

New York State Offshore Wind Master Plan

Aviation and Radar Assets Study



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New York State Offshore Wind Master Plan Aviation and Radar Assets Study

Final Report

Prepared for:

New York State Energy Research and Development Authority

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Acronyms and Abbreviations

ADLS	aircraft detection lighting system
ADS	automatic detection system
AGL	above ground level
AoA	Area of Analysis
ARSR	Air Route Surveillance Radar
ASR	airport surveillance radar
ATC	air traffic control
BMP	best management practice
BOEM	U.S. Bureau of Ocean Energy Management
CFR	Code of Federal Regulations
Contractor	Ecology and Environment Engineering, P.C.
DOD	U.S. Department of Defense
DOT	New York State Department of Transportation
ESRI	Environmental Systems Research Institute
FAA	Federal Aviation Administration
GIS	geographic information system
HF	high frequency
IFR	instrument flight rules
IOOS	U.S. Integrated Ocean Observing System
IRAC	Interdepartment Radio Advisory Committee
km	kilometer
Master Plan	New York State Offshore Master Plan
MHz	megahertz
MOA	military operations area, or Memorandum of Agreement
MSL	mean sea level
MTR	military training route
MW	megawatt
NAS	National Airspace System
Navy	U.S. Department of the Navy
NEPA	National Environmental Policy Act
NEXRAD	next-generation radar
NJDOT	New Jersey Department of Transportation
nm	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NORAD	North American Aerospace Defense Command
NOTAM	Notices to Airmen
NTIA	National Telecommunication and Information Administration

NTM	Notices to Mariners
NVG	night vision goggle
NWS	National Weather Service
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
OCS	Outer Continental Shelf
OE/AAA	Obstruction Evaluation/Airport Airspace Analysis
OLC	obstruction light control
OPAREA	operating area
OSA	offshore study area
PANYNJ	Port Authority of New York and New Jersey
ROC	(NOAA) Radar Operations Center
Sonar	sound navigation and ranging
Study	Aviation and Radar Assets Study
SUA	special use airspace
TDWR	terminal Doppler weather radar
USCG	U.S. Coast Guard
U.S.C.	U.S. Code
VFR	visual flight rules
WSR	weather surveillance radar

Executive Summary

This Aviation and Radar Assets Study (Study) is one of a collection of studies being prepared on behalf of the New York State Energy Research and Development Authority (NYSERDA) to provide information related to a variety of environmental, social, economic, regulatory, and infrastructure-related issues implicated in planning for future offshore wind energy development off the coast of New York State (NYS). In embarking on these studies, NYSERDA initially focused on a 16,740-square-mile area of the ocean extending from the south shore of Long Island and New York City to the continental shelf break that had been identified by the New York State Department of State (DOS) as part of its two-year Offshore Atlantic Ocean study (the “offshore study area [OSA]”) (New York State Department of State DOS 2013) (Figure 1). Each of NYSERDA’s individual studies identifies an Area of Analysis (AoA), which is the geographic scope of analysis for that respective study.

The U.S. Bureau of Ocean Energy Management (BOEM) has jurisdiction over identifying offshore wind development sites within the Outer Continental Shelf (OCS) and for issuing leases for those sites. NYS envisions that its collective studies will form a knowledge base for the area off the coast of New York that serves a number of purposes, including: (1) informing the preliminary identification of areas that NYS believes should be considered by BOEM for offshore wind energy projects; (2) providing current information about potential environmental and social sensitivities, economic and practical considerations, and regulatory requirements associated with any future offshore wind energy development; (3) identifying measures that could be considered or implemented with offshore wind projects to avoid or mitigate potential risks involving other uses and/or resources; and (4) informing the preparation of a Master Plan to articulate NYS’s vision of future offshore wind development. NYS contemplates that the Master Plan will address potential future project areas for BOEM’s consideration, discuss the State’s goal of encouraging the development of 2,400 megawatts (MW) of wind energy off the New York coast by 2030, and set forth suggested guidelines and best management practices (BMPs) that NYS will encourage to be incorporated into future projects. In addition, NYS aims for its work product to be of assistance to developers working to develop offshore wind projects in the future.

As further described below, the AoA for this Study is the area within the OSA that was identified to reflect a shoreward boundary that begins 15 nautical miles from the coast, and certain areas outside of the OSA that were recommended by federal and State agencies for consideration. This Study identifies the uses and users of the National Airspace System (NAS) that may be affected by the construction and

operation of a wind farm in the AoA. The operation of wind energy systems (farms or individual turbines) has the potential to interfere with aviation systems, including airport approaches, radar systems, and military assets (including operational and training areas and routes). In addition, a review of potential impacts on marine radar systems is also included in this study.

This Study includes a desktop geographic analysis; assessment of aviation, airspace, and radar assets; stakeholder input; review of preliminary siting screening tools; and assessment of wind farm obstruction lighting technologies. The analysis includes the development of impact zones between offshore wind energy development and existing aviation and radar facilities (Figure 11). The Study divides the AoA into five distinct areas based on predicted compatibility of potential future wind energy development with aviation and radar assets in the region within the AoA. This Study also considers military consultation areas developed by the U.S. Department of Defense (DOD) in a 2013 assessment of offshore wind development in the area (Engle 2017). The impact prediction is an assessment of the possible interference of offshore wind energy development in each of the areas.

This Study includes a review of online screening tools (Appendix A) for developers and a preliminary assessment of the Federal Aviation Administration (FAA) requirements for obstruction lighting on wind farms (Appendix B), including a review of FAA lighting requirements, lighting control technology, and case studies related to lighting from other wind farm sites.

This Study incorporates input from stakeholders such as the FAA; key users of the NAS, including the DOD and airports near the AoA; and other agencies who own and operate radar systems in the area, such as the National Weather Service (NWS) and the National Oceanic and Atmospheric Administration (NOAA). Additional input was received from the U.S. Coast Guard (USCG), BOEM, and other stakeholders as well.

1 Introduction

This Aviation and Radar Assets Study (Study) is one of a collection of studies prepared on behalf of New York State (NYS) in support of the New York State Offshore Master Plan (Master Plan). These studies provide information on a variety of potential environmental, social, economic, regulatory, and infrastructure-related issues associated with the planning for future offshore wind energy development off the coast of the State. When the State embarked on these studies, it began by looking at a Study Area identified by the New York State Department of State in its two-year Offshore Atlantic Ocean Study (New York State Department of State 2013). This study area, referred to as the “offshore study area (OSA),” is a 16,740-square-mile (43,356-square-kilometer [km]) area of the Atlantic Ocean extending from New York City and the south shore of Long Island to beyond the continental shelf break and slope into oceanic waters to an approximate maximum depth of 2,500 meters (Figure 1). This OSA was a starting point for examining where turbines may best be located and the area potentially impacted. Each of the State’s individual studies ultimately focused on a geographic Area of Analysis (AoA) that was unique to that respective study. The AoA for this study is described below in Section 1.1.

The State envisions that its collection of studies will form a knowledge base for the area off the coast of New York that will serve a number of purposes, including (1) informing the preliminary identification of an area for the potential siting of offshore wind energy areas that was submitted to the U.S. Bureau of Ocean Energy Management (BOEM) on October 2, 2017 for consideration and further analysis; (2) providing current information about potential environmental and social sensitivities, economic and practical considerations, and regulatory requirements associated with any future offshore wind energy development; (3) identifying measures that could be considered or implemented with offshore wind projects to avoid or mitigate potential risks involving other uses and/or resources; and (4) informing the preparation of a Master Plan to articulate NYS’s vision of future offshore wind development. The Master Plan identifies the potential future wind energy areas that have been submitted for BOEM’s consideration, discusses the State’s goal of encouraging the development of 2,400 megawatts (MW) of wind energy off the New York coast by 2030, and sets forth suggested guidelines and best management practices (BMPs) that the State will encourage to be incorporated into future offshore wind energy development.

Each study was prepared in support of the larger effort and was shared for comment with federal and State agencies, indigenous nations, and relevant stakeholders, including non-governmental organizations and commercial entities, as appropriate. The State addressed comments and incorporated feedback into the studies. Feedback from these entities helped to strengthen the quality of the studies and also helped

to ensure that these work products will be of assistance to developers of proposed offshore wind projects in the future. A summary of the comments and issues identified by these external parties is included in the *Outreach Engagement Summary*, which is appended to the Master Plan.

The Energy Policy Act of 2005 amended Section 8 of the Outer Continental Shelf (OCS) Lands Act to give BOEM the authority to identify offshore wind development sites within the OCS and to issue leases on the OCS for activities that are not otherwise authorized by the OCS Lands Act, including wind farms. The State recognizes that all development in the OCS is subject to review processes and decision-making by BOEM and other federal and State agencies. Neither this collection of studies nor the State's Master Plan commit the State or any other agency or entity to any specific course of action with respect to offshore wind energy development. Rather, the State's intent is to facilitate the principled planning of future development off the New York coast, provide a resource for the various stakeholders, and encourage the achievement of the State's offshore wind energy goals.

1.1 Scope of Study

This study identifies the uses and users of the National Airspace System (NAS) that may be affected by the construction and operation of a wind farm off the coast of New York. The NAS encompasses a vast network of airports, air traffic control (ATC) facilities, air navigation facilities and equipment, and flight procedures administered by the Federal Aviation Administration (FAA) to ensure flight safety and efficiency for all airspace users.

Offshore wind farms have the potential to affect aviation in two main ways: through the presence of new structures, which may present an obstruction to aviation in the area, and through the presence of rotating turbine blades, which may interfere with radar operations in the area.

In addition, this study includes a review of potential impacts on ocean-monitoring and marine radar systems, including vessel-borne systems. Early coordination should allow potential impacts on these well-established and planned national assets to be minimized, reducing the risk of significant delays in wind development projects. The goal of this analysis is to identify areas within the AoA where wind farms would be compatible with the operation of civil and military aviation assets and radar systems, and to identify measures which would promote flight safety and minimize interfere with use of aviation and radar assets in the vicinity of a wind farm. To achieve this, aviation and radar assets that operate within or near the AoA were inventoried, including airports, various types of radar systems, special use airspace (SUA), and key routes used by the military for training and operational missions.

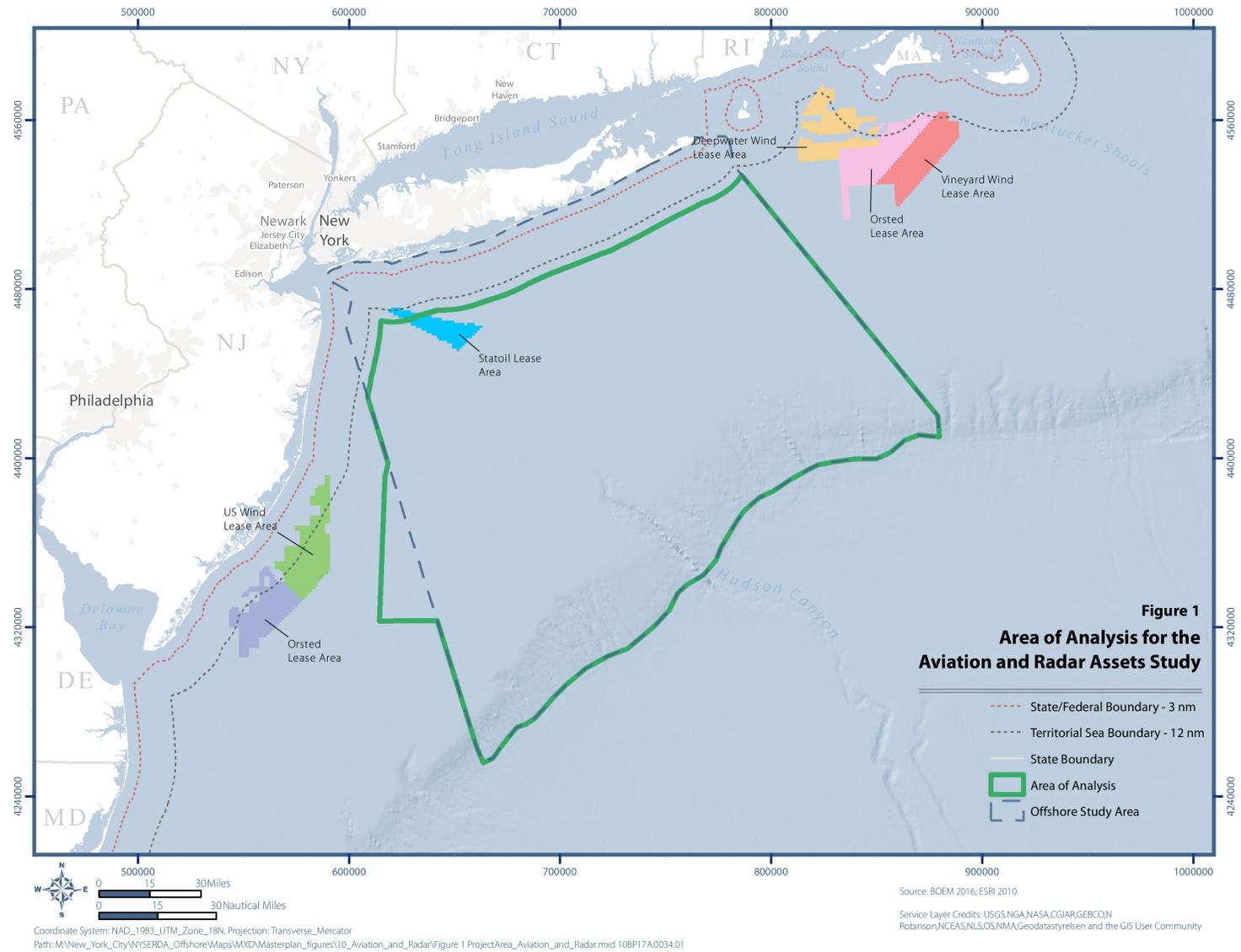
Interviews were conducted with stakeholders such as the FAA and key users of the NAS, including the U.S. Department of Defense (DOD) and airports near the coast, and other agencies who own and operate radar systems in the area, such as the National Weather Service (NWS) and the National Oceanic and Atmospheric Administration (NOAA). Information obtained from these stakeholders have been incorporated into the Study as appropriate. Wind energy has the potential to affect these systems because the rotating blades register on radar systems as moving targets and could potentially produce some distortion in data used to track aircraft and ensure flight safety. A review of the potential for similar impacts on marine radar systems is also included.

Based on the inventory of assets and stakeholder input, a detailed desktop geographic compatibility analysis was then conducted to identify where potential wind energy development would be compatible with the uses and users of the NAS within the AoA. The AoA for this Study is a 14,980-square-mile area of the ocean extending from 15 nautical miles from the coast of Long Island and New York City to the continental shelf break, slope, and into oceanic waters to an approximate maximum depth of 2,500 meters (Figure 1).

This Study is comprised of the following: In addition to the scope of the study, Section 1 provides the Study objectives and an overview of the regulatory framework under which FAA operates and reviews projects that may affect the NAS, as well as the regulatory framework governing radar systems. Section 2 describes the methodology used to develop this Study, including a desktop geographic analysis of aviation and radar assets within and near the AoA, a data review and discussion of the stakeholder interviews. Section 3 discusses the potential risks and sensitivities of wind energy development to aviation and radar assets, and Section 4 presents BMPs that could be employed to potentially avoid or minimize conflicts between offshore wind energy development and existing aviation and radar assets. This Study includes a review of online screening tools (Appendix A) for developers and a preliminary assessment of the FAA requirements for obstruction lighting on wind farms (Appendix B), including a review of FAA lighting requirements, lighting control technology, and case studies related to lighting from other wind farm sites.

Figure 1. Area of Analysis for the Aviation and Radar Assets Study

Source: BOEM 2016, ESRI 2010



1.2 Objectives of this Study

The following objectives of this study are to

- Identify aviation and radar assets located within the AoA based on best available data, and information provided by stakeholders of the NAS.
- Engage stakeholders to solicit feedback on communication, siting, wind farm layouts and other measures to improve the compatibility of offshore wind farms with aviation and radar assets within and near the AoA.
- Provide guidelines and BMPs that future offshore wind developers may consider avoiding or minimizing project impacts on aviation and radar assets.

1.3 Regulatory Framework and Project Oversight

This section provides an overview of the federal and state regulatory framework for management of aviation and radar assets, and how wind energy development projects are reviewed within this framework. While these regulations and procedures are not all designed specifically for offshore areas within BOEM's jurisdiction, they provide additional context to siting procedures in and near the AoA and lay the groundwork for best practices related to wind energy systems built in proximity to aviation and radar assets.

BOEM has primary jurisdiction over siting and development of wind energy projects in the AoA, and any potential future development would be subject to review processes and decision making by BOEM and other federal and State agencies. BOEM's jurisdiction begins 12 nautical miles (nm) from the shoreline. For the purposes of this study, it was assumed that BOEM may follow the FAA's guidelines related to wind energy development beyond the 12-nm zone. For instance, BOEM may choose to follow guidelines for aviation obstruction lighting that, based on the specific nature of these standards, promote safety of flight regardless of proximity to the shore.

1.3.1 Federal Regulatory Framework

This section provides a brief background on aviation and radar operations to provide context for the subsequent discussion of the federal regulations and project review procedures for wind energy development projects in the AoA, and for the discussion of aviation and radar assets within the AoA as presented in Section 2.

1.3.1.1 Federal Aviation Regulations

The FAA's major roles include the following:

- Regulating civilian aviation to promote safety.
- Developing and operating a system of ATC and navigation for civil, commercial, and military aircraft.
- Creating and facilitating programs to control aircraft noise and environmental effects of civil aviation.

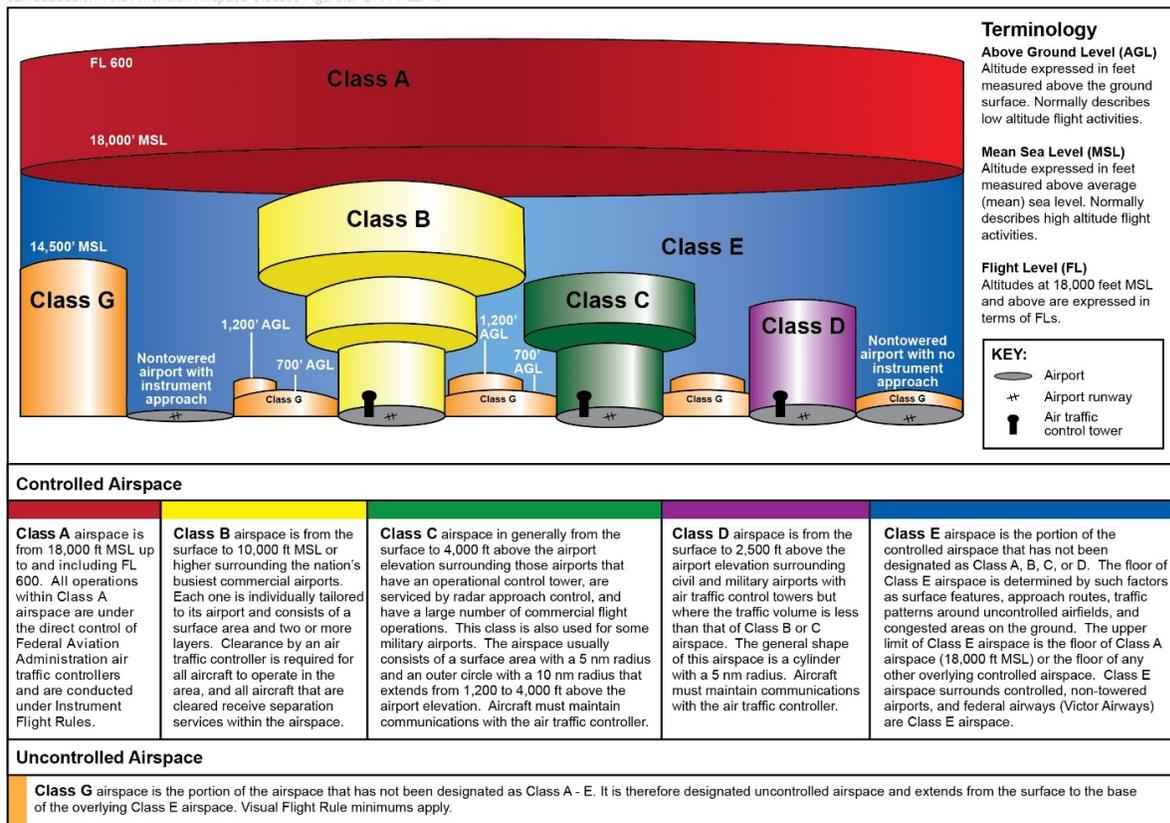
The FAA carries out these roles through activities that include, but are not limited to, safety regulation, airspace and air traffic management, and building and maintaining air navigation facilities (FAA 2010). The FAA created the NAS, which comprises a network of air navigation facilities and equipment, ATC facilities, airports, flight procedures, and the rules, regulations, and associated technology needed to operate the system.

