Wind Turbine Radar Interference Mitigation Working Group

Annual Progress Update for 2024

WIND TURBINE RADAR INTERFERENCE MITIGATION (WTRIM) ANNUAL PROGRESS UPDATE FOR 2024

INTRODUCTION

The Memorandum of Agreement (MOA), by which the efforts of the Wind Turbine Radar Interference Mitigation Working Group (WTRIM WG) are organized, requires the Executive Steering Group (ESG) to provide a yearly progress update at the end of each calendar year. This document includes a brief description of the major projects undertaken by the WTRIM WG for calendar year 2024 categorized under the three strategic themes as detailed in the updated *Federal Interagency WTRIM Strategy*.

In 2024, significant advancements were made in evaluation and mitigation of impacts of electricity-generating wind energy installations on sensitive radar systems, primarily through various collaborative projects funded by the WTRIM Working Group agencies. The U.S. Wind Turbine Database surpassed 20 million views, providing crucial data on wind turbine locations and specifications, while ongoing cumulative impact analyses and wind impact assessments focused on understanding the spatial overlap of wind energy potential with radar line-of-sight. Notable projects began in 2024 including the Wind Impact Assessment to Radar (WIAR), which seeks to assess offshore wind impacts on U.S. Navy and U.S. Coast Guard (USCG) radar systems, and the Federal Aviation Administration's (FAA's) Airspace Non-cooperative Surveillance Radar (ANSR) program aimed to modernize non-cooperative surveillance systems. Outreach activities engaged industry stakeholders to address radar interference challenges. Additionally, a Department of Energy (DOE) Request for Information (RFI) sought input on the most current mitigation technologies available and commercialization strategies, reflecting a comprehensive approach to balancing wind energy development with radar operational integrity.

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2024 MAJOR TASKS AND ACCOMPLISHMENTS

Theme 1: Improving the capacity of government and industry to evaluate the impacts of existing and planned wind energy installations on sensitive radar systems.

U.S. Wind Turbine Database

Funding organization: Department of Energy (DOE), U.S. Geological Survey (USGS), and American Clean Power Association (ACP)

Background: The U.S. Wind Turbine Database (USWTDB; https://eerscmap.usgs.gov/uswtdb) provides the locations of land-based and offshore wind turbines in the United States, corresponding wind project information, and turbine technical specifications. It is a continuously updated geo-rectified set of coordinates and characteristics of the wind turbine fleet of installed onshore and offshore wind turbines. In addition to what is available to the public on the website, the USWTDB team prepares custom datasets for WTRIM members of turbines under construction or in advanced development for both onshore and offshore locations. These data are used to determine likely future cumulative impacts of turbines in certain geographies.

Status: The USWTDB viewer surpassed 20 million views in 2024 with a steady rate over time of roughly 300,000 views per month. 8% of the 2023–2024 views are from .gov including the National Oceanic & Atmospheric Administration (NOAA), DOE, U.S. Department of Agriculture (USDA), FAA, and national labs. Roughly 0.5% are from .mil origins including the US Armed Forces and the Secretary of Defense. Other large users include: .edu users including major colleges and universities and K–12 schools across the US; .st users including state governments; and, finally, developers, equipment manufacturers, utilities, and members of the public. In 2024, the team issued a major interface update to allow USWTDB online users to perform data summary calculations, screening and year-by-year changes of key turbine and project features, which are viewed in graphical format based on whichever turbines are showing in the viewer. Next year, in addition to quarterly updates, Lawrence Berkeley National Laboratory will survey subsets of users to better understand use cases.

Cumulative Impact Analysis

Funding organization: DOE

Background: This effort is a high-level analysis to quantify the amount of wind energy potential that is spatially coincident with defense and weather radar line-of-sight. In addition, this effort seeks to understand the potential for radar line-of-sight to be blocked by future wind energy development under a suite of scenarios. The project team will examine data sources and methods to determine if either needs to be refreshed or updated, given these were last visited in 2019.

Status: Massachusetts Institute of Technology's Lincoln Laboratory (MIT LL) worked closely with the National Renewable Energy Laboratory (NREL) to understand the potential wind growth scenarios that were used to assess the scale of likely impact of wind turbines to Air Route Surveillance Radar (ARSR-4) systems and to compare against the latest North American Aerospace Defense Command (NORAD) Areas-of-Concern (AOC) list. MIT LL's analysis shows a good agreement with NORAD's current AOC list. It was found that for the NREL projected 2050 wind turbine buildout there are a few new radar sites that will be significantly impacted. Combinations of several mitigation options that MIT LL examined show the best promise for minimizing the impact.

