The NOAA Aircraft Plan

Building and Sustaining NOAA's 21st Century Fleet

October 2019

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LETTER FROM THE DEPUTY UNDER SECRETARY FOR OPERATIONS

Since 1807, NOAA and its agency predecessors have provided the country with a wide range of observational data -- from hydrographic coastline surveys, to daily and long term weather forecasts, to natural resource data involving fisheries and other ocean life. As the country's need for observational data has grown, so too has NOAA's suite of products and services.

NOAA's aircraft are-and will continue to be-vital national assets for collecting observational data and providing critical products and services to government agencies, communities, and businesses around the country. In Fiscal Year 2018, NOAA's aircraft conducted more than 1,600 flights in support of hurricane, water supply and weather forecasting, nautical charting, and fisheries management. Unfortunately, based on NOAA aircraft service life expectation and historical usage analysis, we predict that three of NOAA's nine aircraft will reach or exceed their service expectancies between 2019 and 2028 without additional capital investment. This trend could reduce NOAA aircraft capacity by nearly 66 percent.

Aircraft recapitalization is necessary for NOAA to keep its fleet of aircraft operational, and continue to provide essential services to the nation, including accurate flood planning, hurricane forecasting, and data used by the nation's emergency managers; fisheries data that supports the seafood and fishing industries; and hydrographic data to support safe navigation and maritime trade. These services affect individuals throughout the country and beyond, contributing to the Nation's $4.6-trillion seaport-generated economic activity and $200-billion fisheries industry. The loss of this observational capacity will have significant economic, ecological, and societal impacts to the Nation.

One of my top priorities for managing day to day operations at NOAA is to ensure that the critical observational data necessary for decision -makers is collected and disseminated in a timely manner. NOAA's aircraft recapitalization plan does that, by providing a framework for meeting the Agency's mission requirements and the Nation's future aerial observation needs. This plan outlines the Agency's strategy for acquiring new aircraft, incorporating best management practices, reducing operating costs, and improving our effective delivery of aerial observational data.

Benjamin P. Friedman
Deputy Under Secretary for Operations
National Oceanic and Atmospheric Administration

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This plan is dedicated to Captain Kristie Twining, NOAA Commissioned Officer Corps, for her unwavering and tireless efforts to improve NOAA aviation.

EXECUTIVE SUMMARY

Overview

This report assesses the current and future airborne observational infrastructure needs of the National Oceanic and Atmospheric Administration (NOAA) in carrying out its mission of protecting lives, livelihoods, and valuable natural resources for the American public. We examined the current airborne capacity and capability of NOAA's aircraft fleet, while simultaneously evaluating the required aircraft capabilities to meet NOAA's current and future mission needs. By analyzing the status of NOAA aircraft and the current and future capabilities required to meet NOAA's public safety, national security, economic, and stewardship missions, we set a plan of action for ensuring future needs will be met, while minimizing the risk of capacity gaps that would negatively impact mission-critical data needs. The NOAA Aircraft Plan presents an integrated approach consisting of best management practices and long-term recapitalization to extend and sustain capabilities. Capabilities including aircraft chartering and leasing, unmanned aircraft systems, and the federal aircraft fleet to meet NOAA prioritized airborne requirements were evaluated. Balancing available capabilities with prioritized requirements resulted in a long-term strategy of acquiring and instrumenting four aircraft, and embarking on detailed requirements for two aircraft, to meet NOAA core capability requirements within each mission objective. A thorough assessment of the staffing and maintenance requirements is included. The study did not evaluate, and the plan does not address, the recapitalization plans of other federal aircraft fleets.

NOAA's Mission

NOAA is America's environmental intelligence agency. From the surface of the sun to the depths of the ocean floor, NOAA keeps a finger on the pulse of the changing planet. Each day, nearly every American relies on the data, products, and services NOAA provides. These products and services include daily weather forecasts, navigational tools to support the country's nearly $4.6 trillion in economic activity generated by U.S. seaports,[1] assessments on the health of the Nation's $200 billion fisheries,[2] and disaster response. The aggregate amount of variation in U.S. economic activity associated with weather variability is on the order of $485 billion per year.[3] NOAA provides daily and longer-term weather forecasts critical for preparation and response to these kinds of events. Data used for airport approach, departure, and airfield operations supports U.S. civil aviation-related economic activity of $1.5 trillion, which supports 11.8 million jobs with $459 billion in earnings.[4] Through NOAA's network of observations, models, forecasts,

1 Martin Associates for the American Association of Port Authorities. March 2015 "2014 National Economic Impact of the U.S. Coastal Port System." Retrieved from http://www.aapa-ports.org.

2 Fisheries Economics of the United States 2014: Economics and Sociocultural Status and Trends Series. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NOAA Technical Memorandum NMFS-F/SPO-163. May 2016.

3 Lazo, J.K., Lawson, M., Larsen, P.H., and Waldman, D.M. (2011). *U.S. Economic Sensitivity to Weather Variability*. Bulletin of the American Meteorological Society 2011, p. 710. DOI:10.1175/2011BAMS2928.1.

4 The Economic Impact of Civil Aviation on the U.S. Economy. January 2015. U.S. Department of Transportation, Federal Aviation Administration.

and assessments, it continually puts environmental information into the hands of people who need it.

NOAA's network of observational tools (e.g., satellites, radars, aircraft, and ships) is the foundation of the environmental intelligence it provides. Over the years, NOAA has made significant investments to ensure the agency can leverage new technologies to provide the best products and services possible. However, challenges to the agency's observational infrastructure still exist.

NOAA's Aircraft

Currently, NOAA has nine operational aircraft and is in the acquisition process to procure and instrument two aircraft as Congressionally directed with fiscal year (FY) 2018 appropriations. Ranging from a high-altitude jet capable of hurricane surveillance to smaller highly maneuverable aircraft used for water resources and protected species management, NOAA aircraft support a wide range of activities. In FY 2018, NOAA's aircraft conducted more than 1600 flights in support of hurricane, water supply and weather forecasting, nautical charting, and fisheries management. NOAA's line offices, other U.S. government agencies, communities, and businesses around the Nation rely on this data to plan and prepare for hurricanes, floods, and droughts; understand changes to the planet; monitor the health of fish stocks; and respond to severe weather.

NOAA data directly feeds products and services vital to the economy, security and health of the Nation, as well as researching new technology and methodologies to improve the reliability and accuracy of its products and services. Specific products and services NOAA delivers are most efficiently met with data gathered by aircraft with specific capabilities and instrumentation tailored for NOAA's mission. The most efficient approach for using aircraft is for NOAA to acquire a minimal number of types of aircraft that meet its unique mission requirements.

At least four of NOAA's aircraft have been in service for more than 35 years. Between 2018 and 2028, three[5] of NOAA's nine aircraft will incur significantly degraded mission readiness due to age and are scheduled to be retired by the end of 2028. In addition to reduced reliability, these aging aircraft limit NOAA's ability to leverage the latest scientific technologies, navigation and avionic systems, require significant investment to comply with mandated, on-going system upgrades and reduce overall efficiency and effectiveness. The loss, or significantly reduced reliability and effectiveness, of these aircraft will undermine NOAA's ability to meet its mission, resulting in significant degradation of data fundamental to water management and flood planning and response; loss of data critical to hurricane intensity and track forecasts relied on by coastal communities and emergency managers; less capability to conduct marine mammal stock assessments; and reduced ability to provide shoreline and shallow water bathymetry data for nautical charts.

5 Turbo Commander, G-IV, and Twin Otter

The Gulfstream G550 and King Air aircraft procured with FY 2018 appropriations as well as other aircraft identified in this plan, are essential to ensure NOAA maintains the ability to plan for and respond to the Nation's most damaging and deadly weather events, agricultural security and water security. From 1980-2016, hurricanes and other severe storms caused more than $740 billion in damage and 4,700 deaths; inland flooding accounted for more than $110 billion in economic losses and 400 deaths; and drought resulted in more than $220 billion in economic losses and 2,990 deaths.[6,7] Three of the five costliest U.S. Hurricanes on record occurred in 2017: Hurricanes Harvey, Maria, and Irma totaled $265 billion[8]. The Nation's $4.6 trillion in economic activity generated in U.S. seaports,[9] which relies on accurate nautical charts, as well as the $200 billion seafood industry will also be impacted.[10] The loss of capacity will significantly impact the millions of American jobs that depend on maritime and fishing industries, both directly and downstream. The Nation's coastal tourism economies and communities will also be severely impacted. Moreover, the loss of data used to validate and calibrate satellites and feed weather forecasting models will result in less accurate planning for emergency response, agriculture, and coastal management; will increase risk to lives and property; and have negative economic impacts.

The Future of NOAA's Aircraft Fleet

The demand for NOAA's environmental data continues to grow as more people live and work near or on the coasts and are affected by ocean-driven weather patterns. More than 1.2 million Americans move to the coast each year, with 39% of the Nation's population now residing in coastal communities.[11] Moreover, 95% of the U.S. trade goods enter and leave this country through harbors and ports. The economies that rely on the oceans, lakes, and coastal communities have grown at a much higher rate than national economic growth. In 2016, the ocean-related economy accounted for 154,000 business establishments, 3.3 million employees, $129 billion in wages, and $304 billion in goods and services. In 2016, employment in the ocean-related economy had increased 14.5-percent from pre-recession levels (2007) compared to 4.8-percent in the U.S. economy as a whole.[12]

6 Deaths associated with drought are the result of heat waves.

7 NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2017). Retrieved from: https://www.ncdc.noaa.gov/billions/.

8 Fast Facts: Hurricanes Costs. Office for Coastal Management, National Oceanic and Atmospheric Administration. Accessed September 13, 2019 from: http://coast.noaa.gov/states/fast-fatcs/hurricane-costs.html.

9 Martin Associates for the American Association of Port Authorities. March 2015 "2014 National Economic Impact of the U.S. Coastal Port System." Accessed September 28, 2016, at http://www.aapa-ports.org.

10 Fisheries Economics of the United States 2014: Economics and Sociocultural Status and Trends Series. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NOAA Technical Memorandum NMFS-F/SPO-163. May 2016.

11 "What percentage of the American Populations Lives Near the Coast?" Retrieved from http://oceanservice.noaa.gov/facts/population.html.

12 National Oceanic and Atmospheric Administration (NOAA), Office for Coastal Management. 2019. "NOAA Report on the U.S. Ocean and Great Lakes Economy." Charleston, SC: NOAA Office for Coastal Management Available at http://coast.noaa.gov.

NOAA will pursue seven strategies to meet NOAA's need to acquire airborne data: 1) acquire aircraft; 2) extend the design service life of existing aircraft; 3) increase utilization of NOAA aircraft; 4) integrate new technologies; 5) utilize unmanned aircraft systems; 6) increase utilization of charters to supplement NOAA aircraft; and 7) expand partnerships. Acquiring aircraft is NOAA's best long-term strategy for meeting its mission

During the first three years of recapitalization, NOAA will procure two aircraft based on the FY 2018 appropriation: 1) a King Air to replace the current Turbo Commander aircraft, in support of primary missions of weather forecasting, research and modeling, charting and surveying, and a secondary mission of assessment and management of living marine; and 2) a G550 high-altitude jet with the primary mission of weather forecasting, research and modeling, and a secondary mission of charting and surveying. The G550 high-altitude jet will conduct hurricane surveillance; data that directly improves track forecasts by as much as 15%.[13]

Procurement of a King Air will replace the Turbo Commander aircraft and eliminate the current single point of failure for high-resolution mapping, water resource requirements, and remote population surveys. This is critical for collecting the high-resolution images immediately following hurricanes, floods, and earthquakes that emergency managers and the public rely on; providing critical water resource planning and management data; and providing data for aviation charts critical for the aviation industry. During the 2017 hurricane season, more than 65,000 images covering 24,000 square kilometers, provided local, state, and Federal emergency managers, businesses, the public, and Department of Defense 236 terabytes of data and 2.28 billion image requests. This capability is the backbone of National emergency response. The high-altitude jet will perform the mission the NOAA's G-IV currently performs as the only aircraft in the Nation capable of conducting this mission. Due to age, the current G-IV reliability[14] index is only 70% and this is forecast to decline linearly to 55% reliability by 2024.[15]

NOAA currently has funds to acquire the two aircraft mentioned above. This plan will inform NOAA's future aircraft acquisitions and their associated capabilities based on its analysis of prioritized airborne requirements. NOAA's analysis shows that two additional aircraft are needed: 1) a Twin Otter aircraft[16] with the primary mission of charting and surveying, and a secondary mission of assessment and management of living marine resources and weather forecasting, research and modeling; and 2) a third King Air aircraft with the primary missions of charting and surveying, and weather forecasting, research and modeling, and with a secondary mission of assessment and management of living marine resources.

13 Aberson, S.D. 10 Years of Hurricane Synoptic Surveillance (1997-2006). Monthly Weather Review. May 2010, Vol. 138, No. 5.

14 Appendix E: Aircraft Aging – Impacts on Availability.

15 NOAA AOC Aircraft Fleet Plan Service Life Analysis, Gulfstream IV-SP Replacement Aircraft (Report AOC-FP-A4). August 3, 2016. Conklin & de Decker Associates, Inc.

16 Based on the recapitalization and estimated end of service life for existing Twin Otter aircraft, NOAA would have an additional (fifth) Twin Otter from FY 2023 to Y 2028

NOAA's acquisition of these aircraft is subject to the annual budget and prioritization process and the availability of appropriations.

I. INTRODUCTION

NOAA's Mission

The National Oceanic and Atmospheric Administration (NOAA) is a science-based Federal agency within the Department of Commerce with regulatory, operational, information service, and public safety responsibilities. NOAA's mission is to understand and predict changes in the Earth's environment and to conserve, protect, and manage coastal, marine, and Great Lakes resources to meet the Nation's economic, social, and environmental needs. This mission is driven by NOAA's service and legislative responsibilities and the resultant social and economic implications for a wide range of industries and coastal communities. Today, more than 50 major legal mandates and authorities underpin the mission areas that require airborne data (see Appendix G).

As America's environmental intelligence agency, NOAA provides timely, reliable, and actionable information – based on sound science – to communities, defense, and businesses for a wide variety of crucial services. These products and services include providing timely and precise weather, water, and climate forecasts; monitoring the environment; managing fisheries; building resilient coastal communities; and making the Nation more competitive through safe navigation. Performing these activities requires a large amount of underlying scientific data. NOAA relies on its specialized aircraft to make critical oceanographic, atmospheric, hydrographic, and fisheries observations. Without this data, products, and services like weather forecasts and warnings, nautical charts, accurate fishery quotas and stock assessments, harmful algal bloom warnings, climate outlooks, and a host of other products, services, and management activities would not be possible.

NOAA Aircraft Planning

NOAA's aircraft face challenges similar to other observational infrastructure: expanding mission requirements, age and obsolescence, and finite resources for recapitalization. Therefore, the goal of this plan is to ensure that NOAA acquires the observations it needs through the most cost-effective means possible.

Since 2006, the number of NOAA aircraft has decreased from 14 aircraft to the nine currently operational and from eight to five aircraft types; consolidation of aircraft types is a goal associated with the aircraft recapitalization proposed in this plan. The aircraft procured and instrumented with FY 2018 appropriations will result in 10 operational aircraft and four types of aircraft.

NOAA has continually worked to optimize its aircraft capabilities by evaluating and implementing best management and operational practices and has planned for the future through extensive airborne requirements, capability and service life analyses. NOAA's Technology, Planning, and Integration for Observations Office (TPIO) completed a 2-year requirements validation process in 2013 that created a baseline of verifiable and prioritized airborne data requirements. Over 190 critical airborne requirements were prioritized. Following this, additional independent analyses were performed. In 2016, Conklin & de Decker performed operational requirements analysis (aircraft capabilities), business case analysis, and service life assessments on all NOAA aircraft. Analytic Services, Inc. (ANSER) also performed a hurricane research platform replacement analysis of alternatives, including an external benefits analysis. These analyses comprehensively demonstrate the critical need for NOAA aircraft recapitalization and infrastructure investment. In addition, NOAA completed requirements workshops in 2018 that assessed the prioritized requirements for a high-altitude jet and turbo-prop aircraft. These workshops, facilitated by ANSER, provide documentation for current and future airborne requirements on these aircraft types and serve as the basis of capability requirements for the procurement of a G550 high-altitude jet and King Air aircraft.

NOAA aircraft are a key component of the federal aircraft fleet, and NOAA collaborates with other Federal agencies to maximize the opportunities for interoperability to the extent possible to meet airborne data requirements. Through the International Committee for Aviation Policy (ICAP) and the Interagency Coordinating Committee for Airborne Geoscience Research and Applications (ICCAGRA), NOAA collaborates with other federal agencies to optimize the use of federal aircraft. The ICAP, comprised of 18 Federal departments and agencies, was established by the U.S. General Services Administration (GSA) to promote sound aviation policy and establish the highest aviation standards. The 2014 – 2016 ICAP Strategic Plan identified future challenges and provided a guide to ensure efficient and safe government-wide missions. Serving as chair of ICCAGRA, NOAA works with other federal agencies to improve cooperation amongst U.S. aviation agencies, and standardization of U.S. and international airborne data sets and instrumentation on airborne platforms and emerging technology. In addition, all Federal aircraft users are required to report government aircraft data through the Federal Aviation Interactive Reporting System (FAIRS). Through the database, GSA analyzes and reports information on Federal aircraft inventories and cost and use data for Federal and Commercial Aviation Services (CAS) aircraft. This data, compiled in the Federal Aviation Inventory Tool and Summary of FY 2017 Aviation Open Data Set provide robust data on the inventory and operating costs of Federal aircraft in support of aviation program management decisions.

NOAA will update its aircraft planning analyses periodically to adjust to changing conditions, technology, and requirements and to optimize the capability, performance, and affordability of NOAA aircraft. This process will also consider aircraft manning, workforce management requirements and best business practices to match aircraft capabilities to airborne data requirements.

Section II of this report focuses on NOAA's plan to recapitalize and sustain its aircraft. Sections III - V provide detail on the airborne requirements, NOAA's ability to meet current and future requirements, and long-term strategies for sustaining NOAA's critical national assets.

II. The NOAA Aircraft Plan

Long-Term Recapitalization and Sustainment Strategy

NOAA's aircraft need to be adaptable and extensible to provide the platforms and capabilities necessary to meet mission requirements now and in the future. The long-term strategy to sustain NOAA's airborne data collection capabilities includes the procurement and instrumentation of aircraft, incorporation of new cost-effective technologies, sustainment of current and future aircraft, and best management practices to increase current capabilities and capacities. The NOAA Aircraft Plan integrates asset acquisition and management practices and represents the best comprehensive solution for long-term recapitalization and sustainment of NOAA aircraft.

In addition to the aircraft required to meet mission requirements, qualified and experienced personnel are *critical* to mission success. The diversity and specialty of NOAA's aircraft missions require a robust, technically competent, dedicated workforce. Aircraft pilots, engineers, technicians, maintainers, and flight meteorologists that operate NOAA's aircraft and instrumentation are highly specialized and require extensive training and experience. NOAA Corps officers serve as pilots, mission commanders, and navigators aboard NOAA's aircraft while civilian employees typically fill the roles of flight engineers, flight meteorologists, maintainers, systems analysts and electronics technicians. Operating and maintaining aircraft that operate in and around severe weather including hurricanes, tornados, and winter storms, and at low altitudes along mountainous terrain and over the ocean requires proficiency specific to these unique operating environments. NOAA is also committed to workforce planning to support its operational capabilities.

Below are the recommended steps within NOAA's long-term recapitalization and sustainment strategy to replace aircraft that will reach the end of their service lives between 2019 and the end of 2028, while reducing single points of failure and optimizing the use of available assets.

Acquire Aircraft

The future NOAA aircraft fleet will consist of four distinct aircraft types that will each focus on one or two primary missions as well as secondary missions that make the best use of the aircraft's capabilities. The FY 2018 appropriation, which funds procurement and instrumentation of a Gulfstream G550 high-altitude jet and King Air, moves NOAA towards this goal. Table 2-1 identifies the primary and secondary missions met by each aircraft type. NOAA will integrate and leverage instrumentation aircraft mounting points and ports where possible to meet multiple current and emerging mission requirements. Across the fleet, equipment types will also be standardized where possible to reduce operations and maintenance costs, to ensure industry regulatory efficiency and to optimize crewing models. Each aircraft type will incorporate the latest technologies during initial instrumentation and accommodate new technologies as they become available.

Aircraft[17]	Primary Mission	Secondary Mission
King Air	Charting and Surveying and Weather Forecasting, Research & Modeling	Assessment and Management of Living Marine Resources
G-IV and G550	Weather Forecasting, Research & Modeling	Charting and Surveying
Twin Otter	Assessment and Management of Living Marine Resources and Weather Forecasting, Research & Modeling	Charting and Surveying
WP-3D	Weather Forecasting, Research & Modeling and Charting and Surveying	Assessment and Management of Living Marine Resources

Table 2-1: Aircraft and Primary and Secondary Missions

Unlike ships that require specific design and construction to meet mission requirements, aircraft are typically procured pre-manufactured. Bringing an aircraft on-line that meets NOAA's specific mission requirements consists of four phases: requirements analysis, procurement, engineering and testing, and fleet introduction.[18] NOAA completed the requirements analysis and has awarded contracts for the King Air and a G550 high-altitude jet (green aircraft, modification contract to follow) as funded by the FY 2018 appropriation.

