Credit: DNV

Learning from the Experts Webinar Series

Remote Technology to Support Offshore Wind Operations and Maintenance

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August 7, 2024

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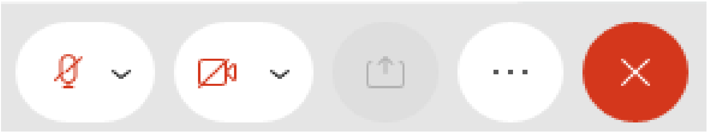
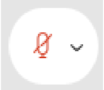


You'll see  **when your microphone is muted**

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Learning from the Experts

This webinar series is hosted by NYSERDA's offshore wind team and features experts in offshore wind technologies, development practices, and related research.

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WHEN TRUST MATTERS

Remote Technology to Support Offshore Wind Operations and Maintenance

Idalia Machuca
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07 August 2024

Agenda

Background

- Transitioning to Operations: The Future of U.S. Offshore Wind
- Overview of Key Offshore Wind Structures and Anticipated Wear
- Approaches to Inspection and Maintenance
- Motivation for Remote Technologies

Remote Technologies

- Overview of Remote Monitoring Methods
- Examples of Remote Technologies:
  Drones, Crawlers, Remotely Operated Vehicles (ROVs), Autonomous Underwater Vehicles (AUVs)
- Deployment Methods
- Examples of Capabilities and Applications
- Benefits: Safety, Operational Efficiency, Cost Efficiency
- Limitations: Technical and Operational Challenges
- Case Study of Recent Innovations: ROV Inspection at WindFloat Atlantic
- Ongoing Innovations and Future Direction

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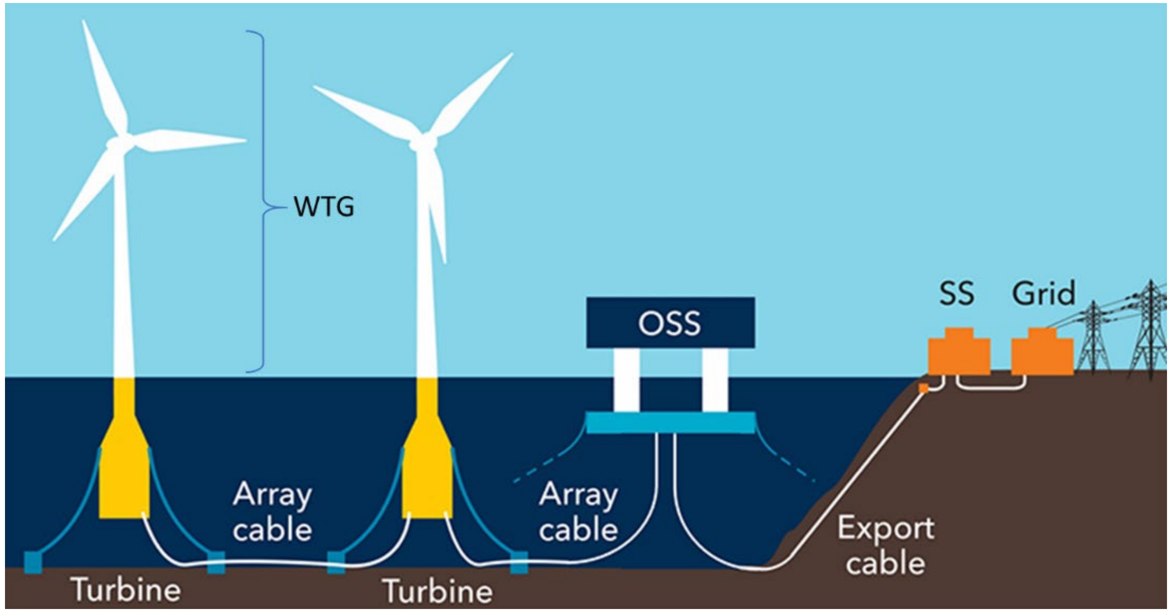
Background

Transitioning to Operations: The Future of U.S. Offshore Wind

Very Early Phase	Permitting & Concept Phase	Mid Phase	Construction Phase	Operational Phase