The FAA categorizes operational flight rules into two types—instrument flight rules (IFR) and visual flight rules (VFR). ATC is used to manage and coordinate aircraft positions and locations and to maintain aircraft separation to ensure flight safety. A key mission of ATC is to maintain separation between IFR and VFR air traffic, which is an integral part of ATC procedures and the NAS as a whole (FAA 2007). The FAA provides air traffic services and radar facilities to aircraft operators through their phases of flight via ATC towers, terminal radar approach control facilities, and combined control facilities (FAA 2017f).

Weather conditions are also an integral part of aircraft operations because these conditions determine the flight rules that aircraft can operate under, as well as the distance required between aircraft referred to as “aircraft separation.” Various weather radar facilities are used in the U.S. and are managed by several entities, including NOAA's NWS Radar Operations Center (ROC) Weather Surveillance Radar (WSR) 88D, which manages 160 next-generation (weather) radars (NEXRADS), and the FAA, which manages 45 terminal Doppler weather radars (TDWRs; Sprayberry 2013).

Airspace is generally classified as uncontrolled or controlled. The FAA utilizes five classifications for controlled airspace: Class A, B, C, D, and E. Class G is the classification for uncontrolled airspace. (The U.S. does not use Class F). These classifications and where they apply are shown on Figure 2.

Figure 2. Airspace Classifications



In addition to these six classifications, there is also airspace that is designated as SUA, and for use by military aircraft. SUA is discussed in more detail in Section 2.1.

To promote air safety and the efficient use of navigable airspace, the FAA administers 14 Code of Federal Regulations (CFR) Part 77, Safe, Efficient Use, and Preservation of the Navigable Airspace. Within these regulations are the definitions of obstructions to navigable airspace, and the procedures for review of projects that may result in obstructions to navigable airspace. Obstructions include very tall objects as well as objects meeting moderate height parameters that are located near an airport. The FAA defines obstructions to aviation under §77.17 as an existing or future object with any of the following attributes (FAA 2017a):

- A height greater than 499 feet above ground level (AGL) at the site of the object.
- A height that is 200 feet AGL, or above the established airport elevation, whichever is higher, within 3 nm of the established reference point of an airport, excluding heliports, with its longest runway more than 3,200 feet in actual length, and where the height increases in the proportion of 100 feet for each additional nautical mile of distance from the airport up to a maximum of 499 feet.

- A height within a terminal obstacle clearance area, including an initial approach segment, a departure area, and a circling approach area, which would result in the vertical distance between any point on the object and an established minimum instrument flight altitude within that area or segment to be less than the required obstacle clearance.
- A height within an en route obstacle clearance area, including turn and termination areas, of a federal airway or approved off-airway route that would increase the minimum obstacle clearance altitude.
- A height greater than the surface of a takeoff and landing area of an airport or any imaginary surface established under §77.19, §77.21, or §77.23. (However, no part of the takeoff or landing area itself will be considered an obstruction.)
- Except for traverse ways on or near an airport with an operative ground traffic control service furnished by an ATC tower or by the airport management and coordinated with the ATC service, the standards of paragraph (a) of this section apply to traverse ways used or to be used for the passage of mobile objects only after the heights of these traverse ways are increased by:
 - Seventeen feet for an Interstate Highway that is part of the National System of Military and Interstate Highways where overcrossings are designed for a minimum of 17 feet vertical distance.
 - Fifteen feet for any other public roadway.
 - Ten feet or the height of the highest mobile object that would normally traverse the road, whichever is greater, for a private road.
 - Twenty-three feet for a railroad.
- For a waterway or any other traverse way not previously mentioned, an amount equal to the height of the highest mobile object that would normally traverse it.

The FAA also maintains regulations addressing tall structures so that they are built in such a way that flight safety is not compromised. The requirements for filing notice with the FAA for proposed structures vary based on the height, proximity to an airport, location, and frequencies emitted from the structure. The FAA administers 14 CFR Part 77 with the objective of further promoting safe and efficient use of navigable airspace (FAA 2017a). Under 14 CFR Part 77.9, notice must be filed with the FAA if requested by the FAA or when any of the following types of construction or alteration is proposed, with certain exceptions (FAA 2017a):

- Any construction or alteration exceeding 200 feet AGL at its site.
- Any construction or alteration that exceeds an imaginary surface extending outward and upward at any of the following slopes:
 - 100 to 1 for a horizontal distance of 20,000 feet from the nearest point of the nearest runway of each airport described in 14 CFR 77.9(d), with its longest runway more than 3,200 feet in actual length, excluding heliports.
 - 50 to 1 for a horizontal distance of 10,000 feet from the nearest point of the nearest runway of each airport described in 14 CFR 77.9(d), with its longest runway no more than 3,200 feet in actual length, excluding heliports.

- 25 to 1 for a horizontal distance of 5,000 feet from the nearest point of the nearest landing and takeoff area of each heliport described in 14 CFR 77.9(d).
- Any construction of a traverse way (highway, railroad, waterway, etc.) of a height which, if adjusted upward as defined in 14 CFR 77.9(c), would exceed a standard of 14 CFR 77.9 (a) or (b).
- Any construction or alteration located on an airport described in 14 CFR 77.9(d).

Notice for construction or alteration of structures does not need to be filed if it meets the following criteria (FAA 2017a):

- Any object that will be shielded by existing structures of a permanent and substantial nature or by natural terrain or topographic features of equal or greater height and located in the congested area of a city, town, or settlement where the shielded structure will not adversely affect safety in air navigation.
- Any air navigation facility, airport visual approach or landing aid, aircraft arresting device, or meteorological device meeting FAA-approved siting criteria or appropriate military service siting criteria on military airports, the location and height of which are fixed by its functional purpose.
- Any construction or alteration for which notice is required by any other FAA regulation.
- Any antenna structure of 20 feet or less in height, except one that would increase the height of another antenna structure.

1.3.1.2 Project Review Procedures

This section provides a discussion of the review procedures that would be employed by the various agencies with responsibility for managing and maintaining aviation and radar assets. In addition, this section identifies on-line tools that can be accessed by wind developers to conduct a preliminary evaluation of a project and its potential to affect aviation and radar assets. These tools are described in more detail in Appendix A.

The FAA's Obstruction Evaluation/Airport Airspace Analysis (OE/AAA) Wind Turbine Group conducts all of the obstruction evaluations for all wind turbine proposals onshore and offshore throughout the United States. The FAA provides an on-line Notice Criteria Tool for public use in applying 14 CFR Part 77 notice criteria as described above to determine whether a proposed project meets the requirements to file a notice of construction or alteration. This optional tool allows the user to enter the proposed latitude, longitude, horizontal datum, site elevation, and proposed structure height to determine whether filing is required (FAA 2017b). Once the information is entered and processed, the tool provides results indicating whether notice is required. The tool can be found online on the FAA's OE/AAA website at: <https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showNoNoticeRequiredToolForm>.

In general, the current filing process for wind turbine obstruction evaluations is

- As part of the developer's filing, the developer must include the location (latitude/longitude) and height of each individual turbine for evaluation.
- Once a developer files, the Wind Turbine Group determines whether the proposal meets the notice criteria.
- If the proposed project meets the notice criteria, the Wind Turbine Group evaluates the project for a determination of hazard or no hazard. For the determination, the proposal will progress through 10 different lines of businesses/agencies (DOD Siting Clearinghouse, U.S. Air Force, U.S. Army, U.S. Department of the Navy (Navy), U.S. Coast Guard (USCG), U.S. Department of Homeland Security, and various offices within the FAA (including Technical Operations, Instrument Flight Procedures, Flight Standards, and ATC). Each of the 10 agencies/departments has approximately 45 calendar days to evaluate the proposed project and can request additional time if needed. The group most likely to need an extension is FAA Technical Operations (Whitten 2017).

In addition, the FAA advises project proponents on the use of lighting equipment on structures to increase the visibility of structures and, consequently, facilitate early obstruction recognition by pilots. Specifications for obstruction lighting equipment are provided in FAA Advisory Circular 150/5345-43H (FAA 2016c). FAA Advisory Circular 70/7460-1L also provides standards for marking and lighting obstructions that have been deemed a hazard to navigable airspace (FAA 2016d). (See Appendix B for a discussion of lighting systems for wind farms.)

The DOD Siting Clearinghouse was established by Congress to coordinate a comprehensive mission compatibility evaluation process for energy production facilities and transmission projects and to identify impacts from energy development that may affect DOD's missions (DOD Siting Clearing House n.d.). Formal review through the clearinghouse is required when an application filed with the Secretary of Transportation under 49 United States Code (U.S.C.) 44718 is determined to pose an unacceptable risk to the United States' national security. An informal review through the clearinghouse may be completed in advance of filing an application with the Secretary of Transportation (Legal Information Institute. n.d.). In addition to the 14 CFR Part 77 and the Notice Criteria Tool, the FAA also provides an optional DOD Preliminary Screening Tool that allows developers to conduct a preliminary review of the potential impacts on long-range and weather radar, military training routes (MTRs), and SUA prior to official OE/AAA filing (FAA 2017e). This tool is described in more detail in Appendix A.

1.3.1.3 Federal Frequency Spectrum Regulations

NOAA's NWS ROC also evaluates wind farms because rotating blades on wind turbines have the potential to affect radar in various ways. The WSR-1988 Doppler (WSR-88D), commonly known as NEXRAD, is a major tool that NOAA forecasters use to track weather and make weather-warning decisions. NEXRAD also supports the operations of the FAA, NAS, the DOD, other government agencies, and industry. NOAA provides a NEXRAD Screening Tool that allows developers to determine the potential for impacts on nearby NEXRAD and other weather radar systems prior to an official OE/AAA filing. This tool is discussed in more detail in Appendix A.

The National Telecommunication and Information Administration (NTIA) manages the federal government's use of the domestic and international spectrums. NTIA's Office of Spectrum Management manages the radio frequency spectrum through the Interdepartment Radio Advisory Committee (IRAC). IRAC establishes and executes policies regarding spectrum use and assigns frequencies. Members of IRAC include, but are not limited to, the U.S. Air Force, Army, and Navy; the U.S. Department of Energy, USCG, FAA, U.S. Department of Commerce, and U.S. Department of Transportation, with the Federal Communications Commission acting as a liaison (NTIA 2017). Developers can submit proposals to the NTIA. The NTIA helps developers to contact federal agencies with an interest in wind energy development. As part of this coordination function, NTIA will conduct case-by-case analyses of proposed projects and work with developers on potential mitigation options to reduce any anticipated impacts.

These evaluation processes and tools allow developers to examine potential impacts that wind farms may have on aviation and radar systems. By identifying these potential impacts early on in project development, delays can be minimized, and stakeholder consensus can be reached earlier in the planning process.

1.3.1.4 National Environmental Policy Act

The National Environmental Policy Act (NEPA) of 1969, 42 U.S.C. 4321 et seq., requires that, prior to making permitting decisions, federal agencies assess the environmental effects of their own activities and development projects, and activities by others that require federal licenses or permits. Federal agencies do this by preparing documents that address the environmental consequences, if any, of the proposed action. An environmental assessment under NEPA contains an analysis for determining whether the impacts of

the action will be significant. If significant, an environmental impact statement is prepared and issued by the agency. If not significant, a finding of no significant impact is issued, which effectively ends the agency's NEPA obligations for that project. NEPA requires opportunities for public participation in the environmental impact review process (40 CFR 1500-1508).

NEPA also established the Council on Environmental Quality, which is within the Executive Office of the President and promulgates guidelines for implementing NEPA procedure that apply to all federal agencies. Federal agencies are also free to create their own additional regulations. The Council reviews and approves federal agency NEPA procedures (40 CFR 1500-1508).

As the lead agency for future offshore wind farms in federal waters, BOEM will, in consultation with other agencies and stakeholders, oversee the required NEPA process for any such proposed offshore wind projects. For offshore wind farms proposed in federal waters, environmental consultations are required for two phases of the development process—the site assessment and leasing phase, and the construction and operations phase. Site assessment and leasing activities for future development would likely require an environmental assessment, while an environmental impact statement would likely be required for construction and operations activities (New York State Energy Research and Development Authority [NYSERDA] 2015). Aviation and radar assets would be a resource assessed in any such NEPA process; if potential significant adverse impacts are identified, mitigation measures would be identified (30 CFR § 585).

1.3.2 State Regulatory and Regional Planning Context

This section provides an overview of state laws and regulations that may impact the siting of wind energy projects that are near military assets, airports, and radar facilities. This section also provides context related to all wind energy systems (both land-based and water-based), so that best practices and suggested parameters may be gleaned from all project types as appropriate (including those based onshore and offshore).

In addition to the federal oversight procedures described above, state and regional agencies also have oversight of aviation systems. At the state level, aviation and air transportation systems in the AoA are managed through both the New York State Department of Transportation (DOT) and the New Jersey Department of Transportation (NJDOT). The DOT's Aviation Bureau was established to provide leadership in addressing the state's aviation needs. As part of this mission, the Aviation Bureau provides aviation users and the public with information on aviation grants, aviation safety and security guidelines,

and planning documents such as the State Airport System Plan (DOT 2017). Similarly, the NJDOT maintains broad oversight of public use airports and restricted use facilities such as airstrips and heliports through their Bureau of Aeronautics. The Bureau of Aeronautics provides information on aviation grants, regulations, and safety guidelines to aircraft operators and the public.

The Port Authority of New York and New Jersey (PANYNJ) operates five airports, including John F. Kennedy International, LaGuardia Airport, and Newark Liberty International Airport, as well as smaller hubs at Teterboro Airport and Stewart Airports. The Port Authority is responsible for maintaining the airports, ensuring safety, tracking use of the facilities, and securing funding for airport capital projects (PANYNJ 2017).

States can vary in their legislative approach to wind energy project facility siting (either land based or within state waters), but the approaches generally involve designating siting authority to state agencies such as public utility commissions, boards, or councils, often in collaboration with local authorities, or designating the siting to local governments and their land use authority. Land use policies and ordinances often include allowable uses on certain land types as well as proximity to facilities such as airports, institutions, and critical environments. Authority can often be split, depending on the size of the wind facility, or involve a combination of state and local government authority on the facility siting. States have also used model ordinances that include land use regulations and standard considerations when siting wind facilities and that provide examples of local government rules concerning siting (Heibel and Durkay 2016). New York is an example of a state that uses model ordinances related to wind energy siting for local governments to consider and implement (Sprayberry 2013).

In NYS, local governments manage land use within their jurisdictions, which includes wind energy development, through local zoning and municipal codes. State law mandates that wind energy siting decisions can be subject to environmental review regulations (Heibel and Durkay 2016.) The Power Act of 2011 created the process for siting electricity-generating facilities and repowering projects. Through this process, the Board on Electric Generation Siting and the Environment leads the permitting process for power plants and facilities of 25 MW or greater (NYS 2017a). As part of the Power NY Act of 2011, provisions of the Public Service Law Article 10 provide a more streamlined review process for power facilities of more than 25 MW by addressing the State and local permit requirements in one process. Wind development projects with a capacity to generate less than 25 MW are not required to go through the Article 10 process. However, as with all wind development projects, these smaller projects can still be subject to regulations, including the State Environmental Quality Review Act and FAA regulations.

Article 10 regulations (Subchapter A, Regulations Implementing Article 10 of The Public Service Law as Enacted by Chapter 388, Section 12, of The Laws of 2011) include other siting review procedures related to aviation (NYS 2017b). These include planning for outreach with applications that are likely to require consultation with airport operators, as well as considering effects on transportation such as airports, airstrips, and any other mass transit systems in the vicinity of the field. Article 10 regulations concerning effects on transportation also state specific requirements needed if the proposed construction or alteration requires a Notice of Proposed Construction submission to the FAA in accordance with CFR Part 77 pursuant to 49 U.S.C., Section 44718. These include that, in certain cases, the applicant obtains informal DOD review of the proposed construction and that the applicant consults with airport operators in various buffer areas around various types of airport facility as stated in the Article 10 regulations (NYS 2017b).

In New Jersey, wind energy projects may need approval from the Division of Land Use Regulation depending on factors of the project such as location and structure types. Local governments may not adopt ordinances that unreasonably limit wind energy facilities.

While some states may not have specific laws related to wind energy siting near civilian and military aviation assets, resources such as the DOD Preliminary Screening Tool and the FAA OE/AAA filing can help determine potential impacts.

- CFR 77 and other FAA regulations related to airspace classifications (discussed in Section 1.3.1) further impact wind energy siting in areas surrounding military assets, airports, and radar facilities.
- Additionally, the DOD has a clearinghouse that provides informal reviews as requested. States, landowners, developers, and local governments can request an initial DOD determination prior to filing their application with the Secretary of Transportation under U.S.C. Title 49 Chapter 44718 (49 U.S.C. § 44718 [DOD n.d.]).

In addition, legislatures can employ policies and regulations at the federal, state, and local level or in areas surrounding military assets or airports that require oversight of wind energy siting to ensure compatibility. These approaches include creating zoning overlays that could require notification to DOD of wind energy projects, memoranda of understanding regarding development in proximity to aviation assets, and updating land use and zoning policies at the municipal level that ensure compatible siting of wind energy development. An example of specific legislation in New York includes a current Senate Bill that has been proposed and, if passed, would restrict wind generation facilities within 40 miles of an airfield or military air installation (NYS Senate 2017).

2 Data Review and Stakeholder Interviews

2.1 Methodology

The following methodology was developed to identify areas within the AoA where potential wind energy development would be compatible with the use and users of aviation and radar assets. The methodology included a desktop review of aviation and radar assets within or near the AoA, stakeholder interviews, and a geographic compatibility analysis using geographic information systems. Section 2.2 presents the aviation and radar assets identified within or near the AoA that may be impacted by development of a wind farm offshore of New York. Section 2.3 presents a summary of the stakeholder interviews, and Section 2.4 presents the results of the geographic compatibility analysis.

The following are the primary data sources used to inventory aviation and radar assets and conduct the geographic compatibility analysis:

- Digital Aeronautical Flight Information File – The Digital Aeronautical Flight Information File is a set of files that contain data on airports, navigational aids, waypoints, SUA, and other relevant features. These data are maintained and provided by the U.S. military through the National Geospatial Intelligence Agency and include geospatial information related to aeronautical operations throughout the entire world.
- 2016-2017 Environmental Systems Research Institute (ESRI) and Tele Atlas North America, Inc., geographic information system (GIS) Data – ESRI data provides maps and data layers, including a variety of base map and thematic layers for the world with scale-dependent renderings and labeling. Detailed metadata are also provided for North America. This data source is located at <http://www.esri.com/data/data-maps>.
- Radar locations collected or geocoded from the FAA and DOD – Radar locations, particularly the airport surveillance radars (ASR-9) and TDWRs, were requested from the FAA during stakeholder interviews. All radar facilities are owned by either the FAA or NOAA. Radar facilities are located at these facilities:
 - John F. Kennedy International Airport has an ASR-9 on-site that is used to support aircraft operations at both John F. Kennedy International Airport and LaGuardia Airport.
 - Newark Liberty International Airport has an ASR-9 on-site.
 - Long Island MacArthur Airport has an ASR-9 on-site.
 - White Plains-Westchester Airport has an ASR-9 on-site.
 - Atlantic City International Airport has an ASR-9 on-site.
 - Joint Base McGuire-Dix-Lakehurst in Wrightstown, New Jersey, has an ASR-11 on-site.
- Weather Radar Locations collected or geocoded from NOAA and the NWS; NOAA provides the locations of the NEXRAD and TDWR. This data source is located at:

<https://www.roc.noaa.gov/wsr88d/maps.aspx> and
<https://www.roc.noaa.gov/wsr88d/Program/NetworkSites.aspx>.

- Ocean Monitoring Radar Locations collected from NOAA’s U.S. Integrated Ocean Observing System (IOOS) – The IOOS oversees a network of high-frequency (HF) radar sites. This data source is the 2017 Coastal Observing Research and Development Center located at: <http://cordc.ucsd.edu/projects/mapping/maps/> and <https://ioos.noaa.gov/project/hf-radar/#coverage>.
- FAA Sectional Aeronautical Charts – This is the primary navigational reference medium used by the VFR pilot community. The 1:500,000-scale Sectional Aeronautical Chart Series is designed for visual navigation of slow- to medium-speed aircraft. This data source is located at: https://www.faa.gov/air_traffic/flight_info/aeronav/productcatalog/vfrcharts/sectional/.
- Flight Aware Data – One year of flight track data was purchased from FlightAware.com. The data spans July 27, 2016, to July 24, 2017, and includes all flights transiting the AoA from the surface to 10,000 feet above mean sea level (MSL).
- GIS data (in-house) – Data include basic layers such as country boundaries, state jurisdictions, cities, and airports.

In order to compile a complete list of potentially affected stakeholders, several agencies and airports in the region were contacted for phone interviews. Section 2.3 provides a summary of the interview and stakeholder comments.

2.2 Description of Aviation and Radar Assets

The aviation and radar facilities included in this analysis were identified through desktop research, stakeholder outreach, and a search of available data sources. The aviation and radar facilities included in the analysis in this study include civilian airports (commercial, reliever, and general aviation), military airports, USCG stations, SUA, MTRs, aerial refueling routes, and radar facilities (aviation, weather, ocean monitoring, ATC/air surveillance, national security systems, and marine navigation).

