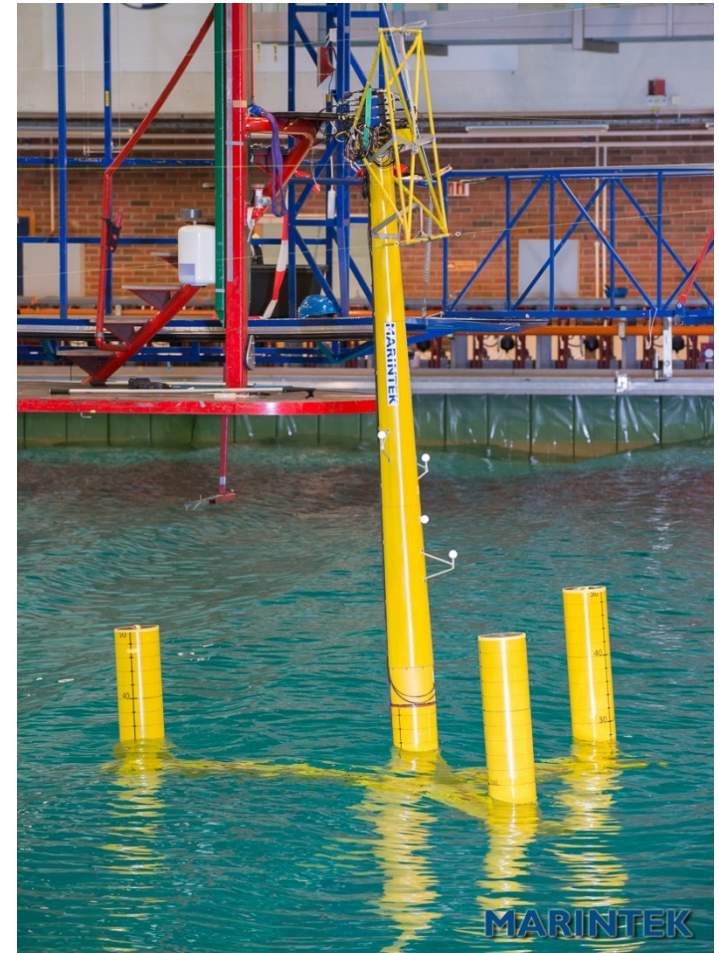
Physical waves and current



Simulated wind loads

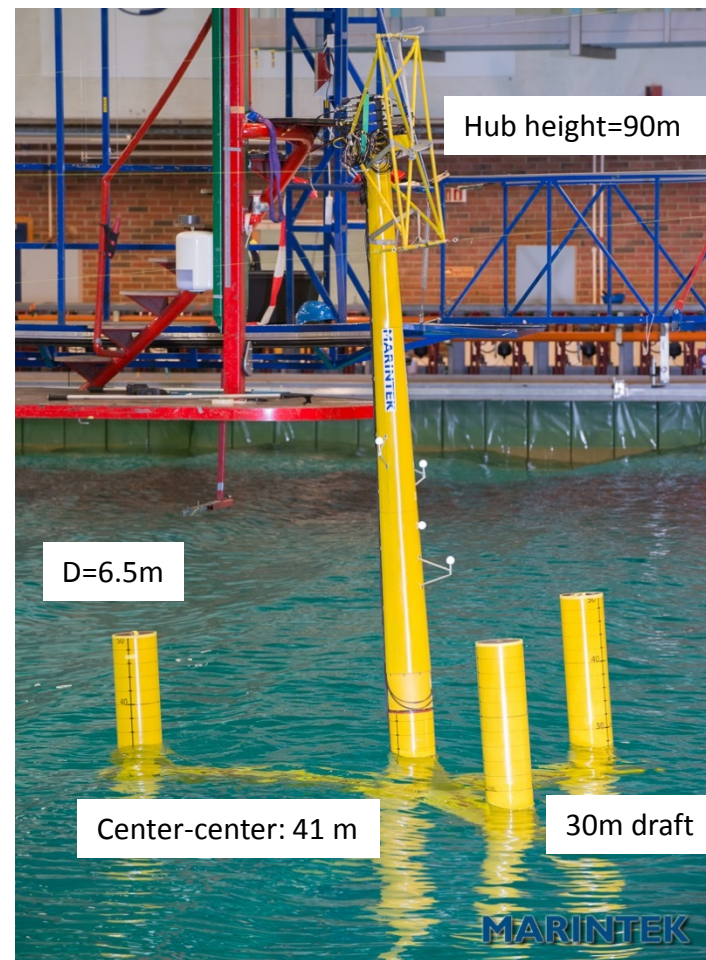
Objectives of the Model Tests

- Quantify the system behavior in environmental conditions representative of the Northern North Sea
- Prove the applicability of the hybrid test method