Offshore Wind Structures and Anticipated Wear

- While key offshore wind structures are designed to withstand various environmental conditions, gradual wear and tear is anticipated over time.
- Above water line: turbine rotor-nacelle-assembly (RNA), turbine tower, tower platform, transition piece, and above-water portion of offshore substations (OSS)
  - Anticipated changes: delamination, erosion, corrosion, cracking, lightning damage, loosening of bolts, ship impacts, etc.
- Below water line: foundations (fixed-bottom or floating), mooring systems (if floating), electrical cable systems, and below-water portion of OSS.
  - Anticipated changes: corrosion, chemical erosion (due to seawater), external degradation, surfacing from recommended burial depths (cables), loosening of bolts, premature rupture due to bending fatigue (moorings), etc.
- Regular inspections and maintenance support long-term durability and optimal performance.



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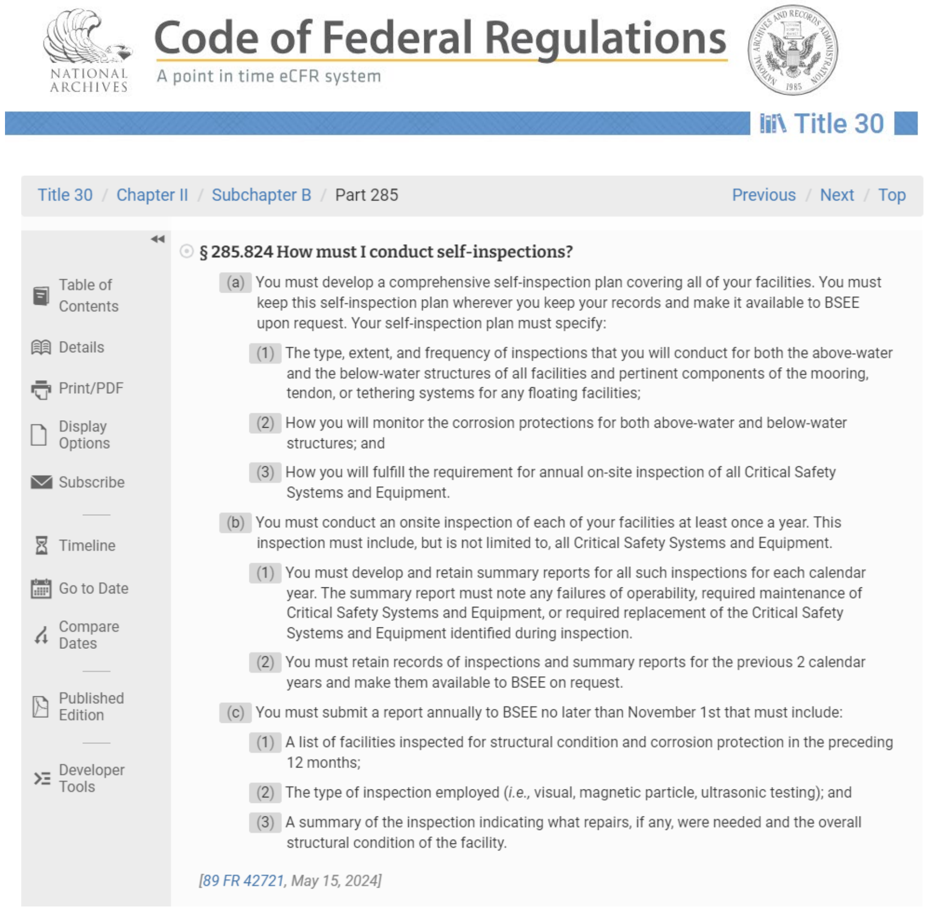
Approaches to Inspections and Maintenance

- Regulatory requirements: Inspections must comply with 30 CFR Part 285, which outlines procedures and obligations for renewable energy activities on the outer continental shelf.
- Industry documents (e.g., standards, recommended practices, service specifications) provide additional guidelines for specific systems.
- Approaches to inspecting and maintaining systems:
  - Prescriptive (periodic) approach: Scheduled servicing driven by regulatory guidelines or best practices.
  - Risk-based (condition-based) approach: Proactive servicing driven by real-time, continuous monitoring.
  - Standards may suggest either approach or a combination for certain systems.



§ 285.824 How must I conduct self-inspections?

