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OPPORTUNITIES FOR A LONG-TERM ARCTIC OBSERVATORY

Kongsberg Discovery

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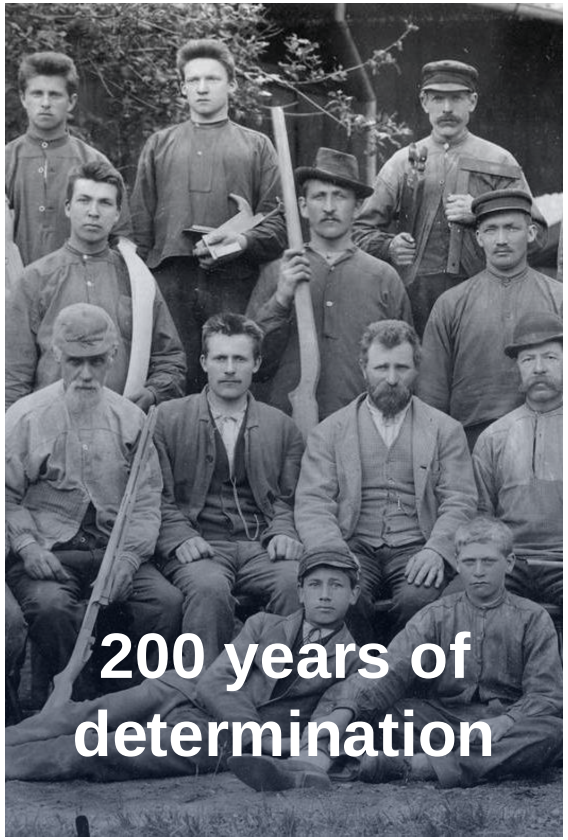
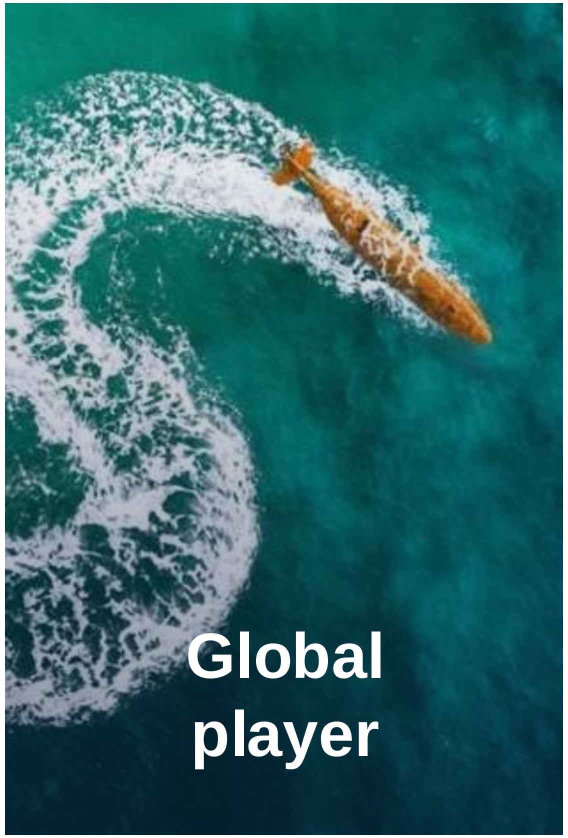
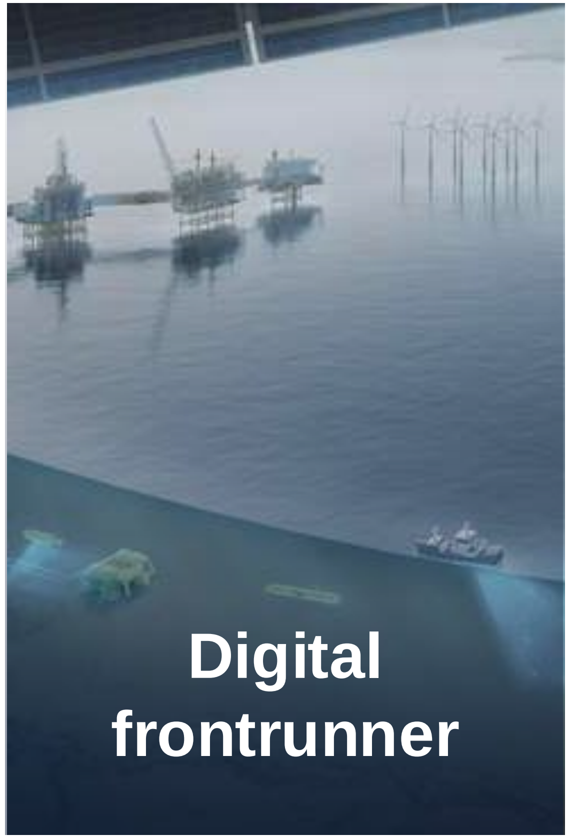
Terje Nilsen, Director of Disruptive Technologies

200 years of excellence

Two centuries of achievement, innovation and transformation
—fuelling a journey that has seen us start as a small munitions business
in Norway and emerge as a pioneering global technology provider.