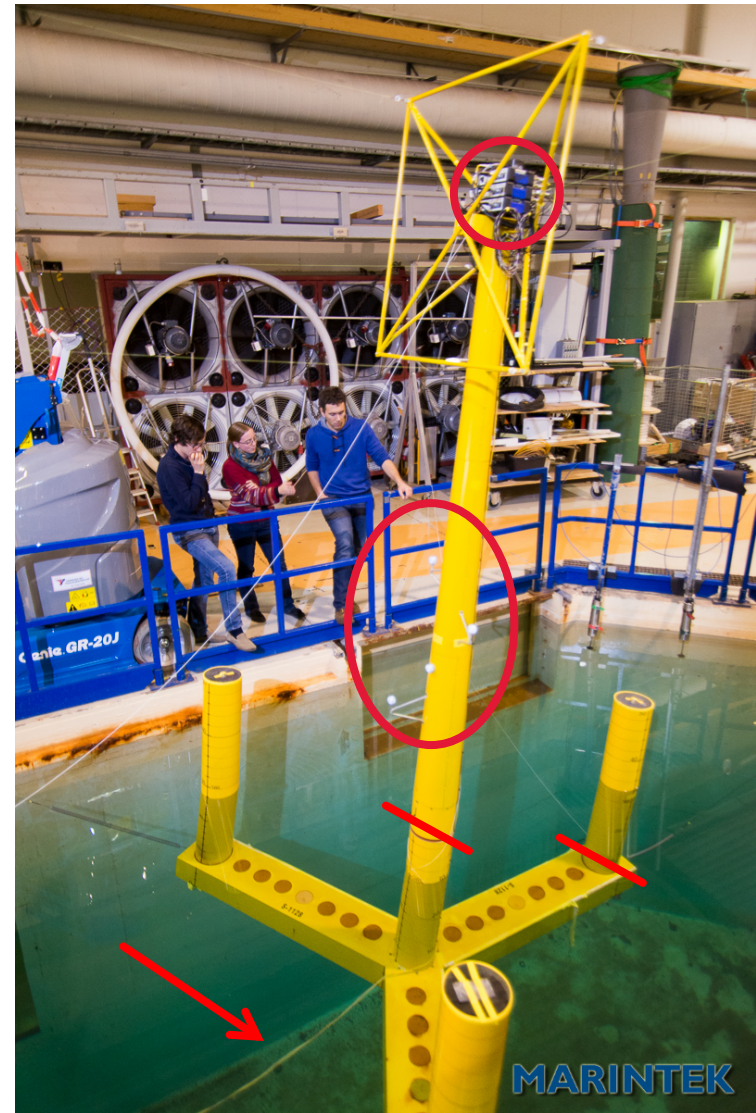
Experimental Setup

- The FWT:
 - 5MW CSC turbine
 - Floater designed by C. Luan for the NOWITECH project
 - 5 MW NREL rotor-nacelle-assembly
- Froude Scale 1/30
- Water depth: 200m
- Mooring: Chain-chain catenary mooring system