(a) You must develop a comprehensive self-inspection plan covering all of your facilities. You must keep this self-inspection plan wherever you keep your records and make it available to BSEE upon request. Your self-inspection plan must specify:

(1) The type, extent, and frequency of inspections that you will conduct for both the above-water and the below-water structures of all facilities and pertinent components of the mooring, tendon, or tethering systems for any floating facilities;

(2) How you will monitor the corrosion protections for both above-water and below-water structures; and

(3) How you will fulfill the requirement for annual on-site inspection of all Critical Safety Systems and Equipment.

(b) You must conduct an onsite inspection of each of your facilities at least once a year. This inspection must include, but is not limited to, all Critical Safety Systems and Equipment.

(1) You must develop and retain summary reports for all such inspections for each calendar year. The summary report must note any failures of operability, required maintenance of Critical Safety Systems and Equipment, or required replacement of the Critical Safety Systems and Equipment identified during inspection.

(2) You must retain records of inspections and summary reports for the previous 2 calendar years and make them available to BSEE on request.

(c) You must submit a report annually to BSEE no later than November 1st that must include:

(1) A list of facilities inspected for structural condition and corrosion protection in the preceding 12 months;

(2) The type of inspection employed (*i.e.*, visual, magnetic particle, ultrasonic testing); and

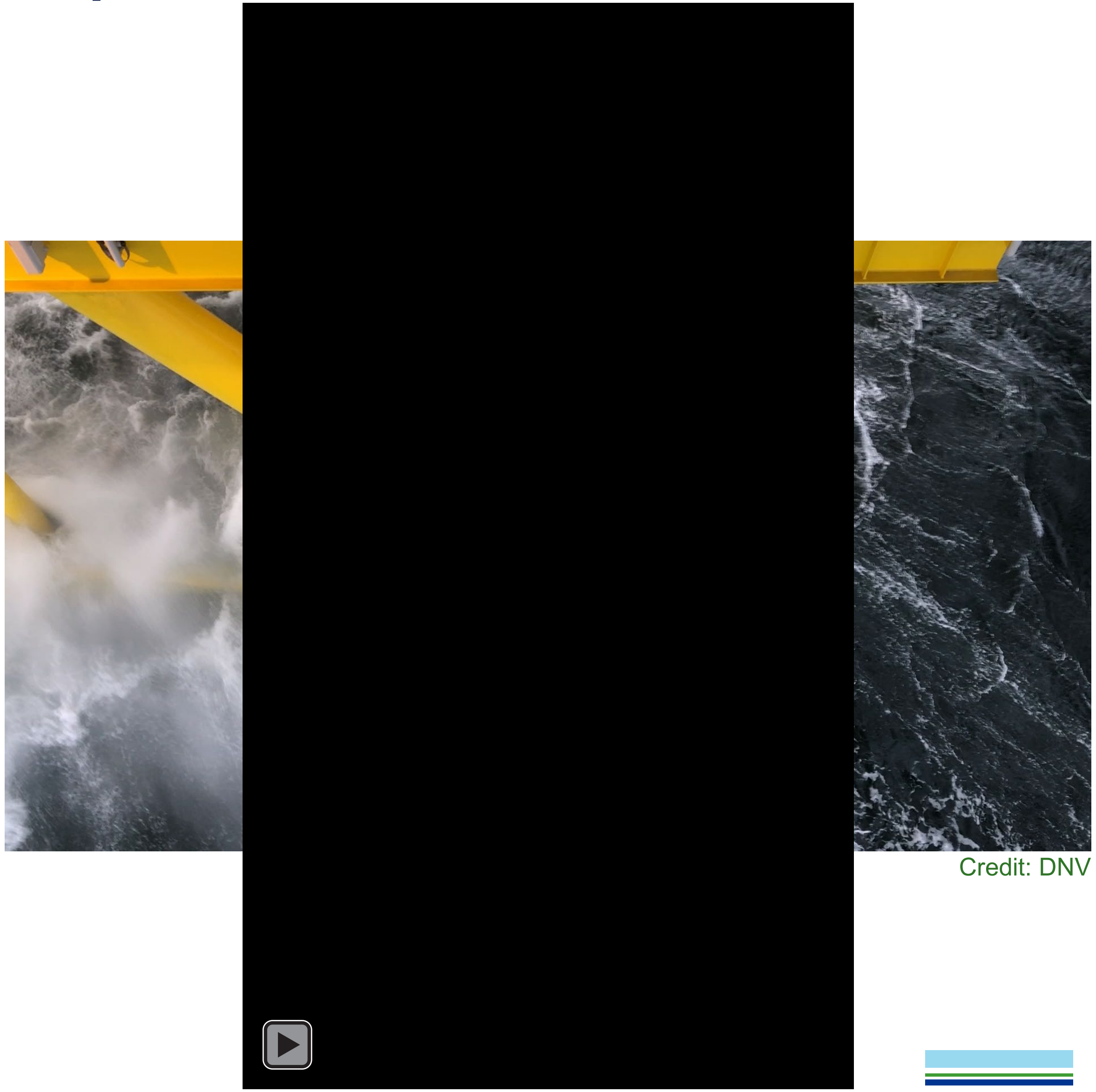
(3) A summary of the inspection indicating what repairs, if any, were needed and the overall structural condition of the facility.