NOAA has collected data to assess lease options for a second G-IV-SP. There are several business case and logistic issues with leasing an aircraft, even without the Tail Doppler Radar (TDR). The aircraft will require significant modification to satisfy the basic surveillance capability required for the mission to include the installation of the Airborne Vertical Atmospheric Profiling System (AVAPS), dropswindonde launcher, basic in-situ measurement sensors (pressure, temperature, humidity, winds, position) with accuracies as required in the National Hurricane Operations Plan (NHOP), a Stepped Frequency Microwave Radiometer (SFMR - for remote measurement of surface wind speed), and at least DSL-speed (250 kbps) Satcom for data transmission to the National Hurricane Center. All of these modifications will have to be removed and repaired to revert the aircraft to a commercial platform. To a certain extent, any ports and structural modifications can't be economically returned to original condition, permanently reducing the value of the aircraft for any other use. When NOAA issued a Request for Information (RFI) to determine the market availability for a leased aircraft, it was determined that having a platform

17 Detailed capability descriptions provided in Appendix B.
18 Additional detail provided in Appendix C.

and crew on standby for the duration of the hurricane season had logistic, liability, and response time issues. It was found not to be a viable option and therefore was not pursued.

The following sequence of steps will be taken to execute this recapitalization strategy. Congress appropriated funds for the G550 and King Air in FY 2018, marking it as the base year of the recapitalization plan. Figure 2-1 shows the timeline for procurement of the King Air and G550 (green aircraft); contracts for these two aircraft were awarded in August 2019.

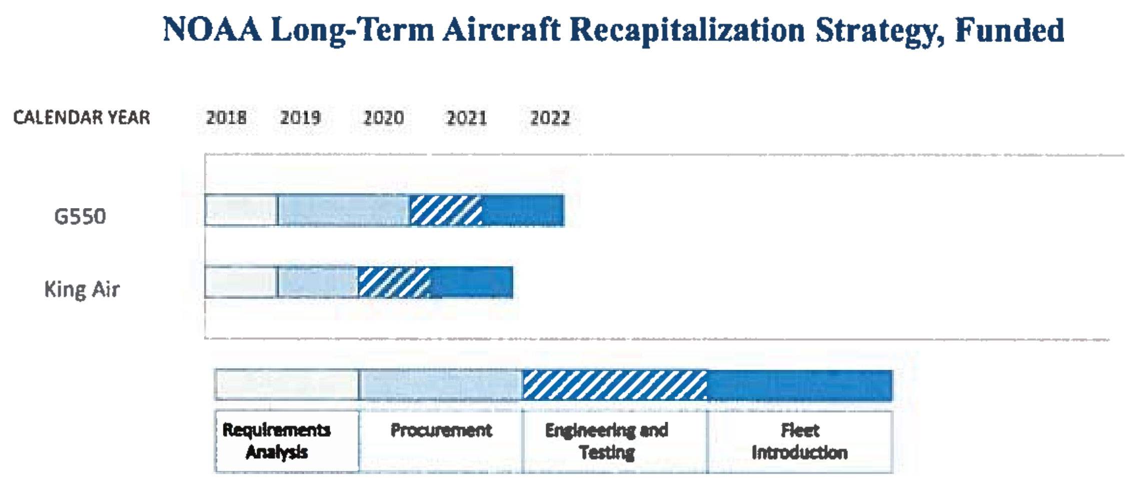

Figure 2-1: NOAA Long-Term Aircraft Recapitalization Strategy, Funded

G550 High-altitude Jet

- First, proceed with the requirements analysis, procurement, engineering/testing, and fleet introduction of a G550 high-altitude jet. The NOAA G-IV is a specialized aircraft that collects hurricane surveillance data – high altitude data (45,000 feet) – that directly improves hurricane track and intensity forecasts by 15%. In addition, acquisition of a high-altitude jet will provide an opportunity for integration of new technology that can meet more diverse mission requirements across Federal agencies such as air sampling and pollution monitoring. On-going upgrades to adhere to avionic and navigation system requirements mandated by the Federal Aviation Administration (FAA), require major investment to ensure capability with specialized aircraft systems including the scientific system and radar. This platform acquisition will provide alignment of airframe, systems, and specialized capabilities that leverages the latest technologies. NOAA has completed primary and secondary mission requirements workshops, preliminary acquisition work, and is proceeding with the aircraft procurement as quickly as possible.

King Air

- Second, continue with the requirements analysis, procurement, engineering/testing, and fleet introduction of a second King Air 350. Data collected by this aircraft is critical for soil moisture and snow survey requirements, information that directly feeds water resource planning across the Nation. In addition, the King Air can collect data used for nautical and aeronautical charting critical for maritime transportation and air transportation industries, pre-storm baseline measurements, and post-storm emergency response. The expanded capabilities of the King Air in comparison to the current Turbo Commander will increase NOAA's ability to meet prioritized mission requirements. Replacing the Turbo Commander with a King Air 350 will consolidate the number of aircraft types in the NOAA aircraft fleet resulting in greater operational, training, and maintenance efficiencies. NOAA has completed a requirements workshop, completed preliminary acquisition work, and is proceeding with procurement as quickly as possible.

In addition to the two aircraft funded in FY 2018, NOAA requires two additional aircraft to meet requirements during the timeframe of this plan, 2018-2028. Table 2-2 shows the acquisition sequence for these aircraft, pending funding.

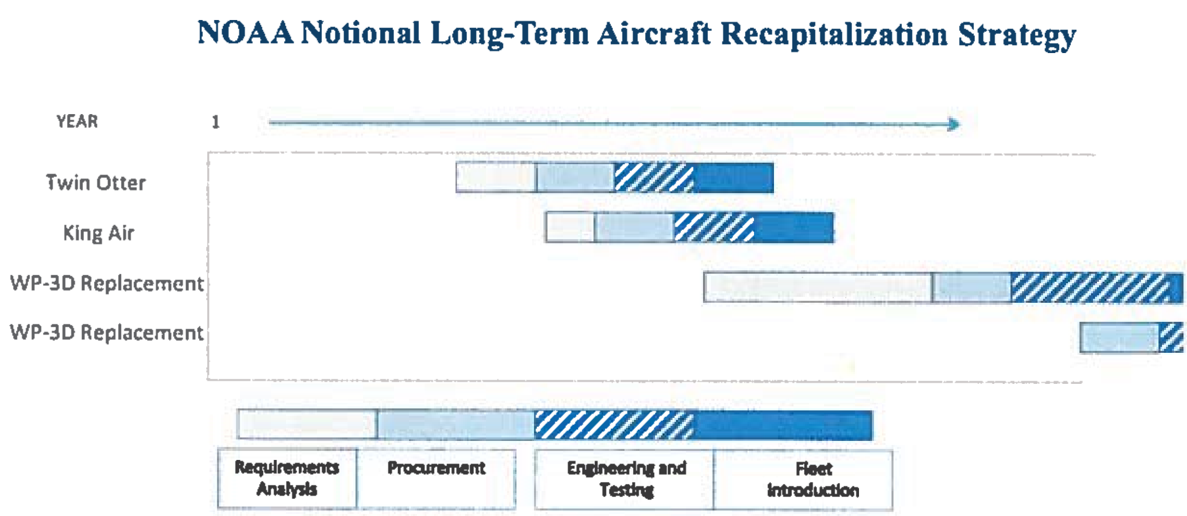

Figure 2-2: NOAA Notional Long-Term Aircraft Recapitalization Strategy

Twin Otter

- Third, update with the requirements analysis to inform the procurement of an additional Twin Otter aircraft. An additional Twin Otter aircraft is required to meet prioritized NOAA airborne requirements to include water resource management, living marine resources, charting and mapping, and emergency response as well as ensuring flight training and proficiency requirements can be met. NOAA conducted a preliminary requirements analysis for the Twin Otter in conjunction with the King Air being procured with FY 2018 appropriation, as it is most efficient to consider the totality of the aircraft capabilities in efficiently meeting prioritized requirements. This highly versatile and capable aircraft collects.

King Air

- Fourth, update the requirements analysis to inform the procurement of a third King Air. NOAA conducted a preliminary requirements analysis for an additional King Air in conjunction with the one being procured with FY 2018 appropriations, as it is most efficient to consider the totality of the aircraft capabilities in efficiently meeting prioritized requirements. Procurement of a King Air aircraft will eliminate the current single point of failure for high-resolution mapping; this critical data provides emergency managers and the public vital imagery immediately following hurricanes, floods, and earthquakes, as well as critical water forecast data. The additional capacity is also critical for meeting living marine resource requirements that are shifting from visual observations to remote sensing as technology evolves. The Twin Otter is NOAA's primary platform for living marine resource airborne data but is not capable of performing certain remote surveys due to range and endurance limitations. The King Air is perfectly suited for such surveys. However, the remoteness of required survey areas such as the Chuckchi and Beaufort prohibit the use of NOAA's current King Air aircraft given the response time for emergency response tasking. A third King Air would serve to eliminate the single point of failure for emergency response and provide for the remote living marine resource requirements.

Aircraft Sustainment

In addition to procuring aircraft, it is essential that NOAA sustain existing and new aircraft. Workforce planning and corresponding levels of personnel, operations, and maintenance, as well as training, aircraft introduction, and data validation is required.

- **Workforce Planning for Pilots** – NOAA performs an annual analysis for pilot planning based on training, designation, and upgrading requirements for NOAA aircraft pilots. The management plan identifies the required authorized complements for each aircraft type, upgrade time and qualification requirements, annual flight hour requirements, attrition, and selection processes for incoming pilots. Pilot staffing must occur well ahead of an aircraft coming on-line in order to meet all required levels of pilot designations to include co-pilot, aircraft commander, mission commander, and hurricane qualification. Pilot retention, which is impacting all uniformed and armed services, is a concern for NOAA and an issue that must be considered in workforce planning.

- **Workforce Planning for Technicians** – NOAA has highly specialized maintenance and avionics technicians that are critical to the operations and maintenance of the aircraft. Prior to an aircraft coming on line, there is a ramp up period to hire, train and qualify required technicians, ensuring proper personnel are in place to support the missions.

- **Operations and Maintenance** – Independent analysis by Conklin & de Decker on the NOAA G-IV in August 2016 determined the aircraft is on par for reliability. Based on this, maintenance costs are projected to increase three-percent per year[19]. The cost for NOAA G-IV operations in a back-up capacity, to include the mid-life maintenance, will be $4.843 million for year one (FY 2023). The operations and maintenance cost for year two is estimated at $3.068 million and expected to increase 3-percent per year. This includes FAA mandated upgrades, and upgrades for all instrumentation and data systems.

- **Training** – Transition from the current to replacement aircraft will require contractor-provided type rating training, aircraft proficiency and qualification flight hours. NOAA has already begun the process of creating and implementing a transition plan from the Turbo Commander to King Air aircraft. The King Air, unlike the Turbo Commander, requires an enhanced level of operator training to meet FAA Type Certificate qualification. Transition from the G-IV to the G550 will also require a transition plan. type rating and maintenance training for the G-IV is not applicable to the G550; each aircraft type requires specific contractor training, proficiency hours and qualifications. In addition, aircraft maintenance technicians must undergo contractor-provider training to qualify for work on the aircraft.

  Continuing operations, even in a back-up capacity, of the G-IV aircraft once the G550 high-altitude jet is on-line has significant training requirements. Even though the manufacturer of the G550 and current G-IV are the same, all pilots must attend bi-annual training for both types of aircraft and fly a set number of hours in each aircraft type monthly to maintain qualification and proficiency.

Aircraft Management Best Practices

Optimal management practices are essential to ensure that the operation of the NOAA fleet is as efficient and effective as possible. In the development of a comprehensive plan that addresses NOAA's current and future airborne observational infrastructure needs, best management practices were evaluated taking into consideration including the condition of the current aircraft and their projected end of service lives, as well as funding required versus return on investment. Best management practices seek opportunities for partnerships and integration of emerging technologies, as well as ways to cost-effectively manage the fleet to meet mission requirements. Extending the service lives of existing aircraft can be a productive strategy for some aircraft types but is not a cost-effective strategy for the aircraft types analyzed in this report. Increasing utilization of current NOAA aircraft and use of charters are not viable options given the current utilization rates of NOAA and charter aircraft. Use of unmanned aircraft systems has been utilized to some degree but does not alleviate the need to recapitalize NOAA aircraft to meet priority requirements. Below are aircraft management best practices that were evaluated to maximize utilization of the existing NOAA aircraft and mitigate the anticipated loss of NOAA aircraft over

19 G-IV maintenance includes contract maintenance, parts, supplies, and premium pay. It does not include labor and benefits costs for maintenance technicians, flight hour or fuel costs for maintenance ferry, and functional flights.

the next decade. NOAA will implement these practices to the extent feasible with current agency resources and budgets.

- **Extend Service Life of NOAA Aircraft** – This option is only viable for two of the current five NOAA aircraft types and has been implemented on both. Based on the 2016 analysis of alternatives to meet prioritized mission requirements, this option was the recommended and utilized option for the two WP-3D aircraft. A service life extension program is also the most cost-effective option for the four Twin Otter aircraft to extend the aircrafts' useful life while ensuring the capabilities to meet prioritized airborne requirements. This is not a viable option for the remaining NOAA aircraft types due to the cost of a service life extension, the limited ability to meet current (and future) requirements, and minimal long-term return on investment.

- **Increase Utilization of NOAA Aircraft** –From FY 2015 to FY 2018, NOAA aircraft flew, on average, 4,971 flight hours per year. This includes mission flights to meet prioritized requirements, as well as training and calibration flights to meet regulatory requirements and ensure instrumentation readiness. The maximum utilization of the current nine NOAA aircraft is a total of 6,400 flight hours per year; the maximum number of flight hours varies by aircraft type. NOAA works annually to maximize the current aircraft to meet prioritized requirements.

- **Integrate New Technology** – NOAA will continue to integrate new technology in its aircraft to the maximum extent possible. Technology integration largely occurs through upgraded and new mission-specific instrumentation installed on and in the aircraft. However, required aircraft hardware – such as wing hard points, camera holes, and data ports required to mount instrumentation – and compatibility limitations between older avionics, navigation systems, , and specialized equipment can limit the integration of new and upgraded data collection systems.

  Utilize Unmanned Aircraft Systems – NOAA will continue to look for opportunities for unmanned systems to meet requirements currently not met by manned aircraft, to supplement manned aircraft, and to assume manned aircraft missions, reducing overall cost and personnel risk. While unmanned systems are supplementing manned aircraft in some assessment and management of living marine resources and weather forecasting, research and monitoring missions, they are currently not a feasible substitute for all manned aircraft. While they have great potential to change the way NOAA collects data, NOAA does not expect UAS' capabilities and airspace requirements will advance sufficiently during the tenure of this plan to replace manned aircraft. However, UASs could provide some data collection, and NOAA plans to implement a coordinated, systematic NOAA-wide approach to evaluating UASs potential to be a cost-effective means of meeting agency priorities.

- **Increase Use of Charters** – Charters are a critical component of the NOAA aircraft fleet, and help NOAA carry out mission critical work. NOAA will continue to charter aircraft to meet prioritized requirements when feasible, cost-effective, and capable. Charters will continue to provide support for protected species management, gravimetry, climate research, coastal mapping, and marine sanctuary management, particularly during seasons of heavy demand on the NOAA aircraft fleet. The ability of charters to meet requirements is limited by aircraft capabilities including instrumentation (and the ability to create ports or holes for installation), size, project frequency, and geography. In addition, NOAA pilots and crews have training and experience specific to the unique aspects of NOAA missions, including maneuvers at low altitudes and low speeds, and in highly volatile weather. Due to the extreme flight profiles and weather conditions, and importance of the data to public safety and national security, many of these missions are considered inherently governmental work.

- **Expand Partnerships** – NOAA will continue to collaborate across Federal agencies and academic institutions by building upon partnerships including with the National Science Foundation's (NSF) National Center for Atmospheric Research (NCAR), the National Aeronautics and Space Administration (NASA), the Naval Research Lab and the United States Air Force Reserve Command (USAFRC) 53rd Weather Reconnaissance Squadron. NOAA will continue to look for additional opportunities to collaborate with others to meet NOAA requirements.

III. The Need to Fly – Now and in the Future

NOAA's Current Airborne Requirements

Each year, the United States averages 10,000 thunderstorms, 5,000 floods, 1,300 tornadoes and two land-falling Atlantic hurricanes within the Continental United States, as well as widespread droughts and wildfires. Weather, water, and climate events cause an average of approximately 650 deaths and $15 billion in damage each year and are responsible for 90-percent of all presidentially declared disasters. About one-third of the U.S. economy – $3 trillion – is sensitive to weather and climate. NOAA provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas for the protection of life and property and the enhancement of the national economy.[20] NOAA flies hurricane reconnaissance and surveillance missions to provide timely and accurate weather and water forecasts, as well as life-saving watches and warnings. NOAA conducts snow surveys using gamma radiation remote sensing to obtain soil moisture and snow water equivalent measurements for flood forecasts, watches and warnings, river level forecasts, and drought outlooks.

The oceans, coasts, inlets, and Great Lakes support the lives, livelihoods, and lifestyles of all Americans. Six ocean-dependent economic sectors (i.e., marine construction, marine transportation, offshore mineral extraction, ship and boat building, tourism, and recreation) make contributions to the national economy and in 2013, the ocean economy's 149,000 business establishments employed more than 3 million people, paid over $117 billion in wages, and produced more than $359 billion in goods and services. The living resources sector (including commercial fishing, aquaculture, seafood processing, and seafood markets) alone accounted for 62,000 employees, $2.5 billion in employee wages and $7.2 billion in goods and services in the U.S. Ocean and Great Lakes economy in 2012.[21] Airborne data are used in the management of living marine resources including protected species population assessments, habitat protection and restoration, sanctuary enforcement, incident response, and for characterizing coastal and ocean environments and implementing management actions. NOAA aircraft use hyperspectral imagery to characterize and map near shore bottom type, collect data for consistent long-term quantifiable habitat mapping, collect stock and population data for protected species management, and to verify and calibrate data from satellites. NOAA aircraft collect data directly used to provide accurate charts of the Nation's 175 ports critical to safe navigation for commercial, military, and recreational vessels. NOAA aircraft have provided data critical for safe operations of the Nation's aviation industry since the 1960s, an industry that contributed $1.5 trillion in total economic activity and 11.8 million jobs in 2012.[22]

20 http://www.noaa.gov/weather

21 NOAA Report on the U.S. Ocean and Great Lakes Economy, pg. 12; retrieved from https://coast.noaa.gov/data/digitalcoast/pdf/econ-report.pdf.

22 "The Economic Impact of Civil Aviation on the U.S. Economy," June 2014. U.S. Department of Transportation, Federal Aviation Administration.

Four NOAA missions – **Charting and Surveying; Assessment and Management of Living Marine Resources; Weather Forecasting, Research and Modeling**; and **Emergency Response** – detailed below encompass the activities that NOAA conducts to gather airborne data.

Charting and Surveying – This NOAA mission includes ensuring safe navigation; management of coastal and ocean resources; restoration and response; and technical assistance for coastal zone management.

- **Navigation, Observations and Positioning –** Nautical charts, or maps, are the tool used by all sectors of the maritime industry (i.e., commercial, military, and recreational) for safe navigation in waterways and coastal areas, including the Nation's ports. NOAA is mandated to acquire and disseminate shoreline and hydrographic data to ensure safe maritime navigation. The value of accurate charts for commercial maritime activity alone is significant. Ocean currents, silt transport from rivers, passage of storms, tectonic activity, and impacts from commercial (one shipping container falls off a commercial ship every hour) and recreational uses result in changes to the shoreline and shallow-water bathymetry that degrades the accuracy of nautical charts. Repeat surveys of the shoreline and nearshore areas are required to keep charts accurate and navigation safe. Accurate charts of ports and waterways directly support imports and exports on ships, associated GDP and jobs, as well as surface transportation industries. By value, vessels carry 53-percent of U.S. imports and 38-percent of exports, representing more than 62,000 port calls in 2010 and 7% of the Nation's GDP. More than $1.9 trillion in imports came through U.S. ports in 2010, and U.S. commercial ports directly supported more than 13 million jobs.[23] Furthermore, traffic in deep draft ports, which accounts for more than 95-percent of all import and export traffic in the United States, supports the $570 billion railroad and motor carrier transportation industries.[24] The GDP from this surface transportation, supported directly by nautical charts, increased from $6 billion to $62 billion in less than 25 years (1984 to 2008).[25] In total, the economic impacts related to America's seaports in 2014 was $4.6 trillion (or about 26-percent) of the entire U.S. economy compared to 20-percent in 2007. The importance of accurate charts will only increase given that the volume of traffic, and value of exports and imports via water in U.S. seaports is expected to double by 2021 and double again shortly after 2030.[26]

  NOAA is mandated by the Coast and Geodetic Survey Act to accomplish surveys in support of aeronautical charting. When tasked by the FAA, the survey data NOAA collects provides critical runway, obstruction, navigation aid, and airport feature information needed to safely fly into airports. NOAA aircraft support the Nation's $1.5 trillion aviation

23 NOAA's State of the Coast Web site, Ports – Crucial Coastal Infrastructure. Retrieved from http://stateof thecoast.noaa.gov/ports/welcome/html.

24 Wolfe, K.E. 2010. Value Added to GDP from International Containerized Freight by Surface Transportation. Silver Spring, MD: National Oceanic and Atmospheric Administration.