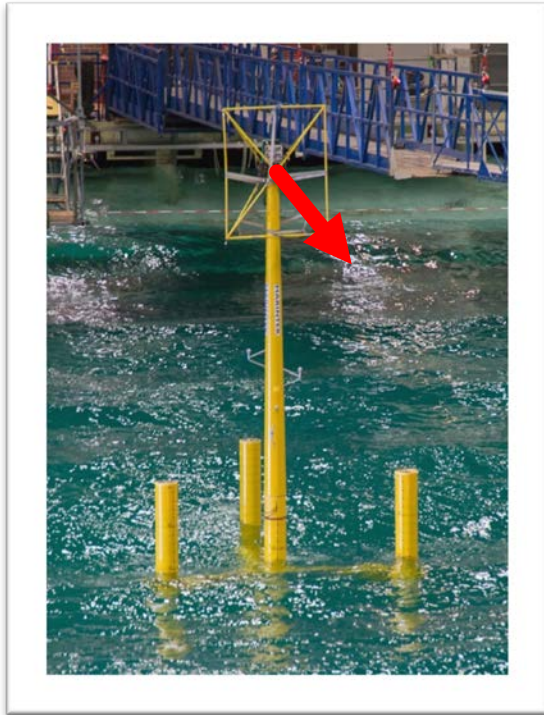


Experimental Setup: Instrumentation

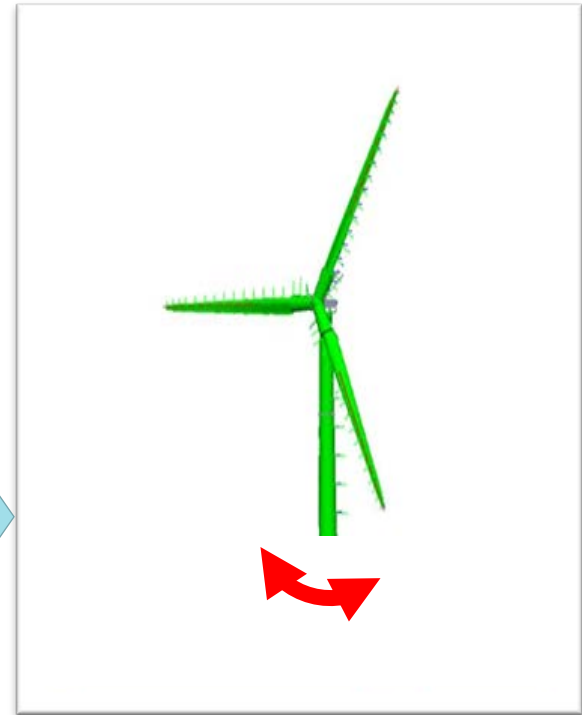
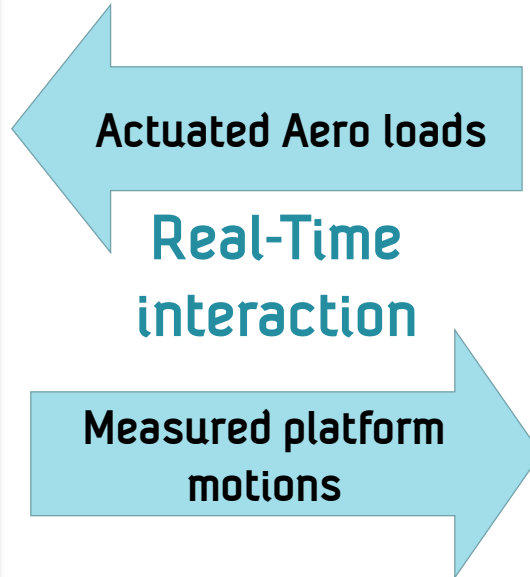
- Position of model by optical positioning system
- Measure linear accelerations and rate of rotation at hub
- "Wind line" and mooring line tensions
- Overturning moment X and Y at base of tower
- Overturning moment X and Y at base of column 3
- Ultra thin instrumentation cable under the model