2.2.1 Airports and Flight Activities

2.2.1.1 Civilian Airports and Airspace

Civilian airports are divided into several sub-categories: commercial, reliever, and general aviation airports. Commercial airports are defined by the FAA as publicly owned airports that have at least 2,500 passenger boardings each calendar year and receive scheduled passenger service. The FAA defines reliever airports as those that relieve congestion at commercial airports and provide improved general aviation access to the overall community. Reliever airports may be privately or publicly owned (FAA 2016a). In addition, many smaller general aviation airports are near the AoA. There are 26 civilian

airports within 50 miles of the AoA, including a mix of commercial, reliever, and general aviation airports. The major facilities (commercial and reliever) and the annual number of operations for each are identified in Table 1. Figure 3 shows the airports and the controlled airspace as defined in Figure 2 identified within and in the vicinity of the AoA. None of the controlled airspace extends into the AoA. Figure 4 shows the low altitude flights (1,300 feet and below) within the AoA during a sample time period of one year. The 1,300-foot threshold was used assuming a rotor-swept zone extending 800 feet MSL plus a 500-foot buffer extending vertically from the rotor-swept zone. The flight activity with the most flights (> 5 flights) within the AoA below 1,300 feet originated from the Cape Cod USCG Station (see Section 2.21.3), and was likely associated with search-and-rescue activities.

Not all airports identified in the region were included in the stakeholder outreach conducted during this study. As discussed in Section 2.1, airports contacted for outreach included those with higher levels of aircraft operations. The outreach with these airport stakeholders emphasized the importance of on-going communication about nearby wind energy development. For example, although operations are not expected to significantly change in the future, runway expansion at the major New York City airports is being analyzed and should be continually monitored to identify potential changes in flight activity as it relates to areas proposed for wind energy development.

Table 1. Total Operations at Select Commercial and Reliever Airports

Sources: GCR, Inc. n.d.

Airport	Commercial Operations	Private Operations	Other Operations	Total Operations^{a, b}
John F. Kennedy International Airport	419,274	30,912	8,644	458,830
LaGuardia Airport	309,563	52,950	6,661	369,174
Newark Liberty International Airport	301,171	111,342	11,573	424,086
Philadelphia International Airport	226,056	153,590	14,376	394,022
Farmingdale Republic Airport	135	10,833	186,556	197,524
Long Island MacArthur Airport	9,056	7,055	97,690	113,801
Atlantic City International Airport	7,836	5,525	57,086	70,447

^a All data shown represent annual operations. Annual reporting period varies per airport based on cyclical FAA reporting requirements.

^b An aircraft operation is defined as one takeoff or one landing, or one aircraft pass through the area in question.

Figure 3. Airspace and Aviation Routes

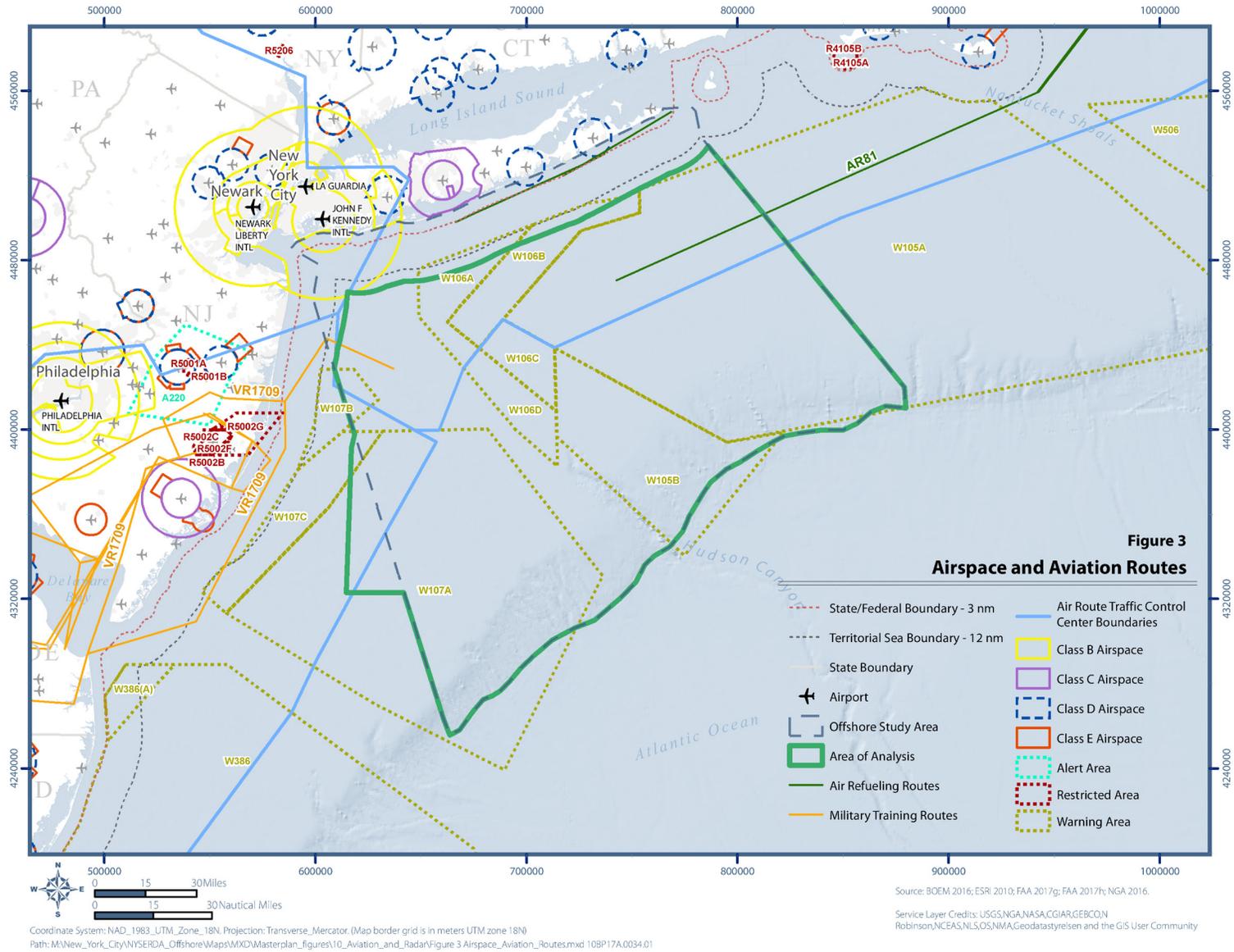
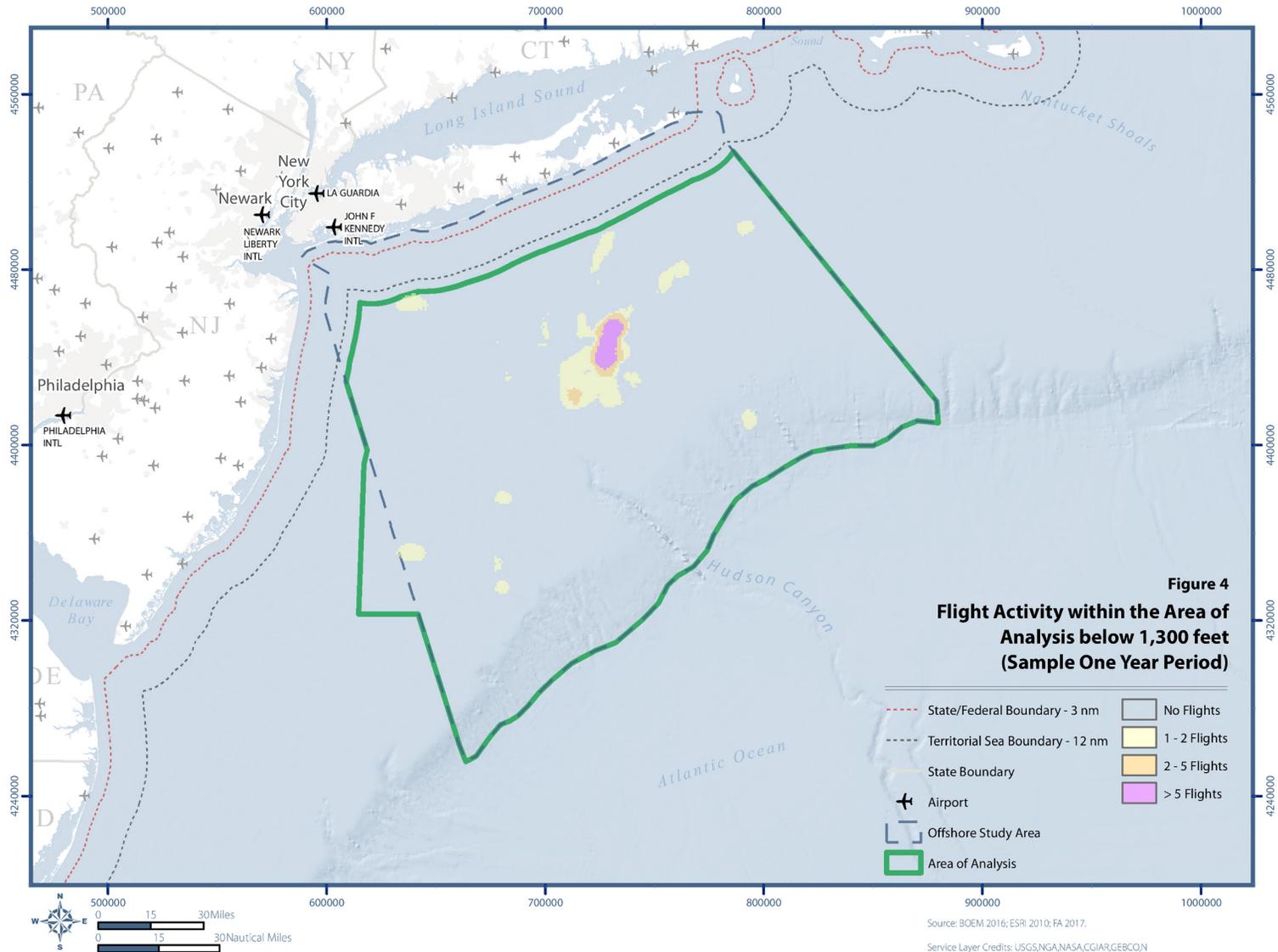


Figure 4. Annual Flight Activity within the AoA below 1,300 feet



2.2.1.2 Military Airports

The DOD manages air bases that typically function with high air traffic volumes related to training and operational missions. Francis S. Gabreski Air National Guard Base is co-located on Francis S. Gabreski Airport, a general aviation airport approximately 20 miles north of the nearest AoA boundary; this is the closest facility to the AoA with military flight operations. The closest dedicated military air base is Joint Base McGuire-Dix-Lakehurst, located 18 miles southeast of Trenton, New Jersey, and approximately 45 miles from the western AoA boundary.

2.2.1.3 United States Coast Guard Stations

Aircraft at USCG stations are used for maritime safety, homeland security, national defense, and environmental protection purposes. The USCG's 1st District Headquarters in Boston is responsible for the region encompassing northern New Jersey, New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, Vermont, and Maine. The 1st District units include USCG Air Station Cape Cod, which is located at Joint Base Cape Cod and is the main USCG aviation facility in the Northeast. USCG Air Station Cape Cod operates both rotary and fixed-wing aircraft for various missions such as ocean search and rescue and homeland security. The USCG's 5th District operates a sector field office at Air Station Atlantic City, located at the William J. Hughes FAA Technical Center at the Atlantic City International Airport in New Jersey.

2.2.2 Military Airspace

2.2.2.1 Special Use Airspace

Some areas of controlled and uncontrolled airspace are classified as SUA, and are associated with military aircraft training operations. Operations within SUA are deemed hazardous to civil aircraft, and, as a result, civil aircraft use in the area may be restricted or limited. SUA overlying the AoA include warning areas, MTRs, and aerial refueling routes (FAA 2007). These types of SUA are described below.

- **Warning Areas.**

Warnings areas contain activities that may be hazardous to non-participating aircraft. The areas can be located over both domestic and international waters and can overlap, adjoin, or be within other SUAs. They are identified with a "W" followed by a two- or three-digit identifying number. Warning areas are individually tailored with specific altitude, time of use, and the controlling agency/contact information. See Table 2 for a description of warning areas and Figure 3 for the warning areas within and near the AoA.

- **Military Training Routes.**
 MTRs are flight corridors used by the military to practice low-altitude, high-speed training missions. Generally, MTRs are established below 10,000 feet MSL for operations in excess of 250 knots (FAA 2007). MTRs are described by a centerline, with defined horizontal limits on either side of the centerline and vertical limits expressed as minimum and maximum altitudes along the flight track. Route widths can vary along the MTR and extend several miles on either side of the charted MTR centerline. Figure 3 shows the MTR centerlines within and in the vicinity of the AoA. One MTR (VR-1709) enters the AoA on the northwest corner, with an altitude setting of below 1,500 feet AGL. Military aircraft conducting low-level training can be anywhere within the MTR parameters.
- **Aerial Refueling Routes.**
 An aerial refueling route is airspace used by military tankers that routinely refuel other military aircraft along published altitudes (in most cases above 10,000 feet AGL). This airspace is not prohibited from other users as long as other aircraft provide vertical or lateral separation from the refueling aircraft. Figure 3 shows one aerial refueling route (AR-81) within the AoA, located south of eastern Long Island and extending to the northeast.
- **Prohibited Areas.**
 Prohibited areas contain airspace of defined dimensions identified by an area within which the flight of aircraft is prohibited. Such areas are established for security or other reasons associated with the national welfare. No prohibited areas are located within the AoA.
- **Restricted Areas.**
 Restricted areas are similar to prohibited areas, from the pilot's perspective. One difference is that restricted areas usually indicate airborne threats to flight safety, such as high-speed military flights or gun-firing maneuvers. Since these hazards are not always present, restricted areas may be active only at certain times. When not in use, no clearance or permission is required to fly through them. No permanent restricted areas are located within the AoA, although temporary restricted areas may be established as needed.
- **Military Operations Areas.**
 Military Operations Areas (MOAs) are designed to separate certain military training activities from other IFR traffic and cover airspace with specifically defined vertical and lateral limits. When the MOA is in use by the military, other nonparticipating users may be diverted or cleared from the area by ATC (FAA 2016b). No MOAs are located within the AoA.
- **Alert Areas.**
 Alert areas are designated to inform nonparticipating pilots of areas that may contain a high volume of pilot training activity or an unusual type of aerial activity. Pilots should be particularly alert when flying in these areas. All activity within an alert area must be conducted in accordance with the CFR, without waiver, and pilots of participating aircraft as well as pilots transiting the area must be equally responsible for collision avoidance. No alert areas are located within the AoA.

Table 2. Description of Warning Areas within the AoA

Source: FAA Order JO 7400.8Z, SUA dated 2/16/17.

Name	Altitude	Times of Use	Controlling Agency	Using Agency
W-105A Narragansett, RI	Surface to FL 500	Intermittent by NOTAM	FAA, Boston ARTCC	Navy, FACSFAC VACAPES
W- 105B Narragansett, RI	Surface to FL 180	Intermittent by NOTAM	FAA, Boston ARTCC	
W-106A Patchogue, NY	Surface to 3,000 feet MSL	Intermittent by NOTAM	FAA, Boston ARTCC	
W-106B Patchogue, NY	Surface to 8,000 feet MSL	Intermittent by NOTAM	FAA, Boston ARTCC	
W-106C Patchogue, NY	Surface to 10,000 feet MSL	Intermittent by NOTAM	FAA, Boston ARTCC	
W-106D Patchogue, NY	Surface to but not including 6,000 feet MSL	Intermittent by NOTAM	FACSFAC VACAPES, OCEANA NAS	
W-107A Atlantic City, NJ	Surface to unlimited.	Intermittent by NOTAM	FAA, Washington ARTCC	
W-107B Atlantic City, NJ	Surface to but not including 2,000 feet MSL	Intermittent by NOTAM	FAA, New York ARTCC	
W-107C Atlantic City, NJ	Surface to but not including FL 180	Intermittent by NOTAM	FAA, Washington ARTCC.	

Key:

- ARTCC = Air Route Traffic Control Center
- FACSFAC VACAPES = Navy, Fleet Area Control and Surveillance Facility, Virginia Capes, Virginia Beach, VA.
- FL = flight level (e.g., FL 500 indicates 50,000 feet above MSL)
- MSL = mean sea level
- NOTAM = Notices to Airmen
- W- = warning area

2.2.2.2 Air Defense Identification Zones

Air Defense Identification Zones are designated to assist the DOD, the U.S. Drug Enforcement Administration, and U.S. Customs in their efforts to intercept an airborne attack, illegal trade, and contraband. All aircraft entering domestic U.S. airspace from points outside must provide identification prior to entry. Air Defense Identification Zones have been established to facilitate early aircraft identification of all aircraft in the vicinity of U.S. and international airspace boundaries.

2.2.3 Radar Systems

2.2.3.1 Weather and Ocean Monitoring Radars

The following describes radar systems in the vicinity of the AoA, including land-based radars used for weather forecasting and ocean monitoring, aviation safety, national defense, national security, and marine navigation.

Weather radar facilities used in the U.S. are managed by two agencies, NOAA and the FAA. NOAA’s NWS WSR-88D ROC manages 160 NEXRADs, and the FAA manages 45 TDWRs (Sprayberry 2013). Table 3 presents the specifications for the two weather radar systems. Figure 5 shows the NEXRAD and TDWR radar locations near the AoA; however, the AoA is outside NOAA’s no-build, mitigation, consultation, and notification zones as discussed in Appendix A (Table A-2).

Table 3. Comparison of NEXRAD and TDWR Systems

Source: NOAA n.d.

	NEXRAD	TDWR
Managing Agency	NOAA’s WSR-88D ROC	FAA
Use	Track severe weather conditions to determine weather warnings	Detect low-level wind shear

The IOOS Program manages a national HF radar network for all U.S. ocean coastlines. (HF denotes that part of the electromagnetic spectrum having frequencies from 3 to 30 megahertz [MHz].) HF radar systems measure the speed and direction of ocean surface currents in near real-time. Presently, approximately 140 HF radars and 30 institutions are part of the nationwide network, and their data are delivered by IOOS national data servers (IOOS 2017). Radar antennas are positioned on shore and can measure surface currents up to 200 km away. The range and resolution of HF radar systems depend on the frequency, transmission power, antenna placement and design, and ambient radio frequency noise levels (IOOS 2012). Typical ranges extend 40 km to 200 km offshore for broadcast frequencies between 5 MHz and 25 MHz. Table 4 and Figure 6 present the IOOS HF radar sites near the AoA along the coasts of New Jersey, New York, Rhode Island, and Massachusetts.

Table 4. NOAA’s IOOS Program High-Frequency Coastal Radar Sites Adjacent to the AoA*Source: Coastal Observing Research and Development Center 2017*

Location	Average Range	Maximum Range	Affiliation
Amagansett, NY (AMAG)	200 km	200 km	Rutgers University
Bradley Beach, NJ (BRAD)	90 km	200 km	Rutgers University
Brigantine, NJ (BRIG)	175 km	200 km	Rutgers University
Brant Beach, NJ (BRNT)	82 km	200 km	Rutgers University
Hempstead, NY (HEMP)	200 km	200 km	Rutgers University
Sandy Hook, NY (HOOK)	200 km	200 km	Rutgers University
Loveladies, NY (LOVE)	200 km	200 km	Rutgers University
Moriches, NY (MRCH)	200 km	200 km	Rutgers University
Martha’s Vineyard, MA (MVCO)	200 km	200 km	Rutgers University
Nantucket Island, MA (NANT)	200 km	200 km	Rutgers University
Old Bridge Waterfront Park, NJ (OLDB)	30 km	200 km	Rutgers University
Port Monmouth, NJ (PORT)	20 km	200 km	Rutgers University
Strathmere, NJ (RATH)	90 km	200 km	Rutgers University
Sea Bright, NJ (SEAB)	90 km	200 km	Rutgers University
Seaside Park, NJ (SPRK)	90 km	200 km	Rutgers University
Staten Island, NY (SILD)	30 km	200 km	Staten Island Technical School
Nauset, MA (NAUS)	175 km	200 km	University of Massachusetts Dartmouth
Block Island, RI (BISL)	42 km	200 km	University of Massachusetts Dartmouth
Montauk, NY (MNTK)	42 km	200 km	University of Rhode Island
Long Point Wildlife Refuge, MA (LPWR)	95 km	200 km	Woods Hole Oceanographic Institution

HF radar data is used by the USCG for search-and-rescue operations and NOAA’s Office of Response and Restoration Emergency Response Division during oil and hazardous material spills to help forecast flow patterns (Harlan et al. 2010). Other applications include water quality monitoring and marine navigation.