25 Wolfe, K.E. 2010. Value Added to GDP from International Containerized Freight by Surface Transportation. Silver Spring, MD: National Oceanic and Atmospheric Administration.

26 National Oceanic and Atmospheric Administration (NOAA), National Ocean Service. 2015. "The Value of PORTS to the Nation: How Real-Time Observations Improve Safety and Economic Efficiency of Maritime Commerce."

industry, including more than 11 million U.S. jobs and $459 billion in earnings. Accurate aeronautical charts are used by all sectors of the aviation industry for safe and efficient air travel across the country and into and out of airfields. NOAA aircraft data directly supported the transport of 798 million commercial passengers in 2015, an all-time high and an increase of 5-percent from 2014.[27] The FAA requires data collected by NOAA aircraft to develop instrument approach and departure procedures, determine maximum takeoff weights, and update aeronautical publications and airport and engineering studies.

- **Coastal Science and Assessment** – This activity gathers data for tsunami modeling, storm surge predictions, sanctuary management, ocean exploration, oil/gas exploration, and environmental management applications. Accurate data directly impacts the more than 40-percent of the Nation's population that lives in coastal shoreline communities. In 2013, economic activity in the shore-line adjacent communities of the U.S. accounted for $7.6 trillion (45-percent of the U.S. total GDP), 53.6 million jobs (47% of the U.S. total), and $3.0 trillion in wages (54-percent of U.S. total).[28] For reference, the U.S. coastal communities alone would rank number three in GDP globally, behind the United States as a whole and China.[29] Accurate mapping of coastal areas is critical for urban planning and emergency management; every dollar invested in storm-surge effects on coastal communities saves the U.S. taxpayer $4 in losses from natural hazards. The gravimetric data collected by NOAA aircraft directly contributes to a projected $522 million in annual benefits, including $240 million in benefits from improved floodplain mapping[30].

Assessment and Management of Living Marine Resources – NOAA is responsible for the stewardship of the Nation's ocean resources and their habitat. Timely, geographically-driven, and capabilities-dependent access to the sea supports the sustainability and economic value of fisheries ensures the resiliency of fishing communities and working waterfronts; protects and recovers threatened and endangered species; and maintains and restores healthy coastal habitats for living marine resources. NOAA uses airborne data to identify, characterize, monitor, and evaluate living marine resources and their surrounding ecosystems.

- **Protected Resources, Science and Management** – Accurate assessment of threatened and endangered marine and anadromous species is critical to fishery, maritime, tourism, and oil and gas sectors. Measurement and prediction of resource abundance, distribution, habitat requirements, and related ecosystem components of protected resources directly impacts quotas for commercial and recreational fishery stocks, commercial shipping

27 U.S. Department of Transportation, Bureau of Transportation Statistics,"2015 U.S.-Based Airborne Traffic Data. Retrieved from: https://www.rita.dot.gov/bts/press_releases/bts018_16.

28 National Oceanic and Atmospheric Administration Office of the Chief Economist. (2016). *Coastal Economy Pocket Guide*. Retrieved February 24, 2017, from http://www.performance.noaa.gov/wp-content/uploads/Coastal-Economic-Pocket-Guide-113016.pdf.

29 NOAA's State of the Coast website, jb The Coast- Our Nation's Economic Engine. Retrieved from http://stateofthecoast.noaa.gov/coastal_economy/welcome.html.

30 National Geodetic Survey, NOS Fiscal Year 2017 Year in Review. Retrieved August 02, 2018 from http://oceanservice.noaa.gov/annualreport17/ngs.html.

(traffic lanes), and conservation. Critical environment assessment data collected using NOAA aircraft is essential for permitting oil/gas and offshore wind exploration and development, and is used by various agencies.

- **Fisheries Science and Management** – Accurate, complete, and timely surveys of protected species are linked to establishing commercial and recreational fishery stock quotas. Poor or uncertain data lead to more conservative constraints. As a result of significant U.S. Stellar sea lion stock decline, the Bering Sea/Aleutian Islands Atka mackerel fishery was decreased by 28,053 metric tons, worth $20 million, in 2014. Aerial surveys are critical for minimizing impacts to the industry through targeted closures and consistent monitoring.[31] Improved abundance estimates of harbor porpoises resulted in relaxed regulatory requirements on the gillnet fishery, directly resulting in additional profits while effectively managing stocks.[32]

- **Habitat Conservation and Restoration** – These activities protect and restore habitat to sustain commercial and recreational fisheries, recover protected species, and maintain resilient coastal ecosystems and communities. Habitat conservation and restoration directly impacts commercial and recreational fishery quotas, the communities that rely on sustained stocks, and the downstream industries fueled by fish and seafood landings. Between 2010 and 2012, recreational fishing associated with the four national marine sanctuaries located off the coast of California supported an average of 1,400 jobs, generating $213 million in output and $75 million in income.[33] In addition, restoration of healthier rivers and coastal habitats resulted in $9 million to $48 million of downstream socio-economic benefits to recreation and ecosystem services, such as flood control and clean water.[34]

Weather Forecasting, Research, and Modeling – NOAA conducts weather surveillance, reconnaissance, and research that increases knowledge of freshwater supply, climate, weather, oceans, and coasts. Weather forecasting, research and modeling contributes to accurate storm and weather forecasts, enables communities to plan for and respond to climate events such as drought and flooding, and enhances the protection and management of the Nation's coastal and ocean resources. Weather data collected by NOAA aircraft with aircraft instrumentation,

31 Assessment of the Atka mackerel stock in the Bering Sea/ Aleutian Islands. Retrieved from: https://afsc/noaa.gov/REFM/Docs/2015/BSAlaska.pdf.

32 Bosack, K., & Magnuson, G. (2014). Measuring the Economic Value of Increased Precision in Scientific Estimates of Marine Mammal Abundance and Bycatch: Harbor Porpoise Phocoena in the Northeast U.S. Gill-Net Fishery. *North American Journal of Fisheries Management*, 34(2), 311-321.

33 National Oceanic and Atmospheric Administration Office of National Marine Sanctuaries. (2015, June). Economic Impact of the Recreational Fisheries on Local County Economies in California's National Marine Sanctuaries 2010, 2011 and 2012 (U.S. Department of Commerce, NOAA Marine Sanctuaries Conservation Series ONMS 2015-07) Washington, DC: U.S.

34 Samonte, G. P.B., Edwards, P.E.T., Royster, J.E., Ramenzoni, V.C. and Morlock, S. (2016). Socioeconomic Benefits of Habitat Restoration. U.S. Department of Commerce NOAA Technical Memorandum NMFS-F/SPO. p.73.

and ocean resources. Weather data collected by NOAA aircraft with aircraft instrumentation, dropwindsondes, and unmanned aircraft systems are directly fed into weather models, forecasts, and oceanographic circulation models.

- **Observations and Forecasting –** NOAA aircraft fly into and around hurricanes, collecting data that feeds directly into hurricane track and intensity models and improves forecast accuracy by 15-percent. Between 1980-2017 hurricanes and other severe storms caused more than $740 billion in damages and 4,700 deaths; inland flooding accounted for more than $110 billion in economic losses and 400 deaths; and drought resulted in more than $220 billion in economic losses and 2,990 deaths. The observations and forecasting data collected by NOAA is critical for public safety and the Nation's economic security.

  NOAA Aircraft and the United States Air Force (USAF) 53rd Weather Reconnaissance Squadron both collect Tropical Cyclone data. The National Hurricane Operations Plan[35], published annually be the Office of Federal Coordinator for Meteorology, defines among other things the aircraft, and observational requirements. The types of missions, and data the aircraft collect differ based on capabilities and specialized instrumentation; the specific aircraft capabilities are listed in Table 3-1.

  The NOAA P-3 and USAF C-130J aircraft both fly reconnaissance missions to fix the center of the tropical cyclone, survey winds, deploy dropwindsondes for temperature, humidity and pressure data, and collect surface level wind data with the Step Frequency Microwave Radiometer.

  However, while both NOAA and the USAF perform reconnaissance, NOAA also carries out critical research that informs and improves forecasting. The NOAA G-IV is tasked for surveillance missions to support national tropical cyclone forecasting. In addition, the NOAA aircraft fly research tasked missions into tropical cyclones. Instrumented with required specialized equipment such as the Tail Doppler Radar, Step Frequency Microwave Radiometer, and Doppler Wind Lidar the aircraft targets specific features of the tropical cyclone to improve track and intensity forecasts. The full suite of research missions is defined in the Hurricane Forecast Improvement Program Plan[36].

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[35] 2019 National Hurricane Operations Plan. Available at: https://www.ofcm.gov/publications/nhop/fcm-p12-2019.pdf.

[36] Hurricane Forecast Improvement Program: http://hfip.org.

Tasking	NOAA P-3	NOAA G-IV	USAF C-130
Reconnaissance: low level invest	X		X
Reconnaissance: fixes	X		X
Tail Doppler Radar Operations	X	X	
Surveillance		X	
Research	X	X	

Table 3-1: Capabilities of NOAA P-3, NOAA G-IV, and USAF C-130 for Hurricane missions

NOAA aircraft also collect data to ground-truth satellite-derived data on weather conditions such as wind speed, improving the interpretation of satellite data that leads to more accurate weather reporting and forecasting.[37]

In addition, NOAA aircraft data provides baseline soil moisture and snowfall measurements critical for flood forecasting and water resource management. In the western United States, snowmelt provides over 70-percent of the water supply. Accurate and timely snow forecasts and snowmelt forecasts are critical components in the management of rivers such as the Columbia and the Colorado. Snow also plays a significant role in the U.S. tourism economy, accounting for over $10 billion in yearly economic gains in New England and the Rocky Mountains alone.[38,39]

- **Long-term Forecasting Research** – Airborne data is fundamental to sub-seasonal and inter-seasonal variations by sustaining atmospheric and oceanic observations and research; understanding and predicting ocean and climate variability and change; and incorporating research into information and products. Data collected by NOAA aircraft directly feed into global models that forecast precipitation and extreme weather events (i.e., tropical cyclones, tornadoes, blizzards). The yearly economic impact of U.S. weather is $485 billion, plus or minus $240 billion, based on a study of 70 years of weather records through 2008.[40] Weather variations cost as much as 3.4-percent of U.S. GDP. The severe weather impacts in the spring of 2011, alone, cost the insurance industry $15 billion.[41]

37 Sapp, J., Alsweiss, S., Jelnak, Z., Chang, P., Frasier, S., & Carswell, J. (2016). Airborne Co-polarization and Cross-Polarization Observations of the Ocean-Surface NRCS at C-Band. *Geoscience and Remote Sensing, IEEE Transactions* on, 54(10), 5975-5992.

38 Adams, R., Houston, L., Weiher, R. (2004, August). The Value of Snow and Snow Information Services. Report prepared for NOAA's National Operational Hydrographic Remote Sensing Center.

39 Valued at $8 billion in 2004; equates to $10 billion in 2016.

40 Changnon, S.. September 1999 "Impacts of 1997-98 El Nino- Generated Weather in the United States." *Bulletin of the American Meteorological Society*. 80: 1819-1827.

41 Weather Costs U.S. Economy Hundreds of Billions Annually. June 29, 2011. Independent Study by Aon Benfield insurance company. Retrieved from http://accuweather.com/en/weather-news/weather-costs-the-us-economy-h-1/51526.

The repeatable and complex data collected by NOAA aircraft directly leads to forecast improvements.

- **Weather and Air Chemistry Research –** Data collected by NOAA aircraft supports research and accurate, timely warnings and forecasts of high-impact weather events. Aircraft data fed directly into El Nino and La Nina weather forecasts is critical for safety of lives and property, emergency management, and economic planning. The 1997-98 El Nino caused property losses of $2.8 billion, including $700 million in agricultural impacts and $200 million in losses to the tourist industry.[42] These impacts result in higher prices on many food items including fish, sugar, and produce.[43] NOAA aircraft also conduct highly technical instrumentation integration and collect complex air chemistry data vital for understanding and managing air pollution and establishing ambient air quality standards. This effort seeks to minimize adverse air pollution effects on human health, poor academic performance, and premature death.[44] The reduction in premature mortalities alone is estimated to save the Nation $2 trillion per year by 2020.[45]

- **Ocean, Coastal and Great Lakes Research –** This activity investigates ocean, coastal, and Great Lakes habitats and resources to help manage and understand fisheries, conserve and restore the Nation's coasts, and build a stronger economy. NOAA aircraft collect shoreline mapping and coastal habitat data used to quantify shoreline losses and changes to shoreline habitat due to anthropogenic and natural causes.[46] This program provides $100 million in direct economic benefits and over $240 million in overall economic benefits annually. The *National Shoreline* (shoreline data generated by the NOAA National Geodetic Survey) provides critical baseline data for updating nautical charts; defining national territorial limits, including the Exclusive Economic Zone (EEZ); and managing U.S. coastal resources. Data collected by NOAA aircraft also contribute to coastal and marine spatial planning, coastal engineering and construction, storm surge and seal level change modeling, pollution trajectories, and coastal flooding and insurance industries.[47]

Emergency Response – In addition to annual flights for hurricane reconnaissance, surveillance and research, coastal mapping, flood and water management planning and coastal mapping,

42 Changnon, S. September 1999 "Impacts of 1997-98 El Nino- Generated Weather in the United States." *Bulletin of the American Meteorological Society*. 80: 1819-1827.

43 Williams, Geoff. March 28, 2016. "El Nino is Raising the Price of Sugar, Fish and other Favorite Foods." Forbes.

44 Pope, C., Scwartz, J., & Ransom, M. (1992). Daily Mortality and PM 10 Pollution in Utah Valley. *Archives on Environmental Health: An International Journal*, 47(3), 211-217.

45 The Benefits and Costs of the Clean Air Act from 1990 to 2020. Retrieved from: https://www.epa.gov/sites/production/files/2015-07/documents/summaryreport.pdf.

46 White, S., Parrish, C., Calder, B., Pe'eri, S., & Rzhanov, Y. (2011). LIDAR-Derived National Shoreline: Empirical and Stochastic Uncertainty Analyses. *Journal of Coastal Research*, (10062), 62-74.

47 Leveson, I. Levson Consulting. 2012. Socio-Economic Study: Scoping the Value of NOAA's Coastal Mapping Program. Retrieved from: https://geodesy.noaa.gov/PUBS_LIB/CMP_Socio Economic_Scoping_Study_Final.pdf.

NOAA aircraft routinely respond to natural and man-made national disasters. Table 3-2: Annual Summary of NOAA Aircraft Emergency Response lists the total annual flights hours and significant events. The data collected by NOAA aircraft is directly used by Federal, state, and local agencies to minimize environmental and economic impacts of hurricanes, floods, earthquakes, and national security events. NOAA emergency response services include collecting imagery immediately following hurricanes and tornados, modeling oil spill trajectories, and managing recovery information. The multi-disciplinary capabilities of NOAA aircraft provide a highly adaptable and responsive national asset in the greatest times of need. This tasking often displaces the scheduled projects on the aircraft. The acquisition of the second King Air aircraft will expand the capacity to meet these critical national needs without displacing prioritized mission previously scheduled on the aircraft.

FY	Flight Hours	Major Emergency Events
2010	850	Deepwater Horizon, Flooding
2011	267	Joplin Tornado, Mississippi Flooding, Deepwater Horizon
2012	325	Hurricane Issac, Deepwater Horizon
2013	71	Hurricane Sandy, Colorado Flooding, Moore Tornado
2014	782	Hurricane Arthur, Coastal Mapping
2015	30	North American Blizzard
2016	90	Hurricane Matthew, Louisiana Flooding
2017	232	Hurricanes Harvey, Irma, and Maria
2018	263	Hurricanes Florence and Michael

Table 3-2: Annual Summary of NOAA Aircraft Emergency Response

NOAA Specific examples of response include:

- **Louisiana Flooding (2016)** – In August 2016, record rainfall and flooding destroyed more than 60,000 buildings and resulted in $10.8 billion in losses, making it the costliest disaster for the U.S. since Hurricane Sandy in 2012.[48] The NOAA King Air responded to this historic flooding in southern Louisiana, collecting nearly 6,000 high-resolution images over a 4,000 square kilometer area and delivering the data to Federal Emergency Management Agency (FEMA) for emergency management and response. The images also provided validation of flood extent vectors derived from satellite imagery. The NOAA aircraft's ability to fly below the cloud cover, unlike satellite imagery, provided the highest value data at the peak of the river crest. This data was critical to accurately determine impact to structures, to expedite search and rescue operations and to direct FEMA individual assistance.

48.U.S. Billion –Dollar Weather & Climate Disasters 1980-2019. NOAA National Centers for Environmental Information. Retrieved from: https://www.ncdc.noaa.gov/billions/events.pdf.

- **Hurricane Matthew (2016)** – Hurricane Matthew caused more than $10 billion in damages and 49 deaths.[49] NOAA aircraft supported Hurricane Matthew forecasting, research, and post-storm survey operations as the storm approached and impacted the Florida, Georgia, South Carolina and North Carolina coasts. NOAA's hurricane hunter aircraft conducted 19 storm reconnaissance, research and surveillance flights, operating a total of 158 hours. After Hurricane Matthew passed, NOAA's emergency response aircraft, the King Air 350CER, flew nearly 50 hours in support of the FEMA, collecting nearly 12,000 high-resolution images covering more than 2,900 miles over five states. This imagery was accessed by more than 44 million website visits with two terabytes of downloads and directly supported damage assessment and response activities by FEMA, the states of Florida, Georgia, North Carolina, and Virginia, the U.S. Geological Survey, and the U.S. Army Corps of Engineers. NOAA aircraft imagery allowed FEMA to respond to more than 150,000 damage assessments within the first 48 hours after the storm's passage and issue immediate support payments in excess of $10.5 million to those in need of expedited service[50].

- **Midwest Flooding (2015)** – NOAA aircraft collected nearly 10,000 aerial images covering over 7,500 square miles of flooded area along the Mississippi River and in Arkansas using specialized remote-sensing equipment. This data was posted near real-time and made available to the public. Emergency and natural resource managers relied on this data to respond to this intense rainfall event that spanned six states and that caused $2 billion in damages and 50 deaths[51].

- **Hurricanes Harvey, Irma and Maria (2017)** – The 2017 Atlantic hurricane season was the most costly and damaging on record. Collaborating with FEMA and State Emergency Coordinators, NOAA Aircraft collected nearly 65,000 aerial images, over more than 24,000 square kilometers, from Texas to the U.S. Virgin Islands. The imagery, posted through the NOAA National Geodetic Survey emergency response website (http://www.storms.ngs.noaa.gov), was available within hours after collection by the NOAA Aircraft. In total, 2.28 billion image requests, totaling 236 terabytes of data, were downloaded by local, state and Federal emergency managers, home and business owners, the insurance industry, and the Department of Defense. This data served as the backbone of information for the Nation as individuals, business owners, and emergency managers rebuilt their lives and communities resulting from the more than $200 billion in damages.

Airborne Capacity Requirements

Airborne data and mission activity requirements determine total flight hour (capacity) requirements. In developing this plan, NOAA incorporated the analyses of flight hour

49 NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2017). Retrieved from: https://www.ncdc.noaa.gov/billions/events.pdf.

50 Florida Hurricane Matthew (DR-4283). Retrieved from: https://fema.gov/disaster/4283.

51 NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2017). Retrieved from: https://www.ncdc.noaa.gov/billions/events.pdf.

requirements and corporate assets, as well as chartering, partnering, and new technology options. The airborne activities conducted to support NOAA's missions drive the line offices' (LO) requirements for time on NOAA aircraft. This section presents the process by which airborne requirements are prioritized and managed and the resulting capacity requirement.

The process for prioritizing airborne requirements occurs at agency, LO, and programmatic levels. The NOAA Technology, Planning, and Integration for Observations Office (TPIO) led a requirements validation process that created a baseline of verifiable and prioritized airborne data and observation requirements. The airborne requests, which are submitted annually via the Aircraft Prioritization, Allocation and Scheduling System (APASS) are vetted through two levels of LO approval and analyzed by the NOAA Aircraft Working Group. The cross-agency representation on the Aircraft Working Group develops a proposed Aircraft Allocation Plan (AAP). The LO leaders on the Fleet Council approve the annual AAP as well as amendments during the course of the year if needed.

APASS creates a disciplined and competitive environment that results in prioritization and corresponding allocation of aircraft time for the highest mission needs. This approach balances requirements selection with core capabilities to flexibly and reliably meet planned and emergent requirements. NOAA will regularly revisit optimal aircraft composition and capacity as the number and types of validated mission critical requests fluctuate.

In FY 2019, NOAA plans to fly 4,520 flight hours with NOAA aircraft. Execution of this number of flight hours is contingent on several factors including unscheduled maintenance requirements, weather, and fuel prices. NOAA's nine aircraft have a maximum total utilization of 6,400 flight hours per year. Acquiring aircraft equipped with sensor ports and mounting points increases mission flexibility, ability to meet expanding mission requirements, and ability to expand data collection during missions resulting in potential increased utilization[52].

In addition to NOAA aircraft, airborne requirements are met with aircraft charters, data buys, and partnerships. Chartering means a NOAA program has contracted for a commercial aircraft operated by the contractor; while the NOAA program provides the science party and, in some instances, the observational equipment. The aircraft operator provides the basic aircraft infrastructure to conduct the airborne operation. In some cases, NOAA aircraft and contract aircraft collect data in support of the same mission, in different survey areas. Data buys are used for charting and surveying data; the contract assigns specific survey areas to the contractor and the contractor provides data to NOAA. Charters conducted 3,290 flight hours annually based on average data from FY 2015-2018. As shown in Table 3-1, about 44-percent of the flight hours allocated annually for airborne activities are provided by charters, including other government aircraft, data buys, and commercial aircraft. In total, NOAA and charters meet approximately 7,500 of the 12,700 flight hour annual requirement. Table 3-1 shows the required flight hours and the use of NOAA and charter aircraft to meet airborne data requirements.

