Summary of Test Results for the Interagency Field Test &Evaluation of Wind Turbine – Radar Interference Mitigation Technologies
PUBLIC RELEASE

Testing Phase: April 2012-April 2013 ❖ Report: September 2013

Distribution Statement A: Approved for Public Release (July 9, 2014).

Purpose of this Fact Sheet: This document includes background information and a summary of three field tests designed to measure the impact of wind turbines on current air surveillance radars and the effectiveness of private sector technologies in mitigating that interference. This fact sheet contains publically-available information from three technical field test reports but excludes proprietary business information from private sector companies and sensitive national defense and security information. The fact sheet also omits information from the report about the test procedures that would provide an unfair competitive advantage to companies involved in potential later tests.

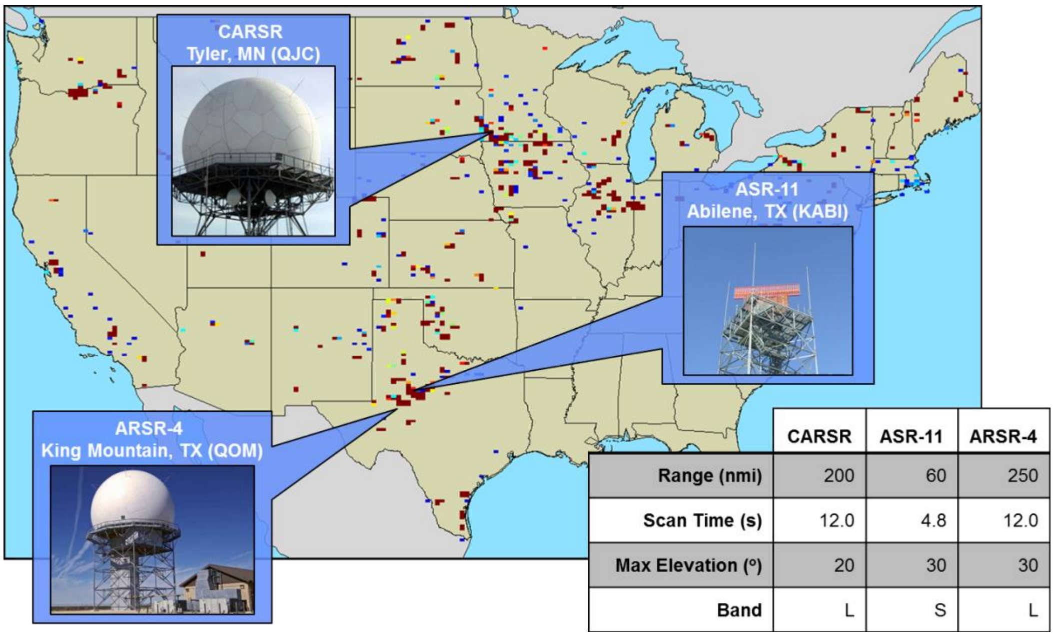
Program Justification: Wind turbines sometimes present a source of interference with our nation's radars. The effects of this wind turbine interference are of concern to flight safety, homeland security, national defense, and protection of life and property from weather events (weather radar, however, were not evaluated as part of the program). Furthermore, to meet the nation's objectives for increased renewable energy and the associated benefits, the number of operating wind turbines in this country is expected to continue to grow in coming years.

Goals of the Program: Supported by directives from Congress, the Administration established the Interagency Field Test and Evaluation (IFT&E) program to investigate and address the concerns of growing interference of wind turbines on our nation's air surveillance radars. The program has three goals: i) characterize the impact of wind turbines on existing Program-of-Record (POR) air surveillance radars; ii) assess near-term mitigation capabilities proposed by industry; and iii) collect data and increase technical understanding of interference issues to advance development of long-term mitigation strategies.

Program Description: This program was a two-year effort, funded and supported by Department of Energy (DOE), Department of Defense (DOD), Department of Homeland Security (DHS), and the Federal Aviation Administration (FAA). The program included a total of three flight campaigns. Each campaign was conducted near an existing Program-of-Record (POR) radar which has a large number of wind turbines in its field of view. The three POR radars were a long-range radar Common Air Route Surveillance Radar (CARSR), a short-range Airport Surveillance Radar (ASR, in this case, an ASR-11), and a long-range Air Route Surveillance Radar (ARSR, in this case, an ARSR-4). Eight different mitigation concepts were assessed during these campaigns. Each two-week flight test campaign involved the collection of data from federally-owned radar systems, several types of government and private aircraft, a variety of wind-radar mitigation technologies, and wind turbines in the test area.