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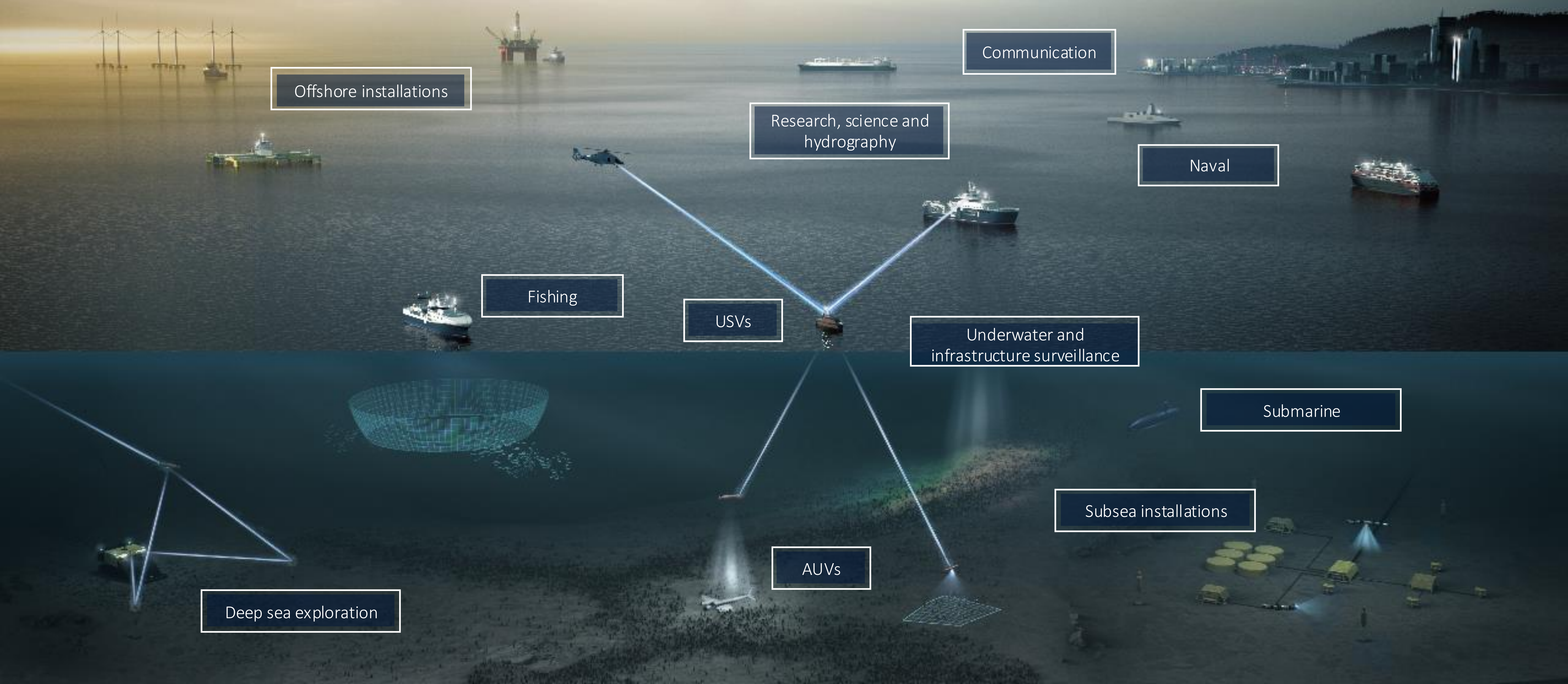
Serving the entire ocean space

Energy | Food | Transportation | Research | Minerals | Leisure travel | Naval



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Supporting equipment for environmental monitoring

- **Kongsberg Digital makes a range of equipment for subsea environmental monitoring.**

  - The most famous is the "Hugin" AUV, an autonomous underwater vehicle that can conduct surveys over several weeks per dive.

  - We also have landers or sensor platforms that can be placed on the seabed.
    - These can operate on batteries or external power.
    - For long-term environmental surveillance purposes, they can use a range of sensors, cameras, echo sounders, sonars, etc.