52 Sensor ports and mounting points result from aircraft modifications to include mounting hard points along the fuselage, and wings of the aircraft, and intake ports along the aircraft fuselage and wings,

Missions & Activities			Capacity (flight hours)			
			Total Requirement (FY 18)[53]	Allocated		Total Allocated (NOAA and Charter)
				NOAA (FY 18)	Charter[54] (FY 16-FY 18 average)	
		Totals	**12,679**	**4,198**	**3,290**	**7,243**
Missions & Activities	**Charting & Surveying**	Navigation, Observations & Positioning	1,800	805	750	1,555
		Coastal Science & Assessment	750	110	500	610
	Assessment & Management of Living Marine Resources	Protected Resources, Science & Management	3,900	1,223	800	2,023
		Fisheries Science & Management	N/A	N/A	N/A	N/A
		Habitat Conservation & Restoration	1,000	340	40	380
	Weather Forecasting, Research & Modeling	Observations & Forecasting[55]	4,129	1,375	1,200	2,575
		Climate Research	500	155	N/A	155
		Weather & Air Chemistry Research	600	190	20	210
		Ocean, Coastal & Great Lakes Research	N/A	N/A	N/A	N/A
	Emergency Response		As required			
	Mission Support	OMAO Mission Support[56]	N/A	701	N/A	701

Table 3-3: Capacity (flight hours) Required and Allocated Airborne Capability Requirements

Just as airborne data and mission activity requirements determine flight hour capacity requirements, airborne data and mission activity requirements drive aircraft capability

53 FY 2017 requirements as submitted in APASS.
54 Most recent execution data available for charter hours.
55 Includes Hurricane Reconnaissance and Surveillance, Winter Storms, and Water resource surveys.
56 Mission support flight hours are for training, maintenance flights, and calibration testing.

requirements. Many missions and airborne activities require aircraft with more than one capability to respond to various data requirements. With the need for multidisciplinary capabilities, there may be overlap in aircraft capabilities to support the temporal and spatial observational requirements demanded by NOAA's programs. NOAA partners with several other Federal agencies to leverage the interoperability of the Federal fleet. Partnerships with the USAF, NASA, NSF, NCAR, and commercial aircraft providers are essential for NOAA to cost-effectively fulfill its airborne data requirements.

NOAA is committed to using charters and expanding its use of charters where feasible and cost-effective. Charters can support some aspects of NOAA's airborne portfolio including protected species management, gravimetry, climate research, coastal mapping, and marine sanctuary management. Advantages to charters include lower costs for some missions, particularly when smaller aircraft can be used, and reduced transit time when charters are based near the work site.

However, charter options cannot satisfy some NOAA flight hour and data collection needs due to schedule requirements and limited capabilities to collect the full suite of scientific data. Increasing use of charters, poses challenges too, such as availability at a specific time and place and varying levels of crew experience, aircraft capabilities, regulatory requirements, data consistency, specialized instrument availability, and Federal contract requirements. Many of NOAA's missions require specialized equipment that cannot be installed in charter aircraft without extensive modifications, making some missions unsuitable for chartering. Additionally, commercial charter options for hurricane observations and forecasting are not viable due to this being an inherently governmental function due to the high-risk mission requirements. Balancing these issues mitigates programmatic risks by ensuring high-quality science and providing short-term flexibility.

More commonly, NOAA partners with other agencies, such as NASA and NSF, to leverage multiple aircraft assets in support of large airborne data campaigns. Doing so allows NOAA, NASA, and NSF to maximize the interoperability of Federal aircraft through geographic and logistical efficiencies. In 2016, NOAA utilized NSF aircraft for observations and forecasting when the NOAA hurricane surveillance aircraft was down for unscheduled maintenance. Also in 2016, NOAA and NASA conducted an extensive aircraft campaign to assess how the warm El Nino waters, among the strongest on record, influence the atmosphere. Multimodal measurements from the air, ocean, and ground contributed to a better understanding of global weather patterns, including improved forecasting of extreme precipitation events on the U.S. West Coast associated with El Niño.[57] Past El Niño events of similar magnitude have resulted in intense rainstorms that caused flooding and landslides resulting in more than $2.8 billion in property losses, including $700 million in agricultural impacts and $200 million in losses to the tourism industry. In 2016, NOAA and NASA partnered again for Operation Ice Bridge. Utilizing the NOAA WP-3D aircraft, scientists

[57] Solomon, A. and G. Compo. March 24, 2016. The El Nino Campaign: Monitoring the 2015-2016 El Nino from the land, sea, and air. Retrieved from: https://www.climate.gov/news-features/blogs/enso/el-ni%C3%B1o-rapid-response-campaign-monitoring-2015-2016-el-ni%C3%B1o-land-sea-and.

collected data on arctic ice to monitor melting rates of fast-retreating glaciers. During the 6-week 2016 phase of the project NOAA aircraft surveyed the ice thickness of the entire western Arctic Basin. NOAA provided pilot support for the Ice Bridge project in FY 2017. This data is critical to assess the impact of polar-regions on the global climate environmental monitoring system.
NOAA also continues to coordinate with its aviation partners to optimize flight hours by assessing and incorporating government and commercially-driven technologies such as unmanned, autonomous, and remotely operated systems, data analytics, and real-time data distribution and visualization that ensure a technological optimization of airborne surveys. These operational assessments have included unmanned operations in hurricanes and species assessments from the Arctic to the Antarctic. Whereas, operational capacity is the quantity of existing NOAA's capabilities, having a multi-mission, inter-operable, and coordinated Federal aircraft fleet through interagency efforts, such as the International Committee for Aviation Policy (ICAP) and the Interagency Coordinating Committee for Airborne Geoscience Research and Applications (ICCAGRA), will improve operational capacity.

NOAA has excised six aircraft in the last 10 years in an effort to standardize a fleet that more effectively and efficiently meets prioritized requirements. Although the one aircraft that came on-line during this time (N68RF – King Air 350ER) has increased capabilities from its predecessor, gaps remain in requirements that cannot be met by NOAA aircraft. To the extent possible, NOAA has implemented mitigation strategies, including increased use of charters, cross-platform mission capabilities, partnerships and new technology to minimize the requirements gaps. These strategies are largely maximized in the current aircraft. Mitigation strategies are limited by capability requirements, aircraft availability, and by project requirements, including temporal, instrumentation, and endurance needs. To assess the impact of the airborne capabilities loss with the retirement of four aircraft by the end of 2028, the capabilities required by each mission and airborne activity were identified. Table 3-2 illustrates the linkage between NOAA's missions, airborne activities, and the aircraft capabilities needed to conduct those activities.

Missions		Required Aircraft Capabilities
Charting & Surveying	Navigation, Observations & Positioning	Multi- and hyperspectral imagery, topographic and bathymetric LIDAR data, gravity measuring survey (GRAV-D)
	Coastal Science & Assessment	Bathymetric data, multi- and hyperspectral imagery, topographic and LIDAR data, aerial surveys and videos
Assessment & Management of Living Marine Resources	Protected Resources, Science & Management	Bathymetric data, low level and low speed aerial surveys and videos, communications
	Fisheries Science & Management	Bathymetric data, low level and low speed aerial surveys and videos
	Habitat Conservation & Restoration	Digital photography, bathymetric data
Weather Forecasting, Research & Modeling	Observations & Forecasting	Vertical atmospheric profiling (dropsonde data system), lower fuselage, tail Doppler radar, gamma radiation detection, real-time large data set transmission, topographic, and bathymetric LIDAR data, high altitude, long range
	Climate Research	Lower fuselage, tail Doppler radar, atmospheric profiling, air chemistry sampling
	Weather & Air Chemistry Research	Lower fuselage, tail Doppler radar, atmospheric and air chemistry sampling, high endurance
	Ocean, Coastal & Great Lakes Research	Topographic and bathymetric LIDAR data
Emergency Response	Various Activities	All in differing combinations specific to response

Table 3-4: Required Aircraft Capabilities by Missions and Activities

Requirement to Maintain NOAA Aircraft Fleet Capabilities and Capacity

While there are more than 900 aircraft in the combined Federal and academic fleet,[58] non-NOAA aircraft are configured for other missions, limiting the interoperability to meet NOAA's full suite of requirements. As compiled in the October 2016 Government Accountability Office (GAO) briefing to the Committee on Oversight and Government Reform, House of Representatives, and based on Federal Aviation Interactive Reporting System (FAIRS) data, 11 Federal civilian agencies, as well as Department of Defense, U.S. Coast Guard and intelligence agencies, own and operate

[58] As reported in the October 31, 2016 GAO-17-73R Federal Owned Aircraft Reported Inventory, Use and Cost of Federally Owned Aircraft.

aircraft for a variety of purposes including law enforcement, scientific research, firefighting, and other activities.

Specialization within the Federal fleet enables it to most efficiently meet the broad array of mission requirements across the Federal Government. Each agency's aircraft have capabilities and capacity designed to meet specific statutory requirements while the academic research fleet is designed to meet a wide array of academic research requirements. Aircraft across Federal agencies have some fundamental design elements such as extensive modifications in airframes, electrical and other systems to support specialized instrumentation, and endurance, speed, and range that are specific to their missions. For instance, the Department of Interior aircraft are designed for law enforcement, wildlife management and wildland firefighting. Department of Energy aircraft support missions of transporting cargo including nuclear materials and other hazardous cargo, power line patrol and installation security. Aircraft owned by the Department of State operate largely in foreign locations to support counter-narcotics, law enforcement, and border security. Department of Justice aircraft primarily support surveillance and law enforcement as required for drug enforcement and U.S. Marshals Service missions. Aircraft owned and operated by the Department of Agriculture focus on firefighting, forest and plant surveys and testing, and aerial pest treatment. NASA uses aircraft to primarily support atmospheric research and education.

Federal agencies, academic institutions, and international bodies collect the majority of airborne data with aircraft specifically designed and instrumented to meet their mission mandates, requirements, or areas of research focus. Just as each of these agencies acquires and outfits aircraft to most efficiently meet their missions, NOAA must invest in its own aircraft to ensure they include specifications capable of meeting NOAA's diverse and critical missions as efficiently as possible.

Future Airborne Requirements

The functional obsolescence of aircraft in NOAA will occur over time. To ensure replacement of appropriate capabilities this plan considered current <u>and</u> future requirements. As defined by the NOAA administration, programs and line offices, NOAA has emerging airborne requirements in four significant areas: 1) Water resource management; 2) Pacific severe storms and navigation; 3) the Arctic; and 4) national marine monuments.

Water Resource Management – Water resource management and flood mitigation and response require airborne snow-water equivalency measurements, supplemented by baseline soil moisture measurements. Due to aircraft capacity limitations, soil moisture measurements are currently limited to antecedent (fall) observations in regions where spring snow melt flooding poses a threat to life, property, or commerce. Accurate forecasts require year-round soil moisture observations for all of the United States and the portions of Canada and Mexico that drain into the U.S. Additional NOAA aircraft capacity is required to meet this requirement and perform complete water resource management, flood forecasts, and storm surge modeling.

Flooding events resulted in $15 billion in damages and 26 deaths in 2016, damaging and destroying tens of thousands of homes, businesses, and requiring tens of thousands of rescues.[59]

Pacific Severe Storms and Navigation – Severe storm activity in the Pacific has increased significantly in the past 8 years, resulting in an unprecedented level of NOAA Hurricane Hunter tasking in 2018. NOAA P-3 and G-IV Hurricane Hunter aircraft were tasked to fly U.S. land threatening hurricanes in the Pacific four times in support of 23 named storms that produced the highest accumulated cyclone energy value on record in the Eastern Pacific basin. Tasking included Hurricane Lane, a Category 5 storm that was the second wettest tropical cyclone on record in the U.S.., only behind Hurricane Harvey. and resulted in $250-million in damage. The P-3 forecast flights into Hurricane Harvey marked the first time a NOAA P-3 has flown Into the eye of a Central Pacific hurricane. Tropical cyclone models and forecasted weather changes project an increase in tropical storm frequency in the Northeast Pacific and near Hawaii, linked to the regional sea service temperature (SST) compared to the tropical mean increase in SST.[60] The response community in the Pacific currently relies on satellite imagery for hurricane forecast information and damage assessment data. The forecast information lacks detailed data collected in and around the storm, and hurricane surveillance data, which improves forecasts by 15-poercent, is largely absent. The images for damage assessment are often blocked or obscured from consistent cloud cover typical in tropical environments, limiting the accuracy of data used by emergency managers and the general public. The data NOAA Hurricane Hunter aircraft provide is also relied on by the Department of Defense (DOD) leadership for preparedness and national security through a shared Advanced Weather Interactive Process System (AWIPS). The requirement for NOAA aircraft data was shared by the NOAA Central Pacific Hurricane Center and DOD Joint Typhoon Warning Center NOAA aircraft perform hurricane research, reconnaissance, and surveillance primarily around the contiguous U.S.. And the NOAA aircraft capable of collecting the high-resolution imagery for emergency response operates exclusively around the contiguous U.S. In addition, most of the shoreline mapping around Pacific landmasses, including Hawaii and the Pacific Islands, is derived from satellite imagery and near-shore bathymetry of these areas is poor or non-existent. Increasing capacity would enable NOAA to collect data vital for safe navigation, as well as provide the most accurate hurricane forecasts and emergency management.

Enhanced Tropical Cyclone Forecasting Requirements – In addition to increased tasking for Pacific Severe Storms, there is an increased requirement for tropical cyclone support with Tail Doppler Radar (TDR) capability. The National Weather Service, National Hurricane Center requires increased support for model accuracy, track and intensity forecasts. Currently, NOAA has two P-3 crews; this allows full tasking and coverage for one tropical cyclone at a time. The requirement expands the tasking to two simultaneous tropical cyclones, requiring the additional of a full third P-3 crew.

59 Billion Dollar Weather and Climate Disasters. National Center for Environmental Information (NCEI). Retrieved from: https://www.ncdc.noaa.gov/billions/events.

60 Knutson, T., Sirutis, J, Zhao, M., Tuleya, R., Bender, M., Vecchi, G., Villarini, G., and Chavas, D. Global Projections of Intense Tropical Cyclone Activity for the Late Twenty-First Century from Dynamical Downscaling of CMIP5/RCP4.5 Scenarios. Journal of Climate, 15 September 2015, pp. 7203-7224.

The Arctic – The Arctic has profound significance for climate and the functioning of ecosystems around the globe as well as for the oil and gas sectors. This region and its communities are particularly vulnerable and prone to rapid climate change. National security concerns are increasing as reductions in sea ice and other climate-induced changes bring increased opportunities for economic development and increased access to Arctic resources. These economic drivers, in turn, can further threaten ecosystems and Arctic inhabitants already impacted by the changing climate. The risks to sound Arctic stewardship are intensified because the science that underpins many of the decision-making processes and support services is largely inadequate. Atmospheric data collected by NOAA aircraft are critical to understanding the complex changes occurring in this region and for modeling the effects of these changes in global and regional climate models. Additionally, commercial maritime traffic in the Arctic continues to increase as more and bigger ships enter the Arctic environment. This increased activity coupled with the fact that only a small portion of the Arctic is charted to modern standards poses challenges to economic development in the region and the health and safety of life and property. New applications of technology, such as remote sensing vice visual observations for protected species management, is changing assessments and surveying and monitoring of critical populations, such as ice seals in the Arctic and Chuckchi Seas. Environmental assessments are critical to permitting exploration of oil and gas in the region, while ensuring minimal disruption of Arctic ecosystems, species and, in turn, coastal communities.

National Marine Monuments – NOAA is responsible for mapping, managing, protecting, and conserving monument resources against threats to allow uses that are compatible with resource protection. During a time of increased global use and demands on the Nation's marine resources, it is increasingly important that we accurately map and protect these economically and ecologically fragile areas. Efficient management of our oceans and ocean resources is critical to preserve long-term viability threatened by increased pressures from; marine debris; future exploration and mining uses; hazardous cargo; invasive species; and recreational use. In August 2016, the Papahānaumokuākea Marine National Monument was expanded by 442,781 square miles, bringing the total protected area that NOAA is responsible for protecting to 582,578 square miles.

These emerging issues will impact requirements for NOAA airborne activities. Aircraft are a primary source of observation data for providing in situ measurements and for supporting NOAA's information and ecosystem assessment and management services. They reliably provide researchers and scientists the ability to collect data at required locations and in specific weather conditions. Despite the steady advancement of remote sensing and sampling technologies, aircraft are fundamental to airborne data collection and for deploying systems that expand an aircraft's observational footprint, as well as critical for testing, evaluating, and transitioning innovative technologies to operations. Aircraft will remain fundamental to airborne data collection for the foreseeable future. This finding is consistent with the Office Federal

Coordinator of Meteorology (OFCM) *Federal Plan for Metrological Services and Supporting Research*[61], and the annual OFCM *National Hurricane Operations Plan.*[62]

61 Office of the Federal Coordinator For Meteorological Services and Supporting Research. *The Federal Plan for Meteorological Services and Supporting Research: Fiscal Year 2016.* FCM-P1-2015. U.S. Department of Commerce/National Oceanic and Atmospheric Administration.

62 Office of the Federal Coordinator for Meteorological Services and Supporting Research. *National Hurricane Operations Plan.* FCM-P12-2016.

IV. Meeting the Need to Fly

Current NOAA Aircraft Fleet

NOAA operates, manages, and maintains a fleet of aircraft that provide a wide range of specialized airborne environmental data collection capabilities vital to understanding the Earth, conserving and managing coastal and marine resources, and protecting lives and property. These versatile aircraft are uniquely modified and instrumented to provide scientists with the airborne platforms necessary to collect the environmental and geographic data essential for NOAA products, services, and research.

NOAA currently operates nine aircraft of five different model types selected for their specific operational capabilities; this will shift to ten aircraft of four different types once the aircraft from the FY 2018 appropriation are operational. The WP-3D, for example, is a robust four-engine turbo-prop aircraft used in the harsh hurricane environment; and the G-IV-SP has high-altitude long-endurance capabilities to fly well above and around hurricanes to collect data on upper level atmospheric steering currents. NOAA's light survey aircraft have a high-wing to enhance visibility and a lower airspeed envelope to optimize survey data collection. Current NOAA aircraft fleet and their primary missions and age are shown in Table 4-1. While there are several factors that may affect aircraft reliability, age is the primary factor. NOAA aircraft maintenance adheres to very strict standards, often exceeding industry standards, making the age of each aircraft the most important data point in recapitalization planning.

Aircraft	Type	Max Gross Weight (lbs)	Primary Mission	Aircraft Age (years)
N42RF	WP-3D	135,000	3	43
N43RF	WP-3D	135,000	3	44
N49RF	G-IV-SP	74,600	3	24
N57RF	DHC-6-300 Twin Otter	12,500	1, 3	37
N56RF	DHC-6-300 Twin Otter	12,500	1, 3	36
N48RF	DHC-6-300 Twin Otter	12,500	1, 3	37
N46RF	DHC-6-300 Twin Otter	12,500	1, 3	33
N68RF	King Air 350ER	16,500	2	9
N45RF	Turbo Commander	11,250	3	34

Mission 1: Assessment and Management of Living Marine Resources
Mission 2: Charting and Surveying
Mission 3: Weather Forecasting, Research and Modeling

the NOAA King Air (N68RF) is 9 years old. Conklin and de Decker, an aircraft costs, aviation research, and consulting firm, has determined that:

> *...as aircraft age, the increase in unscheduled maintenance associated with scheduled inspections also requires a great deal more maintenance down time. Similarly it will take more and more maintenance to achieve any kind of acceptable dispatch reliability. Both detract from the availability of the aircraft for flight operations. Available data shows availability drops from the 95% range for aircraft up to 15 to 20 years of age to an average of 70% at age 25 and 55% at age 30.*[63]

The physical age of an airplane can be a critical element of the service life simply due to the effects of corrosion over time on critical structural components. Generally, corrosion is seen on the wings and horizontal surfaces of the tail, or empennage, which create lift and support the weight of the aircraft in the dynamic flight environment. The total flight hours an airframe has flown is another element of the total service life equation and is a direct indicator of the usage an aircraft has experienced. Manufacturers sometimes indicate the expected service life of their aircraft in terms of total flight hours of usage that can be expected under normal flight conditions; however, in most cases they are not required to publish a life-limiting flight time because an airplane's service life is so dependent on a combination of factors including age, flight time, landing/pressurization cycles, scheduled maintenance programs and storage history, and it would be impossible to predict the conditions an aircraft will experience during its service life.

Landing and pressurization cycles are significant contributors to the fatigue an aircraft experiences throughout its service life. As an aircraft accelerates down a runway on takeoff its wings begin to generate the upward force of lift. As the engines propel the plane forward at faster speeds, the wings generate a greater lifting force and begin to naturally flex upward until the lifting force overcomes weight and the airplane lifts off the ground. The reverse scenario upon landing results in a rapid unloading of the lifting force on the wings as the aircraft decelerates to a stop on the runway and the wings return to their static position. As the number of takeoff/landing cycles increase, and the wings continue to flex with each cycle, it is easy to discern the detrimental effects a high number of takeoff/landing cycles will have on the service life of an aircraft.