Figure 5. NOAA/NWS and FAA Weather Radar Locations

Source: BOEM 2016; ESRI 2010; NOAA 2017b

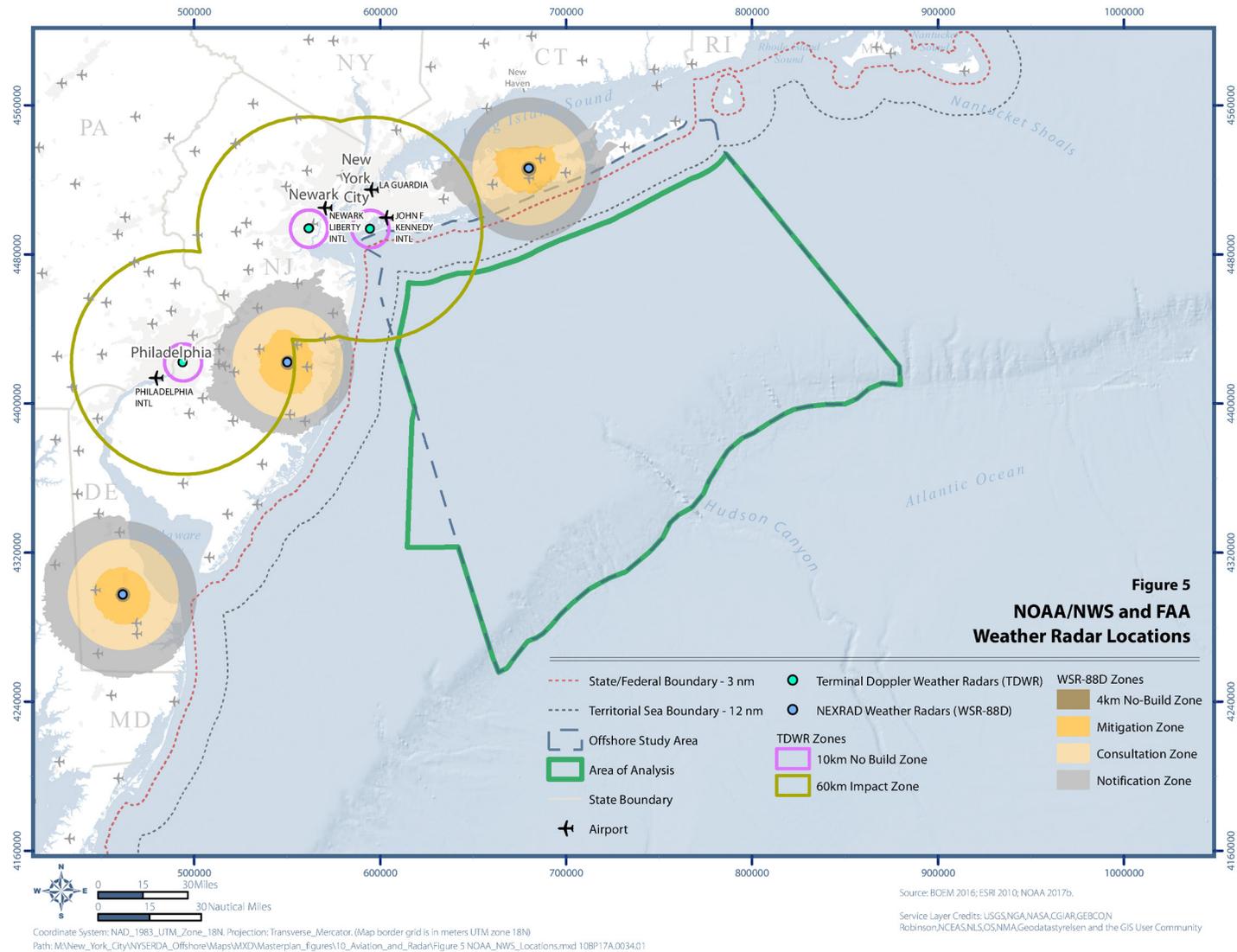
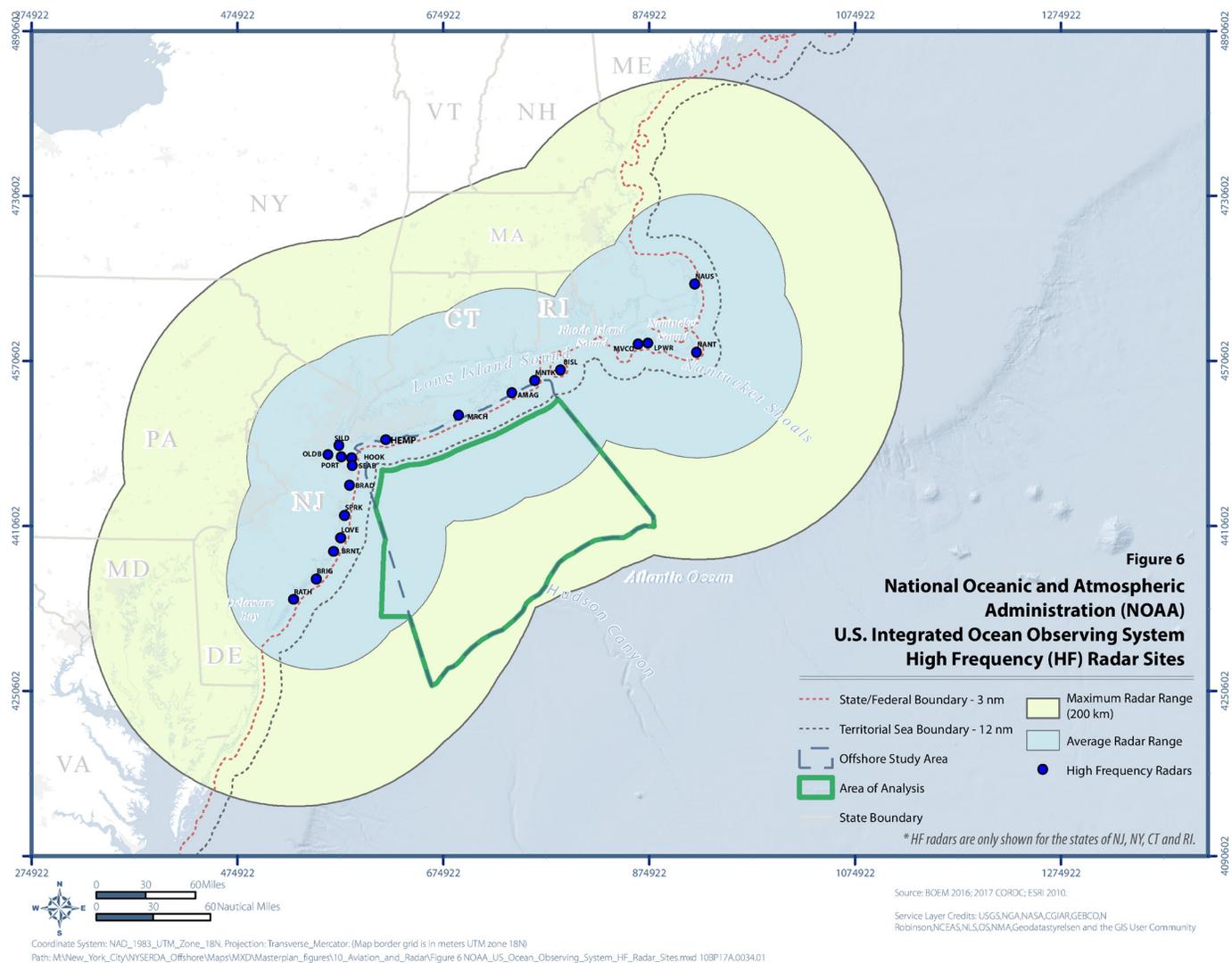


Figure 6. National Oceanic and Atmospheric Administration (NOAA) U.S. Integrated Ocean Observing System High Frequency (HF) Radar Sites

Source:BOEM 2016; 2017 CORDC; ESRI 2010



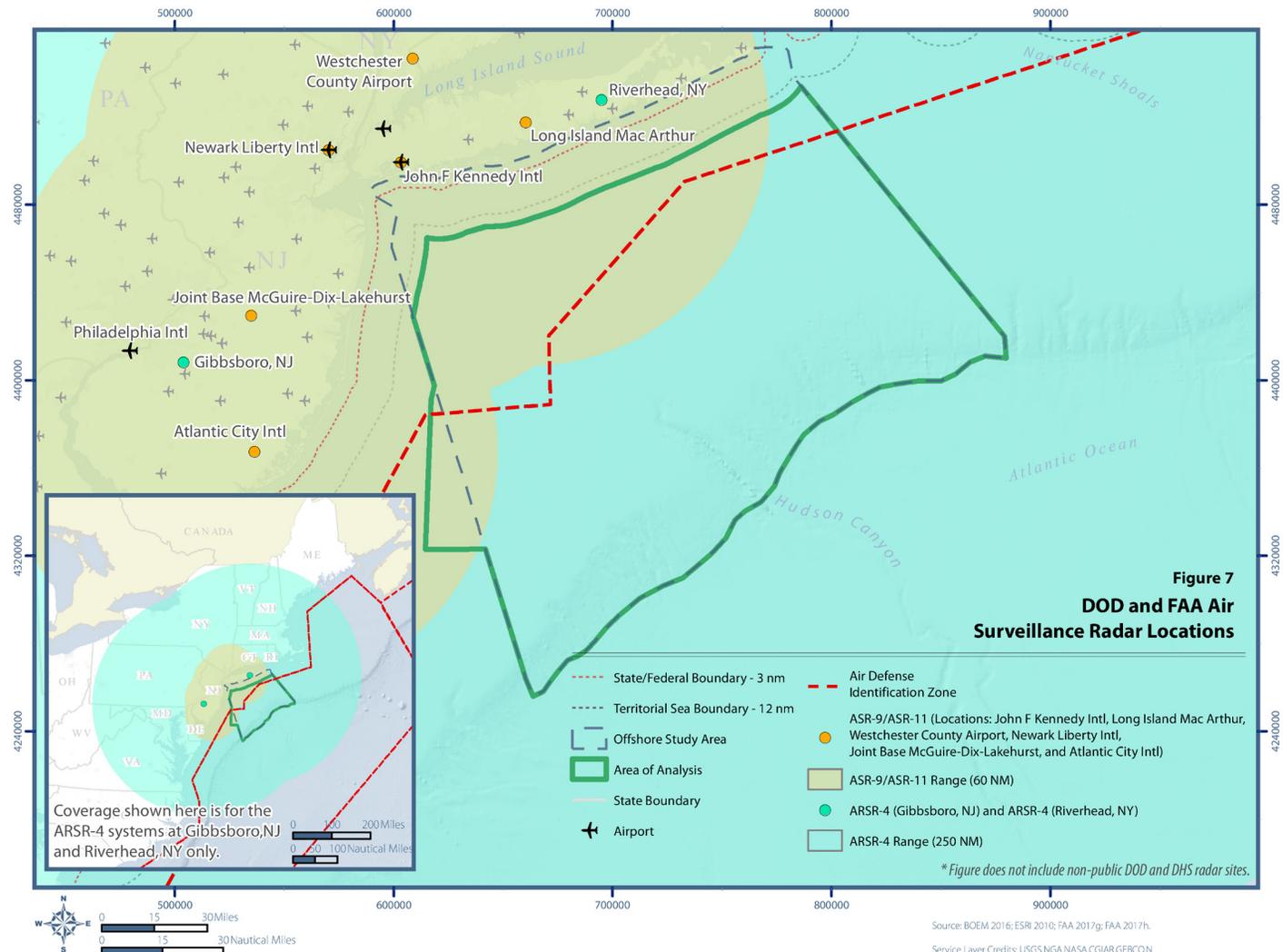
2.2.3.2 Air Traffic Control and Air Surveillance Radar

ATC at major airports use radar systems to detect and display the presence and position of aircraft in the vicinity. The Port Authority's John F. Kennedy International, Newark Liberty International, Long Island MacArthur, White Plains-Westchester, and Atlantic City International Airports all have ASR-9 on-site (Figure 7). An ASR-11 is located at Joint Base McGuire-Dix-Lakehurst in Wrightstown, New Jersey. ASR-9s and ASR-11s are ASRs that display weather and aircraft simultaneously with ranges of approximately 60 nm. LaGuardia Airport uses the ASR-9 located at John F. Kennedy International Airport. Airports can also have security radars on airport perimeters, which may require future review with regard to wind farm siting (Bock 2017). Additional aviation radars relevant to the AoA include long-range air route surveillance radars (ARSR-4), which are located in Riverhead, New York, and Gibbsboro, New Jersey (Figure 7). ARSR-4 radar systems are part of the Joint Surveillance System network of long-range surveillance radar used to track all air traffic en route to the U.S. along the borders and coasts. The Joint Surveillance System is primarily operated and maintained by the FAA but also provides communication and radar data to the DOD, the Department of Homeland Security, and other federal agencies. As early-warning devices, ARSR-4s can detect approaching aircraft at great distances; typical ranges for these radars are approximately 250 nm.

Other U.S. radar facilities in use include national security radar systems such as the Air and Missile Defense Radar and those that are part of the North American Aerospace Defense Command (NORAD). The Air and Missile Defense Radar has capabilities that can support various military missions and long-range exo-atmospheric detection, tracking, and discrimination of ballistic missiles, and provides area and self-defense against both air and surface threats (Navy 2017a). Part of the mission of NORAD is to provide a tactical warning and attack assessment to the U.S. and Canada. To achieve this mission, NORAD utilizes a system of satellites, ground-based radar, and airborne radar to detect, intercept, and deal with possible threats (NORAD 2017). These assets are discussed here for context but are not mapped within this report.

Figure 7. DOD and FAA Air Surveillance Radar Locations

Source: BOEM 2016; ESRI 2010; FAA 2017g; FAA 2017h



2.2.3.3 Marine Navigation - Vessel-Borne Radar and Sonar Systems

Sound navigation and ranging (sonar) systems are used for navigation, exploration, mapping, and detecting objects or features in the ocean (NOAA 2017a). Navy, USCG, commercial, and civilian water-borne vessels operate with onboard radar systems for navigation and surface contact tracking. The DOD uses sonar in training exercises and military operations. The Navy uses mid-frequency sonar systems on vessels such as cruisers, destroyers, frigates, submarines, aircraft, and helicopters. DOD and commercial vessels operate throughout the waters of the AoA.

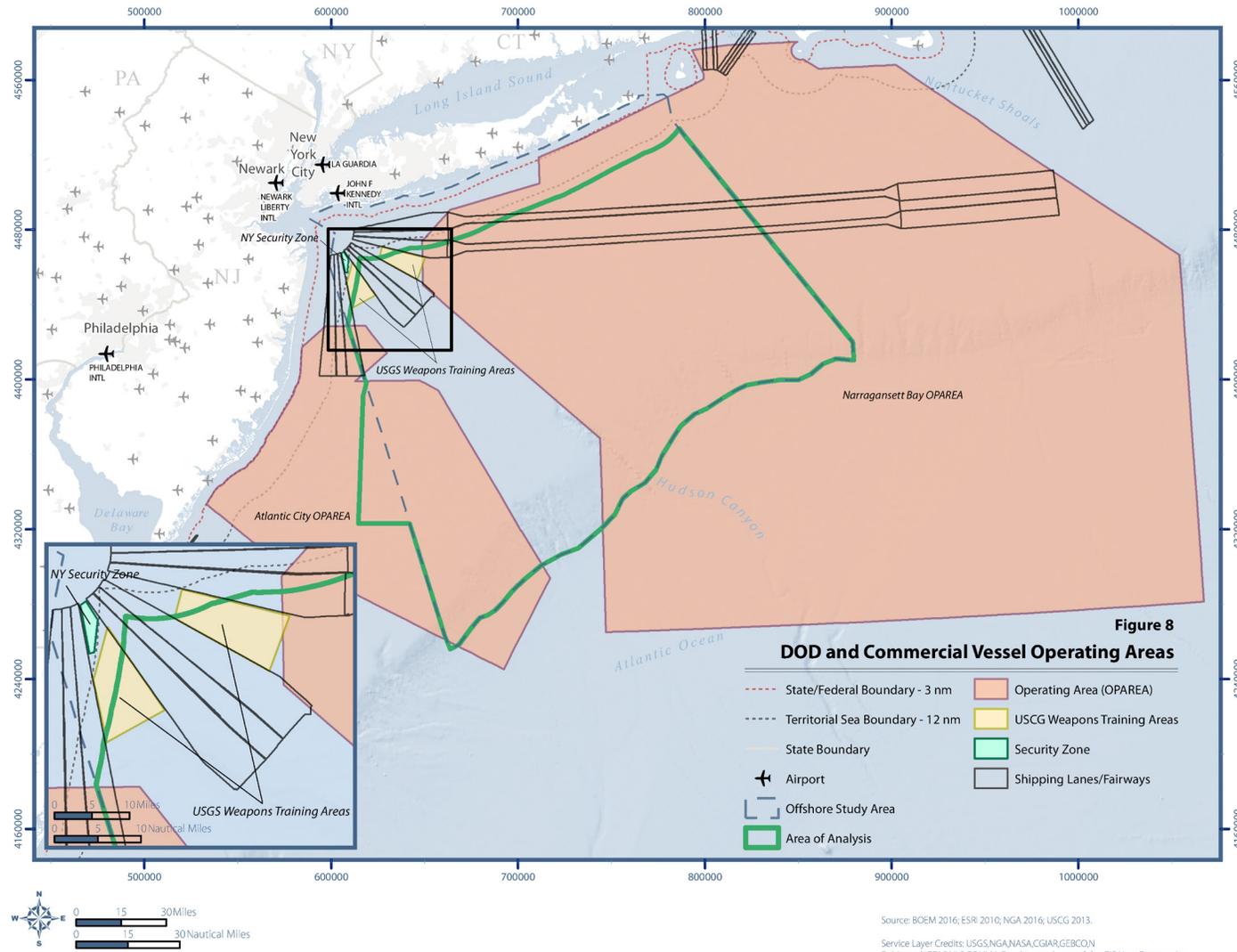
The USCG uses two designated Weapon Training Areas and one Security Zone located within the AoA (Figure 8). The Weapon Training Areas are used by surface vessels to maintain law enforcement proficiency. USCG vessels use onboard radar systems for vessel tracking, search-and-rescue operations, training, and testing. The Security Zone is an Atlantic Ocean approach zone to New York codified in 33 CFR 165.169(a)(12).

The DOD has two offshore training ranges that overlap the AoA, the Narragansett Bay Operating Area (OPAREA) and the Atlantic City OPAREA (Figure 8). The offshore component of the Narragansett Bay OPAREA is located off the coasts of Massachusetts, Rhode Island, and New York. The Narragansett Bay OPAREA extends from the shoreline seaward to approximately 180 nm from land at its farthest point. The Atlantic City OPAREA is located off the coast of New Jersey and consists of sea surface space and subsurface space. The Atlantic City OPAREA extends from the shoreline seaward to approximately 100 nm from land at its farthest point. The OPAREAs are ocean areas defined by geographic coordinates with defined sea surface and subsurface parameters. The Navy's Atlantic Fleet vessels (surface and subsurface) use the areas for training, testing, and system qualification, including onboard radar systems.

More information regarding marine navigation and civilian and commercial marine recreational vessels relevant to the AoA are discussed in the *Marine Recreational Uses Study* and the *Shipping and Navigation Study*, both of which are appended to the Master Plan.

Figure 8. DOD and Commercial Vessel Operating Areas

Source: BOEM 2016; ESRI 2010; NGA 2016; USGC 2013



Source: BOEM 2016; ESRI 2010; NGA 2016; USGC 2013.
Service Layer Credits: USGS,NGA,NASA,CGIAR,GEBCON,Robinson,NCEAS,NLS,OS,NMA,Geodastatysen and the GIS User Community

Path: M:\New_York_City\NYSERDA_Offshore\Waps\MXD\Masterplan_figures\10_Aviation_and_Radar\Figure 8 DOD_and_Commercial_Vessel_Operating_Areas.mxd 108P17A.0034.01

2.3 Summary of Stakeholder Interviews and Comments

Stakeholder engagement and feedback is an important element of this Study in identifying concerns and evaluating the potential for conflicts with aviation systems, including airport approaches, radar systems, and military assets within and adjacent to the AoA, and in informing recommended BMPs to site, construct, and operate offshore wind farms in the AoA to avoid or minimize interference with aviation and radar assets. This Study included interviews prior to Study development along with stakeholder review and comment on early drafts of the Study. Feedback from state and federal agencies, airport managers, and other stakeholders were incorporated into this Study to ensure recommendations, concerns, and other suggestions pertaining to aviation and radar assets were addressed early and throughout the offshore master planning process.

2.3.1 Interviews

In order to compile a complete list of potentially affected stakeholders, several agencies and airports in the region were contacted for phone interviews. Outreach to stakeholders was initially conducted via phone calls to introduce the Master Plan effort and identify a contact person who would be the most appropriate to answer questions regarding potential impacts on aviation and radar assets. A script was developed for the initial phone call and for follow-up emails in order to maintain consistency across the agencies and airports. After the appropriate contact person at the agency or airport was identified, a conference call was scheduled and conducted.

While both commercial and other public airports were identified during initial research, only commercial airports (large and small hubs) were selected for outreach due to their higher levels of total operations, presence of significant air taxi volume, or based military aircraft. The three major New York City commercial airports and Philadelphia International Airport were selected as the highest priority to contact, with the remaining airports chosen based on total operations. Data for the airport operations were collected from Airport IQ 5010 (GCR, Inc. n.d.). Table 5 identifies the agency offices and airports contacted during stakeholder outreach and whether interviews were conducted.