[89 FR 42721, May 15, 2024]

https://www.ecfr.gov/current/title-30/chapter-II/subchapter-B/part-285

Motivation for Remote Techniques

- Regular inspections and maintenance are crucial to maintain the structural integrity and functional reliability of offshore wind structures, thus helping to prevent operational issues or disruptions.
- Traditional methods for monitoring and inspection come with inherent risks involving harsh weather conditions and accessibility challenges.
- Remote monitoring methods and remotely operated technologies may increasingly be used to support and enhance traditional practices, leading to safer and more efficient operations.
- Remote technologies can be employed in conjunction with continuous monitoring from condition monitoring systems (CMS).
- Remote technologies are also well suited to support inspections and minor repairs following extreme environmental scenarios (e.g., icing, extreme temperatures, storms, and seismic events).



Credit: DNV

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Remote Technologies in Offshore Wind

Remote Monitoring Methods

Monitoring Method	Description
Visual Inspection	Visual inspection of external surface to identify surface condition.
Radiographic Inspection	X-rays allow inspection of internal components made of materials through which X-rays can travel.
Ultrasonic Inspection	Ultrasonic waves transmitted into materials to detect internal flaws or characterize external surfaces as well as internal areas in metallic and non-metallic (e.g., composite) components.
Thermographic Inspection	A nonintrusive, usually non-contact inspection technique that involves measuring temperature. Can be used to get a point measurement or provide a contour map showing temperature variations over an area.
Infrared Thermography	A specific type of thermographic inspection that measures temperature differences to within 0.05 ° C. Provides a contour map showing temperature variations over an area, where thermal signatures may be caused by friction in structural cracks, or changes in air flow such as boundary layer turbulence over a blade.
Accelerometer	Measures vibrations, detecting specific frequencies related to structures (e.g., natural frequencies) and rotational components (e.g., gear mesh frequencies)
Acoustic Emissions	Measures acoustic signals from an elastic wave (20-1000 kHz) generated by rapid release of energy from within a material. Can be cracking or popping noises due to structural damage, or tonal signals due to air passing over a feature (e.g., on blade surface)
Microwave	Detects changes in dielectric constant of materials
Fiber Optics	Measures strain
Fiber Optics - Optical	Time domain reflectometry is used to identify anomalies in the fiber optic cable (embedded in subsea cable) along its length
Fiber Optics - Thermal	Distributed Temperature Measurement System (DTMS) uses the change in optical signal to determine the temperature of the fiber optic and therefore adjacent conductor/cable
Strain Gauges	Measure state of strain [stress] of a structure using a gauge attached to the structure
Digital Twin	Virtual model (software tool) designed to accurately reflect a physical system. The tool collects and processes various inspection data to represent the state of the components and predict their behavior.
Magnetic Flux Leakage	Magnetic field applied to external post-tensioned tendons, metallic cables, steel structures to detect location and extent of corrosion
Coupon Inspection	Small samples of materials that are exposed to the environment in operating equipment. They are removed at specified intervals and inspected to monitor structural/material integrity.