Pressurized aircraft (including NOAA's WP-3s, G-IV, Turbo Commander and King Air) have the capability to increase the atmospheric pressure inside the aircraft to simulate the life-sustaining pressures of lower elevations. This capability allows flight at higher altitudes where aircraft engines are typically more efficient and lower altitude weather events such as icing and thunderstorms can be avoided. The pressurization cycle uses compressors to effectively pack more air molecules into the fuselage and raise the internal pressure, but this process also

[63] "Aircraft Aging-Impacts on Availability" model by Conklin & de Decker, applied in August 2016 report for NOAA.

creates an outward-pushing force on the entire pressurized portion of the airframe or pressure vessel. This outward-pushing force causes additional flexing of the airframe fuselage components as it pressurizes and depressurizes, similar to the flexing of the wings on takeoff and landing. Hereto, it can be easily discerned that a greater number of pressurization cycles equals greater fatigue.

For consistency in this plan, the service life of an aircraft is defined as the age where unscheduled maintenance events decrease the reliability of the aircraft and the rising maintenance costs become prohibitive to efficient and cost-effective operations. The proposed aircraft retirement dates shown in Figure 4-1 are based on aircraft reliability data and 2016 Independent Service Life Analyses and Aviation Business Case Analysis by Conklin and de Decker Associates, Inc., as well as NOAA reliability and maintenance data on each aircraft.

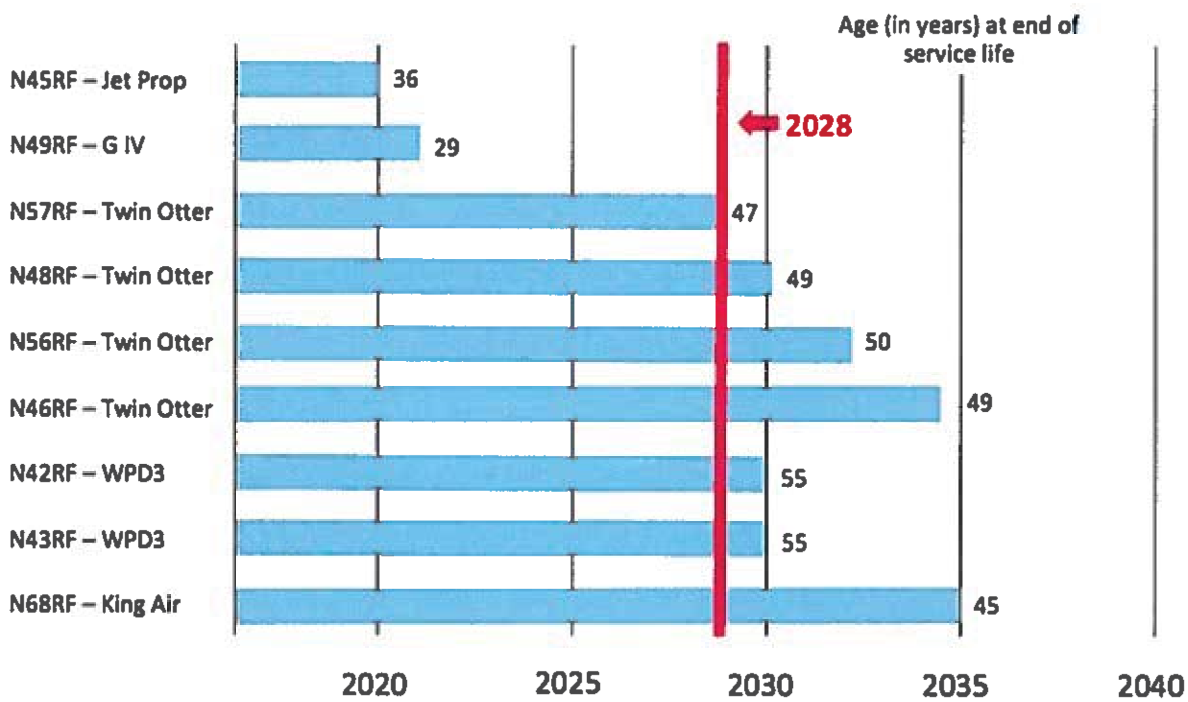


Figure 4-1: Estimated Service Life of NOAA Aircraft[64]

Based on NOAA aircraft service life expectation and historical usage analysis, NOAA predicts three of its aircraft will reach or exceed their service life between 2019 and the end of 2028. The FY 2018 appropriation supports the recapitalization of two of the three aircraft. That loss of *capacity* as shown in Table 4-2 will have a significant impact on NOAA's ability to conduct its airborne activities. By 2029, the NOAA aircraft capacity will be reduced by nearly 66-percent with the most significant reduction in the three activities in the assessment and management of living marine resources (-90 to -100-percent); observations and forecasting (-50-percent); and coastal science and assessment (-95-percent).

[64] Additional detail on aircraft material condition can be found in Appendix D.

			NOAA Airborne Capacity in FH 2017 to 2028[65]			
			2018	2022	2024	2028
		Number of Aircraft	9	9*	9	8
		Total flight hours (FH)	4,198	4,198	4,198	3,401
Missions & Activities	Charting & Surveying	Navigation, Observations & Positioning	805	805	805	805
		Coastal Science & Assessment	110	110	110	110
	Assessment & Management of Living Marine Resources	Protected Resources, Science & Management	1,223	1,223	1,223	653
		Fisheries Science & Management	N/A	N/A	N/A	N/A
		Habitat Conservation & Restoration	340	340	340	340
	Weather Forecasting, Research & Modeling	Observations & Forecasting[66]	1,375	1,375	1,375	1,365
		Climate Research	155	155	155	155
		Weather & Air Chemistry Research	190	190	190	190
		Ocean, Coastal & Great Lakes Research	N/A	N/A	N/A	N/A
	Emergency Response	Various				
	Mission Support[67]	OMAO Mission Support	701	701	701	500

Table 4-2: Loss of NOAA Airborne Capacity, 2018 to 2028[68], in Flight Hours (FH) without recapitalization beyond G550 and King Air

* If G-IV is retired or serves strictly in back-up capacity for a high-altitude aircraft

Impact of Loss of Airborne Capabilities and Capacity

The loss of *capability* resulting from these impacts will be distributed unevenly across mission and airborne activities as shown in Table 4-3. This illustrative distribution is based on the current allocation of aircraft to mission and region. Actual impacts could change depending on

65 Denoted hours are based on current allocation of aircraft assets to meet requirements; reallocation could results in different distribution and impacts across mission and activity areas.
66 Includes Hurricane Reconnaissance and Surveillance, and Water resource surveys.
67 Mission support flight hours are for training, maintenance flights, and calibration testing.
68 Denoted hours are based on current allocation of aircraft assets to meet requirements; reallocation could results in different distribution and impacts across mission and activity areas.

geographic and mission allocation decisions made in the future, although the opportunities for redistribution are limited due to the specific airborne requirements and NOAA aircraft capabilities and capacity.

Within the weather forecasting, research and modeling mission, the observations and forecasting activity will be detrimentally impacted if aircraft are not sustained, and there is not an adequate requirements assessment to include instrumentation development for the P-3. Decreased reliability of the G-IV, or interruption to the current G550 acquisition as scheduled, will significantly impact NOAA's ability to collect critical hurricane and other severe storm data at high altitudes in the storm environment. This significant loss of capability will negatively impact NOAA's ability to provide accurate forecasts critical for protection of lives, property, and the national economy. Postponement or absence of requirements analysis, to include instrumentation development for the P-3, will detrimentally impact the Nation's ability to accurately track storms and improve hurricane forecasts, satellite calibration and validation, and predict and understand tornado formation and growth. Absence of an additional King Air will directly impact NOAA's ability to respond to National emergency response data needs during events including hurricanes, tornadoes, and flooding, as well as the agency's ability to provide data for nautical and aeronautical chart updates relied on by industry and military sectors and collect water resource data essential for accurate hydrological forecasts. Additionally, the loss of a Twin Otter will affect NOAA's ability to collect data critical for protected resources science and management, fisheries science and management and habitat conservation, and restoration activities within the assessment and management of living marine resources mission. This data is one of the critical drivers for accurate fishery quotas, and the losses cannot be readily mitigated. Charter options with the right capabilities in the required regions are scarce beyond what is already procured by NOAA. The Arctic and Pacific Islands are highly vulnerable regions, and the loss of capabilities in these regions will be detrimental to NOAA products and services. Details on the impacts of the loss of these capabilities are provided in Table 4-3.

Mission & Activities			Geographic Area: Atlantic & Caribbean	Pacific	Continental U.S.	Alaska & Western Arctic	Pacific Islands & Tropical Pacific
Mission & Activities	Charting & Surveying	Navigation, Observations & Positioning	Orange	Red	Orange	Red	Red
		Coastal Science & Assessment	Yellow	Red	Yellow	Red	Red
	Assessment and Management of Living Marine Resources	Protected Resources, Science & Management	Green	Red	Green	Green	Red
		Fisheries Science & Management	Green	Red	Green	Green	Red
		Habitat Conservation & Restoration	Green	Red	Green	Green	Red
	Weather Forecasting, Research & Modeling	Observations & Forecasting	Orange	Orange	Orange	Orange	Orange
		Climate Research	Yellow	Yellow	Yellow	Yellow	Yellow
		Weather & Air Chemistry Research	Green	Green	Green	Green	Green
		Ocean, Coastal and Great Lakes Research	Green	Red	Green	Green	Red

Table 4-3: Impact of Loss of NOAA Airborne Data Collection Capability by Geographic Area by 2028[69]

- Red = 90 – 100% capability loss
- Orange = 60 – 89% capability loss
- Yellow = 59 – 30% capability loss
- Green = 0 – 29% capability loss

69 Detail on the loss of which aircraft impact each geographically area is provided in Appendix F.

Impact on Weather Forecasting, Research and Modeling

Approximately 163 million Americans live near the coast and approximately 89 million people vacation on the coasts every year.[70] Growing coastal populations and competition for marine space and resources heavily stress ocean, coastal, and Great Lakes resources. Travel and tourism are estimated to provide $746 billion to the U.S. GDP and are the second largest contributor to GDP just behind combined wholesale and retail trade.[71] America's coastal communities and shorelines face increasingly frequent and intense extreme weather events, causing dangerous conditions and dramatic economic losses. Increasing population density along the coast puts more people in the path of coastal storms. There are 6.8 million homes in the Atlantic and Gulf coast regions that are vulnerable to hurricane storm surge; the estimated reconstruction cost value is $1.54 trillion.[72] NOAA aircraft collect the data that directly provides hurricane forecasts, water resource planning, flood and drought predictions – vital information used by every industry, person, and in every emergency management event. These challenges convey a common message: human health, prosperity, and wellbeing depend upon the accuracy and timeliness of forecasts and the health and the resilience of coastal ecosystems. Managing this interdependence requires timely and usable information to make decisions. NOAA's aircraft collect data integral to addressing many of the challenges facing the Nation and preserving the lives and economic prosperity that transcends region, occupation and lifestyle.

With the loss of the G-IV, the inability to collect vital data around and above the storm environment will directly result in decreased confidence in storm track and intensity forecasts. No other aircraft or observational tool in the Nation, including NOAA's WP-3Ds, can perform the full mission requirements that directly improve hurricane forecasts by 15-percent. NOAA's ability to collect this suite of data that is fed directly into hurricane track and intensity forecasts, forecasts that are relied on by emergency managers, the insurance industry, and the general public, will be completely eliminated.

The loss of the Turbo Commander will severely damage NOAA's ability to collect soil moisture and snow survey data, the critical drivers for accurate water resource and flood planning, as well as agriculture and drought forecasts. In the western United States, snowmelt provides over 70-percent of the water supply, and yearly snow pack water storage has been valued as high as $348 billion. In addition, accurate snow forecasts play a significant role in the $8 billion winter tourism industry of New England and the Rocky Mountains, and the $2.3 billion generated in recreational,

70 NOAA's 2013 State of the Coast Report: National Coastal Population Report, U.S. Commission on Ocean Policy: An Ocean Blueprint, 2004.

71 Cicin-Sain, B., R.W. Knecht. Trends and Future Challenges for U.S. National Ocean and Coastal Policy. August 1999. DIANE Publishing. Pg. 73.

72 CoreLogic. (2016, June 1). CoreLogic Storm Surge Analysis Identifies More Than 6.8 Million U.S. Homes at Risk of Hurricane Storm Surge Damage in 2016 [Press Release]. Retrieved February 23, 2017, from, http://www.corelogic.com/about-us/news/corelogic-storm-surge-analysis-identifies-more-than-6.8-million-us-homes-at-risk-of-hurricane-storm-surge-damage-in-2016.aspx.

cold-water fishing.[73,74] A decrease in high quality data available for warning and forecasting decisions will adversely impact warning and forecasting capabilities and U.S. economic activity.

Impact on Assessment and Management of Living Marine Resources

Airborne data are essential to the accomplishment of protected species stock assessments. For many species, they provide the only means of data collection that can be used for these assessments. Protected species may be the only taxa NOAA monitors where airborne observations are as important as (or more important than) at sea data collection. Loss of this data will impede NOAA's legislative responsibility to protect and recover marine mammals and sea turtles. Without proper assessments protected species populations may decline to unacceptable levels. By law,[75] poorly-assessed protected species populations require the fishery management councils to make more conservative harvest decisions when managing fisheries that potentially affect the protected populations. The impacts in places where protected marine species co-exist with large-scale commercial fisheries, such as Alaska, are significant. For example, lack of data on harbor seal populations require the Alaska fishery management councils to make more conservative harvest decisions when managing Alaska commercial fisheries; an industry that contributes approximately $6.5 billion to gross national product (GNP) annually.[76] New information from protected resource aerial surveys are routinely included in the environmental impact assessments (EIA) required for various permits and authorizations needed by the oil and gas industry and agency partners (Bureau of Ocean Energy Management/ Department of Interior, Navy/ Department of Defense).

NOAA's reduced capacity to meet airborne requirements for protected resources, science, and management will detrimentally affect the ability to monitor and manage stocks. If a scientifically reliable estimate of the population indicates that it is responding to management actions and is recovering above the necessary threshold for stability, then management actions that restrict commercial fishing, shipping, oil and gas development, and development in general may be re-evaluated and, if appropriate, restrictive management activities can be relieved provided the population in question and its critical habitat are not compromised in the future. A lack of fishery data will result in more conservative stock quotas and lost revenue for the fisheries and coastal economies that depend on them for their livelihood. Timely, statistically sound protected species data is critical for management of the Nation's $200 billion fishing industry, development of oil and gas resources, and maritime port channel management.

Impact on Charting and Surveying

NOAA collects hydrographic data and produces nautical charts for the safe and efficient navigation critical for the $4.6 trillion in economic activity generated by U.S. seaports and the

[73] 2004 dollars.

[74] Adams, R., Houston, L., Weiher, R. (2004, August). The Value of Snow and Snow Information Services. Report prepared for NOAA's National Operational Hydrographic Remote Sensing Center.

[75] 16 U.S.C. §§ 1801-1882: P.L. 101-627, as amended in 1996 and reauthorized in 2006, P.L. 109-479.

[76] National Marine Fisheries Service (NMFS) Value Added Model for Commercial and Recreational Fishing published annually in Fisheries of the U.S.

$1.5 trillion in economic activity generated by aviation.[77, 78] With the loss of one Twin Otter during the time frame of the plan, NOAA will lose some of its capabilities to collect the shoreline data that is required and used by a multitude of mission areas, including updating nautical charts for safe navigation in the Nation's 175 ports. NOAA shoreline maps provide accurate delineations of coastlines, coastal features, and port facilities. This data supports NOAA's navigation products like electronic navigational and raster charts required for safe navigation and reduced risk of maritime accidents. The data also provide the basis for tsunami and flood modeling, marine habitat mapping, coastal resource management, engineering projects, long-term sea level trends, and homeland security needs. Accurate shoreline data incorporated into digital elevation models and tools decreases the risk to coastal communities vulnerable to inundation, tsunamis, and storm surge. Improving the ability to reduce coastal hazard impacts is a direct result of updated shoreline data for digital elevation models, flood evacuation route planning, and other short and long-term exercises to mitigate coastal hazards. Loss of aircraft capacity results in a decrease in shoreline areas mapped, which impacts NOAA's ability to deliver adequate mapping coverage for coastal community resilience and hazard mitigation decision support tools. NOAA's emergency response capability is also impacted by a loss of access to flight hours. Emergency managers, responders, Federal, state and local officials, and the public depend on NOAA's geo-referenced shoreline imagery taken after an emergency to make more effective decisions on response plans and follow-on actions.

Additionally, with the loss of the Turbo Commander aircraft, 100-percent of NOAA's ability to collect data in support of the gravimetric redefinition of the American vertical datum (GRAV-D) project will be lost. GRAV-D is multi-year project designed to produce next generation datums by 2022. Datums underpin all position data in our country and are an essential component of the National Spatial Reference System. GRAV-D will result in a new, gravity-based vertical datum, providing accurate vertical heights throughout the United States within 2 cm, a vast improvement over the current vertical datum. Accurate height measurement is essential to accurate mapping and surveying, as well as floodplain mapping and management nationwide. GRAV-D will provide $522 million in annual estimated benefits to the Nation once completed, with $240 million in annual estimated benefits resulting from improved floodplain management alone. GRAV-D coverage is a reportable Government Performance and Results Act (GPRA) metric. Without the aircraft to perform this essential mission, NOAA is not likely to meet the GPRA target.

[77] FY 2017 Congressional Budget Justification, pg. 720.

[78] "The Economic Impact of Civil Aviation on the U.S. Economy," June 2014. U.S. Department of Transportation, Federal Aviation Administration.

V. Long-Term Recapitalization Strategies and Aircraft Management Best Practices for Maintaining NOAA's Airborne Capabilities

Previous sections of this plan detailed NOAA's required missions and airborne activities, the required aircraft capabilities and the flight hours requested for delivery of NOAA's products and services. As discussed in Section III, by the end of 2028 the design service lives of three NOAA aircraft are projected to end. The funded recapitalization of the high-altitude jet and King Air to replace the Turbo Commander are critical to sustain airborne capacity and capabilities. Associated sustainment for staffing, operations, maintenance, and training is critical to safely and efficiently operate and maintain these assets vital for public safety, economic security and national security.

There are strategies that can potentially mitigate the impending loss of capabilities and ultimately preserve NOAA's airborne capabilities including: 1) acquire aircraft; 2) extend the design service life of existing aircraft; 3) increase utilization of NOAA aircraft; 4) integrate new technologies; 5) utilize unmanned aircraft systems; 6) increase utilization of charters to supplement NOAA aircraft; and 7) expand partnerships. Each strategy was assessed and this section provides an overview of each for replacing lost capabilities while sustaining or increasing capacity.

Strategy 1: Acquire Aircraft
Acquisition of aircraft is the best long-term strategy for sustaining NOAA's ability to provide the airborne data essential for meeting legally mandated responsibilities and national priorities. Acquisition of aircraft will provide the best capabilities to meet NOAA's airborne data requirements and allow NOAA to retain a core capability in each mission area. This finding was substantiated in the requirements, service life and business case analyses done by Conklin & de Decker.[79] The FY 2018 appropriation for a G550 high-altitude jet and King Air put NOAA on a good path.

There are three NOAA aircraft scheduled for retirement in the next 11 years and analysis indicates the best option for replacing capacity lies in the acquisition and instrumentation of one G-IV replacement aircraft, two King Air aircraft, and one Twin Otter aircraft. The FY 2018 appropriation provided for two of these aircraft, the King Air and G550 high-altitude jet, to be procured and instrumented. The acquisition of these aircraft provides consolidation of aircraft types and standardization of core instrumentation, training, maintenance, and regulatory requirements resulting in decreased maintenance, operating and instrumentation costs. The first King Air will meet the requirements for the weather forecasting, monitoring and research, and charting and surveying missions. This aircraft will eliminate the capability and capacity gaps resulting from the estimated end-of-service life of the Turbo Commander, as well as provide additional capacity for the charting and surveying mission critical for safe maritime and aeronautical navigation. Second, the acquisition and instrumentation of a G550 high-altitude jet

[79] Conklin & de Decker Aviation Information, August 2016.

will assume the critical missions, including hurricane reconnaissance, performed by the G-IV, currently a single point of failure.

Third, analyses indicates acquisition and instrumentation of a Twin Otter aircraft is required to meet current and emerging prioritized requirements critical for accurate weather and water forecasts, management of protected resources and fisheries, and air chemistry. Fourth, the acquisition and instrumentation of a second King Air will eliminate the single point of failure of the aircraft that performs critical charting and surveying and emergency management requirements.

These four aircraft will also provide the capacity and capabilities to meet evolving mission requirements due to new applications of technology. The use of remote sensing such as Infrared sensors and high-resolution color imaging, versus the conventional methodology of visual observations, increases the ability to detect protected species in the Arctic. This technology application also improves efficiency by surveying at higher speeds and altitudes. The increase in survey standardization in remote regions such as the Arctic and Chuckchi Seas directly provides data required for fishery management and oil/gas exploration.

Acquiring aircraft allows NOAA to modify and instrument the selected airframes to take advantage of current and future technology to most efficiently and effectively meet NOAA requirements. As with all capital asset acquisitions, evaluating lease versus buy options will be part of the procurement process. NOAA has evaluated lease options for the G-IV replacement. Airframe modifications, which require non-recurring engineering and type certifications are costly, time-intensive, and limit the versatility of aircraft for future uses. In addition, the total cost of the lease life-cycle drives the time to establish a lease as defined by the federal government Procurement Action Lead Time (PALT); the PALT is 240-360 days for a contract over $1.5-milliion. The capabilities of a leased G-IV aircraft would include a limited flight-level data system and dropwindsonde capability; it will not include the full flight-level data system and Tail Doppler Radar.