Table 5. Agencies and Airports Contacted

Agency/Airport	Contact Information	Status of Stakeholder Outreach
Federal Agencies		
FAA – Obstruction Evaluation Group	Cindy Whitten, Obstruction Evaluation Group	Interview conducted
FAA – William J Hughes Technical Center	Jim Paterson, Manager, Airport Safety Research and Development Section	Interview conducted
FAA – Radar Technical Expert	Jamal Watts, Radar Environmental Manager Thomas Fuller, Navigational Communications Manager	Interview conducted
NOAA/Department of Commerce NTIA ROC	Peter Tenhula, Deputy	No interview conducted; referred to the NOAA NEXRAD Screening Tool described in Appendix A
NOAA – IOOS Program Office	Jack Harlan, Project Manager, High Frequency Radar Ocean Remote Sensing	Interview conducted
BOEM	Dr. Mary Boatman, Project Manager	Interview conducted
U.S. Department of Defense		
Office of the Secretary of Defense	Fred Engle, Office of the Deputy Under Secretary of Defense for Readiness	Interview conducted
Airports		
John F. Kennedy International Airport, LaGuardia Airport, and Newark Liberty International Airport	Tom Bock, PANYNJ, Regulatory Safety Management Office	Interview conducted
Farmingdale Republic Airport	Rick McElroy, Airport Manager	Interview conducted
Long Island MacArthur Airport	Shelley Larose-Arken, Air Manager	No interview conducted; referred to the FAA

Note: Additional interviews were requested from Philadelphia International Airport and Atlantic City International Airport. To date, neither of these requests have been accepted.

Agencies and airport personnel interviewed have corroborated that the current system works well—with the FAA reviewing notices of construction or alteration and forwarding them to airports for input as appropriate. The following key points were provided by the agencies:

- FAA personnel noted that, in general, conflicts decrease the farther offshore wind energy projects are developed. Wind energy developments located onshore typically produce more radar interference than those located offshore, due to their closer proximity to airports and radar systems.
- Airports deferred in large part to the FAA, noting that the OE/AAA process has been an excellent resource in identifying and mitigating issues to ensure the protection of airspace and preservation of radar coverage.
- The PANYNJ reported that, due to their height, wind turbines could affect arrival and departure corridors of the airports in the area, depending on where they are sited.

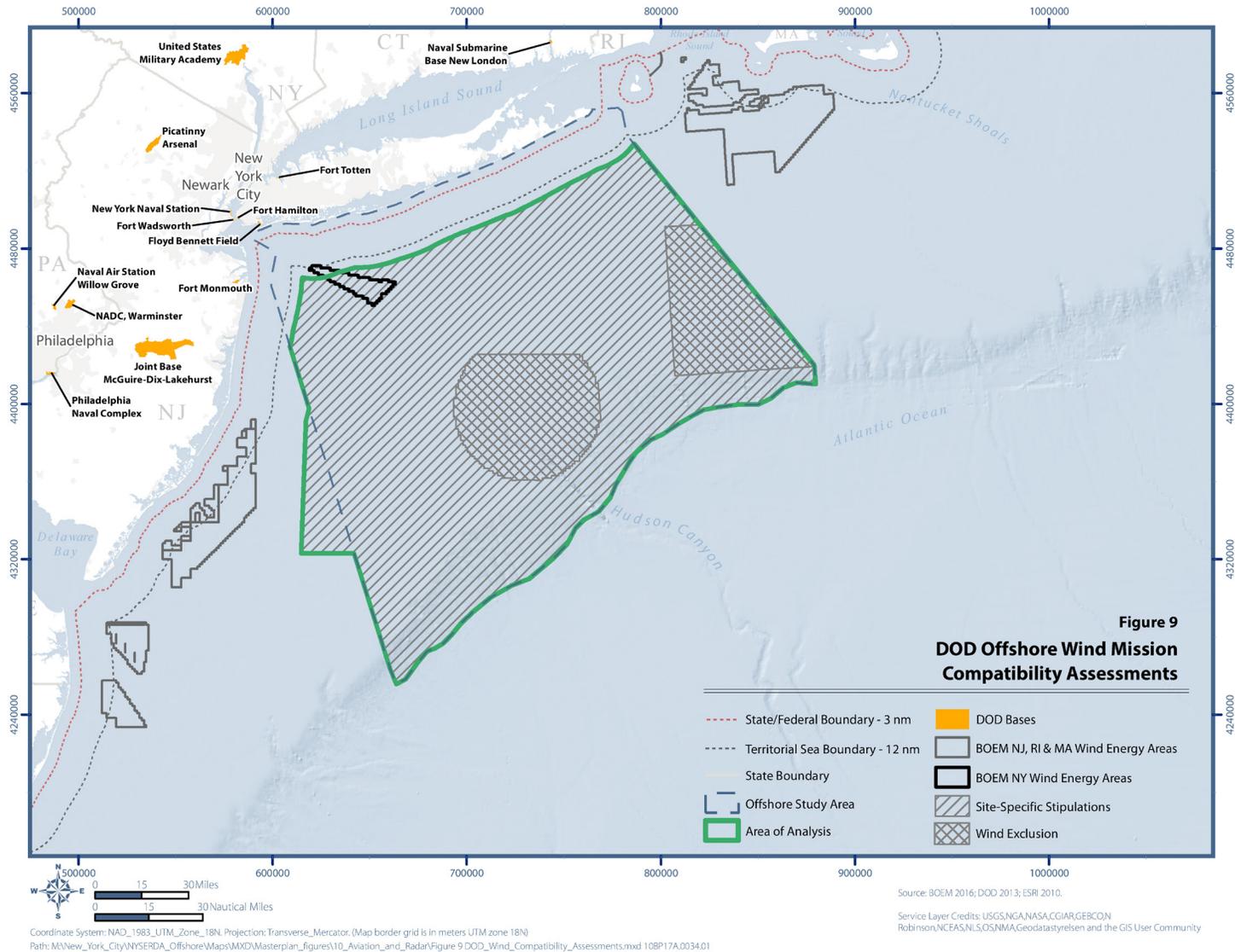
- The FAA, which currently analyzes only individual turbine locations, is also updating the OE/AAA process by analyzing and identifying blocks of airspace that would be deemed compatible for wind turbine development. Since the current process requires detailed analysis of each turbine, an updated process that identifies a block of airspace as compatible will make the review process more efficient and streamlined for both wind developers and the FAA.
- The DOD noted that the entire AoA represents an area of potential impact on their operations, including aviation, surface ships, submarines, and air defense radar systems. The DOD provided the results of an *Offshore Wind Mission Compatibility Assessment* they completed in 2013 (shown on Figure 9) to aid in this analysis (Engle 2017). This figure identifies some areas as “wind exclusion” where DOD notes that wind energy development would be incompatible with on-going military operations. Other areas are identified as needing “site-specific stipulations” in order to be compatible with on-going military operations in the area. While many of the military’s operational concerns are not available for public dissemination, the representatives noted that any wind energy development proposed in the AoA should be coordinated directly with the DOD through the DOD’s Siting Clearinghouse. The Siting Clearinghouse manages the review process for all energy developments that have the potential to impact national defense missions.
- USCG reviewed the earlier draft of this document and provided information regarding USCG Air Station Atlantic City, as well as the USCG *Report of the Effect on Radar Performance of the Proposed Cape Wind Project* (USCG 2008) as part of the *Cape Wind Final Environmental Impact Statement* (U.S. Department of the Interior 2009). Further discussion on the findings of the report is provided in Section 3.2.2.

2.3.2 Review and Comment

Subject matter experts from a variety of state and federal agencies were also given an opportunity to review earlier drafts of this document and provide comments. Those comments were received and have been incorporated into this final version of the document.

Figure 9. DOD Offshore Wind Mission Compatibility Assessments

Source: BOEM 2016; DOD 2013; ESRI 2010



2.4 Results of Geographic Compatibility Analysis

A spatial analysis was conducted to compare the potential for wind energy development within the AoA to all potentially affected aviation and radar assets. This analysis identified and assessed potential impacts that wind energy development in the AoA might have on such assets. The analysis also included assessment of potential impacts on approach corridors at air facilities, radar systems' viewsheds (discussed in more detail below), and altitudes at which training and operational military missions take place in offshore areas.

The analysis included the use of overlay mapping techniques that used aviation, airspace, and radar asset GIS data to identify potential impact areas in the AoA (Figures 10 and 11). The overlays aided in the identification and development of the following impact areas between offshore wind energy development and existing aviation and radar facilities:

- Level 1: Coordination and Mitigation Anticipated.
- Level 2: Coordination and Mitigation Likely.
- Level 3: Coordination and Mitigation Possible.
- Level 4: Mitigation Not Anticipated.

These categories were designed to communicate the results of this Study, overlaying various agencies and stakeholders' areas of concern and operational footprints. This assessment also considered military consultation areas developed by the DOD in a 2013 assessment of offshore wind development in the area (Engle 2017). The impact prediction is an assessment of the potential for interference between an offshore wind turbine in each of the areas and nearby aviation and radar assets.

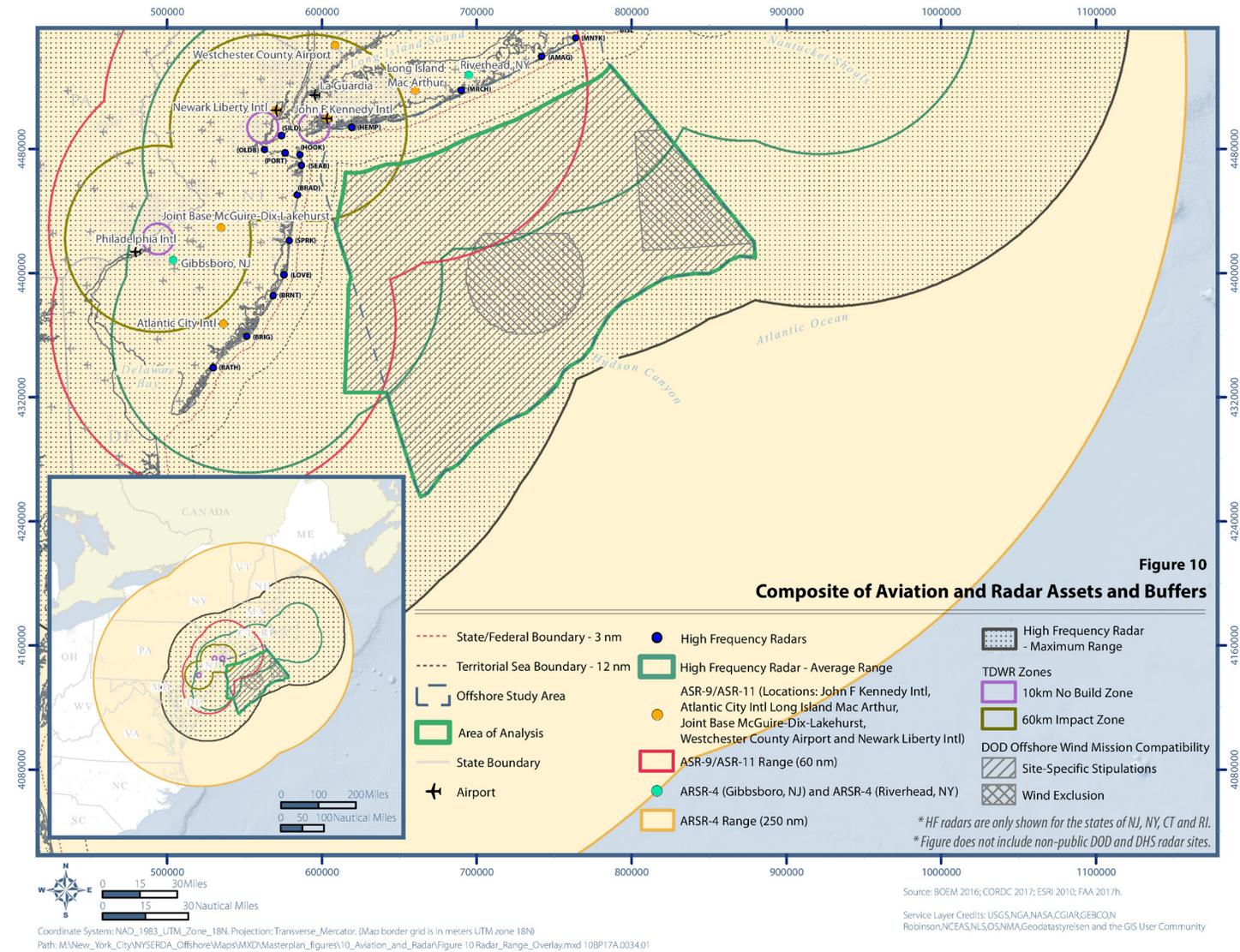
The overlay analysis included the use of impact buffers around each of the various assets to reduce the potential for aviation and radar interference resulting from wind farm development. These impact buffers are related to airport approaches, low-altitude flight activity, radar viewsheds, and other operational issues discovered during the desktop analysis. The sizes and types of these buffers are based on screening guidelines (discussed in Appendix A, many of which are location-specific), system specifications, and stakeholder outreach interviews.

- Impact buffers for approach corridors were determined by stakeholder outreach interviews with representatives from the FAA and the PANYNJ, as well as through DOD guidelines. Per stakeholder outreach with the Port Authority, for commercial airports, a five- to seven-mile (statute) impact buffer for approach corridors was determined to be sufficient. The Port Authority official reported that five to seven miles is typically the distance at which approaching aircraft will line up with the runways. For military airports, the impact buffer for the approach corridor is up to 10 miles. This distance for military airports is determined based on the approach guidelines outlined for the FAA and DOD in 14 CFR Part 77.
- Radar viewshed buffer areas were determined based on stakeholder outreach with representatives from the FAA, NOAA, USCG, and BOEM. Different types of radars have different lines-of-sight based on factors such as geography, the systems used, etc., and therefore have different buffer areas. Per the FAA, ASR-9s have a 60-nm line-of-sight, and long-range ARSR-4 radars have a 250-nm line-of-sight. The line-of-sight and resolution of HF radar systems extend 40 to 200 km, depending on the frequency setting. The HF buffers include both the average and maximum (200 km) line-of-sight, as shown on Table 4. NOAA's NWS WSR-88D and the FAA's TDWRs buffer areas were assigned based on the NOAA NEXRAD Screening Tool (see Appendix A), with a 60-km buffer for both the WSR-88D and the TDWR.
- The DOD's assessment of offshore wind energy development's mission compatibility in 2013 identified areas within the AoA as exclusion areas for offshore wind energy development. These exclusion areas were incorporated into the analysis as a DOD Consultation Area. In these areas, consultation with DOD is recommended in order to mitigate any impacts that may result due to offshore wind energy development.

The results of this composite analysis of aviation and radar assets and buffers is shown in Figure 10.

Figure 10. Composite of Aviation and Radar Assets and Buffers

Source: BOEM 2016; CORDC 2017; SRI 2010; FAA 2017h



3 Potential Sensitivity and Risk

This section reviews the potential risk of future offshore wind energy development activities interfering with existing aviation and radar facilities. Offshore wind farms have the potential to affect aviation in two main ways: through the presence of new structures, which may present an obstruction to aviation in the area, and through the presence of rotating turbine blades, which may interfere with radar operations in the area. These potential issues are discussed in the following sections.

3.1 Obstructions to Aviation

To promote air safety and the efficient use of navigable airspace, the FAA administers 14 CFR Part 77, Safe, Efficient Use, and Preservation of the Navigable Airspace. Obstructions include very tall objects as well as objects meeting moderate height parameters that are located near an airport. Specific details on the FAA definition of obstructions to aviation is presented in Section 1.3.

To ensure flight safety, proposed structures that meet certain criteria must file for FAA review via the OE/AAA process described in Section 1.3. In addition, the FAA requires lighting equipment on all structures to increase the visibility of structures and, consequently, facilitate early obstruction recognition by pilots. Lighting systems can include aircraft detection lighting systems (ADLS) and other types of lighting systems. Obstruction lighting may include aviation red obstruction lights, medium-intensity flashing white obstruction lights, high-intensity flashing white obstruction lights, dual lighting, obstruction lights during construction, obstruction lights in urban areas, or temporary construction equipment lighting (FAA 2016c). For the purposes of this study, it was assumed that BOEM may follow FAA's guidelines for these aviation obstruction lights, based on the specific nature of these standards, which are applicable for safety of flight in all areas, regardless of proximity to the shore. (See Appendix B for a discussion of lighting systems for wind farms.)

3.2 Potential Radar Interference

3.2.1 Potential Interference with Land-Based Radar Systems

Wind farms located within the line-of-sight of radar systems have the potential to interfere with land-based radars used for national defense, national security, aviation safety, ocean monitoring, and weather forecasting by inhibiting aircraft/target detection, generating false targets, interfering with aircraft tracking, impeding critical weather forecasts, and hindering ocean surface current monitoring. The significant physical size of the turbine blades results in a substantial radar cross

section signature, and the tip velocities for these blades fall within a speed range applicable to aircraft. The turbine blades thus may appear as a moving target of significant size to the radar system. The magnitude of the impact depends on the number and locations of the wind turbines. However, wind farm radar interference can be minimized or eliminated through collaboration, research and development, and deployment of mitigation solutions (Gilman et al. 2016).

Mitigation processes have been identified to help reduce the potential for wind farms to interfere with critical land-based radar systems used in weather, ocean, and air traffic surveillance. These processes include mechanisms to evaluate new wind farm proposals, including pre-screening tools to better predict the potential for impact (see Appendix A).

Studies using simulations of offshore wind turbine interaction with a HF coastal radar operation indicate that rotating turbine blades can cause interference with HF radar data that could have negative impacts on the received signals, degrading the data (Teague and Barrick 2012; Naqvi and Ling 2013). The presence of the offshore wind turbines near Block Island, Rhode Island (adjacent to the AoA), provides an opportunity for real-world assessment of the potential impacts of wind turbines on the HF coastal radars by BOEM. BOEM's *Impact Assessment of Offshore Wind Turbines on High-Frequency Coastal Oceanographic Radar* study is currently underway and will allow BOEM to collect in-depth data on wind turbine operating parameters, including turbine blade rotation rates, construction materials, and sizes of turbines and blades. This data can be used to develop mitigation techniques, including filtering and beam-forming algorithms for radar software. Currently, five continuously operating HF radars are collecting data covering areas in and around the Block Island Wind Farm. Partnering with the IOOS Program Office, BOEM will be able to obtain on-site measurements from nearby HF radars during wind turbine operation at Block Island to quantify adverse impacts of rotating wind turbines on HF radars. The study began in October 2016, and the final report is expected to be released in September 2018.

3.2.2 Potential Interference with Marine On-Board Radar Systems

Past investigations and studies on the effect of offshore wind farms on marine navigation systems found that wind farms have the potential to create clearly visible clutter on radar screens, which can impact operational capabilities under certain conditions (Ling et al. 2013). Other studies have determined differing degrees of impacts of wind turbines on typical marine radars, ranging from minimal to severe (Marico Marine Group 2008; Brookner 2008). In 2008 the USCG completed an assessment of potential impacts on marine radar as part of the *Cape Wind Final Environmental Impact Statement* (U.S. Department of the Interior 2009). The report cited two principal concerns:

the potential for impact of radar antenna beamwidth and sidelobes on the detectability of other vessels and interference caused by secondary reflections off the wind turbines, resulting in false targets (USCG 2008). According to the report, secondary reflections are caused when the radar signal is reflected from a wind turbine then back, and between turbines then back to the radar. Each of these scenarios can cause false targets to appear.

Historically, marine radars have not included Doppler processing, although this is no longer true of all vessel radars. Doppler systems are now available for smaller commercial and recreational vessels. For radar that utilize Doppler, the moving blades of a wind turbine can have a significant negative effect on the system's ability to detect other moving targets and vessels (USCG 2008). Other potential interference can result from echoes created by the turbines, which present high radar cross section values (Marico 2007). Radar echoes of small crafts within a wind farm could potentially merge with strong echoes generated by the turbines when the craft pass close to the towers, making the craft invisible to radar systems (Marico 2007).

Although no specific interference concerns related to onboard radar systems were identified during DOD outreach and engagement, coordination with the DOD, USCG, and commercial vessel operators about potential wind energy sites is recommended. The specific types and occurrences of potential interference are assumed to be accounted for in the DOD *Offshore Wind Mission Compatibility Assessment*, completed in 2013 (Engle 2017). However, specific details are not provided in the version of the assessment available for non-DOD personnel, and thus coordination at the project development stage should occur to ensure the highest degree of compatibility possible.

4 Best Management Practices Related to Coordination and Mitigation of Potential Interference

Developers may wish to incorporate a variety of BMPs to mitigate and reduce the risk of future project delays that may be caused by potential interference with aviation and radar systems. Examples of BMPs obtained from previous studies of offshore wind farm developments in the U.S. and Europe are provided below. Input on BMPs was also received during stakeholder interviews.

