Wind Turbine Radar Interference Mitigation Working Group

Annual Progress Report for 2023

WIND TURBINE RADAR INTERFERENCE MITIGATION (WTRIM) ANNUAL PROGRESS REPORT FOR 2023

I. INTRODUCTION

In 2023, the WTRIM WG executed the updated Memorandum of Agreement (MOA), by which the efforts of the Wind Turbine Radar Interference Mitigation Working Group (WTRIM WG) are organized. Signatory members of the MOA include the Department of Energy (DOE), the Department of Defense (DOD), the Federal Aviation Administration (FAA), the National Oceanic and Atmospheric Administration (NOAA), and the Bureau of Ocean Energy Management (BOEM). The Department of Homeland Security (DHS) is an observer of the WTRIM WG. The MOA requires that a yearly progress report be prepared by the Executive Steering Group (ESG) 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 2023 categorized under the three strategic themes as detailed in the updated *Federal Interagency WTRIM Strategy*.

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II. 2023 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.

Federal WTRIM Strategy Update

Funding organization: DOE

Background: This strategy document elaborates on and serves as the action plan for the Memorandum of Agreement for the Wind Turbine Radar-Interference Mitigation Working Group. DOE developed this strategy and coordinated it with the other memorandum signatories. DOE has been responsible for developing a strategy in coordination with signatory partners of the Wind Turbine Radar Interference Mitigation Working Group. In response to this requirement, DOE developed this strategy and coordinated it with the other memorandum signatories.

Status: This strategy document elaborates on and serves as the follow-on action plan to the Federal Interagency Wind Turbine Radar Interference Mitigation Strategy published in 2016.

While work on terminal radars and long-range radar has come a long way since 2016, with the addition of offshore and weather radar systems to the WTRIM WG's responsibilities, the timeline to accomplish the objectives of the 2016 strategy was extended to 2035 based on the technology available and tested to date. These objectives, reiterated in this updated strategy, continue to be pursued through collaboration and coordination amongst WTRIM WG agencies, with an added focus on coastal surface radar and weather radar systems.

U.S. Wind Turbine Database

Funding organization: DOE, USGS, and 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 14 million views in 2023 with a steady rate over time of roughly 250,000 views per month. 8% of the 2022-2023 views are from .gov including NOAA, DOE, USDA 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; .state users including state governments; and, finally, developers, OEMs, utilities, and members of the public. This year we scoped the release of the growing number of decommissioned turbines that are removed from the dataset each year. Those data will be released to the public in FY24. Next year, in additional to our quarterly updates, we plan to survey subsets of users to better understand use cases. No major changes are planned for the USWTDB site.

ROTHR Graphical User Interface

Funding organization: DOD

Background: Developing models for wind turbine interference impacts on unique DoD radar systems, particularly the Navy's Relocatable Over-The-Horizon Radar (ROTHR). The Primary purpose of this program is 1) determining the impact of wind turbine farms on over-the-horizon

radar systems; and 2) improving the capacity of government and industry to evaluate the impacts of existing and planned wind energy installations on sensitive radar systems.

Status: MIT LL delivered a Graphical User Interface (GUI) update for the Texas ROTHR that included an automated propagation code to allow modeling of turbines over variable terrain and an updated 5 wire model for land parameters. MIT LL also optimized solar farm design to increase square footage without increasing the estimated level of wind turbine interference observed at ROTHR, analyzed additional test cases provided by developer, and developed automated code to evaluate new solar farms. MIT LL provided feedback on whether newly proposed wind and solar farms are likely to cause interference to ROTHR and require further modeling.

FY24 Project plans are to deliver a Solar Farm Update to ROTHR Wind Turbine Interference Simulation GUI, deliver Offshore Wind Farm Update to ROTHR Wind Turbine Interference Simulation GUI, and perform Saturation Analysis of Solar Farm Inverters. The analysis will study how many solar farm inverters at various ranges from the ROTHR receive site it will take to raise the ROTHR noise floor.

NEXRAD Public Screening Tool

Funding organization: DOE

Background: The NEXRAD Public Screening Tool enables wind developers to obtain a preliminary review of potential impacts to weather radar systems prior to an official filing with the OE/AAA. The tool is an online GIS-enabled site that includes the U.S. Wind Turbine Database.