Laboratory Roles: The federal agencies used two national laboratories—DOD's Massachusetts Institute of Technology Lincoln Laboratory (MIT LL) and DOE's Sandia National Laboratories (SNL)—to manage the test and evaluation program because of their world-class expertise on radar and wind technologies, their ability to access and protect sensitive and proprietary data, and their credibility in providing objective and independent assessment for the tests and evaluations.

Test Participant Selection Process: SNL issued a public notification through a Request for Information to acquire information from radar developers, radar-related software producers, radar operators, wind turbine and wind turbine component manufacturers, service providers, and others on the availability of the marketplace to provide for and participate in a technology demonstration of Commercial Off-the-Shelf or other mature technology mitigation capabilities. After a technical review of private sector proposals by a technical panel of government and laboratory experts, the Interagency Steering Committee invited ten companies to participate in the three IFT&E tests; in the end, eight mitigation technologies were evaluated.



	CARSR	ASR-11	ARSR-4
Range (nmi)	200	60	250
Scan Time (s)	12.0	4.8	12.0
Max Elevation (°)	20	30	30
Band	L	S	L

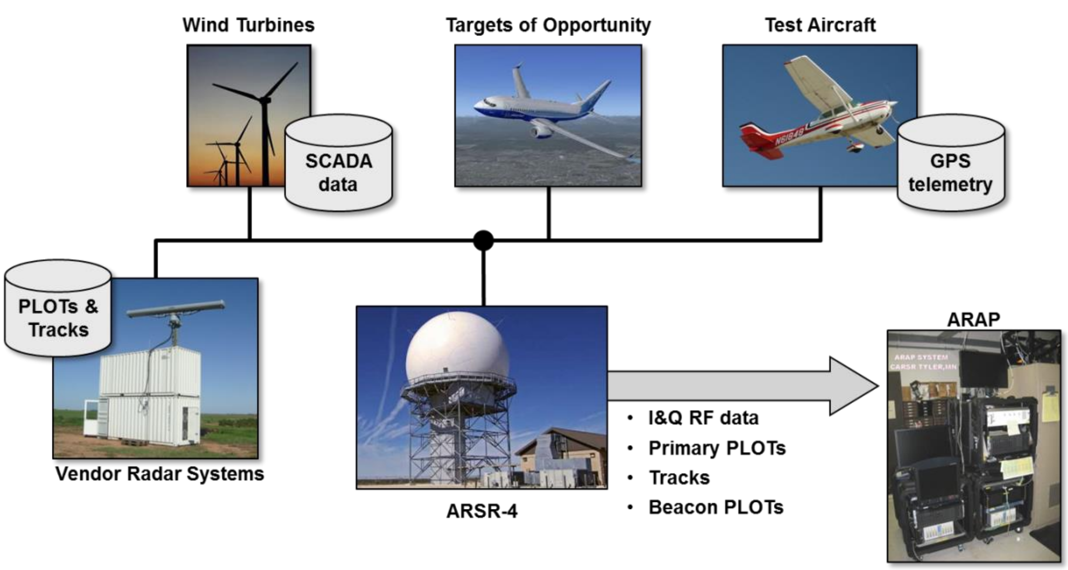
Test 1: The first campaign took place in April 2012. The purpose of the first test was to characterize the performance of a newly upgraded Common Air Route Surveillance Radar (CARSR), a long range surveillance radar system, in Tyler, MN. Three private sector companies that demonstrated their mitigation systems were: the C Speed Lightwave in-fill radar, the SRC LSTAR(V)3 in-fill radar, and the Raytheon Long Range Radar processing upgrade.

Test 2: The second campaign took place in October 2012. The purpose of the second test was to characterize the performance of the Airport Surveillance Radar (ASR)-11, a terminal airport surveillance radar system in Abilene, TX. Two private sector companies demonstrated their mitigation systems: Terma with their Scanter 4002 in-fill radar and Booz Allen Hamilton with their RF Precision Nulling Device (RPND).