Examples of BMPs potentially applicable to future wind turbine development near aviation and radar assets are listed below and detailed throughout the remainder of this section. These BMPs include the following types of activities, listed in chronological order from the planning phase through the construction and operational phases:

1. Conduct pre-development consultation with appropriate agencies to enhance communication about potential impacts early, before significant investment is made.
2. Provide an early Obstruction Evaluation application to the FAA.
3. Follow available guidelines to minimize potential impacts on radar assets.
4. Consider alternative wind farm layouts and turbine heights as an option during the pre-development consultation phase to reduce radar interference, if warranted.
5. Consider stealth-coating treatment to minimize radar returns being reflected off wind turbines, including nacelles, blades, and towers.
6. Update Notices to Airmen (NOTAMs) and Notices to Mariners (NTMs) procedures during the construction phase.
7. Consider use of an ADLS.

4.1 Conduct Pre-Development Consultation and Coordination with Appropriate Agencies

Offshore wind farm developers may choose to be proactive and may conduct pre-development consultation with appropriate agencies. Pre-development consultation enhances communication between the developer and the regulatory agencies and can help the developer to identify potential issues that may arise, including geographic areas that may be best to avoid. The agencies can provide guidance on the developer's proposed project as well as offer lessons learned from previous projects. Appropriate agencies to consult include the FAA, DOD, NOAA, NWS, USCG, and BOEM, as well as nearby airports.

The FAA can provide the DOD Preliminary Screening Tool, which allows developers to conduct preliminary reviews of potential impacts on long-range and weather radar, MTRs, and SUA before official Obstruction Evaluation filing. In addition to providing preliminary feedback to the developer for project siting, the tool also provides a point of contact for the developer to reach out to agencies for discussions on potential impacts and mitigation efforts. More information on this tool is available in Appendix A.

Radar interference should be addressed early during the planning phase of a specific wind farm proposal. Since radar systems are used by multiple agencies for a number of uses, collaboration on potential issues is important.

Several working groups and systems have been established to foster the type of collaboration that could assist with the development of specific mitigation and conflict-avoidance measures:

- OE/AAA Process – The FAA includes radar interference mitigation in their review process.
- The Wind Turbine Radar Interference Mitigation Working Group – This group includes representatives of several federal agencies, national laboratories, and consultants that are committed to finding viable solutions to wind turbine radar interference (Gilman et al. 2016).
- The DOD Siting Clearinghouse – This clearinghouse provides a timely, transparent, and repeatable process to assess potential mission-compatibility impacts of energy-related projects filed in the FAA’s Obstruction Evaluation process (Gilman et al. 2016).

Specific recommendations or suggestions by agencies may include the following types of actions:

- Use wind siting prescreening tools to determine potential impacts as described in Appendix A. For example, the screening tools offer insight into whether the potential wind project is compatible with radars or military operations and provides contact information for the developer to seek further guidance to mitigate identified potential conflicts. This allows developers to mitigate potential effects early in the planning phase.
- Incorporate stealth-coating treatment to minimize radar returns reflected off wind turbines. (See also Section 4.5 for more information on BMPs).
- Collaborate with agencies early in the planning process to further reduce impacts. Wind farm layout and height of turbines may be adjusted by coordinating with impacted agencies and partners to reduce the potential for interference.
- Coordinate with potentially affected agencies to temporarily cease wind farm operations in the event of an emergency. For instance, if an HF radar system is needed to help a search-and-rescue operation and a wind farm is currently producing clutter in the range needed, the wind farm operation may be curtailed while search and rescue is conducted.

- The concept of using designated reference buoys or other appropriate targets to aid adjustment of radar settings could be a valuable aid to the operation of marine radar near and within wind farms (Marico 2007).

4.2 Provide an Early Obstruction Evaluation Application to the FAA

The FAA strongly recommends that developers file for OE/AAA analysis (via FAA Form 7460-1) as early as possible with the most accurate details possible. Submittal of Form 7460-1 triggers a preliminary aeronautical study by the FAA’s Obstruction Evaluation Group. The FAA will issue one of three notices for the structures’ compliance with obstruction standards: “does not exceed,” “exceeds but OK,” or “notice of presumed hazard.” If a “notice of presumed hazard” is issued, the developer can then coordinate with the Obstruction Evaluation Group for further study to reach either a “determination of no hazard” or a “determination of hazard” (Meyers and Figg 2015).

The planning phase for projects provides an opportunity to assess project impacts, coordinate with key agencies and stakeholders, and incorporate OE/AAA filing as early as is reasonably possible. In addition, as noted in Section 2.3, the FAA is considering adopting a process in which blocks of airspace may be reviewed rather than single turbine sites, greatly streamlining this OE/AAA review process.

By filing early and allowing the FAA to identify any potential issues early in the process, the developer has more time to address the issues and adjust design criteria after submitting the filing. As a form of early communication, this practice may allow developers to identify areas of concern and mitigation as early in the planning phase as possible.

4.3 Follow Guidelines to Minimize Impacts on Radar Assets

Several regulatory bodies have published guidelines on analyzing and avoiding the potential impacts of wind farms on radar services. The World Meteorological Organization, a specialized agency of the United Nations, and the Network of European Meteorological Services have issued general guidelines for the development of wind farms in the vicinity of weather radars. According to their guidelines, no wind turbines should be developed within 5 km of a weather radar. Additionally, it is recommended that wind farm developers submit plans of wind farms located within 20 km of a radar for a compatibility analysis (de la Vega et al. 2013).

In addition to the DOD Preliminary Screening Tool discussed above, NOAA provides the NEXRAD Screening Tool (discussed in greater detail in Appendix A), which can be used by developers to determine the potential impacts their project may have on nearby NEXRAD and other weather radar systems. By using this tool, developers can better understand the impacts their projects may have before submitting their Obstruction Evaluation filing. Additionally, advanced information allows for impact analysis and siting consultation in the early project stages.

4.4 Consider Alternate Wind Farm Layouts and Turbine Heights to Minimize Impacts on Radar Systems

In addition to predevelopment consultation between the wind farm developer and appropriate agencies discussed above, developers may consider performing detailed modeling of the wind farm array layout to identify any potential impacts with area radar systems. The modeling should include technical specifications of the radar services and threshold values for evaluating any potential conflict. Threshold values are based on various parameters and are used to detect interference (i.e., if below the threshold value, then the interference is insignificant, and if above the threshold value, the interference could degrade the radar function).

The results of such modeling could indicate the advisability of modifying the proposed wind farm layout or turbine height. The wind farm design could then be modified, where practicable, to reduce the potential impacts on the radar systems. For example

- If a few turbines are expected to be located within the line-of-sight of a radar, removing and relocating those turbines may be the most cost-effective way to avoid a potential problem.
- Increasing the spacing between the wind turbines within the development may decrease their overall cumulative visibility on radar and thereby reduce their potential impact.
- Wind developers may work with potentially affected agencies to mitigate radar interference by altering the height of the wind turbines. In 2012, Naval Air Station Kingsville in south Texas signed a Memorandum of Agreement (MOA) with a wind developer who was attempting to construct a wind farm on land in the area. The MOA allowed the wind developer to construct the wind farm with various stipulations. To lessen the impact on the installation radars, the MOA stated that the developer would not construct the wind turbines higher than 500 feet AGL in total height. The wind developer also worked with the installation to determine optimal turbine siting within the project site (DOD et al. 2012).

Depending on the flexibility of the turbine layout and height, the developer may have the opportunity to work with the area agencies and airports to modify the wind farm layout to avoid or reduce the potential for interference with their systems (de la Vega et al. 2013).

4.5 Consider Stealth Treatment of Wind Farm Components

The adoption of stealth technologies or stealth coating on wind turbines has the potential to shield wind turbines and reduce the power scattered towards radar systems. Stealth treatment of wind turbines can be applied in the following ways:

- By the shaping of the turbine and/or blades.
- Application of stealth coating on the main elements of the turbine (mast, nacelle, and blades).
- Shaping the tower into a more conical shape to direct the return away from the radar.
- Application of stealth coating or radar-absorbing materials as an option in order to better mitigate the negative radar return (de la Vega et al. 2013).

One of the first wind developments to implement stealth technologies in an effort to reduce radar impacts was the Ensemble Eolien Catalan Wind Farm in France. The “stealth blade” technology was the first field implementation of stealth technology on wind turbines. Instead of traditional turbine blades, the wind turbines at the Ensemble Eolien Catalan complex are fitted with “stealth blades” that significantly reduce their radar footprint. The stealth technology was invented as a result of significant research and development efforts between the developer (EDF Energies Nouvelles), Danish turbine manufacturer Vestas, and QinetiQ, an international defense, security, and technology company. Equipped with “stealth blades,” the turbines had a significantly reduced radar footprint on nearby weather radars when compared with traditional blade models (EDF Energies Nouvelles 2016).

4.6 Match NOTAM and NTM Procedures during Construction Phase

Temporary activities during wind turbine installation are not published on aeronautical or navigational charts, so throughout the installation period, developers can provide updates to ensure NOTAMs and NTMs are issued and updated accordingly. Developers can share the latest construction information with nearby FAA, Air Traffic Controllers, pilot organizations, and other relevant parties to ensure safety of flight, and share this same information with mariners through these well-established processes.

The FAA’s Order 7930.2R, NOTAMs, provides direction regarding NOTAMs and air obstacles, including directions for obstructions such as wind turbines. The directions generally follow a format starting with OBST (for obstruction), the type of obstruction, obstruction identifier, coordinates, altitude, height AGL, and condition and can include additional comments. An example of a NOTAM for a wind turbine in Order 7930.2R reads in part “OBST WIND TURBINE FARM WI AN AREA DEFINED AS 4NM RADIUS OF 411931N0822776W (17NM W LPR) 2820FT (410FT AGL) NOT LGTD...” (FAA 2017d).

The NTMs are issued to provide timely marine safety information to ensure the safety of life at sea. NTMs are issued to provide updates and corrections to the inventory of water-based infrastructure such as lights, hydrographic features, and other related items on behalf of the National Geospatial-Intelligence Agency, National Ocean Service, and USCG.

4.7 Consider Implementation of Aircraft Detection Lighting Systems

Obstruction lights are typically set to an intensity appropriate to assist pilots navigating in worst-case scenario visibility conditions (Technostrobe 2017). However, federal and State agencies and stakeholders may have concerns about potential daytime or nighttime visual impacts from proposed obstruction lights. These impacts may be mitigated using ADLS technology (discussed in Appendix B), which can improve the success rate of wind farm deployments by reducing light pollution (Terma 2012). ADLS technology needs to meet the performance requirements identified in FAA Advisory Circular 70/7460-1L, which outlines specific requirements for detection, illumination, operation, voice/audio, and system failure (FAA 2016d).

The Laufer Wind Aircraft Detection System and Terma Obstruction Light Control System have been tested by the FAA and are approved for use in the United States. In addition, a factor of safety may be considered when using ADLS to ensure that obstruction lighting is turned on before aircraft enter the zone of interest identified by the FAA Advisory Circular.

During this Study, four sample wind farm sites were assessed throughout the AoA. Based on a series of conservative assumptions, the assessment concluded that ADLS would reduce the use of nighttime obstruction lighting from 100% of darkness hours to a maximum of 0.08% of darkness hours throughout a sample one-year period at each of these sample sites. Additional details on ADLS, the sample analysis, and ADLS case studies are provided in Appendix B.

4.8 BMP Conclusion

Since each wind farm is unique in terms of its location, turbine layout, surrounding environment, orientation, and range with respect to radar systems and flight paths, BMPs that are relevant for one development may not be suitable or warranted for another. Therefore, to maximize compatibility with surrounding aviation and radar activities, each prospective wind farm developer can work with relevant federal and State agencies and stakeholders to identify the best options for the site in question, offering BMPs in a collaborative planning environment where flight and navigation safety, preservation of radar viewsheds, and wind energy project success are balanced for the best interest of all parties.

5 Findings and Recommendations for Wind Energy Development in the Vicinity of Aviation and Radar Assets

As a result of the composite analysis, the AoA was divided into five distinct areas based on predicted compatibility of potential future wind turbine projects with aviation and radar assets in the region. These areas were designated during the course of this Study through the geographic overlay of concerns raised by various federal and State agencies and stakeholders and potential interference possible for various systems as discussed in Section 2. The resultant five areas are stratified into “Levels” as described below, each with decreasing impact potential on aviation and radar assets anticipated:

- **Level 1: Coordination and Mitigation Anticipated** – This area identifies the portion of the AoA in which it is anticipated that, based on the current locations of aviation and radar assets and existing technology, a wind turbine sited in this area could directly interfere and disrupt aviation and radar assets and/or negatively impact vessel-borne radar and sonar systems. This impact area is not recommended for offshore wind energy development without extensive site-specific and design-specific impact analysis, consultation, and mitigation (shown in dark orange on Figure 11). This area encompasses approximately 2% (267 square miles) of the AoA. (For the purposes of this analysis, the AoA starts at 15 nm offshore and encompasses a total of 14,980 square miles). This small portion of the AoA is overlapped by multiple radar-impact buffer areas, including the ASR 60-nm and 250-nm line-of-sight, the FAA’s TDWR 60-km impact zone, and the HF radar average and maximum (32 to 200 km) line-of-sight.
- **Level 2: Coordination and Mitigation Likely** – This area identifies the portion of the AoA in which it is probable that a wind turbine sited in this area could directly interfere with and disrupt aviation and radar assets. Development of offshore wind energy in this potential impact area would likely require mitigation efforts after consultation with relevant agencies. Advanced coordination with controlling agencies as well as prescreening impact analysis is recommended for perspective developers. This area encompasses approximately 31% (4,625 square miles) of the AoA. The factor contributing to the “likely impact” designation includes the overlap of two types of radar buffers (ASRs and the HF radar). This area is shown in light orange on Figure 11.
- **Level 3: Coordination and Mitigation Possible** – This area identifies the portion of the AoA where impacts on aviation and radar assets are possible and should be reviewed in coordination with key agencies during the early planning phase. True impact determination would be on a case-by-case basis. The majority of the AoA is located within this area, which encompasses 7,157 square miles, or approximately 48% of the AoA. This area includes the zone for which the DOD recommends “site-specific stipulations” on wind energy development. This area includes only the HF radar and the long-range ASR-4 line-of-sight radar. Research and stakeholder engagement indicate that mitigation techniques such as software algorithms and upgrades can be expected to filter out potential HF radar interference from wind turbines (Boatman 2017). This area is shown in yellow on Figure 11.

- **Level 4: Mitigation Not Anticipated** – This designation indicates areas where wind farm development is expected to have no impact on aviation and radar assets. Based on the analysis described within this Study, no area within the AoA warranted this designation. The entire AoA encompasses multiple aviation, airspace, and radar assets and their viewsheds, approach corridors, and impact areas to some degree; therefore, no area could be entirely eliminated from the need for some pre-development screening and consultation.
- **Level 5: DOD Consultation Area** – This area includes two exclusion areas, encompassing approximately 20% (2,931 square miles) of the AoA, that the DOD identified as incompatible for wind turbine development in the 2013 assessment (Engle 2017) (shown in gray on Figure 11). Development of offshore wind energy in this area would require consultation with the Office of the Secretary of Defense and other regional DOD Commands.

In addition to the areas described above, the following recommendations emerge from this Study:

- ATC and ASR systems in the AoA could experience interference as the result of wind turbine siting based in close proximity or specific operating conditions. Site-specific, prescreening investigation should be conducted, and BMPs and mitigation measures should be considered. Agencies such as the FAA, DOD, USCG, BOEM, and others may be consulted early to ensure maximum compatibility between potential new wind energy projects and existing aviation and radar assets in the region.
- Weather and ocean monitoring radars may experience interference as a result of wind turbine siting in the AoA. However, research and stakeholder engagement suggest that mitigation techniques (including software filtering and beam-forming algorithms) are expected to filter out potential interference from wind turbines (Boatman 2017). Site-specific, pre-screening investigation and BMPs may address these potential impacts.
- Airborne and vessel-borne radar and sonar systems may experience interference. However, the degree of interference will vary, depending on whether wind turbines are located within the line-of-sight of the radar and depending on radar software. Site-specific, prescreening investigation and BMPs may address these potential impacts.

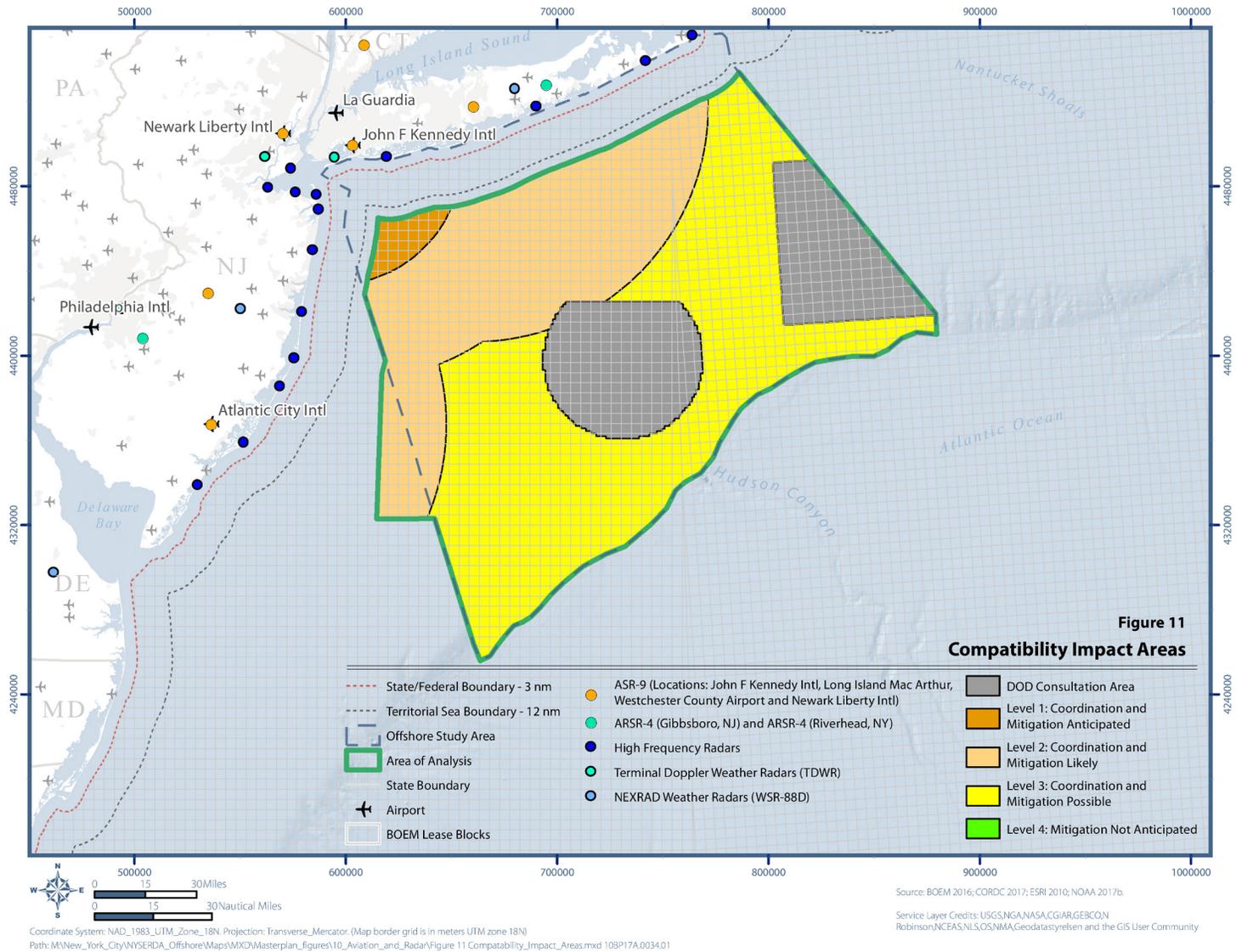
Prospective developers should maintain situational awareness of industry trends and infrastructure improvements. Preliminary recommendations for future work at the project development stage include other trends and industry changes that may be taking place, including items such as the following:

- Consider the effects of lighting selections on potential night-time helicopter landings at wind turbine platforms. Coordinate with search-and-rescue and maritime communities as needed. Be aware of and sensitive to impacts that lighting may have on Night Vision Goggle (NVG) usage, for instance.
- Coordinate with the PANYNJ to understand any major changes to regional airspace or runway designs. These types of infrastructure changes may inform requirements related to nearby construction of wind turbines.
- Consider following up with Philadelphia International Airport and Atlantic City International Airport for additional inputs about their potential operational concerns in the AoA.

- Monitor any changes to obstruction lighting requirements that may impact NVG users.
- Monitor the changes that the FAA's Wind Turbine Group are proposing related to reviews of blocks of airspace rather than individual turbines.
- Coordinate with the IOOS to identify and mitigate any impacts on the HF radar network along the region's coast.
- Incorporate the latest technology to reduce the radar cross sections of the turbines to reduce the likelihood of secondary reflections and false targets.