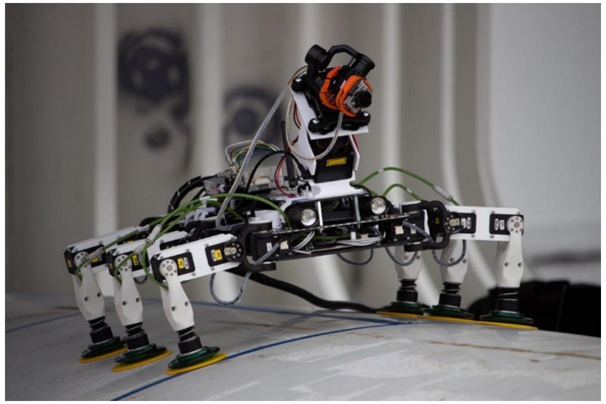
Examples of Remote Technologies in Offshore Wind

Credit: DNV

Drones (unmanned aerial vehicles) are aerial devices that operate without an on-board human pilot and can be controlled remotely by an operator. Drones can be equipped with sensors and cameras to conduct inspection, data collection, and minor repair tasks.

Credit: Image courtesy of Centre for Robotics & Intelligent Systems (CRIS) (https://cris.ie/)

Remotely Operated Vehicles (ROVs) are tethered underwater robots that can be controlled by an operator on a vessel and can be used to inspect and maintain subsea components. ROVs transmit real-time video and sensor data during underwater operations.



Credit: Image courtesy of BladeBUG (https://www.bladebug.co.uk/)

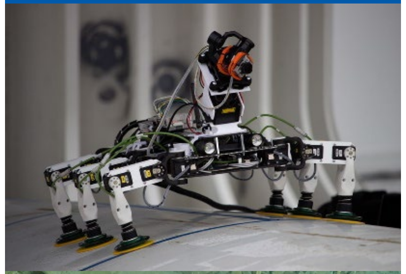
Crawlers are robotic devices equipped with wheels, tracks, or robotic legs and arms to facilitate movement across surfaces. Crawlers can conduct detailed, close-proximity inspections and maintenance tasks.

Credit: Image courtesy of the Bureau of Safety and Environmental Enforcement (BSEE). (https://commons.wikimedia.org/wiki/File:Undersea_Remote_Sensing_Research_(51842835224).jpg)

Autonomous Underwater Vehicles (AUVs) are untethered, self-propelled vehicles that can conduct underwater surveys without direct human intervention. They can perform seabed mapping, environmental monitoring, and inspection of underwater structures.

Deployment Methods of Remote Technologies

Drones
- Launched from Crew Transfer Vessels (CTV) or Service Operation Vessels (SOV)
- Launched directly from the nacelle or from inside the hub
- Operated remotely with real-time data transmission
- Use: inspect the condition of key external components that are above water, e.g., turbine blades, tower, connections to the transition piece, platform, ancillary structures above the water line

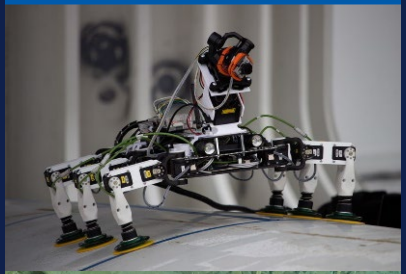


Crawlers
- Deployed from the hub (internal blade inspections) or from the tower base (external inspections)
- Lifted or lowered via rope from the nacelle
- Navigate autonomously or semi-autonomously, out of line of sight
- Use: inspect the condition of internal and external portions of key structures above the water line, e.g., the interior and exterior of blades

ROVs
- Tethered to a service vessel by cables that transmit commands and data between the device and operator and provide power to the vehicle
- Operated by technicians from the surface using cameras and sensors for navigation
- Well-suited for missions involving complex manipulation of the environment
- Use: inspect the condition of components below the water line and above the seabed, e.g., fixed or floating foundations, transition piece, subsea cables, mooring lines, anchors

AUVs
- Launched from service vessels or platforms
- Can operate independently using pre-programmed missions or be remotely controlled through updated instructions
- Store collected data on onboard computers and return to a predetermined location for data retrieval or charging
- Well-suited for long-term missions that do not require human intervention
- Use: collects data on environmental conditions and the condition of underwater structures

Capabilities of Remote Technologies



Drones
- Visual inspection – high-resolution cameras used to provide an aerial view of external structures from different angles to detect surface defects or structural deformations (e.g., cracks, dents, corrosion)
- Ultrasonic inspection – ultrasonic sensors used to inspect the integrity of blade structures, measure material thickness, and detect internal flaws
- Repairs – various tools for minor repairs on blade surfaces (e.g., fixing surface cracks, applying protective coatings)