  - We are also working on a new extreme long-term temperature sensor string with very high MTBF and little drift over time.
    - **This I will discuss today.**

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The challenge

Measuring temperature to a heigh degree of accuracy over a long time

- **Scientists want us to be able to accurately measure the temperature in the ocean over decades without servicing the sensors.**

- There are several problems in doing this:
  - The sensor must be small and light enough to be mounted on/to a cable.
  - The sensors will have to be operated without service for several decades.
  - The sensors must have as close to zero drift as possible.
  - The sensor technology must have an evenly distributed drift.
    - If all sensors drift in the same direction, measurements seem accurate but are drifting.
  - Power consumption is an issue as many sensors are needed on the sensor string.
  - Price per unit is an issue.

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Our solution

Measuring temperature to a high degree of accuracy over a long time

- In the future, I believe the solution may be a quantum technology-based sensor.
- However, they do not yet exist, and the few that do are large and expensive.
- We are working on a technology that will meet these demands today.
  - It can be called a hybrid sensor, mixing atomic motion with classic technology.

- Each component of our new technology is not new, but the way of putting it together is.
- It uses custom-designed quarts-crystals as the sensor element.
  - Tuned and calibrated for the expected temperature range.
  - However, the reference clock is not located with the sensor but at a sight on shore.
    - Being on shore enables us to use an atomic clock, like the heartbeat of the GPS system, as a reference.
    - We only need one reference clock for an infinite number of sensors, which can be retrieved from any GPS system today or by a local atomic clock if operating GPS-denied.

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How it works

Measuring temperature to a heigh degree of accuracy over a long time

- Each sensor element consists of a quarts-crystal that oscillates at a given frequency at a given temperature.
- This has very little drift over time and is a known technology.
- Also, the frequency is very stable, even if the power should vary a little over time.
- In the sensor housing is also a small microcontroller whose sole purpose is to listen for its address to be sent out from the on-shore station and then enable the clock signal to be transmitted.
- The frequency generated by this oscillator is not used inside the sensor but rather clocked out directly to the fiber cable at request using a microcontroller-enabled gate.
- This clock is not affected by latency or gateway delay as long as they are all constant.
- Then, the clock signal (in the range of hundreds of kilohertz) reaches the on-shore station; it is counted over a set time.
  - This time can be set by scientists at any time. The atomic reference clock controls the time.

How it works

Measuring temperature to a heigh degree of accuracy over a long time

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- Let us say we measured at 300Khz and measured each sensor for one minute.
- That is 18.000.000 counts, and we say that is 2 deg. Then, if the crystal changes only a few ppm pr. deg. C, the counter will see a very different number when the temperature changes. Also, one may count over a longer time to get a more accurate measurement.

- **As an example:**
- $\Delta f = f \times (\alpha \times (T - T_0) + \beta \times (T - T_0)^2)$
- At an actual temperature of 2° C and a reference temperature of 1° C, the frequency deviation of the 262.144 kHz crystal with α = 34.5 ppm and β = 0.018 ppm is approximately 9.05 Hz.
- That gives us an accuracy of approximately 0.002 deg. C over one minute. If you measure for two minutes, the accuracy will approach 0.001 deg. C. + some random noise.
- We can also achieve an accuracy of close to 0.1 deg. C in just one second.
- The oscillator always runs, so no warmup time is needed.

- The scientist can alter the calibration parameters for each sensor and the measuring method at any time from the on-shore station.

The advantage

Measuring temperature to a heigh degree of accuracy over a long time

- The sensor itself needs very few components, so its cost will be reasonable.
- The sensor itself can be made very small.
- The sensor's power consumption is in the range of milliwatts.
- Any number of repeaters can be used, as long as the delay created is constant.
- The drift over time for these sensor elements is very low.
- Only one on-shore station is needed.
- The on-shore station can use the GPS heartbeat or its own atomic clock as a reference.
- Scientists can change measuring methods over time.
  - They can measure fast normally, and then once a mount measures very slowly and accurately, as an example.
- The solution also describes a method that does NOT need a dark cable for sensing.
- It is possible to attach other sensors, like accurate pressure, to the same system.
  - For seabed surveillances etc.

Next step

Measuring temperature to a heigh degree of accuracy over a long time

- We are now in the process of producing some of these sensors so that we can start the qualification.

- As the sensing technology is quite known, we expect it to be a not-too-complicated job.

- Hopefully, we can do some of the testing together with Olaf Schjelderup and others.
  - There are still a few unknown we need to solve regarding the communication part.


Thank you for your time