Wind Impact Assessment to Radar

Funding organization: Department of Defense (DOD)

Background: Emerging offshore wind development in coastal United States waters will impact DOD and USCG operating areas in various ways. The Wind Impact Assessment to Radar (WIAR) is focused specifically on understanding and mitigating potential offshore wind interference effects to U.S. Navy and USCG radar systems. The objective of the WIAR project is to conduct a baseline assessment of impacts to currently fielded airborne and shipboard systems from offshore wind farms on a scale that currently exists only in other parts of the world but is anticipated to be in place in the next few years along the East Coast of the United States.

Status: In 2024, the WIAR team held a multi-organization stakeholder kickoff meeting to identify highest-priority mobile USN and USCG radar systems and to establish technical and operational points of contact. The team also initiated coordination with fleet operators and United Kingdom partners for data collection events in 2025. In addition, the team has begun the process of organizing for and developing plans for ancillary collection of data using targets of opportunity, as ships and aircraft pass wind farms in the North Sea area during routine transit.

Impacts of Wind Turbines on Airborne Surface Surveillance Radar Systems

Funding organization: DOD

Background: This project seeks to understand the impacts and identify mitigations of wind turbines to airborne surface surveillance radars critical for safe range clearance of offshore weapons test areas.

Status: In 2024, the project team completed the Phase I effort on the modeling, simulation, and assessment of the operational performance of radars of interest at detecting sea vessels within proximity of wind turbines of various sizes and placements amongst various sea states. Phase II will focus on refining the project area and developing mitigation solutions that overcome predicted limitations to radar performance to gain and maintain awareness of surface vessel traffic as well as ensure safe operations in the test area.

Underwater Acoustic Impacts of Offshore Wind

Funding organization: DOD

Background: This project seeks to evaluate impacts of wind turbine-generated underwater acoustic noise on DOD assets, operations, and capabilities.

Status: In 2024, the team mapped locations and characteristics of current and planned turbine arrays, along with noise characteristics and noise fields of wind farm arrays relative to military operating areas. The team is continuing to examine the impact of noise fields on military acoustic sensor performance.

Theme 2: Developing and facilitating the deployment of hardware and software mitigation measures to increase the resilience of existing radar systems to wind turbines.

Implementation of In-phase & Quadrature (IQ) Range-azimuth Gating (RAG) Map Algorithm

Funding organization: DOE

Background: The collection of algorithms which control the Airport Surveillance Radar Model 11's (ASR-11) Constant False Alarm Rate (CFAR) adaptive thresholds were not designed to work in the presence of wind turbine clutter. A study was undertaken by the FAA to reduce the impact of wind

turbine interference to the CFAR thresholds. The results from the study show that the enhancements will improve target tracking capabilities. These enhancements will be implemented into the ASR-11 system and validated.

Status: In 2024, the FAA conducted a test event in Abilene, Texas for the purpose of verifying the installation of the IQ RAG Map, gathering data, gauging the performance of the algorithm in the presence of wind turbines, and validating the usage of offline tools for remote optimization. Future work will include a full performance analysis to adjust the IQ RAG Map algorithm and to adjust other radar functionality to make better use of the IQ RAG Map.

MIT LL ASR/ARSR Multi-static Project

Funding organization: DOD

Background: This project seeks to enhance the capabilities of existing air surveillance radar systems by deploying multiple receivers around regions of high-priority airspace to improve sensitivity for small targets, to increase resolution, and to reject ground clutter from wind turbines and other sources.

Status: In 2024, efforts focused on data collection near a wind farm in Burlington, Vermont using target of opportunity aircraft. Following the test collection and resulting data analysis, efforts will focus on developing real-time operating capabilities for the signal processing code, data fusion and tracking methodologies with multiple receivers, and approaches for system integration with the primary transmit radar.

Wind Turbine Interference Mitigation via Adaptive Nulling Feasibility Study

Funding organization: DOD

Background: Analyze potential and value of replacing Air Route Surveillance Radar Model 4 (ARSR-4) components to improve the ability of the radar to detect targets above wind turbines.

Status: 2024 actions included general project planning, identifying, and securing appropriate datasets, developing test plan and supporting capabilities to demonstrate fixed beamforming.

Wind Turbine Interference Mitigation Modeling & Analysis – Phase II

Funding organization: DOD

Background: Quantitatively assess the impact of wind turbines on ground-based radars and investigate potential mitigation approaches that leverage machine learning or other novel signal processing approaches.

Status: In 2024, the project team completed initial collection of a wind turbine computer-aided design model, ASR-11 parameters & signal processing chain, and typical wind turbine installation parameters. The team also developed a high-fidelity in-motion radar scattering model of a wind turbine at selected frequencies, aspect models, and rotation rates. Finally, a high-fidelity simulation environment was developed that is capable of emulating ASR-11 data containing radar returns from clutter, thermal noise, targets, and wind turbines.

Wind Turbine Interference Mitigation via Adaptive Beam Steering ("Sidekick") – Phase II

Funding organization: DOD

Background: Develop and provide a technical mitigation solution using higher radar sample rates and multiple beam processing to minimize impacts on Airport Surveillance Radar (ASR) systems from wind farm installations.