Crawlers
- Visual inspection – high-resolution cameras used for close-proximity inspections of internal and external surfaces to detect structural defects
- Infrared thermography – infrared cameras to detect heat signatures and identify areas of overheating in electrical and mechanical components (e.g., insulation breakdown, electrical faults)
- Repairs – robotic arms and grippers for minor repairs (e.g., applying protective coatings, sealing cracks, tightening bolts)

ROVs
- Visual inspection – high-resolution cameras to capture videos of underwater structures (e.g., foundations, subsea cables)
- Environmental surveys – sensors to collect environmental data (e.g., water quality, chemical properties, physical oceanography, seabed conditions)
- Repairs – robotic arms and manipulators for handling objects, cutters for ropes and cables, cleaning brushes and water jet systems for cleaning tasks

AUVs
- Seabed surveys – sonar systems used for high-resolution mapping of the seabed to detect seabed changes (e.g., scouring, geological hazards, sediment stability)
- Environmental monitoring – sensors used to monitor environmental conditions
- Visual inspection – high-resolution cameras and sonar systems to inspect underwater structures (e.g., foundations and subsea cables) for physical damage, corrosion, scouring, and marine growth

Benefits of Remote Technologies

Enhanced Safety

Minimizing safety risks to personnel from exposure to harsh weather and potentially hazardous environments.

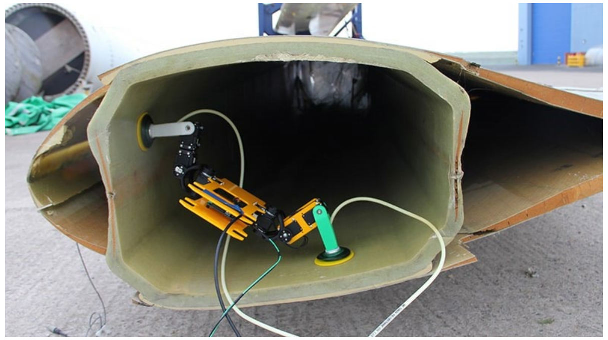
- Drones can perform aerial inspections of exterior structures, eliminating the need for technicians to work at heights and rappel down structures.
- Crawlers can be equipped with sensors and tools to handle hazardous materials or to operate in confined spaces.
- AUVs and ROVs can conduct underwater inspections of subsea components in harsh marine conditions (e.g., strong currents, low visibility) and deep waters that would otherwise be inaccessible or dangerous to divers.

Improved Accessibility

Enabling inspections and maintenance tasks in difficult or impossible-to-reach places.

- Drones can access high and difficult-to-reach areas, such as the top of wind turbine towers and blades without requiring rope access by personnel.
- Crawlers can manoeuvre through confined spaces, such as the interior of blades and nacelles, and complex surfaces.
- AUVs and ROVs can operate at great depths and in hazardous marine environments that would be difficult or dangerous to reach by divers.

BladeBUG robot operating at heights.
Credit: Image courtesy of BladeBUG (https://www.bladebug.co.uk/)



BladeBUG robot operating in confined spaces.
Credit: Image courtesy of BladeBUG (https://www.bladebug.co.uk/)

Benefits of Remote Technologies

Improved Operational Efficiency

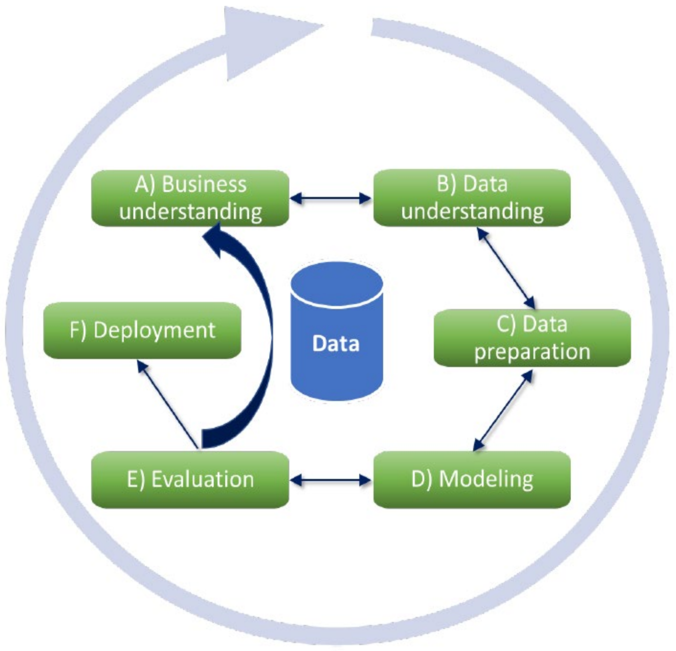
Enabling continuous, real-time monitoring and maintenance through immediate or long-term deployment.