The Hybrid System



Physical waves and current

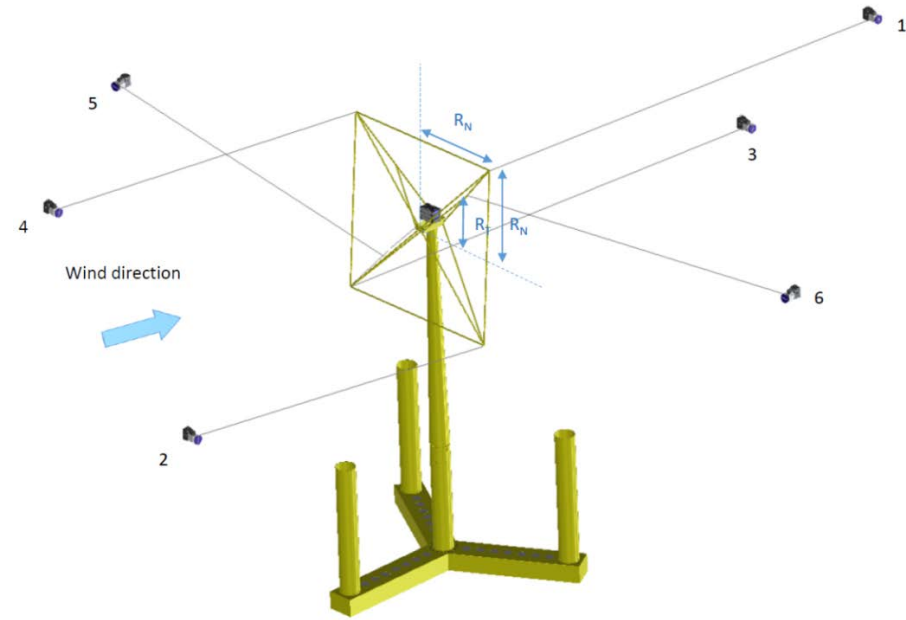
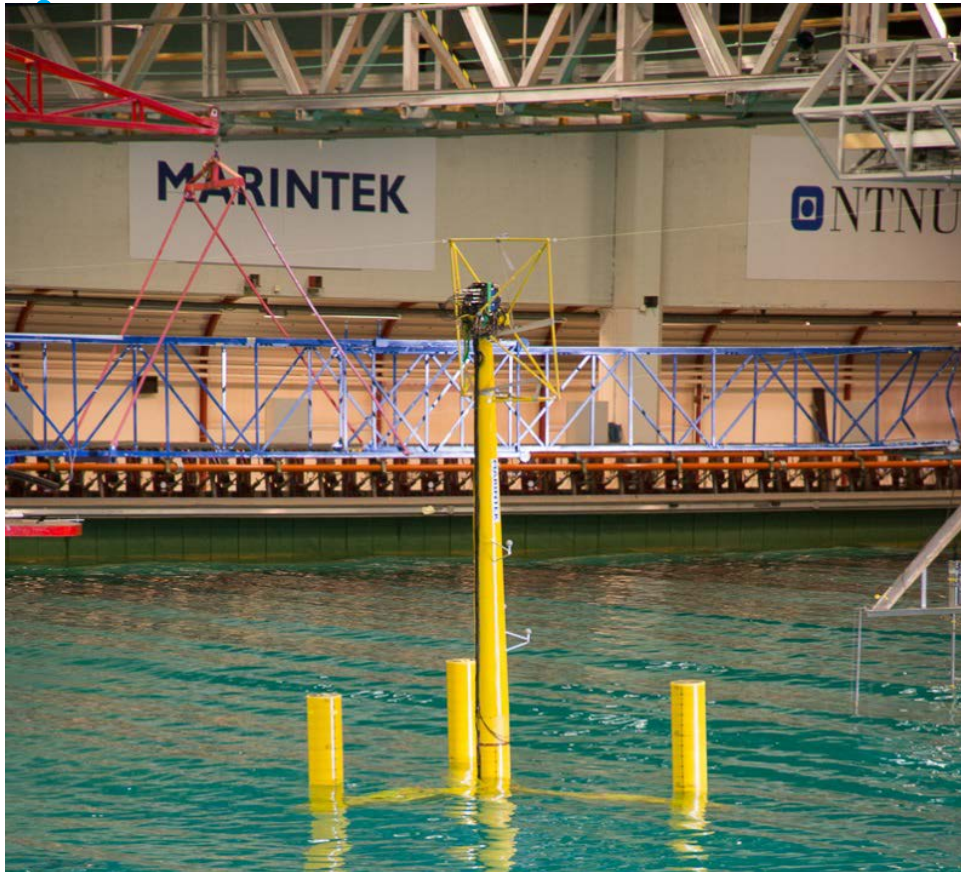