The ability to meet NOAA's prioritized current and future requirements, as well as other Federal airborne data priorities, requires specific airframe modifications such as wing hard points, instrumentation ports, data systems, and fuselage and wing reinforcements to handle increased instrumentation load requirements. For current airframes, these modifications are either not feasible for current airframe or prohibitively expensive with an inadequate return on investment given remaining service life.

Strategy 2: Extend the Service Life of Existing NOAA Aircraft

Extending the design service life of current NOAA aircraft is a confluence of economics and capability. Based on independent analyses, this option is only viable for two of the current five NOAA aircraft types – the WP-3Ds and Twin Otters.

This option was recommended and utilized for the two WP-3D aircraft. Given the inability of existing aircraft to meet instrumentation requirements for prioritized missions, such as hurricane research, NOAA proceeded with service life extensions including replacement of wings, engines, and avionics on the two WP-3D aircraft; both aircraft have completed maintenance and are back in operation. Other agencies operating WP-3D aircraft, including Customs and Border Patrol, have elected this option for extending WP-3D service life. This has enhanced the availability of maintenance facilities and parts to perform this work. This service life extension will extend the lives of the WP-3D aircraft to 2030 and 2031.

NOAA's four Twin Otter Aircraft have been in a service life extension program since 2007 when the FAA approved NOAA's Twin Otter Inspection Program. Elements of the program include corrosion inspections every five years and wing replacements at 33,000 flight hours. This program extends the reliability and service lives of the aircraft; the recapitalization dates of the Twin Otters in this plan include these extensions. In addition, NOAA has completed a program to standardize Twin Otter performance, capability and configuration, which reduces maintenance costs, increases utilization, and improves reliability and customer satisfaction. The current aircraft configuration, including instrumentation ports and long-range fuel capacity, can meet all prioritized airborne mission requirements. Even with this program, one NOAA Twin Otter will reach the end of its service life by 2028 and the other three by 2034.

There is no holistic extension program for the G-IV Aircraft. Even with the required mid-life maintenance, which include engine replacements, reliability rates will continue to decline due to other age factors, such as corrosion and outdated aircraft systems. For example, compliance with on-going avionic and navigation systems upgrades mandated by the FAA requires major investment for modifications to ensure specialized capabilities such as scientific systems and radars are compatible. In addition to the significant resources required, the age of the aircraft systems limits the ability to upgrade critical technology, such as the nose radar. A new airframe with new systems is required to leverage the latest technology and most efficiently link it with the safest, most up-to-date navigation and avionic systems.

Although all aircraft have aspects of service life extensions, such as replacement of wing components, engine overhauls, and avionic upgrades, the degree to which a service life extension was performed on the WP-3D aircraft is not a long-term option for other aircraft due to the cost of a service life extension, the limited ability of the aircraft to meet current (or future) requirements, and an inadequate long-term return on investment. In addition, the service life extension elements performed on the WP-3Ds and the Twin Otters are not supported by industry and manufacturers of the other airframes. Similarly, there is no extension program for the NOAA's Turbo Commander aircraft.

Strategy 3: Increase Use of NOAA Aircraft

Maximum utilization of NOAA aircraft, in total, is 6,400 flight hours per year. This utilization is based on 1,000 hours for the Turbo Commander; 1,000 hours for each King Air; 750 hours for each of the four Twin Otters; 600 hours for the G-IV; and 400 hours for each of the two WP-3Ds. NOAA aircraft flew, an average of 4,971 flight hours per year from FY 2015 to FY 2018. This includes mission flights to meet prioritized requirements, as well as training and calibration flights to meet regulatory requirements and ensure instrumentation readiness. An additional impediment to aircraft utilization is the fact that NOAA currently operates only one Turbo Commander aircraft, one King Air, and one G-IV aircraft. The required maintenance, training, and system integration dramatically reduces the utilization rate of these aircraft given there is no back-up readily available.

An increase from the current number of annual hours flown to the maximum utilization will require additional mechanics, pilots, crew, technicians and engineers, as well as contract maintenance. Maximum daily, weekly, and monthly flight time and crew rest are regulated by the FAA and agency policy for safety reasons; increasing utilization will require additional pilots to meet rest requirements. Aircraft maintenance requirements, by flight hours and calendar time, are also regulated by industry and will require additional contract and in-house maintainers to perform increased maintenance resulting from more flight hours. The increased requirement for instrumentation integration design, fabrication, install, and de-install will require additional technicians and engineers.

Even with additional personnel and contract support, achieving maximum aircraft utilization to meet prioritized airborne requirements is contingent on several factors. First, there is an inherent risk of unscheduled maintenance, especially for the older aircraft that are single points of failure. Second, executing additional flight hours is contingent on the programs' needs for scientific personnel travel and other logistical requirements. Third, there are simply some missions that the contract aircraft cannot support due to lack of mission instrumentation attachment points on the aircraft and capabilities and limited aircraft performance. Some high-priority aircraft requirements cannot be met because of the limited number of specialized aircraft and the seasonality of high-priority missions (i.e., snow surveys in the upper Midwest, surveys for Arctic protected resources, stand-by requirements for response following severe storms, and surveys for protected resources). Increasing utilization of the current fleet is a short-term solution.

Strategy 4: Integrate New Technology

Efficiency in operations will be sought through integration of technology to leverage available flight hours. NOAA will consider all sources of new technologies when determining the types, configuration and composition of the future aircraft fleet. In addition to making aircraft more effective and efficient, technologies can serve as force multipliers. Data collection technology includes instrumentation, sensors, and unmanned systems. The primary benefit from incorporating data collection technology into aircraft is the increased quality and quantity of products and services that the agency can provide.

NOAA has successfully implemented new technologies on existing aircraft to maintain efficient operations and to improve aircraft effectiveness. For example, NOAA has upgraded the integrated data systems on the Twin Otters to improve the quantity and quality of data, create standardization across all four Twin Otter aircraft, and create parity with other NOAA aircraft. NOAA also replaced all four engines on the WP-3D aircraft, significantly improving fuel efficiency. Advancements in aircraft technology include infrastructure options such as wing hard point mounts, fuselage ports, and valves.

Technology integration is critical for both near-term mitigation and long-term recapitalization of NOAA aircraft and new technology will play a critical role in shaping the capability and capacity of the future of NOAA aircraft. While incorporation of technology can increase data collection capacity and improve aircraft efficiency, it cannot replace aircraft. Regardless of the technology, aircraft are needed to transport data collection sensors to wherever they are needed and to support other technology.

Strategy 5: Utilize Unmanned Aircraft Systems

The potential to use unmanned aircraft systems (UAS) to bridge key information gaps between instruments on Earth's surface and on satellites is rapidly expanding due to technological advances and an improved regulatory environment. UAS have potential to revolutionize NOAA's ability to monitor and understand the global environment and have the potential to be an important research and operational tool for multiple NOAA programs. While there are examples of instances in which UAS' have met NOAA prioritized airborne requirements in lieu of manned aircraft, they are isolated. Based on current technology, capabilities, and airspace requirements it is not anticipated that UAS' will replace any manned aircraft during the tenure of this plan (2019-2028).

UAS have been evaluated throughout NOAA in a variety of applications and there is significant interest in continuing to investigate the use of this new technology. NOAA held its first UAS Symposium in October 2016 with the goal of assembling NOAA scientists, including those with extensive experience with UAS assets, NOAA aviation professionals, and NOAA managers to devise a framework to develop UAS technologies and best practices. In preparation for the symposium, NOAA conducted a survey to capture NOAA requirements that could be met by UAS. NOAA LOs identified 53 specific mission requirements[80] that could potentially be met by UAS in the next 5 years. Most of these missions could be conducted using small UAS flown below 1,200 feet and within line of sight. These mission requirements span multiple NOAA domains and reveal a number of common mission classifications across all LOs, such as aerial mapping, photogrammetry, and aerial photography and videography. Participants in the symposium were also asked if their mission requirements could be met with manned aircraft and why UAS would be preferred over manned aircraft. While UAS cannot meet most requirements performed by manned aircraft, UAS can fill some data gaps due to their ability to be operated independently with field office staff, to operate in remote locations and to enhance existing data collections.

The ability for small UAS to meet many NOAA airborne requirements, currently being met by manned aircraft, is limited at this time due to regulatory, operational, and capability constraints. It is now straightforward to obtain FAA approval for small UAS operations that are conducted within visual line of sight range below 1,200 feet in altitude. However, a FAA Certificate of Authorization (COA) is currently required for UAS operations that are beyond visual line of sight range. It is currently difficult to obtain FAA approval for low altitude (below 18,000 feet) UAS operations beyond visual line of sight, a requirement for most fisheries science and management surveys. The restriction is to compensate for the fact that most small UAS do not have the ability

[80] Mission requirement details provided in Appendix I.

to detect and avoid (DAA) other aircraft. NOAA has tested UAS systems in remote, beyond line-of-sight operations but, to date, it has been extremely challenging to obtain approval for these types of flights. Stipulations, when approvals were granted, required significant resources. Additionally, small, high-performance, marine UAS have been designed mostly to meet Department of Defense (DOD) intelligence, surveillance, and reconnaissance requirements. These UAS are expensive and are not easily modified for the integration of unique and customized payload needed to meet NOAA's requirements.

NOAA has tested and utilized small UAS for a variety of requirement types. In a very limited context, UAS have provided operational tools to meet requirements more efficiently than manned aircraft, particularly for situations where requirements can be met successfully by within line of sight flights. For example, in 2014 a traditional manned aerial survey was augmented with a vertical takeoff and landing (VTOL) UAS to survey Steller sea lions in the western Aleutian Islands; a region where the weather routinely precludes long-distance, low altitude, manned flights. The addition of the VTOL UAS to the manned aircraft flights resulted in the most complete survey of the western Steller sea lion population since the 1970s; acquiring complete survey data is critical given the population's 90-percent decline in the past 30 years and the impact to commercial fisheries.[81] UAS have also been used to meet existing requirements through collection of new data sets. For example, VTOL UAS are the primary tool to collect data on nutritive and reproductive condition of southern resident killer whales.[74] VTOL UAS are also utilized from small boats to collect photogrammetric data and breath samples of Northeast right whales and Puget Sound killer whales; this is a new type of data set that is critical to assessing the health of these endangered species.[82] In addition to providing a more complete data set, the UAS operation is safer and more efficient than sending personnel in small boats to make close approaches on large whales to collect samples. The VTOL UAS was also used to meet NOAA requirements to estimate abundance, colony area, and density of krill-dependent predators in Antarctica, a labor-intensive requirement conventionally performed through manual counting.[83] Overall, portability, stability in flight, limited launch area requirements, safety, and limited sound when compared to fixed-wing engine aircraft make VTOL UAS particularly useful in wildlife applications.[74] UAS have also been tested to meet airborne requirements in atmospheric regions that cannot be sampled by manned aircraft or other observational tools. The Coyote UAS launched from the WP-3D into a mature hurricane, has successfully collected data in the air/sea boundary layer that compares favorably with conventional GPS dropsondes and WP-3D flight

81 Sweeney, K.L., V.T. Helker, W.L. Perryman, D.J. LeRoi, L.W. Fritz, T.S. Gelatt, and R.P. Angliss. 2016. Flying beneath the clouds at the edge of the world: using a hexacopter to supplement surveys of Stellar sea lions (*Eumotopias jubatus*) in Alaska. J. Unmanned Veh. Sys. 3(3): 114-122.

82 Durban, J. W., Fearnbach, H., Barrett-Lennard, L. G., Perryman, W., and LeRoi, D. J. 2015. Photogrammetry of killer whales using a small hexacopter launched at sea. Journal of Unmanned Vehicle Systems 3(3)131-135.

83 Goebel, M.E., Perryman, W.L., Hinke, J.T., Krause, Hann N.A., Gardner, S., and J.L. Donald. "A Small Unmanned Aerial System for Estimating Abundance and Size of Antarctic Predators," Polar Biology: 08 February 2015.

level data. The study verified the feasibility of small UAS to observe the lowest altitudes in a hurricane, a data void region where critical processes driving intensity change occur.[84]

In other applications, the operational and regulatory requirements, and UAS capabilities limited the application of the UAS for NOAA requirements. For example, a long-range, fixed-wing UAS was tested to assess whale distribution and density in the Arctic, requirements that have been obtained with manned aircraft for decades. The logistical requirements of the UAS project were complex and required extensive outreach to local government leadership, an interagency agreement with DOD to obtain airspace permissions from the FAA and operate the UAS; transportation of equipment on a large, manned aircraft that would have been prohibitively expensive for NOAA if it had not been provided in kind by the U.S. Navy; preparing and maintaining the on-site team for operations and maintenance of the UAS in a remote area with severe weather; vessel support during the UAS flights; and significant labor to manually process the images. The UAS observations from this project were limited by the same weather conditions as manned aircraft, the UAS could not transit through precipitation (the manned aircraft does), and the UAS surveyed a smaller area than the manned aircraft, so the resulting data were not as precise as the data from a traditional manned aerial survey. It cost significantly more to collect whale density data using a UAS than it would have taken using a traditional, manned aerial survey due to the increases in labor, transportation of equipment, planning/permitting, and data processing.[85] Reductions in cost and improvements in efficiency are likely to be realized over time as additional projects are implemented.

Through a partnership with Federal agencies and industry, use of large high-altitude, long-endurance (HALE) UAS are being evaluated to collect atmospheric data used for high-impact weather prediction and satellite gap mitigation. NOAA's G-IV aircraft uses a similar sensor system to collect vertical atmospheric profiles. Flights were flown into tropical storms during the campaign and interim data studies noted that the UAS "...has the potential to positively impact forecasts of tropical cyclones and other high-impact weather events when added to existing observing systems."[86] The results of this study are still being developed and will also include detailed operational costing information. This will be useful in helping to determine if large HALE UAS can be a viable operational tool in the future to meet NOAA airborne requirements. NOAA is also exploring use of optionally-piloted UAS' for GRAV-D through Small Business Innovation Research (SBIR). NOAA will continue to evaluate opportunities for transition to operations following completion of the first full GRAV-D survey, which began in March 2017 as part of the SBIR Phase III.

84 Cione, J.J., Kalina, E.A., Uhlhorn, E.W., Farber, A.M., and B. Damiano. "Coyote Unmanned Aircraft System observations in Hurricane Edouard (2014). Earth and Space Science. Retrieved from: http://onlinelibrary.wiley.com/doi/10.1002/2016EA000187/full.

85 Ferguson, M.C., R.P. Angliss, V. Helker, A. Kennedy, B. Lynch, A. Whiloughby, A.A. Brower, J.T. Clarke. 2017. Comparing estimates of arctic cetacean density derived from manned and unmanned aerial surveys. Poster presented at the Alaska Marine Science Symposium, January 2017.

86 Wick, G., Walker, J., Dunion, J. and R. Hood. Sensing Hazards with Operational Unmanned Technology (SHOUT) to Mitigate the Risk of Satellite Observing Gaps.

Overall, these projects have demonstrated that in some areas, small UAS are supplementing data provided by manned aircraft and small and large UAS have demonstrated potential to replace some manned aircraft missions in the future. Currently, due to operational, regulatory, and cost constraints, it is more practical and cost effective for manned aircraft to meet the majority of NOAA's airborne data requirements. At a Tropical Cyclone Research workshop in October 2015, national experts from NOAA, NASA, and academia unanimously agreed that manned aircraft will be required for tropical cyclone research and hurricane forecasting for at least the next 15 years.[87] NOAA will continue to evaluate and support UAS platform, sensor, and analytical development with the expectation that eventually UAS will cost-effectively meet a significant number of NOAA airborne requirements.

The growth in UAS utilization presents opportunities for enhancing NOAA's data collection capabilities as well as challenges for the management and oversight of an increasingly diverse UAS fleet. NOAA's decentralized approach to UAS governance enables the users of these systems great freedom in platform selection and diversity of operations. However, it creates numerous management challenges in safety, policy, staffing, training and standardization. The FAA has established policy for UAS operations in the National Airspace System (NAS). NOAA currently has four distinct methods for obtaining FAA authorization for operations, depending on the mission requirements such as altitude, operation as a civil or public (government) UAS, or the need for emergency authorizations. Overlapping policy and authorizations has created a complex regulatory framework.

NOAA policy directs that all UAS operations will be approved by the Office of Marine and Aviation Operations (OMAO). NOAA is developing an UAS asset management program that standardizes platforms, training, and operations of UAS that meet common mission requirements. This centralized and comprehensive approach to UAS acquisitions, training, and operations will increase efficiency and safety within the agency. A coordinated, systematic approach across NOAA to meet prioritized requirements, operational, regulatory, cyber, privacy, and information technology requirements is the most efficient method to leverage unmanned system technologies. Funding for a NOAA UXS Operations Center is included in the FY 2020 President's Budget. This office will provide centralized operations, training, certification, and acquisition services to meet NOAA prioritized requirements with unmanned systems.

Strategy 6: Increase Use of Charters

NOAA will continue to charter aircraft to meet prioritized requirements as feasible and appropriate. Charters will continue to provide support for protected species management, gravimetry, climate research, coastal mapping, and marine sanctuary management activities, particularly during the spring and summer when there are competing high-priority requirements for NOAA aircraft. The ability of charters to meet requirements is limited by aircraft capabilities including specialized instrumentation, size, project frequency, and geography. Given these limiting factors and inherently governmental work including hurricanes, snow survey, and

87 Hurricane Research Platform Replacement Analysis of Alternatives. July 18, 2016. ANSER (Analytic Services Inc.). Contract: WC-133M-15-CN-0043.

disaster response missions, as well as requirements to maintain capacity and data quality assurance for nautical and aeronautical charting, NOAA must maintain a core capability to provide products and services to the Nation.

Strategy 7: Expand Partnerships

NOAA leverages partnerships, as well as commercial charter aircraft, to meet prioritized airborne data requirements. Partner platforms are critical to the accomplishment of NOAA missions and NOAA relies on various partnerships to help meet requirements for airborne data collection, obtaining about 900 flight hours from partners annually. There are several initiatives to facilitate collaboration between Federal and non-Federal observing systems and networks. The Interagency Coordinating Committee for Airborne Geosciences Research and Applications (ICCAGRA) increases effective utilization of Federal airborne aircraft in support of airborne geoscience research programs conducted by Federal agencies. And the American Society for Photogrammetry and Remote Sensing (ASPRS) and International Society for Photogrammetry and Remote Sensing (ISPRS) bring together government and non-government entities to leverage resources to improve the quality of remote sensing data. The U.S. Group on Earth Observations (USGEO), a subcommittee under the National Science and Technology Council, includes 13 government agencies and facilitates data interoperability, access, use, and stewardship. The Inter-agency Working Group on Facilities and Infrastructure and Subcommittee on Unmanned Systems Technology (IWG-FI/SUST) facilities' implementation of unmanned systems across the Federal agencies, leveraging the best commercial technology available.

NOAA has partnered with a number of government agencies to meet NOAA airborne requirements. Partnerships with NASA Dryden, NASA Wallops, and the joint NOAA/NASA Global Hawk program have promoted data sharing and collection through joint field campaigns. In 2016, NASA and NOAA leveraged the NOAA G-IV, the NASA Global Hawk, and NOAA Ship *Ronald Brown* to support the El Nino Rapid Response Campaign; airborne and at-sea data was used to improve weather and water forecasts across the United States. NOAA also partners with the NSF, the Office of Naval Research and the Naval Research Lab to leverage Federal assets in support NOAA's airborne data requirements.

NOAA has a long-standing government partnership with the USAFRC 53rd Weather Reconnaissance Squadron to collect prioritized airborne requirements; the USAFRC 53rd flew an average of 1000 hours per year in support of winter storm and hurricane reconnaissance missions from 2014-2016. The tropical cyclone warning service is an interdepartmental effort to provide the U.S. and designated international recipients with forecasts, warnings, and assessments concerning tropical and subtropical weather systems. NOAA does not have the capacity to fully support all operational requirements for tropical cyclone and winter storm aerial reconnaissance. DOD, through the USAFRC 53rd and NOAA through its Aircraft Operations Center (AOC), operate a complementary fleet of aircraft to conduct hurricane/tropical cyclone reconnaissance, synoptic surveillance, and research missions. NOAA is responsible for providing forecasts and warnings for the Atlantic and Eastern and Central Pacific Oceans while the DOD provides the same services for the Western Pacific and Indian Ocean. The USAFRC 53rd maintains ten WC-130 aircraft to meet hurricane reconnaissance requirements. By agreement, the USAFRC

53rd will conduct up to five sorties per day in support of National Hurricane Operations Plan requirements and up to two sorties a day in support of National Winter Storms Operations Plan requirements. DOD bears all costs directly attributed to providing aircraft weather reconnaissance support but is limited to the number of congressionally funded aircraft flying hours per year. USAFRC aircraft do not have the capabilities to conduct hurricane research, or to test new sensors to better understand hurricane formation and intensification with the goal to improve the accuracy of hurricane track and intensity forecasts. USAFRC aircraft also do not have the capabilities to perform hurricane surveillance, the targeted observations of weather around hurricanes that improve track forecasts by 15-percent.