Status: After being mothballed for some time, Sandia reopened the NEXRAD Public Screening Tool and tested the functionality of the current version and updated where needed. Sandia converted the map data to a server-compatible geoserver series of ESRI shapefiles for the NEXRAD viewshed layers. The tool is currently in a state ready to deploy. Sandia has encountered some internal challenges with hosting the tool on the public site and is working with the Sandia IT team to address these challenges.

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

FAA Infill Radar Certification

Funding organization: FAA

Background: The Travis Air Force Base Pilot Mitigation Project deployed and operated two infill radars to cover the Wind Resource Area (WRA) south of Travis AFB. The project integrated the infill radars with the local radar into the STARS G1 platform, collected data for radar and STARS system performance over the WRA, and explored STARS operations and resulting screen display for air traffic controllers. After the completion of this project, the FAA took the next steps to explore a process to validate the use of infill radars.

The FAA and the Air Force defined processes and developed a Concept of Operations, Requirements, and Test Plan with the goal of moving infill radars as a mitigation to wind turbine interference forward.

Status: The FAA and AFFSA completed their first reimbursable agreement in February 2022. The following deliverables were completed and submitted to the Air Force:

1. Concept of Operations for Wind Turbine Radar Clutter Mitigation
2. Infill Radar Qualification Requirements Document
3. Test Plan for the Infill Radar Project

4. Potential Certification Process for an Infill Radar

Data collections with C Speed infill radars indicated an issue with target detections for a single infill radar and AFFSA requested that the FAA address a multiple sensor feed of infill radar to STARS. The FAA was working on a second reimbursable agreement (RA) with AFFSA that included an Operational Capability Demonstration for the multi-sensor infill radar system that will collect data and refine radar merge draft requirements. This second RA was discontinued because the FAA decided any infill radar would need to go through FAA Federal Acquisition Process for deployment in the NAS and there was no viable infill radar available.

MIT LL ASR/ARSR Multi-static Project

Funding organization: DOD

Background: Lincoln Laboratory is continuing to develop novel, low-cost receivers 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 FY23, MIT LL researchers focused their efforts on improving the system performance of individual receivers while scaling from a single fieldable unit to multiple receiver systems. A key accomplishment was the design and testing of a new, multi-channel antenna with improved beam steering and nulling capabilities. GPS timing circuits were also developed and incorporated to properly improve timing synchronization between each of the receivers within the overall system, a functionality that is critical as the system scales in the number of individual receivers. Additionally, the receiver signal processing code was completely overhauled to an object-oriented approach which is more modular, flexible, and eases future scalability. Four complete receiver systems have been built, undergone laboratory unit testing, and taken to Burlington, VT to collect data from the ASR-11 operating in the area and benchmark system performance against aircraft targets of opportunity.

Upcoming FY24 efforts will concentrate initially on conducting a data collection campaign utilizing multiple receivers near the Abilene, TX ASR-11. 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.

Software Tools for the Mitigation of Wind Turbine Interference in the U.S. IOOS Network

Funding organization: NOAA IOOS and BOEM

Background: This project will develop and field test software-based mitigation of offshore wind turbine interference for oceanographic high-frequency radar (HFR) surface current and wave sensors. Building on initial mitigation research efforts by HFR manufacturer CODAR Ocean Sensors that were funded by the Bureau of Ocean Energy Management, this project will conduct the necessary system integration, testing, validation, and verification needed for operational capacity. In addition, this project will: collect wind turbine interference data using a range of HFR systems; develop a focused dataset of simulated, hybrid, and observed wind turbine interference to test mitigation; document operational changes of the networked IOOS HFR systems that will increase the accuracy of mitigation methods; and conduct a full scale, in situ validation of mitigation methods at the first major U.S. offshore wind farm.

Status: The BOEM-funded SeaSonde® WTRIM Software Project was completed. Results of this project are:

1. Developed a tool to realistically simulate offshore WTI on coastal HFRs, so the efficacy of WTRIM methods can be tested before wind farms are installed.
2. Determined the best settings for a SeaSonde® to use when a wind farm is within field-of-view.
3. Implement a real-time software solution for WTRIM.

These methods together reduced wind turbine interference by 86.4% at the Block Island wind farm. However, offshore turbines that are currently under consideration are larger than those at Block Island and will generally have lower RPMs worsening the interference, will be spaced more widely which will reduce the number of turbines within a single HFR range cell, and will be placed farther offshore making more difficult to identify and remove interference. The NOAA IOOS OTT Project will be intentionally delayed with a no-cost extension to wait for the operation of larger offshore wind farms in the U.S. before the field test are done.