Simulated aerodynamic loads

- Thrust
- Aerodynamic sway force
- Aerodynamic pitch and yaw moment
- Generator torque

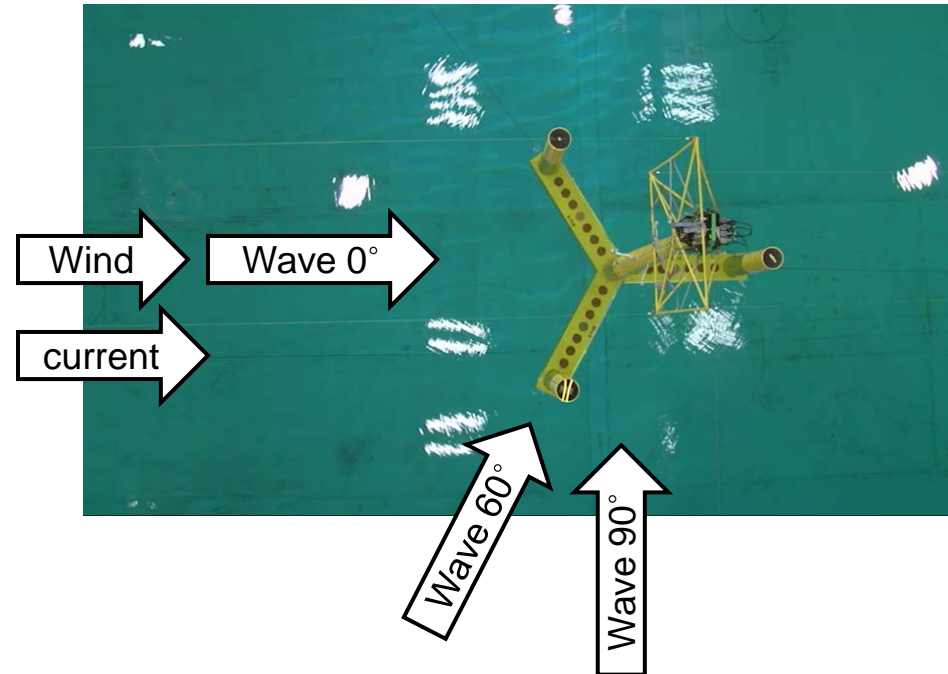
The Hybrid System

How do we apply the aerodynamic loads in 5DOF on the model?



Model Test program

- Tests without hybrid system
 - Decay, Regular waves, Irregular waves
- Tests with zero wind
 - Decay, Regular waves, Irregular waves
- Tests with constant wind
 - Decay and Regular waves
- Tests with turbulent wind
 - Wind-only
 - Irregular waves
 - Below rated, rated, above rated
 - One test with current
 - Misaligned waves
 - Fault conditions



Step by step increase in complexity with repetitions and decomposed conditions

Conclusions about the Hybrid Model Tests

- Performed model tests with a FWT in the Ocean Basin at MARINTEK:
 - with physical waves and current
 - simulated aerodynamic and generator loads on the wind turbine
- The hybrid system was found to perform well
 - Damping and irregular wave tests without the system and with the system in following mode showed little influence
- The wind turbine (including the control system) was found to have significant effects on the natural periods and damping of the system
- Interaction between aerodynamic and hydrodynamic loads was observed primarily at low frequencies
- Studied two fault conditions for the wind turbine
- Step forward toward commercialization of hybrid testing
- Further publications planned for OMAE 2016

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 **NTNU**

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Thank you for your attention.