Figure 11. Compatibility Impact Areas

Source: BOEM 2016; CORDC 2017; ESRI 2010; NOAA 2017b



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Appendix A. Online Review Tools

Online review tools are publicly available to enable wind energy developers to conduct preliminary reviews of the potential impacts of their proposed projects. Two prominent online review tools include the U.S. Department of Defense (DOD) Preliminary Screening Tool and the National Oceanic and Atmospheric Administration (NOAA) next-generation radar (NEXRAD) Screening Tool. The sections below describe these tools and where they can be located, the input parameters needed to use them, examples of possible outputs the tools can provide.

A.1 DOD's Preliminary Screening Tool

The Federal Aviation Administration (FAA) provides an optional DOD Preliminary Screening Tool that allows developers to conduct a preliminary review of the potential impacts on radars (long-range and weather), military training routes, and SUAs before filing an official Obstruction Evaluation/Airport Airspace Analysis (OE/AAA; request FAA 2017a). The tool is not a replacement for OE/AAA review. The tool gives preliminary feedback and points of contact for the user to use in discussions of possible impacts and mitigation efforts on the military operations and radar systems in the area. This tool is available to the public on the FAA's OE/AAA website (<https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showLongRangeRadarToolForm>).

The tool supports prescreening of military operations, weather surveillance radar (WSR; such as NEXRAD), and long-range radar. To use the tool, a developer can enter either a point or several points (polygon), depending on the screening type selected, as well as the location (latitude/longitude) of a proposed wind energy project. The map legend varies depending on what screening type is selected. Table A-1 provides more detail on the results found when using the tool. An example of a sample output from running the tool is shown on Figure A-1.

Table A-1. DOD Preliminary Screening Tool - Description of Online Tool Categories^a

Source: FAA 2017e

Screening Type	Legend Feature	Description
Long-Range Radar	Green	No anticipated impact on Air Defense and Homeland Security radars. Aeronautical study required.
	Yellow	Likely impact on Air Defense and Homeland Security radars. Aeronautical study required.
	Red	Highly likely impact on Air Defense and Homeland Security radars. Aeronautical study required.
NEXRAD	Green ^b	No Impact Zone - Impacts not likely. NOAA will not perform a detailed analysis but would still like to know about the project.
	Dark Green	Notification Zone - Some impacts possible. Consultation with NOAA is optional, but NOAA would still like to know about the project.
	Yellow	Consultation Zone - Significant impacts possible. NOAA requests consultation to discuss project details and to perform a detailed impact analysis. NOAA may request mitigation of significant impacts.
	Orange	Mitigation Zone - Significant impacts likely. NOAA will likely request mitigation if a detailed analysis indicates that the project would cause significant impacts.
	Red ^c	No-Build Zone - Severe impacts likely. NOAA requests developers not build wind turbines within 3 kilometers (km) of the NEXRAD. Detailed impact analysis required.
Military Operations	No Legend Features	A preliminary determination is made. A message may appear that identifies possible conflicts and an appropriate point of contact to for more information

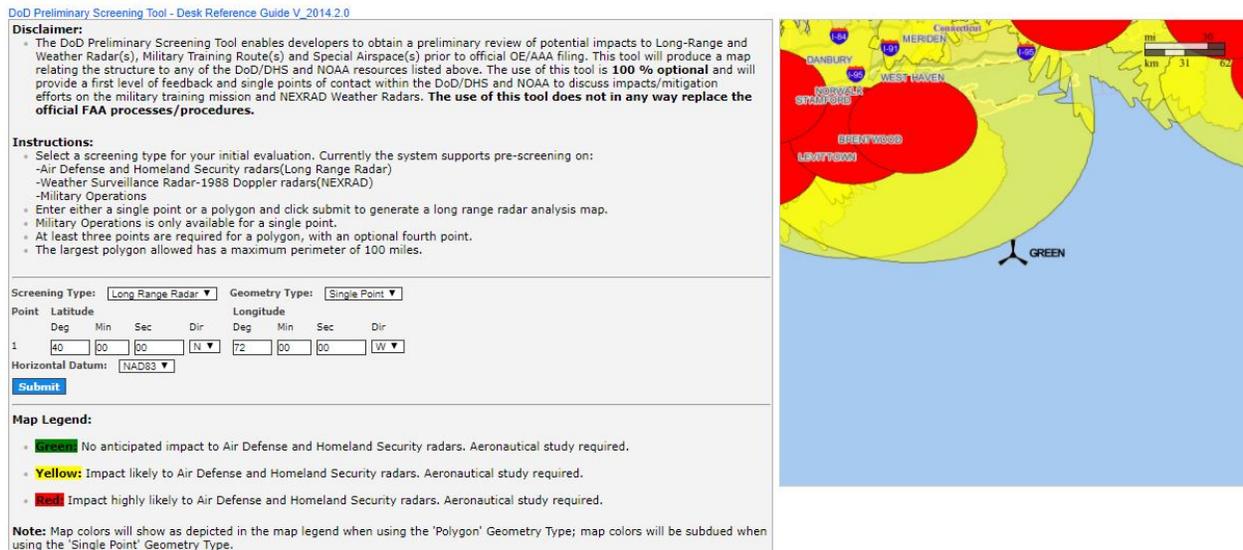
^a This does not represent results of a specific review in the context of this study.

^b The DOD Screening Tool provides an extra category—No Impact Zone—in the NEXRAD screening type that is not used on NOAA’s NEXRAD Screening Tool.

^c The DOD Screening Tool labels the NEXRAD No Build Zone as an area of 3 km; the NOAA NEXRAD Screening Tool labels the No Build Zone as an area of 4 km.

Figure A-1. Sample of DOD Preliminary Screening Tool Results

(Does not represent results of a specific review in the context of this study)



A.2 NOAA's NEXRAD Screening Tool

The NOAA NEXRAD Screening Tool is provided as a voluntary tool that developers can use to determine the potential impacts of their projects on nearby NEXRAD and other weather radar systems before making an official OE/AAA filing. The tool does not replace any official FAA filing process or procedures. However, advanced information on planned projects or alterations allows for impact analysis and siting consultation earlier in the project lifecycle. The tool allows users to input development criteria such as location and turbine blade height and provides multiple layers to examine the potential development in relation to NOAA NEXRAD weather radars, terminal Doppler weather radars, and other wind turbines identified through inventory provided by the U.S. Geological Survey. This tool is available to the public at <http://pikes.peakspatial.org/NOAA/ScreeningTool>.

Using the tool criteria, the NOAA Radar Operations Center created four color-coded areas surrounding the radar systems. Green signifies a “Notification Zone,” yellow a “Consultation Zone,” orange a “Mitigation Zone,” and red a “No Build Zone” (NOAA 2016a). Descriptions of these zones and details on the other layers shown in the NEXRAD screening tool are provided in Table A-2. An example of a sample output from running the tool is shown on Figure A-2.

Table A-2. NOAA NEXRAD Screening Tool – Sample Output^a

Source: NOAA 2016a, 2016b

Layers	Legend Feature	Description
NOAA NEXRAD Weather Radars	Green	Notification Zone – Wind farm would occasionally be visible in the radar data but not to the extent where significant impacts are likely.
	Yellow	Consultation Zone – Significant operational impacts are possible, depending on the height and number of wind turbines and distance from the radar. Area is as close as 3 km and 36 km where a 160-meter turbine only penetrates the 1 st elevation angle, or when a 160-meter-tall turbine will penetrate more than one elevation angle between 36 km and 60 km.
	Orange	Mitigation Zone – Significant operational impacts are likely and adjustments to the project or other mitigation efforts would be requested. Area is between 3 km and 36 km where a 160-meter-tall turbine would penetrate more than one elevation angle.
	Red ^b	4 Km No Build Zone – Wind turbines are certain to cause significant impacts on radar returns and forecast operations. Area is a 3-km radius red circle around the WSR-88D on the map.
Terminal Doppler Weather Radars	Yellow	Impact Zone – 60-km radius. Turbines need to be evaluated for impacts by the FAA
	Red	No Build Zone – 10-km radius
USGS Compiled Wind Turbines	Various colors	Each color point indicates a range, in 10s of meters, for the height of surrounding turbines. The range is from 10 to 180+ meters in height.

^a Does not represent results of a specific review in the context of this study.

^b The DOD Screening Tool labels the NEXRAD No Build Zone as an area of 3 km while the NOAA NEXRAD Screening Tool labels the No Build Zone as an area of 4 km.

Figure A-2. Sample of NEXRAD Screening Tool Results.



Appendix B. Wind Farm Obstruction Lighting

This section provides a preliminary assessment of the Federal Aviation Administration (FAA) requirements for wind farm obstruction lighting, including a review of FAA lighting requirements, lighting control technology, and best practices and case studies related to lighting from other offshore project sites.

The FAA requires lighting equipment on structures to increase the visibility of structures and, consequently, facilitate early obstruction recognition by pilots. Specifications for obstruction-lighting equipment are defined in FAA Advisory Circular 150/5345-43H (FAA 2016c). FAA Advisory Circular 70/7460-1L also states the standards for marking and lighting obstructions that have been deemed a hazard to navigable airspace (FAA 2016d).

B.1 Lighting Control Technology

Various technologies in the United States and abroad are being developed to meet the FAA's obstruction-lighting requirements. Two examples of emerging lighting technologies are discussed below for consideration as potentially applicable for wind energy development in the Area of Analysis (AoA).

B.1.1 Aircraft Detection Lighting Systems

Aircraft detection lighting system (ADLS) technology is a sensor-based system designed to detect aircraft approaching an obstruction or group of obstructions. An ADLS automatically activates the appropriate obstruction lights as an aircraft approaches until the aircraft does not need the lights. This automation reduces the impact of nighttime lighting on nearby communities and migratory birds and extends the life expectancy of obstruction lights (FAA 2016d). The detection system is mounted directly on the obstruction or on a standalone structure near the obstruction (Patterson 2016a).

B.1.2 Variable Intensity Lighting

Obstruction lights are typically set at an intensity designed to assist pilots navigating through worst-case scenario visibility conditions. Variable intensity lighting, or light dimming, tailors the light intensity to current conditions (e.g., under clear sky conditions, lights are dimmed significantly) (Technostrobe 2017).

This technology is not yet used on wind farms in the U.S. but has been used elsewhere, e.g., the Finnish company Vaisala has developed the Visibility Sensor PWD20W, and the Canadian company Technostrobe has developed LIDS™ (Vaisala 2017; Technostrobe 2017).

The FAA is negotiating with a company to complete research in the U.S. with the expectation that a system could be installed and flight tested in 2017 (Patterson 2017a).

B.2 Federal Aviation Administration Standards

Project sponsors planning to implement an ADLS can apply for FAA approval of its use by submitting an application. Each application must include the following:

- Maps or diagrams indicating the location of the proposed sensors.
- The range of each sensor.
- A visual indication showing how each sensor’s detection arc provides the full horizontal and vertical coverage.
- Multiple maps or diagrams that indicate coverage at affected altitudes where detection coverage is not 100% due to terrain masking (FAA 2016d).

FAA acceptance of ADLS applications is on a case-by-case basis, and the FAA reserves the right to modify, adjust, or deny an application based on proximity of the obstruction or group of obstructions to known activity areas, including airports, low-altitude flight routes, military training areas, or other areas of frequent flight activity (FAA 2016d).

Standards for the use of an ADLS, set forth in FAA Advisory Circular 70/7460-1L: Chapter 14, Air Detection Lighting Systems, are summarized in Table B-1.

Table B-3. Federal Aviation Administration Aircraft Detection Lighting System Standards

Source: FAA 2016d

DETECTION	
Area:	Should be able to detect an aircraft with a cross-sectional area of 1 square meter or more within the volume. ^a
Coverage:	Horizontal: Prior to aircraft penetrating the perimeter of the volume (a minimum 3 nautical miles [nm] away from the obstruction or the perimeter of a group of obstructions). Vertical: Prior to aircraft penetrating the volume (extends from the ground up to 1,000 feet above the highest part of the obstruction or group of obstructions for all areas within the 3-nm perimeter).
Exceptions:	In their application to the FAA, the sponsor should identify areas for further evaluation where it is not possible to meet the volume area because the terrain may mask the detection signal for acquiring an aircraft target within the 3-nm perimeter.

Table notes are on the next page.

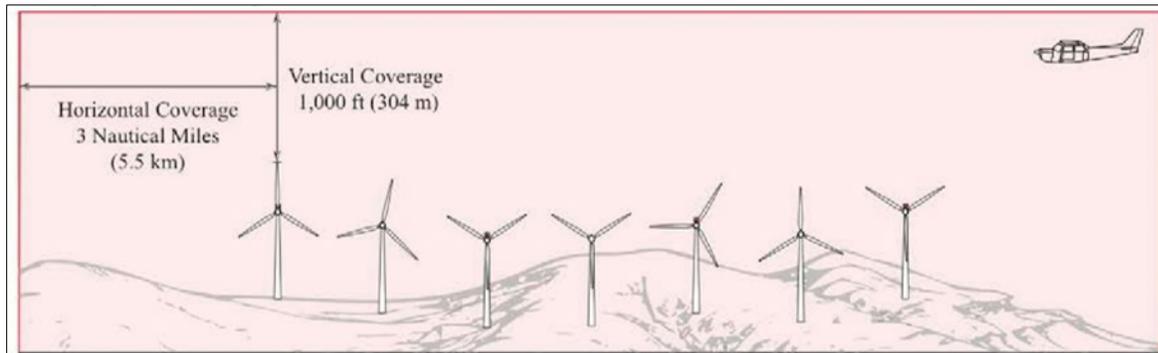
Table B-1 continued

ILLUMINATION	
Activation:	Allow the lights to illuminate and synchronize to flash simultaneously prior to an aircraft penetrating the volume.
Duration:	<p>For an ADLS capable of monitoring aircraft while they are within the 3-nm, thousand-foot volume, lights should stay on until the aircraft exits the volume.</p> <ul style="list-style-type: none"> ▪ If an aircraft is lost while being continuously monitored within the volume, the ADLS should initiate a 30-minute timer and keep the lights on until the timer expires to provide the untracked aircraft sufficient time to exit the area and give the ADLS time to reset. <p>For ADLS without continuous monitoring capability, the lights should stay on for a preset amount of time.</p> <ul style="list-style-type: none"> ▪ Single obstructions: 7 minutes. ▪ Groups of obstructions: (the widest dimension in nm + 6) x 90 seconds = the number of seconds the lights should remain on.
Exceptions:	Obstructions close to known activity areas may need to be illuminated during nighttime hours while the remainder of the group's lighting is controlled by the ADLS.
OPERATION	
Maintenance:	The ADLS's communication and operational status shall be checked at least once every 24 hours to ensure both are operational.
Data Logs:	Should maintain a log of activity data for a period of no less than the previous 15 days that includes date, time, duration of all system activations/deactivations, track of aircraft activity, maintenance issues, system errors, communication and operational issues, and lighting outages/issues.
Frequency:	<p>Unlicensed devices (including Federal Communications Commission [FCC] Part 15) devices cannot be used for this type of system.</p> <p>Any frequency used for the operation of ADLS must be individually licensed through the FCC.</p>
VOICE/AUDIO (OPTIONAL)	
Voice/Audio Feature:	<p>Transmit a low-power, audible warning message (in accordance with FAA regulations) to provide pilots additional information on the obstruction they are approaching. The audible message should be:</p> <ul style="list-style-type: none"> ▪ Three quick tones followed by a verbal message that describes the type of obstruction the system is protecting (appropriate terms include tower, wind turbine, or power line). ▪ Repeated three times or until the system determines the aircraft is no longer within the audible warning area. ▪ Considered a secondary, final warning. ▪ Activated when an aircraft is within ½ nm horizontally and 500 feet vertically of the obstruction.
Frequency:	<p>Should be over an aviation frequency licensed by the FCC and authorized under 14 Code of Federal Regulations Title 47- Part 87.483 (excluding 121.5 megahertz [MHz]).</p> <p>Use of ATC frequencies in the 117.975 MHz to 137 MHz frequency band is prohibited for this operation.</p>
SYSTEM FAILURE	
Detection:	In the event of an ADLS component or system failure, the ADLS should automatically turn on all the obstruction lighting and operate in accordance with the Advisory Circular as if it were not controlled by an ADLS.
Illumination:	The obstruction lighting must remain in this state until the ADLS and its components are restored.
Operation:	<p>In the event that an ADLS component failure occurs and an individual obstruction light cannot be controlled by the ADLS, but the rest of the ADLS is functional, that particular obstruction light should automatically turn on and operate in accordance with FAA Advisory Circular 70/7460-1L as if it were not controlled by an ADLS; the remaining obstruction lights can continue to be controlled by the ADLS.</p> <p>The obstruction lighting will remain in this state until the ADLS and its components are restored.</p>

^a see Figure B-1 for an illustration of the volume.

Figure B-3. Illustration of Aircraft Detection Lighting System Coverage

Source: (FAA 2016d)



It is recommended that the detection area be larger than that defined by the FAA Advisory Circular (described above). Though the FAA Advisory Circular requires a 3-nm horizontal and 1,000-foot vertical coverage area, these areas are the minimum specifications that must be met. Detection in a larger area would ensure that the lights are on by the time an aircraft hits the parameters in the FAA Advisory Circular, allowing the system ample time to detect aircraft, establish a track, and turn on the system (Patterson 2017b).

B.3 Best Practices and Case Studies

This section provides examples of domestic and international best practices and case studies related to lighting in offshore project sites. Examining best practices and case studies related to lighting from other offshore project sites can assist developers in identifying lessons learned and apply them to their potential projects. By learning from these practices and cases, developers can apply standards that have proven effective or avoid situations that proved unsuccessful or caused delays.

B.3.1 Laufer Wind Aircraft Detection System

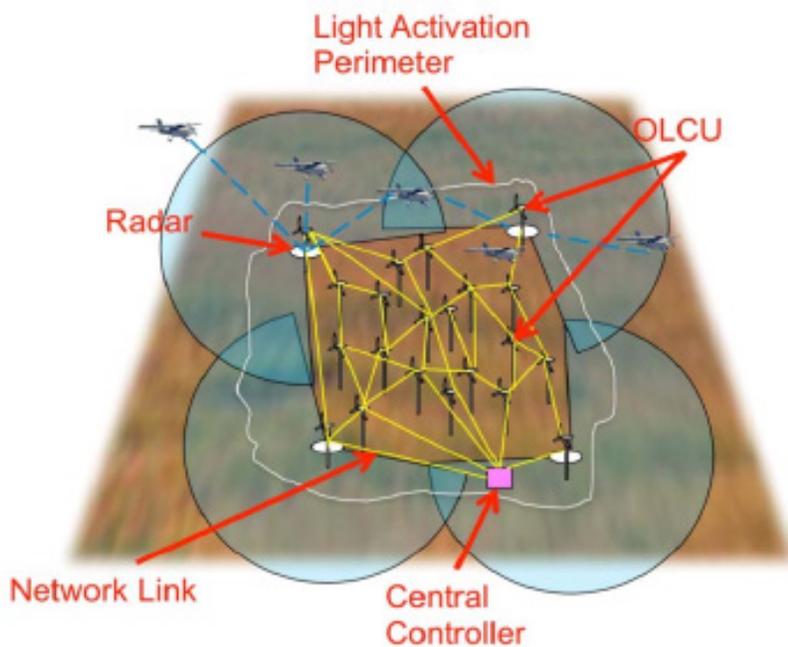
Laufer Wind Group, LLC (Laufer Wind) has been developing ADLS technology since 2008 (Laufer Wind 2016). The company's automatic detection system (ADS) deploys a proprietary MD-12 Pulse Doppler Radar designed to

- Detect small moving targets in high-clutter environments.
- Integrate detection and tracking capabilities.
- Tune to discriminate targets of interest such as aircraft, drones, and birds.
- Withstand harsh environments.
- Allow for easy up-tower maintenance (Laufer Wind 2015).

Figure B-2 illustrates the major subsystems in the Laufer Wind ADS. The Laufer Wind ADS was developed through a Technical Services Agreement with the U.S. National Renewable Energy Laboratory at the National Wind Technology Center in Boulder, Colorado. The agreement allowed Laufer Wind and the National Renewable Energy Laboratory to build upon University of Colorado drone research (Scanlon 2015).

Figure B-4. Laufer Wind ADS Major Subsystems

Source: (Patterson 2016a)



United States National Renewable Energy Laboratory Testing. In 2016, the FAA evaluated the Laufer Wind ADS installation at the National Wind Technology Center through a series of flight patterns over the course of 600 flight hours to evaluate the system’s response to aircraft operating around the wind farm at various altitudes, flight paths, and speeds. The installation consisted of three radars; three flash-synchronized FAA L-864, medium-intensity obstruction lights with three associated obstruction light control (OLC) units; and a single central controller. Fail-safe mechanism tests were also conducted to assess compliance with FAA Advisory Circular 70/7460-1 L (Patterson 2016a).

The FAA determined that the Laufer Wind ADS performed according to the manufacturer’s specifications and met the performance requirements identified in FAA Advisory Circular 70/7460-1 L. The evaluation also led the FAA to conclude that the ADLS performance requirements

set forth in Advisory Circular 70/7460-1 L are valid, facilitate a satisfactory level of safety for the flying public, and reduce the impact of obstruction lights on communities and migratory birds (Patterson 2016a).