FAA CFAR Processing Enhancements

Funding organization: DOE

Background: The collection of algorithms which control ASR-11 Constant False Alarm Rate (CFAR) adaptive thresholds can be ineffective in the presence of wind turbine clutter. They can reduce detection of aircraft near turbines due to elevated lead/lag thresholds and elevated clutter map levels. The project goal is to investigate enhancements to these algorithms. Each potential enhancement will be developed and evaluated using the ASR-11 simulator. Algorithms which prove beneficial will become candidates for integration into a future ASR-11 software release.

Status: The FAA has reviewed the theory behind the CFAR process utilized in the ASR-11 with new test points in the ASR-11 simulator. Based on those findings, modules of the radar source code have been modified to introduce a RAG map early into the data processing chain. This allows for the removal of wind turbine interference from the Target Clutter Map and CFAR process.

Note: This project will be moving forward into FY24. The adaptable process will be ported to the ASR-11 system itself and tested. Once that is done, then it will be incorporated into the next ASR-11 release build. More than likely Build 16.

FAA Clutter Map Enhancements per Doppler Filter

Funding organization: DOE

Background: ASR-11 Software Build 12 introduced the ability to create clutter maps for each Doppler Filter along with parameters to adjust behavior. This feature is not widely used because the benefits in a normal clutter environment and in the presence of wind farms has not been investigated fully. Because wind farm interference primarily occurs via contamination of the Doppler Filters, this feature has potential to mitigate WTRI. The ASR-11 simulator provides the capability to optimize this mitigation approach.

Status: The FAA has reviewed all the parameters required to utilize the Clutter Map per Doppler Filter process. A plan was implemented using the ASR-11 simulator to generate test runs with different parameter values to assess any patterns/behaviors that will benefit a 2nd Level ASR-11 Engineering optimizer. The ASR-11 simulator was modified to allow for test point data to be utilized for this effort to see how the maps update every scan. Results were gathered and put into the optimization procedures that exist for the Clutter Map per Doppler Filter process.

FAA Investigation into Binary Integration Mode for CARSR

Funding organization: DOE

Background: During porting of CARSR WTRIM algorithms to ASR-11, the FAA found code for a 'Binary Integration Mode'. It was later determined that the CARSR did not use that code (dead) and it was removed from the ASR-11 implementation. While this code led to a large number of cluster validation errors, the results when it was in use appeared better than final project results. This project will revisit the binary integrator mode through a review of old data and restoring the code to produce further test runs.

Status: The FAA has re-evaluated the work done with the previous iteration of the ASR-11 simulator that utilized the SDTS algorithm (from the CARSR group). The simulator was reverted to the previous state and the algorithm was cleaned up. With new test runs, results with this updated simulator did not show any benefit. Work was halted on this project due to the failure to produce improved performance.

FAA ASR-11 Simulator Updates

Funding organization: DOE

Background: The ASR-11 simulator development was paused at the point where the CARSR feasibility investigation and simulation could be conducted. This project would complete development ASR-11 simulator features in support of new enhancement investigations. It will also update the simulator to Software Build 14 which will allow evaluation of Weather Edge Tagging in FY24.

Status: The FAA has reviewed the work done with the previous iteration of the ASR-11 simulator that utilized the SDTS algorithm (from the CARSR group). The data was too sparse, so the simulator was reverted to that state and any issues seen were fixed. With new test runs, none of the results with this updated simulator showed any benefit. Work was halted on this project due to the failure to reproduce the old results.

FAA Investigation into use of Machine Learning

Funding organization: DOE

Background: The FAA has partnered with the University of Oklahoma to create projects for senior engineering students. The current effort is to see if Artificial Intelligence can be used to improve ASR-11 performance in the presence of WTRI. This is done by analyzing the output from the radar. The project is conditional on positive results from the student project to justify the effort to code new functionality into the ASR-11.