- Drones can be launched from vessels or directly from the turbine nacelle for immediate inspections over large areas.
- Crawlers can provide detailed and comprehensive coverage of the condition of both internal and external components.
- AUVs can operate independently, allowing for continuous underwater surveys over extended periods of time.
- ROVs provide real-time video and data feeds, enabling precise underwater operations.

Improved Data Accuracy

Collecting precise and detailed data that can be used to support decision-making for maintenance and repairs.

- Drones and crawlers can collect high-resolution data through various sensors and tools and perform predefined inspection routines with consistency and repeatability.
- AUVs can perform precise data collection and mapping following pre-programmed paths, depths, and speeds for uniform data collection.
- ROVs offer stability in underwater environments for more reliable and accurate data collection.



Cross-industry standard process for data science
https://www.datascience-pm.com/crisp-dm-2/

Benefits of Remote Technologies

Supports Proactive Maintenance

Enabling early detection of issues through continuous monitoring and regular maintenance, thereby preventing critical disruptions (condition-based approach).

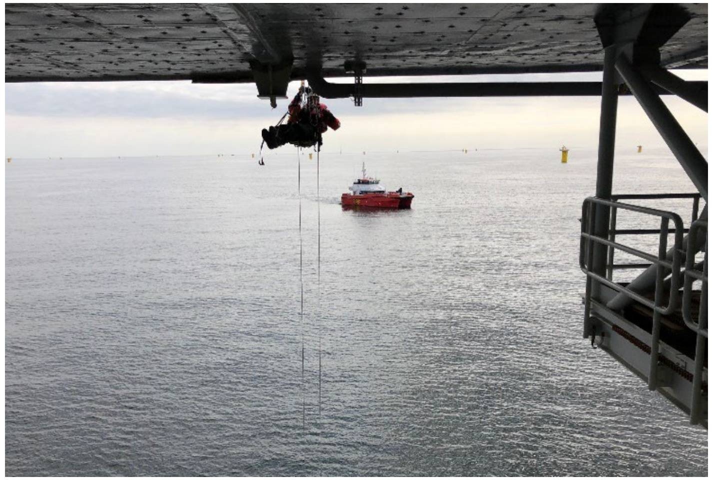
- Drones and crawlers can perform routine inspections of external and internal structural conditions, detect damage early, and perform minor repairs.
- AUVs can conduct frequent surveys of the seafloor and underwater assets, identifying sediment movement and potential risks to infrastructure.
- ROVs collect real-time data on the condition of assets and can be equipped with tools to perform minor repairs.

Improved Cost Efficiency

Minimizing the costs associated with operational downtime.

Remote technologies can support precise, rapid, and consistent inspection tasks that help to identify issues before they become critical, thereby facilitating timely intervention and preventing costly disruptions.

- Drones are reported to reduce inspection costs by 35% to 80% through quick and efficient aerial surveys.
- Crawlers can perform detailed and frequent inspections without the need for extensive setup or support infrastructure, simplifying operational logistics.
- AUVs can conduct extensive underwater surveys and inspections autonomously, reducing the need for costly ship-based operations.



Credit: DNV

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Limitations of Remote Technologies

Technical Limitations

Current technologies may still require significant human oversight and control, with potential for technical issues.

- Drones have limited battery life, restricting flight duration and distance coverage.
- Crawlers may face challenges in navigating rough, uneven, or slippery surfaces.
- AUVs have limited battery life, which constrains the duration of underwater missions.
- ROVs: Tethered operations can limit range and manoeuvrability.

Weather Sensitivity

Operations can be affected by extreme weather conditions.