Status: 2024 efforts included upgraded radar receiver to operate at the frequencies used by ASRs. This includes radio hardware and firmware. Planning is underway for data collection with instrumented test aircraft in early 2025.

Theme 3: Encouraging the development of next-generation radar systems that are resistant to wind turbine radar interference.

FAA ANSR Program

Funding organization: FAA

Background: The Airspace Non-cooperative Surveillance Radar (ANSR) Program seeks to develop and deploy a modern technology capability for current but aged non-cooperative terminal surveillance systems (ASR-8, ASR-9, ASR-11) in the National Airspace System (NAS). Non-cooperative surveillance will continue to be an integral part of the NAS to detect aircraft not equipped with either an Automatic Dependent Surveillance-Broadcast (ADS-B) or radar beacon transponder, provide service resiliency, and provide air traffic control with precipitation and advisory 6- level weather information. The ANSR program will analyze and acquire the long-term solution to meet the FAA's terminal non-cooperative surveillance service requirements.

Status: ANSR reached its first FAA process milestone looking at alternatives in September. The next step is the FAA Initial Investment Decision process where the preferred alternative is presented.

Outreach & Engagement Activities

To carry out the wide array of activities noted above, the WTRIM WG team maintained a full slate of internal core collaboration activities (bi-monthly teleconferences, sub-committee meetings, quarterly meetings, etc.) and supported a series of interagency and industry outreach and engagement activities. The WTRIM second quarter in-person meeting held in Norman, Oklahoma featured a Technical Interchange Meeting with experts on weather radar systems. During the WTRIM fourth quarter meeting, the American Clean Power Association was invited to speak about the industry's perspectives on offshore wind development and radar interference issues.

DOE RFI regarding Challenges and Opportunities at the Interface of Wind Energy and Radar Technology

On November 7, 2023, the Department of Energy's Wind Energy Technologies Office issued an RFI that sought information and input on:

- Siting challenges of wind energy developers related to radar interference;
- Potential mitigation technologies at the radar and/or turbine level that currently exist or are in development to address wind turbine-radar interference;
- Commercialization and market adoption of wind-radar interference mitigation measures, and what obstacles need to be overcome to accelerate commercialization and maximize adoption;
- Bipartisan Infrastructure Law Provisions and Requirement and Buy America Requirements; and
- Effective solicitation process, Funding Opportunity Announcement (FOA) structure, and implementation strategies to enable the commercialization and market adoption of wind-radar interference mitigation measures.

Responses from the RFI were received in early 2024 from research institutions such as federally funded research and development companies, universities, non-profits, wind turbine

manufacturers, wind farm developers and consultants, radar manufacturers, radar operators, and radar modeling and simulation companies. Responses varied from simple email replies to detailed mitigation techniques and general recommendations for the WTRIM WG.

DOE Wind Energy Technologies Office Peer Review

In July of 2024 the Department of Energy's Wind Energy Technologies Office conducted its Peer Review of projects that it funds. The FAA, Sandia National Laboratories, and MIT LL presented overviews of their projects from fiscal years 2022 and 2023.

2025 WTRIM Working Group Objectives

In 2025, the WTRIM WG will continue to cooperate and coordinate to advance near- (5 years), mid- (10 years), and long-term (20 years) mitigations. Consistent with the activities specified in the Federal Interagency WTRIM Strategy and the MOA, the WTRIM WG will focus on the following list of objectives:

- Continue to support development and execution of technical analyses to identify, characterize, and mitigate impacts of wind turbines on member Agency capabilities and mission areas.
    - Increase focus of technical analyses to potential offshore wind impacts to Federal agencies and the public equities they support.
    - Support testing and evaluation activities related to WTRIM and Federally-funded studies.
- Continue to support the efforts to mature and deploy mitigation capabilities through field testing and analysis.
- Continue to identify issues related to offshore wind energy deployment.
- Continue to address concerns associated with impacts to oceanographic and meteorological weather radars.

For more information on this topic, please visit the following websites:

U.S. Department of Defense Military Aviation and Installation Assurance Siting Clearinghouse
https://www.dodclearinghouse.osd.mil/

U.S. Department of Energy Wind Program
https://www.energy.gov/eere/wind/mitigating-wind-turbine-radar-interference

Federal Aviation Administration Obstruction Evaluation / Airport Airspace Analysis
https://oeaaa.faa.gov/oeaaa/external/portal.jsp

Bureau of Ocean Energy Management
https://www.boem.gov/renewable-energy

National Oceanic and Atmospheric Administration Radar Operations Center
https://www.roc.noaa.gov/wsr-88D-program.php

National Oceanic and Atmospheric Administration Integrated Ocean Observing System
https://ioos.noaa.gov

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