Risk and Mitigation Strategy Summary
Based on the dates current aircraft will be retired and the proposed acquisition schedule, there are two geographic regions and two mission areas at significant risk that will require targeted mitigation:

- If the G-IV reliability continues to decline based on recent reliability data, aircraft age and aircraft aging impacts on availability metrics, there will be significant impacts to the Weather Forecasting Research and Modeling observations and forecasting activities in all regions. This includes impacts to hurricane forecasts.

- If the Turbo Commander reliability continues to decline, as indicated by recent reliability data, and aircraft aging impacts on availability metrics, there will be significant impacts to the Charting and Surveying navigation, observations and positioning activities, and Weather Forecasting Research and Modeling observations and forecasting activities in all regions, most notably the Continental United States, Alaska, and Atlantic where the majority of the capacity is currently focused. This includes impacts to data used directly for water resource management and flood forecasting.

- There will be capability gaps in the Pacific, Pacific Islands, and Tropical Pacific for Charting and Surveying activities including navigation, observations and positioning, and coastal science and assessment; and Management of Living Marine Resources activities including protected resources, science and management; fisheries science and management; and habitat conservation and restoration; and Weather Forecasting Research and Modeling observations and forecasting activities.

The following mitigations will address the significant gaps highlighted above:

All Regions, Observations, and Forecasting:

- Prioritize maintenance for the Turbo Commander and G-IV aircraft. Service life extensions are not viable options on these aircraft; continuing to maintain them to the highest possible standards is the only viable maintenance option.
- Pursue additional federal partnerships to collect data. These missions are largely inherently governmental functions and cannot be chartered.

Pacific, Pacific Islands and Tropical Pacific, Charting and Surveying and Assessment and Management of Living Marine Resources:

- Utilize NOAA ships, emerging technologies, and small boats to the extent possible to collect near-shore bathymetric data and protected species data.
- Continue to seek opportunities for charter and partner aircraft to perform non-inherently governmental airborne mission.

VI. Conclusion

NOAA aircraft face challenges similar to other observational infrastructure – expanding mission requirements, age and obsolescence, and finite resources for recapitalization. The NOAA Aircraft Plan is based on current and projected airborne data requirements and considered recent analysis conducted on recapitalization planning, airborne data requirements validation and prioritization, availability of charter assets, and the state of new technology for use in gathering and processing airborne data.

Procurement and sustainment of aircraft specialized for priority airborne activities are NOAA's best strategy for meeting its mission. To ensure NOAA aircraft meet critical airborne data collection requirements, NOAA will procure a total of four aircraft to replace the capabilities lost with the retirement of three aircraft. NOAA is proceeding with the procurement and instrumentation of two of these aircraft, the G-550 high-altitude jet and King Air, utilizing the FY 2018 appropriation. The second two aircraft, a Twin Otter and additional King Air aircraft, will be procured if funding is available at a future time. In addition, the recapitalization plan addresses the extensive requirements analysis process for the WP-3D aircraft. The sophisticated instrumentation requirements, extreme flight profiles, and adaptability result in a lengthy and complicated process. The primary and secondary missions of the four aircraft are shown below in Table 6-1.

Aircraft[88]	Primary Mission	Secondary Mission
King Air	Charting and Surveying and Weather Forecasting, Research and Modeling	Assessment and Management of Living Marine Resources
G-IV and G550	Weather Forecasting, Research and Modeling	Charting and Surveying
Twin Otter	Assessment and Management of Living Marine Resources and Weather Forecasting, Research and Modeling	Charting and Surveying
WP-3D Replacement	Weather Forecasting, Research and Modeling and Charting and Surveying	Assessment and Management of Living Marine Resources

Table 6-1: Aircraft and Primary and Secondary Missions

The long-term recapitalization and sustainment strategy combined with specific best management practices for more efficient use of the existing aircraft fleet will lessen the impact of losing these three aircraft. The recapitalization and sustainment plan balances all of NOAA's aircraft assets and will:

- Replace lost capability with aircraft;
- Use charter aircraft as feasible and appropriate;
- Strengthen partnerships with other agencies;
- Continually develop and integrate emerging technologies; and
- Use a coordinated, systematic approach across NOAA to leverage unmanned systems.

NOAA's aircraft need to be adaptable and extensible to provide the infrastructure and capabilities necessary to meet mission requirements now and in the future for national security, public safety, and economic security.

88 Detailed descriptions provided in Appendix B.

APPENDICES

APPENDIX A
GLOSSARY, TERMS and ACRONYMS

AAP	Aircraft Allocation Plan
APASS	Aircraft Prioritization, Allocation, and Scheduling System
CAS	Commercial Aviation Services
DOD	Department of Defense
ECS	Extended Continental Shelf
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessments
FAA	Federal Aviation Administration
FAIRS	Federal Aviation Interactive Reporting System
FY	Fiscal Year
GAO	Government Accountability Office
GDP	Gross Domestic Product
GIS	Geographical Information System
GNP	Gross National Product
GRAV-D	Gravity for the Redefinition of the American Vertical Datum
ICAP	International Committee for Aviation Policy
ICCAGRA	Interagency Coordinating Committee for Airborne Geoscience Research and Applications
LIDAR	Light Detection and Ranging
LMR	Living Marine Resources
NASA	National Aeronautics and Space Administration
NPV	Net Present Value
NSF	National Science Foundation
TAO	Tropical Atmosphere Ocean
TPIO	Technology, Planning, and Integration for Observations Office
UAS	Unmanned Aircraft Systems
USCG	United States Coast Guard

APPENDIX B
AIRCRAFT CAPABILITY DESCRIPTIONS

The following are high-level descriptions of NOAA aircraft types and capabilities needed to meet priority airborne observation requirements.

Beechcraft King Air 350CER

The Beechcraft King Air 350CER, is a versatile, twin-engine, extended-range turboprop aircraft. With extended range capabilities, this aircraft can collect critical information while remaining airborne for 7 to 8 hours depending on fuel and payload. Equipped with the latest aircraft technology, the King Air's main feature is the two large, downward-facing sensor ports that allow simultaneous data collection from multiple sensors, and can support a wide variety of remote sensing systems, including digital cameras, multispectral and hyperspectral sensors, and topographic and bathymetric LIDAR systems. Other aircraft features include a cargo door, bubble windows, two window blanks, and additional mission power. Optical grade glass plates in the sensor ports allow the cabin to remain pressurized; the optical plates can be removed and the aircraft operated unpressurized. Normal aircraft configuration includes seating for two pilots, a sensor operator, and 1-2 additional crew members, depending on the amount of sensor equipment installed. The King Air primarily supports coastal mapping and emergency response missions.

De Havilland Twin Otter DHC 6-300

The De Havilland Twin Otter is a highly maneuverable aircraft which can be flown slowly (80-160 knots/150-300 km/hr) and in tight circles. The Twin Otter is a high-winged, unpressurized, twin-engine turboprop aircraft equipped with color weather radar, radar altimeter, dual global positioning systems (GPS)/Loran-C navigation systems with scientific data drops, and camera ports in the nose and belly areas. Known for its reliability, short takeoff and landing capabilities, payload capacity and excellent external visibility with an endurance of 4-6 hours at survey speeds, the Twin Otter is capable of covering over 600+ nautical miles of low altitude survey in a given flight at max fuel loads. Known for its stability at slower speeds, the Twin Otter is capable of surveying between 90-140 knots over the ground, making it ideal for missions that require a slower aircraft for data collection. Normal crew size is two pilots with a cabin capable of seating six people with smaller science equipment installed. In support of NOAA missions, this platform conducts low-level slow speed aerial surveys of marine mammals, aerial video surveys of coastal erosion, various remote sensing missions, atmospheric air chemistry sampling, and atmospheric eddy flux and concentration gradient assessments. These aircraft support airborne marine mammal, hydrological, remote sensing, air chemistry and emergency response programs.

Gulfstream AC 695A Turbo Commander

The Gulfstream Turbo Commander is a stable high-wing, pressurized, twin-engine turboprop aircraft that is suitable for a variety of missions. The aircraft can conduct snow water equivalent measurements in snow affected regions using a gamma radiation detection system mounted in the cabin of the aircraft. During survey flights, this system is flown at 500 feet above the ground at ground speeds ranging between 100 and 120 knots. In the summer months the Turbo Commander can collect background soil moisture information, which helps determine water levels when snow is not present. In addition, the Turbo Commander can also support emergency response tasking, and a gravity measuring survey (GRAV-D) which establishes vertical datums and measures orthometric heights over time which is used by NOAA for cartography and calibrating GPS. Information collected during snow survey missions, along with photographic data, is used by NOAA's River Forecasting Centers (RFC) to forecast river levels, water flow, and potential flooding events due to snowmelt water runoff. The aircraft plays a vital role in collecting data vital to flood forecasts and water resource management. Standard configuration allows for mission equipment, two pilots and one observer. However, the aircraft can be configured for two scientists/observers and mission equipment in the cabin.

Gulfstream IV-SP

The Gulfstream IV-SP (G-IV) is a high altitude, high speed, twin turbofan jet aircraft. With a range of nearly 4,000 nautical miles and a cruising altitude of 45,000 feet, this aircraft provides observational coverage at high altitudes critical for defining weather systems in the upper atmosphere. The G-IV is currently configured for operational support of the National Hurricane Center synoptic surveillance mission which collects, processes, and transmits vertical atmospheric soundings in the environment of the hurricane. The principle tool used for vertical soundings is the GPS dropwindsonde. The dropsonde is released from the G-IV measuring and transmitting back to the aircraft the pressure, temperature, humidity, and GPS Doppler frequency shifts as it descends to Earth. The Doppler shifts are used to compute the horizontal and vertical wind components. Another important tool is a tail Doppler radar (TDR) mounted to the rear of the aircraft. The TDR is an 8,000 watt radar system that spins slowly as the aircraft passes by the storm and looks at the structure using radar to determine the intensity of tropical cyclones. The product of the TDR is similar to the layers in a slice of wedding cake. The images collected by the TDR allow forecasters and researchers to see the different layers of a storm, which help improve forecasting capabilities. Standard configuration allows for mission equipment, two pilots and up to 13 engineers and meteorologists.

Lockheed WP-3D Orion

The Lock heed WP-3D Orion are versatile four engine turbo prop aircraft equipped with a variety of scientific instrumentation, radars and recording systems for both in-situ and remote sensing measurements of the atmosphere, the Earth and its environment. NOAA operates two Lockheed WP-3D Orion aircraft to conduct low-altitude data collection to fill gaps in data not available from ground based radar or satellite imagery. To obtain the best possible data within the storm environment, crewmembers deploy expendable probes (i.e., GPS dropwindsondes) through a launch tube in the aircraft. As they parachute to the sea below, the probes transmit pressure, temperature, humidity, wind speed and wind direction data back to the aircraft. The Orions are equipped with lower fuselage (LF) and TDR systems that play a key role in collecting data vital to tropical cyclone research and forecasting. Mounted to the belly of the aircraft, the LF radar scans the storm horizontally while the TDR scans vertically. Together, these systems provide researchers and forecasters an MRI-like look at the storm, allowing them to see all the different layers and internal structure from within the storm. NOAA's Orions are the only aircraft in the Nation's hurricane hunter fleet equipped with these radar systems. These aircraft are also equipped with step frequency microwave radiometers (SFMR). SFMRs sense wind speed at the surface of the ocean by measuring and computing radiation emitted by sea foam that is created by the high winds at the surface. Standard configuration allows for mission equipment, four pilots and up to 30 crew members.

APPENDIX C
PROCUREMENT PHASE DESCRIPTIONS

Requirements Analysis

The requirements analysis phase collects, reviews, assesses and determines the initial/general requirements for each aircraft. These activities guide the identification of the primary and secondary aircraft mission capabilities, concept of operations, program plan, and initial cost estimates. Other elements would include technology assessments, trade off studies and analysis of alternatives. At this stage the focus is in gross terms that drive key parameters.

Procurement

Procurement includes activities related to the procurement, production, and modification of the aircraft. During this phase an acquisition strategy that leverages contract type and performance incentives to deliver the best value mission performance will be developed.

Engineering and Testing

Engineering and testing verifies and validates performance capabilities documented as requirements, assesses attainment of technical performance parameters, and determines whether systems are operationally effective, suitable, survivable, and safe for intended use. Engineering and testing determines the operational effectiveness and operational suitability of the system.

Fleet Introduction

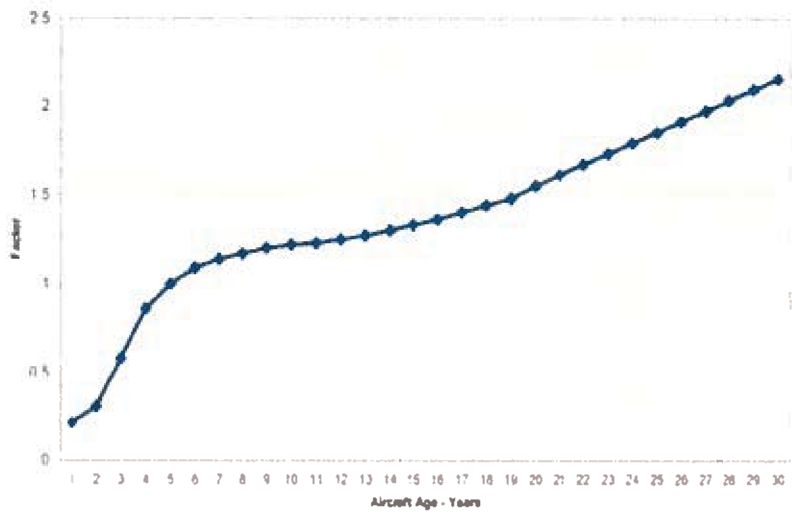
Fleet introduction fields a capability (aircraft) for operational use.

APPENDIX D
CURRENT NOAA AIRCRAFT MATERIAL CONDITION

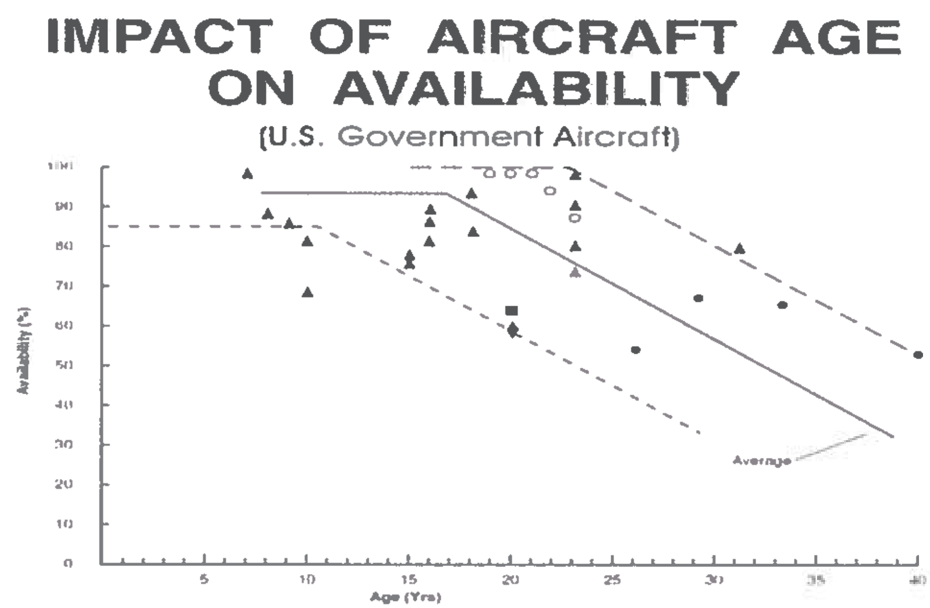
Aircraft		Service Life or Material Condition	Total Time	Required Action FY 2017 - FY 2032
WP-3D (N42RF)		End of service life (EOSL) by FY 2031	12,826	Service life extension (SLE) Begin new platform concept FY 2021 Platform procurement in FY 2026
WP-3D (N43RF)		End of service life by FY 2032	12,065	SLE Platform procurement in FY 2028
G-IV (N49RF)		Engine midlife needed FY 2022 & overhaul by FY 2032	7,760	Recapitalize by mid-life (2022)
Turbo Cmdr (N45RF)		Aircraft fatigue inspection required in FY 2022	10,614	Recommend EOSL/disposal in FY2020
Twin Otter (N46RF)		Estimated service life of wings is 33,000 hours (FY 2034)	14,700	Progressive maintenance program; monitor reliability /availability
Twin Otter (N48RF)		Estimated service life of wings is 33,000 hours (FY 2030)	20,820	Progressive maintenance program; monitor reliability /availability
Twin Otter (N56RF)		Estimated service life of wings is 33,000 hours (FY 2032)	14,500	Progressive maintenance program; monitor reliability /availability
Twin Otter (N57RF)		Estimated service life of wings is 33,000 hours (FY 2028)	23,656	Progressive maintenance program; monitor reliability /availability
King Air		EOSL not currently Identified	4,559	None

APPENDIX E
AIRCRAFT AGING – IMPACTS ON AVAILABILITY

Aging Factor



- Aircraft Age Availability
- 0 – 20 years 95%
- 25 years 70%
- 30 years 55%



APPENDIX F
IMPACT OF LOSS OF AIRCRAFT

Lost Capabilities by 2028
(% lost from 2017 Capabilities)

	GEOGRAPHIC AREA				
Mission and At-Sea Activities	Atlantic & Caribbean	Pacific	Continental US	Alaska & Western Pacific	Pacific Islands & Tropical Pacific
CHARTING & SURVEYING					
Navigation, Observation & Positioning	(KA,) GIV, TC	GIV	(KA) GIV, TC	GIV, JP (KA)	
Coastal Science & Assessment	TC, (TO*4 ,KA)		TC, (TO*4, KA)	TC	
ASSESSMENT & MANAGEMENT OF LIVING MARINE RESOURCES					
Protected Resources, Science & Management	(TO*4)		(TO*4)	(TO*4)	
Fisheries Science & Management	(TO*4)		(TO*4)	(TO*4)	
Habitat Conservation & Restoration	(TO*4, KA)		(TO*4, KA)	(TO*4)	
WEATHER FORECASTING, RESEARCH & MODELING					
Observations & Forecasting	GIV,TC, (TO*4, P3*2, KA)	GIV (P3*2)	GIV, JP, (TO*4, KA, P3*2)	TC, GIV, (TO*4, P3*2)	GIV (P3*2)
Climate Research	GIV (P3*2)	GIV (P3*2)	GIV (P3*2)	GIV (P3*2)	GIV (P3*2)
Weather & Air Chemistry Research	(TO*4, P3*2)	(P3*2)	(TO*4, P3*2)	(TO*4, P3*2)	(P3*2)
Ocean, Coastal and Great Lakes Research	(KA)		(KA)	(KA)	

Red	= 90 – 100% capability loss
Orange	= 60 – 89% capability loss
Yellow	= 30 – 59% capability loss
Green	= 0 – 29% capability loss

( ) indicates aircraft operational in 2028

KA = King Air
P3 = WP-3D
GIV = Gulfstream IV
TO = Twin Otter
TC = Turbo Commander

APPENDIX G
LEGAL MANDATES and AUTHORITIES

NOAA products and services support management of Federal trust resources, monitoring of marine ecosystems and their environment, production of weather warnings and forecasts, predictions of climate change, delivery of navigation information for safe, efficient transportation, and daily protection of the Nation. An overview of the major legal mandates and authorities that underpin NOAA's mission areas is provided below.

<u>Assessment and Management of Living Marine Resources</u>

***Coastal Wetlands Planning, Protection, and Restoration Act*[89]**

The Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) authorizes critical funding and support for the restoration, protection, conservation, and enhancement of threatened wetlands in the Louisiana coastal zone. Under CWPPRA, NOAA and other participating Federal and state agencies are required to plan and implement large-scale coastal wetlands restoration projects that are significant on a local and national level. In 2004, Congress reauthorized the funding for the CWPPRA program through 2019.

***Comprehensive Environmental Response, Compensation, and Liability Act*[90]**

The Comprehensive Environmental Response, Compensation, and Liability Act authorizes the President to act on behalf of the public as trustee for natural resources regarding the release or threatened release of hazardous substances in the environment. This authority has been delegated to NOAA for resources for which the agency has management or protective responsibilities. As such, the Act requires NOAA to seek damages on behalf of the public to restore natural resources within the scope of its trusteeship that are injured by the release of hazardous materials.

***Coral Reef Conservation Act*[91]**

The Coral Reef Conservation Act, which served as the Congressional response to Executive Order 13089, Coral Reef Protection, establishes a national program to preserve, sustain, and restore the condition of coral reef ecosystems and to develop sound scientific information on the condition of coral reef ecosystems and the threats to such ecosystems. In addition to creating a National Coral Reef Conservation Grant Program and the Coral Reef Conservation Fund (in partnership with the National Fish and Wildlife Foundation), the Act authorizes mapping, monitoring, assessment, restoration and scientific research that benefits the understanding, sustainable use, and long-term conservation of coral reefs and coral reef ecosystems.

89 Pub L. 101-646, Title III CWPPRA.
90 42 U.S.C. §§ 9601 *et seq.*, Chapter 103.
91 16 U.S.C. § 6401; Pub. L. No. 106-562.

Deepwater Port Act [92]

The 1974 Deepwater Port Act establishes a licensing system for ownership, construction, operation and decommissioning of deepwater port structures located beyond the U.S. territorial sea and authorizes the Coast Guard to license these facilities. NOAA reviews new technologies and their impacts to ecosystems important to NOAA trust species.