Status: The FAA investigated and reviewed three different machine learning algorithms. The investigation utilized the sanitized data the students used (removed any military targets and any site identifiable information from the data in accordance with the National Data Release Board [NDRB]) and recorded site data. Due to time constraints and resource limitations, only the 'Random Forrest' model was fully investigated. The remaining models (Support Vector Machine and Neural Network) showed some promise, but gathering appropriate truth data for those algorithms would have taken longer than what was allotted. The 'Random Forrest' model did show some promise in correctly classifying real aircraft over wind farms. Note: this will not regain any lost returns due to the wind farm interference, but it will help better track the returns the system does receive.

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 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:

The FAA has established DoD Stakeholder working groups to identify collaboration opportunities and developed a market survey to determine industry capability for both Full System and Subsystem Replacement that includes wind turbine mitigation needs. The ANSR Program is challenged regarding FY25 funding availability due to FAA F&E funding shortfall and competing priorities.

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 telecons, sub-committee meetings, quarterly meetings, etc.) and supported a series of interagency and industry outreach and engagement activities.

III. 2024 WTRIM Working Group Objectives

In 2024, 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 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 DOD capabilities and mission areas.
    - Increase focus of technical analyses to potential offshore wind impacts to DOD.
    - Support testing and evaluation activities related to WTRIM and DOD funded studies.
- Continue to address the C-Speed Light Wave Radar certification deficiency that was established from the 2021 Pilot Mitigation Project.
- Develop and release a Request for Information (RFI) targeted at both the wind development industry and the radar systems manufacturers to better understand the perceived siting challenges of the wind development industry as it relates to radar interference, and to identify potential mitigation technologies that are needed address wind turbine-radar interference.
- 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 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
www.dodclearinghouse.osd.mil/

U.S. Department of Energy Wind Program
www.energy.gov/eere/wind/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
www.boem.gov/renewable-energy

National Oceanic and Atmospheric Administration Radar Operations Center
www.roc.noaa.gov/WSR88D/

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

Appendix A: WTRIM WG FY24 R&D PROJECT LIST

Radar Class	Project Name	Project Description	Primary Funding Organization(s)	Other Supporting Organizations	Expected Completion Date
All types	United States Wind Turbine Database	A continuously-updated georectified set of coordinates and characteristics of the fleet of installed onshore and offshore wind turbines. A curated set of data is prepared just for the WTRIM members that has additional fields beyond what is available to the public. Additionally, the USWTDB team prepares custom datasets for WTRIM members of turbines under construction or in advanced development for both onshore and offshore locations. These are used to determine likely future cumulative impacts of turbines in certain geographies.	DOE	USGS ACP	Ongoing Project
ROTHR	ROTHR Evaluation Mission Compatibility Analysis Tool	Developing models for wind turbine interference impacts on unique DoD radar systems, particularly the Navy's Relocatable Over-The-Horizon Radar (ROTHR). The Primary purpose of this program is 1) determining the impact of wind turbine farms on over-the-horizon radar systems; and 2) improving the capacity of government and industry to evaluate the impacts of existing and planned wind energy installations on sensitive radar systems.	DOD		1-Aug-2023
NEXRAD	NEXRAD Public Screening Tool	The NEXRAD Public Screening Tool enables wind developers to obtain a preliminary review of potential impacts to weather radar systems prior to an official filing with the OE/AAA. The tool is an online GIS-enabled site that includes the U.S. Wind Turbine Database.	DOE		1-Aug-2023
Terminal	Investigate CFAR Processing Enhancements	The collection of algorithms which control ASR-11 Constant False Alarm Rate (CFAR) adaptive thresholds can be ineffective in the presence of wind turbine clutter. They can: Reduce detection of aircraft near turbines due to elevated lead/lag thresholds and elevated clutter map levels. Fail to suppress turbine clutter due to insufficient clutter map thresholds. The project goal is to investigate enhancements to these algorithms. Each potential enhancement will be developed and evaluated using the ASR-11 simulator. Algorithms which prove beneficial will become candidates for integration into a future ASR-11 software release.	DOE		1-Jul-2023
Terminal	Investigate Clutter Map per Doppler Filter	ASR-11 Software Build 12 introduced the ability to create clutter maps for each Doppler Filter along with parameters to adjust behavior. This feature is not widely used because the benefits in a normal clutter environment and in the presence of wind farms has not been investigated fully. Because wind farm interference primarily occurs via	DOE		1-May-2023