In 2016, Laufer Wind deployed the first FAA-approved ADLS on an 80-megawatt wind farm, Pioneer Wind Park, in Converse County, Wyoming (Laufer Wind 2017). Pioneer Wind Park is the first utility-scale wind project to be constructed in the state since 2011; construction began in February 2016, and the ADLS become operational in October 2016 (Enyo Renewable Energy 2017; Renewable Northwest 2009).

B.3.2 Terma Obstruction Light Control System

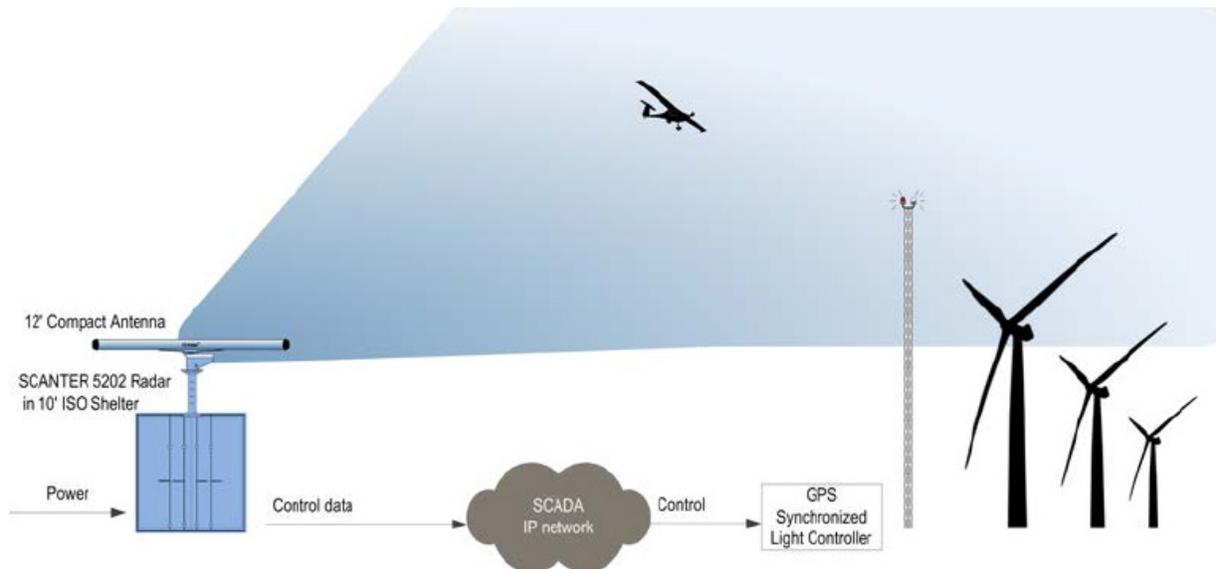
Terma developed radar-based OLC to improve the success rate of wind farm deployments by reducing light pollution. Ideal for larger wind farms or wind farms with a scattered layout, Terma's SCANTER 5000 radar series covers up to approximately 386 square miles (Terma 2012). The SCANTER 5202 primary surveillance radar OLC system is designed for the following:

- Detect and track aircraft prior to reaching the light activation perimeter of the warning zone.
- Send a signal through the supervisory control and data acquisition internet protocol network to the geographic information system-synchronized OLC system when the aircraft reaches the light-activation perimeter of the warning zone.
- Turn on the obstruction light(s).
- Track the aircraft until it exits the warning zone light-activation perimeter.
- Determine when to turn the lights off after verifying that no aircraft are within the warning zone (Patterson 2016b).

The Terma OLC System concept is depicted on Figure B-3. Terma has been field-testing this technology for five years (Terma 2012).

Figure B-5. Terma OLC System Concept

Source: (Patterson 2016b)



Tehachapi Wind Resource Area Testing. The Tehachapi Wind Resource Area is used for manufacturing, testing, and training related to wind energy technology (GTEDC 2017). In 2015, the FAA evaluated the Terma OLC System, which was installed in the Tehachapi Wind Resource Area, to determine whether the system meets the FAA’s ADLS standards, described in Table B-1. The FAA tested the system through two flights with six specific flight patterns to assess basic function, detection performance, and component failure. The FAA determined that the Terma OLC System performed according to the manufacturer’s specifications and met the performance requirements identified in FAA Advisory Circular 70/7460-1L (Patterson 2016b).

B.3.3 Vestas IntelliLight™ System

Vestas Wind Systems A/S (Vestas), a Denmark-based energy company, developed the Vestas IntelliLight™ to deliver reliable activation of aviation lights. The system continuously and autonomously scans a wind farm’s surrounding area within a minimum range of approximately 5 miles (Vestas 2017). Obstruction lights remain powered until an active off-signal is received from the system, which comprises radar unit(s), an aviation light controller, and the Vestas IntelliLight™ Control Center (Patterson, Jr., James and Garrison Canter 2017). The system is designed for the following capabilities:

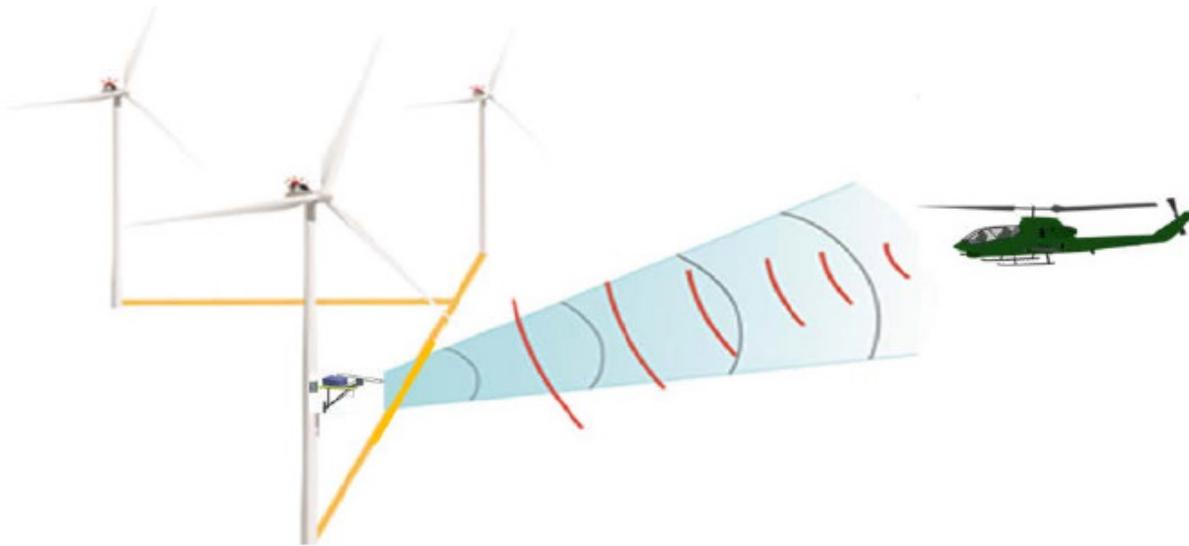
- Detect and track all aircraft within a minimum range of 8 km while keeping the obstruction lights in “actively off” mode.

- Switch to “actively on” mode when an aircraft is detected and tracked entering the system warning zone.
- Maintain timers for each aircraft detected within the warning zone.
- Return obstruction lights to the “actively off” state once all countdown timers have expired and no aircraft are detected within the warning zone light activation perimeter (Patterson, Jr., James and Garrison Canter 2017).

A depiction of the Vestas IntelliLight™ Radar mounted on a wind turbine is shown on Figure B-4.

Figure B-6. Vestas IntelliLight™ Radar Mounted on a Wind Turbine

Source: (Patterson, Jr., James and Garrison Canter 2017)



Braderup Wind Park Testing, Germany. Braderup Wind Park is a 9,200-kilowatt wind farm in Schleswig-Holstein, Germany (Wind Power 2015). A Vestas IntelliLight™ System is installed at the wind park. In 2016, the FAA evaluated the Vestas IntelliLight™ System through a series of flight patterns to assess the system’s basic function, detection performance, and component failure. The testing environment was considered cluttered, since Braderup Wind Park includes 47 wind turbines within the 3-nm perimeter and the Sportfluggruppe Leck Air Base. The FAA determined that the Vestas IntelliLight™ System performed according to the manufacturer’s specifications and met the performance requirements identified in FAA Advisory Circular 70/7460-1L. However, the FAA will test the system again after it is installed at a wind farm in Hancock County, Maine, in October 2017 to confirm that it performs in the U.S. equal to or better than the system tested in Germany (Patterson, Jr., James and Garrison Canter 2017).

The Vestas IntelliLight™ System was initially not approved for use in the U.S. because it used a radar frequency that fell on the edge of the frequency band being vacated to make available for mobile and fixed wireless broadband use, per a 2010 Presidential Memorandum. Vestas asked the FAA to conduct the assessment in Europe, where Vestas was able to support a performance assessment in an alternative frequency band. The FAA agreed on the condition that, if Vestas received approval for this alternative band, a second assessment would need to be completed in the U.S. before the system could be operated in the U.S. (Patterson, Jr., James and Garrison Canter 2017).

B.4 Assessment of Concerns Regarding Reduced Nighttime Lighting Using ADLS

A trial assessment of the radar-controlled ADLS was conducted at four sample sites in the AoA to test for the number of hours during which the wind turbines would be illuminated throughout the nighttime hours of darkness. The assumptions used in the analysis are described in Section B.4.1; results of the analysis are described in Section B.4.2.

B.4.1 Assumptions

The assumptions for the lighting analysis fall involve three major factors: notional wind farm design, flight information, and FAA requirements. Table B-2 provides an overview of all assumptions from the analysis. Subsequent text describes these assumptions further.

Table B-4. Overview of Lighting Analysis Assumptions

Factor		Assumption
Notional Wind Farm	Location	Four sample sites
	Size	11,088-meter by 11,088-meter square
	Layout	100 turbines (10 turbines by 10 turbines)
	Turbine Height	800 feet
	Turbine Rotor Length	154 meters
	Spacing between Turbines (mast to mast)	8 times the rotor length (8 x 154 m = 1,232 m)
	ADLS Technology	Not capable of continuously monitoring aircraft targets
Flight Information (time assumptions)	Study Period	One year (July 27, 2016 – July 24, 2017)
	Hours of Darkness	Shortest day (longest hours of darkness) each month in 2017 in New York City

Table notes are on the next page.

Table B-2 continued

Factor		Assumption
FAA Requirements	Horizontal Coverage	5 nm from the perimeter of the notional wind farm
	Vertical Coverage	2,800 feet MSL (2,000 feet above an 800-foot turbine)
	ADLS Illumination Duration	27.75 minutes

Key:

ADLS = Aircraft Detection Lighting System

FAA = Federal Aviation Administration

MSL = mean sea level

nm = nautical miles B.4.1.1 Notional Wind Farm

Four sample sites were analyzed to present a reasonable amount of coverage within the AoA. The notional wind farm was an 11,088-meter by 11,088-meter square containing 100 turbines in a 10-turbine by 10-turbine layout. Rotor length of each turbine was 154 meters, and turbine spacing was eight times the rotor length from mast to mast. The largest possible turbine height (800 feet) was used to ensure a conservative analysis. It was also assumed that the ADLS technology for the notional wind farm could not continuously monitor aircraft, which dictates illumination duration (see Section B.4.1.3).

B.4.1.2 Flight Information

One year of flight track data was purchased from FlightAware.com spanning July 27, 2016 through July 24, 2017. Hours of darkness were determined based on the shortest day of each month in 2017 in New York City, as listed in Table B-3. This assumption allowed a conservative review of flight track data based on the longest night or most hours of darkness possible.

Table B-5. Hours of Darkness by Month in 2017

Source: U.S. Department of the Navy 2017b; National Oceanic and Atmospheric Administration (NOAA) ESRL 2017

Month	Shortest Day	Sunrise	Sunset	Hours of Darkness
January	1	0720 EST	1640 EST	14.67 hours
February	1	0706 EST	1714 EST	13.87 hours
March	1	0630 EDT	1748 EDT	12.70 hours
April	1	0539 EDT	1821 EDT	11.30 hours
May	1	0454 EDT	1853 EDT	10.02 hours
June	1	0427 EDT	1921 EDT	9.10 hours
July	31	0452 EDT	1912 EDT	9.67 hours

Table B-3 continued

Month	Shortest Day	Sunrise	Sunset	Hours of Darkness
August	31	0522 EDT	1829 EDT	10.88 hours
September	30	0552 EDT	1739 EDT	12.22 hours
October	31	0625 EDT	1653 EDT	13.53 hours
November	30	0700 EDT	1630 EDT	14.50 hours
December	21	0720 EST	1638 EST	14.70 hours

Key:

EDT = Eastern Daylight Time

EST = Eastern Standard Time

B.4.1.3 Federal Aviation Administration Lighting Requirements

As described in Table B-1, the FAA requires obstruction lights with ADLS technology to illuminate when flights are within the specified coverage area (“the volume”). The FAA defines horizontal coverage for detection in the volume as 3 nm from the perimeter of a group of obstructions (FAA 2016d). To ensure a conservative analysis for the purposes of this trial assessment, horizontal coverage was increased to 5 nm from the perimeter of the notional wind farm. The FAA defines vertical coverage for detection in the volume as 1,000 feet above the highest part of a group of obstructions (FAA 2016d). To ensure a conservative analysis, for the purposes of this trial assessment, vertical coverage was increased to 2,000 feet above the highest part of the group of wind turbines. Since the highest part of the notional wind farm would be the 800-foot turbines, vertical coverage for the analysis was set to 2,800 feet MSL.

As noted in Table B-1, when ADLS technology can continuously monitor aircraft in the volume, the FAA requires that obstruction lights should stay on until the aircraft exits the volume. When ADLS technology cannot continuously monitor aircraft in the volume, the FAA uses an equation to determine the pre-set amount of time obstruction lights should stay on to ensure that obstructions remain illuminated while the aircraft is in the volume. It was assumed that ADLS technology for the notional wind farm could not continuously monitor aircraft in the volume. A modified version of the FAA’s equation was used to determine illumination duration.

Original Equation from FAA Advisory Circular 70/7460-1L:

Required Illumination Duration = (the widest dimension in nm + 6) × 90 seconds

Modified Equation for Analysis:

Modified Required Illumination Duration = (the widest dimension in nm + 10) × 90 seconds

In the original equation, the + 6 accounts for the 3 nm horizontal coverage on either side of the obstruction, as required by the FAA. Since this analysis used a more conservative 5-nm horizontal coverage, the + 6 was replaced with + 10 in the modified equation. The notional wind farm is an 11,088-meter by 11,088-meter (or 6-nm by 6-nm) square, and the widest dimension is the diagonal: 8.5 nm miles. Using 8.5 nm in the modified equation results in an illumination duration of 27.75 minutes. Note that in the event flights overlapped during a 27.75-minute illumination period, illumination duplication was removed during this analysis.

B.4.2 Results

The lighting analysis found that at all four sample sites, obstruction lights would be illuminated less than 1% of the time during darkness over the course of a year. The greatest percentage of illumination during darkness over the course of the year was Site 1, in which obstruction lights would be illuminated 0.08% of the time. The smallest percentage of illumination during darkness over the course of a year was Site 3, in which obstruction lights would be illuminated 0.03% of the time. Tables B-4, B-5, B-6, and B-7 detail the results of the analysis, including the number of flights during darkness (as defined in Section B.4.1.2), minutes of illumination during darkness (as defined in Section B.4.1.3), and total minutes of darkness for the month. The results indicate that, with the use of ADLS technology, obstruction lights would be illuminated for a minimal amount of time over the course of a year at each of the sample sites. Without the use of ADLS technology, obstruction lights would be illuminated 100% of the time, which indicates that, applying the assumptions of this analysis, the use of ADLS technology reduces illumination of obstruction lights during darkness by more than 99%.

Table B-6. Results of Lighting Analysis for Site 1

Source: NOAA ESRL 2017

Month	Number of Flights during Darkness^a	Minutes of Illumination during Darkness^b	Total Minutes of Darkness for Month
January	1	28	26,681
February	0	0	22,376
March	0	0	22,365
April	0	0	19,210
May	2	56	17,723
June	3	84	16,120
July	2	56	17,220
August	2	62	19,099
September	0	0	20,512
October	1	28	24,005
November	0	0	25,348
December	0	0	27,320
Totals for year:	11 flights	314 minutes of illumination	257,979 minutes of darkness
Site 1 Illumination Summary: Obstruction lights would be illuminated at Site 1 for 0.12% of the year during darkness^c			

Notes:

- ^a As defined in Section B.4.1.2.
- ^b As defined in Section B.4.1.3.
- ^c Calculated by dividing 314 minutes of obstruction light illumination by 257,979 minutes of darkness for the year.

Table B-7. Results of Lighting Analysis for Site 2

Source: NOAA ESRL 2017

Month	Number of Flights during Darkness ^a	Minutes of Illumination during Darkness ^b	Total Minutes of Darkness for Month
January	0	0	26,681
February	0	0	22,376
March	1	28	22,365
April	0	0	19,210
May	0	0	17,723
June	1	34	16,120
July	1	28	17,220
August	1	36	19,099
September	0	0	20,512
October	0	0	24,005
November	1	28	25,348
December	0	0	27,320
Totals for year:	5 flights	154 minutes of illumination	257,979 minutes of darkness
Site 2 Illumination Summary: Obstruction lights would be illuminated at Site 2 for 0.06% of the year during darkness^c			

Notes:

^a As defined in Section B.4.1.2.

^b As defined in Section B.4.1.3.

^c Calculated by dividing 154 minutes of obstruction light illumination by 257,979 minutes of darkness for the year.

Table B-8. Results of Lighting Analysis for Site 3

Source: NOAA ESRL 2017

Month	Number of Flights during Darkness ^a	Minutes of Illumination during Darkness ^b	Total Minutes of Darkness for Month
January	0	0	26,681
February	0	0	22,376
March	0	0	22,365
April	0	0	19,210
May	0	0	17,723
June	1	34	16,120
July	0	0	17,220
August	2	65	19,099
September	0	0	20,512
October	0	0	24,005
November	1	30	25,348
December	0	0	27,320
Totals for year:	4 flights	129 minutes of illumination	257,979 minutes of darkness
Site 3 Illumination Summary: Obstruction lights would be illuminated at Site 3 for 0.05% of the year during darkness^c			

Notes:

^a As defined in Section B.4.1.2.

^b As defined in Section B.4.1.3.

^c Calculated by dividing 129 minutes of obstruction light illumination by 257,979 minutes of darkness for the year.

Table B-9. Results of Lighting Analysis for Site 4

Source: NOAA ESRL 2017

Month	Number of Flights during Darkness ^a	Minutes of Illumination during Darkness ^b	Total Minutes of Darkness for Month
January	0	0	26,681
February	0	0	22,376
March	0	0	22,365
April	1	29	19,210
May	0	0	17,723
June	1	37	16,120
July	0	0	17,220
August	2	161	19,099
September	1	36	20,512
October	0	0	24,005
Month	Number of Flights during Darkness ^a	Minutes of Illumination during Darkness ^b	Total Minutes of Darkness for Month
November	0	0	25,348
December	0	0	27,320
Totals for year:	5 flights	263 minutes of illumination	257,979 minutes of darkness
Site 4 Illumination Summary:			
Obstruction lights would be illuminated at Site 4 for 0.10% of the year during darkness^c			

Notes:

^a As defined in Section B.4.1.2

^b As defined in Section B.4.1.3

^c Calculated by dividing 263 minutes of obstruction light illumination by 257,979 minutes of darkness for the year.

Implementation of ADLS technology is highly recommended for consideration by developers in the AoA because of the opportunity to reduce illumination and, consequently, reduce nighttime lighting concerns while complying with the FAA’s lighting obstruction requirements in place to ensure safety of flight. Development in the AoA would likely be under conditions that are either as conservative or less conservative than those used in this analysis; therefore, if ADLS technology was implemented, obstruction light illumination could be expected to be reduced by at least 99%.

B.5 Additional Considerations Related to Obstruction Lighting

In 2009, the FAA published a Safety Alert for Operators (SAFO 09007), which provided advisory information about certain red color light-emitting diode (LED) lights that may not be fully visible to night vision goggle (NVG) users (FAA 2009). These obstruction lights are of most critical importance in bad weather or other adverse conditions, which may be the same conditions that prompt NVG use by pilots and air operators (e.g., during a search-and-rescue mission). Since SAFO 09007 was published in 2009, the FAA has been testing various lighting and NVG technologies to identify the best path forward to ensure flight safety. This is something that should be considered in future lighting applications to ensure that flight safety is maximized. In addition, when the FAA updates the red LED obstruction lighting criteria, or offers safety solutions related to it, wind energy projects should be poised to adopt changes that will improve flight safety within the AoA.

Additional considerations that should be made include the effects of obstruction lighting on helicopter operations that may require access to land their aircraft on wind turbine platforms during hours of darkness, which may occur because of emergencies, weather impacts, or work schedules. The use of ADLS, red LED lights not visible to NVG users, and other lighting exceptions may present unanticipated flight safety concerns.

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