Test 3: The third campaign took place in April 2013. The purpose of the third test was to characterize the performance of the Air Route Surveillance Radar (ARSR-4), a long-range surveillance radar system in King Mountain, TX. Three private sector companies demonstrated their mitigation systems: Lockheed Martin with their TPS-77 radar, Aveillant with their Holographic in-fill radar, and Raytheon with their X-band in-fill radar.

Site Selection and Timing: The agencies wanted the tests to take place in safe airspace in a location with a high concentration of wind turbines during times of year when wind turbine farms generate the greatest electromagnetic interference effects on radar systems. Each POR radar is located within the line of sight of hundreds of wind turbines. The spring and fall seasons are the times of year when winds blow most consistently at high velocities. In order to fully assess the POR radars and the selected mitigation technologies using known targets (test program aircraft), the test area was chosen and test flights were timed to avoid disrupting the local traffic patterns. Additional aircraft data were leveraged from local air traffic as they provided targets of opportunity with little incremental cost to the government.

Flight Tests: Key stakeholders from the federal agencies provided guidance and support to MIT LL and SNL as they designed, executed, and analyzed the tests. The FAA provided extensive support in managing the flight operations and air traffic control, as well as technical support regarding the POR radars. DOD's 84th Radar Evaluation Squadron also provided technical radar support. DHS, DOD, DOE, and NOAA provided critical test aircraft, flight tracking, and air operations. Eight to twelve different aircraft types were flown at varied speeds and altitudes for an average of about 150 hours of flying time over eight to ten day campaigns. This ensured that tests were conducted under a wide range of wind turbine-related interference conditions to evaluate the effectiveness of different mitigation technologies in improving radar surveillance coverage in test areas with a high concentration of wind turbines. Neither the government radar operators nor the test participants were provided with advanced information about the test program aircraft regarding their type, number, speed, altitude, or flight routes.



Scientific Instrumentation: MIT LL built an Adjunct Radar Analysis Processor to collect and analyze flight test data. This computer hardware was attached to each of the POR radars in turn to gather echo returns from the aircraft with radar frequency signal measurements (the In-Phase and Quadrature data), as well as detection messages from the primary and secondary radar. All primary test aircraft carried Global Positioning System (GPS) receivers and other equipment to analyze the POR radars' and the mitigation technologies' performance following the flight tests. These data were used to baseline the POR radar's performance when aircraft flew over and around wind farms and to compare performance with the mitigation technologies.

Wind Industry Involvement: SNL coordinated the data collection effort from wind farm owners in the three test areas. Wind turbine characteristics and operating data including wind speed, wind direction, and rotation rate were gathered from hundreds of wind turbines in and around the test areas. These data, when combined with the radar and flight data, enable the laboratories to characterize the effects of wind turbine interference and predict effects on similar radar systems in other locations with a high level of confidence.