		contamination of the Doppler Filters, this feature has potential to mitigate WTRI. The ASR-11 simulator provides the capability to optimize this mitigation approach.			
Terminal	Investigate Alternative CARSR Algorithm	During porting of CARSR WTRIM algorithms to ASR-11, we found code for a 'Binary Integration Mode'. It was later determined that the CARSR did not use that code (dead) and it was removed from the ASR-11 implementation. While this code led to a large number of cluster validation errors, the results when it was in use appeared better than final project results. This project will revisit the binary integrator mode through a review of old data and restoring the code to produce further test runs.	DOE		1-Sep-2023
Terminal	ASR-11 Simulator Updates	The ASR-11 simulator development was paused at the point where the CARSR feasibility investigation and simulation could be conducted. This project would complete development ASR-11 simulator features in support of new enhancement investigations. It will also update the simulator to Software Build 14 which will allow evaluation of Weather Edge Tagging in FY24.	DOE		1-Aug-2023
Terminal	Investigate Use of Machine Learning	The FAA has partnered with the University of Oklahoma to create projects for senior engineering students. The current effort is to see if Artificial Intelligence can be used to improve ASR-11 performance in the presence of WTRI. This is done by analyzing the output from the radar. The project is conditional on positive results from the student project to justify the effort to code new functionality into the ASR-11.	DOE		1-Jun-2023
Coastal HFR	Software Tools for the Mitigation of Wind Turbine Interference in the U.S. IOOS Network	This project will develop and field test software-based mitigation of offshore wind turbine interference for oceanographic high-frequency radar (HFR) surface current and wave sensors. Building on initial mitigation research efforts by HFR manufacturer CODAR Ocean Sensors that were funded by the Bureau of Ocean Energy Management, this project will conduct the necessary system integration, testing, validation, and verification needed for operational capacity.	NOAA	Woods Hole Oceanographic Institute	31-Aug-2024
ASR/ARSR	ASR/ARSR Multistatic Prototype	Analyze, develop, and prototype a wind-turbine-radar interference mitigation approach to improve the performance of Airport Surveillance Radar (ASR) and Air Route Surveillance Radar (ARSR) systems. It will act as a multistatic infill radar system. It will rely on existing primary radars, such as the CARSR, ARSR-4, ASR-11, or DASR for illumination, but provide additional passive receiver sites to reduce interference from wind turbines. The following task phases and objectives will be used to develop the prototype.	DOD	DOE	Fy25/26
N/A	Radar and BCS-F Test	6 month test of passive and BCS-F	DOD		FY24/25
	Infill Radar Project	AFFSA has C-Speed under contract through DHS (Congressional Add funding), using Regulus to conduct System Engineering for the project	AFFSA, DHS		FY25

		that will take place at Travis AFB, CA & Rio Vista, CA airport within the same area location. **Highlights of our end goal:** **1. Address the C-Speed Light Wave Radar (LWR) certification deficiency list (Latency, False Target Returns, Probability of Detection) that was established from the 2021 Pilot Mitigation Plan (PMP)** **2. Implement changes to LWR system to address these deficiencies** **3. There is a LWR at Travis currently, and after testing in Eagle Pass, TX with another LWR C-Speed will take that radar unit to Rio Vista. They will use the testing at Eagle Pass, TX to establish a baseline and use that to address the latency issues** **4. Utilize Targets of Opportunity and at least 2 CAP flights to validate addressing deficiency items** **5. Deliver data to AFFSA for analysis**			
Navy Air/Surface Radars	**Assessment of Offshore Wind Turbine Development on Fielded Naval Systems**	**Evaluate impact of offshore wind turbines to fielded naval (airborne, shipboard, and land-based) radar systems and identify interference mitigation measures, either available, or that may be technically feasible to develop**	**DOD Siting Clearinghouse**	**Various Navy elements**	**September 2025**
Airborne Surveillance Radars	**Impacts of wind turbines on airborne surface surveillance radar systems**	**Understand impacts and identify mitigations of wind turbines to airborne surface surveillance radars critical for safe range clearance of offshore weapon test areas**	**DOD Siting Clearinghouse**	**Various Navy elements**	**September 2024**
TBD	**Underwater Acoustic Impacts of OSW**	**Evaluate impacts of wind-turbine generated underwater acoustic noise on DOD assets, operations, and capabilities.**	**DOD Siting Clearinghouse**	**Various Navy elements**	**December 2024**
Terminal	**Airspace Non-cooperative Surveillance Radar (ANSR)**	**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).**	**FAA**		