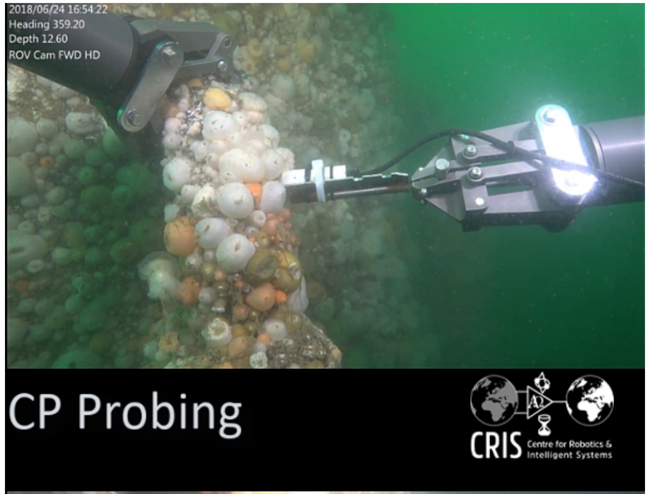
- Drones: High winds, extreme temperature, and moisture can affect battery performance or affect electronic components.
- Crawlers: Slippery surfaces can affect crawler stability.
- ROVs: Poor visibility due to turbulent marine conditions or strong underwater currents can hinder camera and sensor performance and make it difficult for ROVs to perform precise tasks.
- AUVs: Rough sea conditions can complicate deployment and recovery operations and affect stability of AUV during missions.

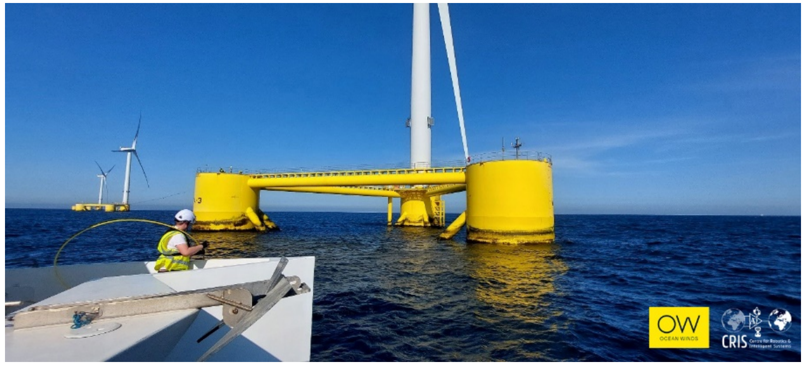
Regulatory Gaps

The regulatory landscape for remote technologies is still evolving to accommodate their expanding applications.

- In the U.S., drones under 55 pounds flown for commercial purposes are regulated by the Federal Aviation Administration (FAA) and are required to be flown by certified pilots.
- There is generally little regulatory framework for unmanned underwater vessels (ROVs, AUVs), though every vessel must obey International or Federal navigation rules preventing collisions at sea.

Case Study: ROV Inspection at WindFloat Atlantic





Recent Industry Milestone

The Centre for Robotics & Intelligent Systems (CRIS) at the University of Limerick successfully tested an ROV at WindFloat Atlantic for inspection purposes.

July 31, 2024
https://www.offshorewind.biz/2024/07/31/robotic-solution-for-floating-wind-farm-inspection-tested-at-windfloat-atlantic

Images courtesy of the Centre for Robotics & Intelligent Systems (CRIS) at the University of Limerick: https://cris.ie/

Case Study: ROV Inspection at WindFloat Atlantic

Inspection of the Semi-submersible Offshore Wind Farm - OW WindFloat Atlantic

Jul 29, 2024
https://www.youtube.com/watch?v=5OjUmzOz6dY

Ongoing Innovations in Remote Technologies

Digital Twins - Offshore Wind Turbines
Credit: DNV

- Current status: Some remote technologies are commercially available, while others are in various stages of development, from initial grant funding to near commercialization and prototype demonstration in offshore testing facilities.
- Digital innovations underway:
  - Data collection, processing, storage, and security
  - Machine learning
  - Artificial intelligence
  - Virtual reality
  - Data-driven modeling
  - Digital twins
- Data collection sources:
  - In-person inspections
  - Condition monitoring systems
  - Asset design and construction information
  - Environmental surveys

Thank you!

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