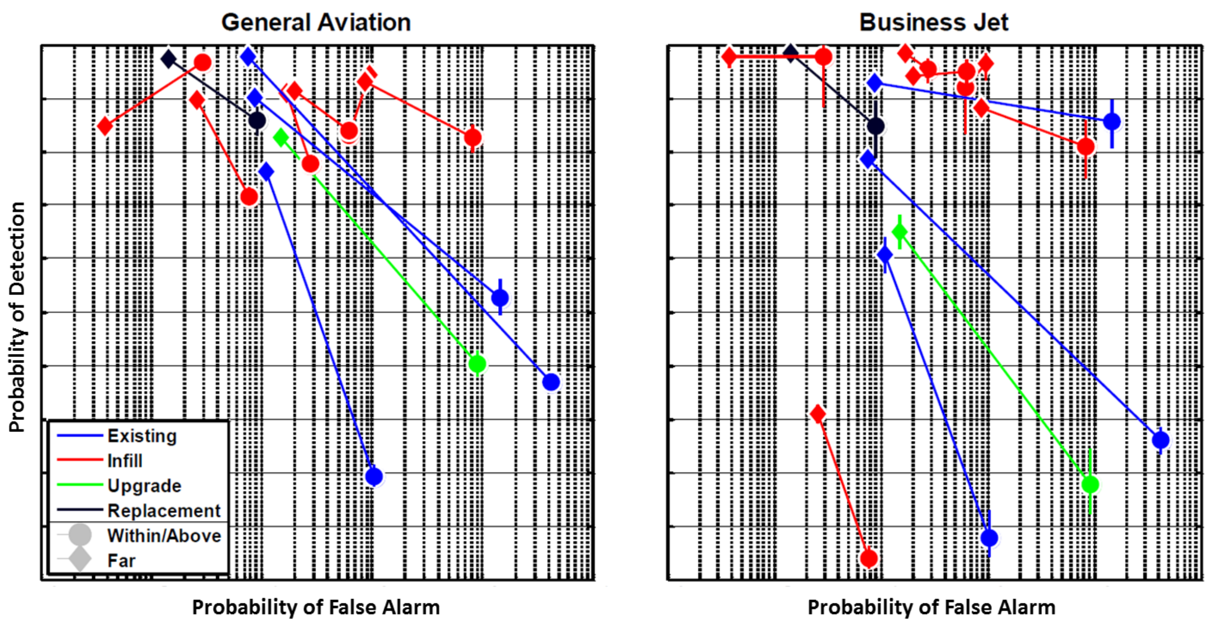
Test Participants: The test participants were: Raytheon, Lockheed Martin, SRC, C Speed, Aveillant, Terma, and Booz Allen Hamilton. Each paid their own costs to participate in the evaluation and operated their mitigation technologies during the tests. The test participants provided data to the laboratories on their system's detection of aircraft over the test area at the end of each day. Their radar detections were compared to actual GPS data from test program aircraft to evaluate their technology's performance and potential to mitigate wind turbine interference.

Performance Metrics: The data from the tests were used to evaluate the radar systems' performance based on widely accepted metrics for plots (probability of detection, probability of false targets, and accuracy of range and azimuth) and tracks (probability of track and false track, probability of track break and survival, and accuracy of range and azimuth).

Major Findings: The first important finding was in characterizing the impact of wind turbines on the CARSR, ASR-11, and ARSR-4. For areas without wind turbines, all POR radars demonstrated the ability to meet or exceed their specifications for detecting aircraft. However, in the regions directly above and very near the wind turbines within line-of-sight, all of the POR radars demonstrated a significant drop in ability to detect aircraft and also produced more false detection reports. These factors combine to detrimentally impact the ability of current trackers at the radar or remote automation systems to track aircraft as they fly over the viewable wind farms.

On the other hand, the beacon transponder-based secondary surveillance radars (SSR) did not appear to be affected by wind turbines, nor did GPS performance.

Several of the mitigation technologies tested show great promise. However, most systems were still not fully mature at the time of testing, and require additional testing and/or integration issues to be addressed. Nevertheless, several technologies succeeded in detecting and tracking aircraft over wind farms. General results can be seen in the figures below. This test program only considered performance, and not cost or other suitability metrics. More specific findings regarding the mitigation technologies are not approved for public dissemination at this time. The figures below show that while all systems tested were impacted by wind turbines, many of the mitigation systems were significantly less impacted by wind turbines than the existing POR radars. The replacement radar and most of the infill radars performed better than the existing POR radars in the Within/Above wind turbine region.



Additional Benefits: The test data will provide additional insights and a deeper scientific understanding into the phenomenology of wind turbine interference with radar systems. The data will be used by government researchers to develop and evaluate new mitigation technologies. The test participants will be able to use their proprietary information from the tests for product improvements.

Conclusions: All three IFT&E flight campaigns have been successful, meeting program objectives by quantifying POR radar impacts, evaluating eight different mitigation technologies, and providing a very extensive data set and much deeper understanding of the wind turbine-radar interference problem. These tests provide important answers that can guide decisions for future wind development and air surveillance improvements. In addition, the program has been a model of government interagency and industry collaboration to address our nation's critical needs. The specific assessments of the technologies evaluated are not included here due to sensitive private and government information concerns.

Next Steps: The government is now moving into the second phase of the program, by focusing on maturing and integrating mitigation technologies in operational settings.

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