Endangered Species Act [93]

The Endangered Species Act (ESA) is a comprehensive attempt to protect identified species and to consider critical habitat protection as an integral part of that effort. In coastal and marine waters, NOAA administers its provisions for listed marine mammals, turtles, and other species. Species of plants and animals are listed as either "endangered" or "threatened" according to assessments of the risk of their extinction. Once a species is listed, legal tools are available to aid the recovery of the species and to protect its habitat. These tools include strict substantive provisions of law provided by Congress that are lacking in other laws such as the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA) and the Marine Mammal Protection Act, which effectively trump most legal challenges to Federal actions to conserve and rebuild listed species.

The determination of whether a species should be listed as endangered or threatened must be based on several scientific factors related to a species and threats to its continuance. The ESA expressly states that listing determinations are to be made "...solely on the basis of the best scientific and commercial data available."[94] Economic factors cannot be taken into account at this stage because Congress directed that listing be fundamentally a scientific question: is the continued existence of the species threatened or endangered? When a species is listed, the Secretary must also designate critical habitat (either where the species is found or, if it is not found there, where there are features essential to its conservation).[95] The preparation of recovery plans for the conservation and survival of listed species is also required.[96] Congress requires a biennial report on the status of efforts to develop and implement recovery plans for all listed species and on the status of all species for which such plans have been developed.

Energy Policy Act of 2005 [97]

The Energy Policy Act of 2005 (EPAct) requires the Departments of Commerce, the Interior, and Agriculture to conduct trial-type hearings for disputed issues of material fact raised by the permit applicant or other parties involved in hydropower licensing projects concerning the Departments' Federal Power Act prescriptions and conditions. It requires the Departments to analyze effects of prescriptions, conditions and all submitted alternatives on non-resource related issues (e.g., energy supply, flood control, air quality). The EPAct also amended the Outer Continental Shelf

92 33 U.S.C § 1501 *et seq.*; Pub. L. No. 93–627.
93 16 U.S.C. §§ 1531-1544; Pub. L. No. 93-205, reauthorized in 1992.
94 16 U.S.C. § 1533(b)(1)(A).
95 16 U.S.C. § 1533(b)(2).
96 16 U.S.C. § 1531(f)(1).
97 42 U.S.C. § 15801; Pub. L. No. 109-58.

(OCS) Lands Act to authorize the Secretary of the Interior to grant leases, easements or rights-of-way for alternative energy-related uses on the OCS of the United States.

Estuary Restoration Act [98]

The Estuary Restoration Act of 2000 establishes an interagency Council that includes NOAA, the U.S. Fish and Wildlife Service, the Environmental Protection Agency, the United States Department of Agriculture/Natural Resources Conservation Service (NRCS) and Army, to promote the restoration of estuary habitat, to develop a national strategy for coordination among public agencies and between the public and private sectors, to provide financial and technical assistance for restoration projects, and to develop enhanced monitoring and research capabilities. In addition, NOAA is specifically assigned monitoring and data coordination responsibilities under the Act, including the development and maintenance of a national inventory of restoration projects.

Federal Power Act[99]

Under the Federal Power Act (FPA), the Federal Energy Regulatory Commission (FERC) has the exclusive authority to license non-federal hydropower projects on navigable waterways and Federal lands. FERC also uses its FPA authority to exercise jurisdiction over alternative, or hydrokinetic (i.e., wave, tidal, current), ocean energy development projects through the issuance of preliminary permits for pre-licensing activities in coastal and offshore waters. FPA grants NOAA the authority to prescribe fishways and propose conservation measures to address any adverse effects to fish and wildlife resources at hydropower projects licensed by FERC.

Fish and Wildlife Coordination Act[100]

The Fish and Wildlife Coordination Act (FWCA), as amended in 1964, requires that all Federal agencies consult with NOAA, the U.S. Fish and Wildlife Service, and State wildlife agencies when proposed actions may result in modification of a natural stream or body of water. Federal agencies must consider effects that these projects would have on fish and wildlife resources, take action to prevent loss or damage to these resources, and provide for the development and improvement of these resources. The FWCA allows NOAA to provide comments to the U.S. Army Corps of Engineers during review of projects under § 404 of the Clean Water Act (concerning the discharge of dredged materials into navigable waters) and § 10 of the Rivers and Harbors Act of 1899 (obstructions in navigable waterways). NOAA comments provided under FWCA are intended to reduce environmental impacts to anadromous, estuarine, and marine fisheries and their habitats.

[98] 33 U.S.C. § 2901 *et seq.*; Pub. L. No. 106-457.
[99] 16 U.S.C. § 791a *et seq.*; 41 Stat. 1063.
[100] 16 U.S.C. § 661 *et seq.*

Harmful Algal Bloom and Hypoxia Research and Control Act [101]
The Harmful Algal Bloom and Hypoxia Research and Control Act, originally passed in 1998 to combat the growing threat of harmful algal blooms (HABs), reaffirms and expands the mandate for NOAA to advance the scientific understanding and ability to detect, monitor, assess, and predict HABs and to develop programs for research into methods of prevention, control, and mitigation of HABs. In addition to calling for the reestablishment of the Federal Interagency Task Force on HABs and Hypoxia, the Act enables NOAA to carry out research and assessment activities, including the Ecology and Oceanography of Harmful Algal Blooms project, research projects on management measures that can be taken to prevent, reduce, control, and mitigate harmful algal blooms, and to carry out Federal and state annual monitoring and analysis activities.

Magnuson-Stevens Fishery Conservation and Management Reauthorization Act [102]
The Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA) establishes a "...national program for the conservation and management of the fishery resources of the United States...to prevent overfishing, to rebuild overfished stocks, to insure conservation, and to realize the full potential of the Nation's fishery resources." This law establishes a regulatory system applicable to management of domestic fisheries within the U.S. 200-mile EEZ.

The MSRA gives primary responsibility to eight regional Fishery Management Councils to prepare and implement Fishery Management Plans (FMP), any subsequent FMP amendments, and fishery regulations, all which are subject to prescribed national standards. [103] FMPs and FMP implementing regulations must "...prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery."[104] The MSRA also defines overfishing as the rate at which mortality "...jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis."[105]

The 2006 MSRA, signed into law on January 12, 2007, set new requirements to prevent overfishing, including setting new annual catch limits (ACL) and accountability measures (AM) on the basis of best scientific advice for Federally managed fisheries. Ending overfishing of all stocks undergoing overfishing, preventing overfishing of all stocks, and rebuilding overfished stocks back to levels of abundance that can produce maximum sustainable yield (MSY) on a continuing basis are essential to achieving the objectives and goals of the MSRA. Section 104(b) directs that ACL and AM requirements take effect in fishing year 2010 for stocks subject to overfishing.

The MSRA also encourages development of direct fishery management policies and procedures toward a broader ecosystem-based approach. Ecosystem approaches require significantly more information including marine environmental data and information on species that may be the predators or prey of target species. The requirements for the next generation of fish stock

101 33 U.S.C. § 4001 *et seq.*; Pub L. No. 105-383, reauthorized in 2004.
102 16 U.S.C. §§ 1801-1882, Pub. L. No. 94-265, as amended in 1996 and reauthorized in 2006, Pub. L. No. 109-479.
103 16 U.S.C. §§ 1853, 1852(h), 1851(a)(1)-(7).
104 16 U.S.C. § 1851(a)(1) .
105 16 U.S.C. § 1802(34).

assessments will necessitate continued improvements to data and refinements to models to allow managers to emphasize ecosystem considerations, such as multi-species interactions and environmental effects, fisheries oceanography, and spatial and seasonal analyses. Currently there are 530 species nationwide that are managed under MSRA. At-sea data collections are essential for providing conservation information necessary for managment.

***Marine Debris Research, Prevention, and Reduction Act*[106]**

The Marine Debris Research, Prevention, and Reduction Act (MDRPRA) established programs within the National Oceanic and Atmospheric Administration (NOAA) and the United States Coast Guard (USCG) to identify, determine sources of, assess, reduce, and prevent marine debris. MDRPRA also reactivates the Interagency Marine Debris Coordinating Committee, chaired by NOAA.

***Marine Protection, Research, and Sanctuaries Act*[107]**

The Marine Protection, Research, and Sanctuaries Act authorizes the Secretary of Commerce to designate and manage areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational, or esthetic qualities as national marine sanctuaries. The Act's primary objective is to protect marine resources, such as coral reefs, sunken historical vessels or unique habitats. Implementation of the Act and management of national marine sanctuaries is delegated to NOAA's National Marine Sanctuary Program (NMSP).

The Act provides several tools for protecting designated national marine sanctuaries. If a federal action is likely to destroy, cause the loss of, or injure a sanctuary resource, the NMSP recommends alternatives that will protect sanctuary resources if implemented by the agency in taking the action. The Act also allows the Secretary to issue regulations for each sanctuary designated and the system as a whole that, among other things, specify the types of activities that can and cannot occur within the sanctuary. The Act requires preparation and updating of management plans that guide day-to-day activities at each sanctuary in furtherance of the goals of that sanctuary. It also provides for the assessment of civil penalties and the assessment of damages against people that injure sanctuary resources.

***National Environmental Policy Act*[108]**

The National Environmental Policy Act requires that all federal agencies prepare detailed environmental impact statements for all major federal actions significantly affecting the quality of the human environment. Under the Act, NOAA comments on actions by other Federal agencies to address possible harm to NOAA trust resources. NOAA also prepares NEPA documents for its activities that may affect the environment.

106 16 U.S.C. § 1951 *et seq.*

107 16 U.S.C. § 1401 *et seq.*, as amended through Pub. L. No. 106-513.

108 42 U.S.C. § 4321 *et seq.*; Pub. L. No. 91-190.

National Marine Sanctuaries Act[109]

The National Marine Sanctuaries Act (NMSA) authorizes the Secretary of Commerce to designate and protect areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational, or esthetic qualities as national marine sanctuaries. Day-to-day management of national marine sanctuaries has been delegated by the Secretary of Commerce to NOAA's Office of National Marine Sanctuaries. The primary objective of the NMSA is to protect marine resources, such as coral reefs, sunken historical vessels or unique habitats. Among other things, the amendments to the NMSA over the years have modified the process of how sites are designated, given the Secretary the authority to issue special use permits, enhanced the ability to enforce the Act, and established civil liability for injury to sanctuary resources.

NOAA Authorization Act of 1992 and NOAA Re-Authorization Act of 2002[110]

Under the NOAA Authorization Act of 1992 and NOAA Re-Authorization Act of 2002, NOAA Chesapeake Bay Office (NCBO) is tasked with functions to aid in research or resource management efforts in the Chesapeake Bay that address requirements of habitat restoration, including: (a) assessing the processes that shape the Chesapeake Bay system and affect its living resources; (b) identifying technical and management alternatives for the restoration and protection of living resources and the habitats they depend upon; (c) monitoring the implementation and effectiveness of management plans; and (d) carrying out a community-based fishery and habitat restoration small grants program in the Chesapeake Bay watershed.

Nonindigenous Aquatic Nuisance Prevention and Control Act, as amended by the Nonindigenous Invasive Species Act[111]

The Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, as amended by the Nonindigenous Invasive Species Act, amends the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 and charges NOAA with invasive species prevention, detection, monitoring, control and restoration activities. It directs NOAA to co-chair a national aquatic nuisance species task force, which will coordinate activities among federal agencies and between Federal agencies, regional, State, tribal and local organizations involved in carrying out the Act. The Act also instructs NOAA and the Fish and Wildlife Service to undertake development of technologies and practices that may prevent introduction and spread of non-indigenous species through ballast water discharge.

Oil Pollution Act[112]

The Oil Pollution Act of 1990 authorizes the President to act as a trustee for natural resources and recover damages to natural resources for the discharge or threatened discharge of oil into

109 16 U.S.C. § 1431 *et seq.*, Pub. L. No. 106-513.
110 15 U.S.C. § 313; Pub. L. No. 102-567.
111 16 U.S.C. § 4701 *et seq.*; Pub. L. No. 101-646.
112 33 U.S.C. § 2701 *et seq.*; Pub. L. No. 101-380.

navigable waters or adjoining shorelines. NOAA has been delegated this trustee authority with respect to natural resources for which the agency has management or protective responsibilities.

Office of Management and Budget Circular Number A-16, National Spatial Data Infrastructure
Office of Management and Budget Circular Number A-16 provides direction for Federal agencies that produce, maintain, or use spatial data either directly or indirectly in the fulfillment of their mission. This Circular requires the development, maintenance, and dissemination of a standard core set of digital spatial information for the Nation that will serve as a foundation for users of geographic information.

Whaling Convention Act[113]
The 1946 Whaling Convention Act has as its objective the proper conservation of world whale stocks, thus making possible the orderly development of the whaling industry. The Convention established the International Whaling Commission to provide for a continuing review of the condition of whale stocks and for such additions to or modifications of the agreed conservation measures as might appear desirable. The Act authorizes U.S. actions to implement and comply with the Convention.

Weather Forecasting, Research and Modeling

Arctic Region Policy[114] ***and US National Strategy for the Arctic Region (NSAR)***[115]
The Arctic Region Policy is a Presidential directive that establishes the policy of the United States with respect to the Arctic Region and directs related implementation actions. In furtherance of this policy, the U.S. National Strategy for the Arctic Region (NSAR) is intended to position the United States to respond effectively to challenges and emerging opportunities arising from significant increases in Arctic activity due to the diminishment of sea ice and the emergence of a new Arctic environment. NOAA's Arctic Vision and Strategy strategic goals are aligned with the three lines of effort in the NSAR: 1) Advance United States Security Interests; 2) Pursue Responsible Arctic Region Stewardship; and 3) Strengthen International Cooperation. NOAA provides the backbone of basic research, including providing a better understanding of climate issues necessary to address many aspects of the NSAR.

Global Change Research Act [116]
The Global Change Research Act mandates the development of a research program whose goal is to understand climate variability and its predictability. This Act ensures the establishment of global measurements and worldwide observations, and requires an early and continuing

113 16 U.S.C. § 916 *et seq.*; 64 Stat. 421.
114 National Security Presidential Directive-66/Homeland Security Presidential Directive-25, January 2009.
115 White House, May 2013.
116 15 U.S.C. § 2921 *et seq.*; Pub. L. No. 101-606.

commitment to the establishment and maintenance of worldwide observations and related data and information systems.

Global Climate Protection Act[117]

The Global Climate Protection Act of 1990 requires the establishment of a United States Global Change Research Program aimed at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment, to promote discussions toward international protocols in global change research, and for other purposes.

Global Earth Observation System of Systems

The Global Earth Observation System of Systems (GEOSS) will provide decision-support tools to a wide variety of users. GEOSS will be a global and flexible network of content providers allowing decision makers to access an extraordinary range of information. This 'system of systems' will proactively link together existing and planned observing systems around the world and support the development of new systems where gaps currently exist. It will promote common technical standards so that data from the thousands of different instruments can be combined into coherent data sets.

Implementation Plan for the Global Observing System for Climate (GCOS-92, October 2004)

The United Nations Framework Convention on Climate Change (UNFCCC) endorses the Implementation Plan for the Global Observing System for Climate, which lays out specific recommendations for the ocean observing system for climate. The plan responds to the Second Report on the Adequacy of the Global Observing System for Climate in Support of the UNFCCC, which concluded that "...the ocean networks lack global coverage and commitment to sustained operations ... Without urgent action to address these findings, the Parties will lack the information necessary to effectively plan for and manage their response to climate change."

National Climate Program Act [118]

The National Climate Program Act authorizes global data collection, and monitoring and analysis activities to provide reliable, useful and readily available information on a continuing basis. In addition, the Act authorizes measures for increasing international cooperation in climate research, monitoring, analysis and data dissemination.

National Weather Service Organic Act [119]

The National Weather Service Organic Act directs NOAA to forecast the weather, issue storm warnings, collect and transmit marine intelligence for the benefit of commerce and navigation. The Act requires the establishment of meteorological observation stations in the Arctic Region

117 15 U.S.C. § 2901 *et seq.*; Pub. L. No. 95–367.
118 15 U.S.C. §§ 2901-2908, at 2904(d)(4).
119 15 U.S.C. § 313.

and requires NOAA to establish the Institute for Aviation Weather Prediction to provide forecasts, weather warnings, and other weather services to the United States aviation community. And the nature of the prescribed duties "...to develop adequate warning system for the severe hazards of nature – hurricanes, tornadoes floods, earthquakes and seismic sea waves..." provides the requirement for tsunami (seismic sea wave) warning activities. The National Weather Service Organic Act also directs NOAA to take such meteorological observations as may be necessary to establish and record the climate conditions of the United States. The Act outlines NOAA's responsibility to produce climate forecasts as well as to monitor and record climate information used in assessment products.

Strategic Plan for the United States Climate Change Science Program

The United States Climate Change Science Program Strategic Plan (July 2003) articulates a number of climate observation objectives, including the overarching goals of completing the required atmosphere and ocean observation elements in a manner consistent with Climate Monitoring Principles in the Implementation Plan for the Global Observing System for Climate.

Clean Air Act[120]

The Clean Air Act tasks NOAA with conducting a research program to improve understanding of the short-term and long-term causes, effects, and trends of damage from air pollutants on ecosystems. In addition, NOAA is charged with monitoring and understanding the physics and chemistry of the stratosphere and for early detection of potentially harmful changes to stratospheric ozone levels.

Coast and Geodetic Survey Act[121]

The Coast and Geodetic Survey Act authorizes the Secretary of Commerce, and by extension NOAA, to conduct geomagnetic, seismological, gravity, and related geophysical measurements and investigations. In addition, the Act authorizes NOAA to conduct hydrographic and topographic surveys. These surveys along the U.S. coasts aid the development of digital elevation models that are used for inundation mapping activities that increase the preparedness of communities and reduce their vulnerability to sudden sea level rises caused by such phenomena as tsunamis and storm surge. (Full description under Charting and Surveying)

Inland Flooding Forecasting and Warning Systems Act of 2002[122]

The Inland Flooding Forecasting and Warning Act authorizes NOAA, through the United States Weather Research Program, to conduct research and development, training, and outreach activities relating to inland flood forecasting improvement, and for other purposes. The Act instructs NOAA to improve its capability to accurately forecast inland flooding. In addition, through research and analysis of previous trends assess the long-term trends in frequency and severity of inland flooding.

120 42 U.S.C. § 7401 *et seq.*
121 33 U.S.C. § 883a *et seq.*
122 15 U.S.C. § 311 *et seq.*; Pub. L. No. 107-253.

Memorandum of Understanding on Cooperation in Research to Combat the Effects of Airborne Environmental Pollution Between the EPA and NOAA

The Memorandum of Understanding (MOU) on Cooperation in Research to Combat the Effects of Airborne Environmental Pollution reaffirms the ongoing collaboration between EPA and NOAA in the conduct of research related to the origins, dispersion, transformation, and deposition of air pollutants, and to expand this collaboration to include related research that addresses the shared interests of both Agencies. The MOU identifies several long-term, joint research objectives to improve: observations, emission inventories, air quality models, air quality forecasts and products, interaction of air quality models with water, land and biomass, and understanding the effects of climate on air quality.

National Hurricane Operations Plan

The National Hurricane Operations Plan (NHOP) is an interdepartmental effort to provide the United States and designated international recipients with forecasts and warnings concerning tropical and subtropical weather systems. Under the Plan NOAA is responsible for providing forecasts and warnings for the Atlantic and Eastern and Central Pacific Oceans. The Plan also tasks NOAA, along with other federal agencies such as the U.S. Navy and the National Aeronautics and Space Administration (NASA), to conduct supporting research efforts to improve tropical cyclone forecast and warning services and to conduct reconnaissance flights, including synoptic surveillance. The National Hurricane Operations Plan requires NOAA to provide weather reconnaissance flights, including synoptic surveillance in order to ensure the necessary preparedness actions are taken to minimize loss of life and destruction of property.

National Response Framework[123]

The National Response Framework (NRF) aligns Federal coordination structures, capabilities, and resources into a unified, all-discipline, and all-hazards approach to domestic incident management. The Department of Commerce is a signatory partner in the plan and NOAA has direct or supporting responsibilities in 10 of the 15 Emergency Support Functions (ESF). NOAA is also listed in the Nuclear/Radiological Incident Annex as the point of interaction for international coordination for hydrometeorological responses. NOAA's services are utilized in ESF #1, #9, #10, #11, and #13, to protect people, resources and transportation by providing:

- Trajectory/dispersion forecasts and scientific support for marine spills;
- Information on ice and oceanographic conditions for coastal waters;
- Charts and maps for coastal and territorial waters and the Great Lakes;
- Emergency hydrographic surveys, search and recovery, and obstruction location to assist safe vessel movement; and
- Aerial mapping and satellite remote sensing for damage assessment.

National Search and Rescue Plan of the United States

The National Search and Rescue Plan of the United States coordinates civil search and rescue (SAR) services to meet domestic needs and international commitments. The Department of

123 Presidential Policy Directive (PPD) 8, National Response Framework (NRF), May 2013.

Commerce participates in or supports SAR operations through NOAA. NOAA provides nautical and aeronautical charting; information on tides and tidal currents; marine environmental forecasts and warnings for the high seas, and coastal and inland waterways; and satellite services for detecting and locating aircraft, ships, or individuals in potential or actual distress.

National Winter Storms Operations Plan – FCM-P13-2005 (Updated Annually)

The National Winter Storms Operations Plan coordinates the efforts of the Federal meteorological community to provide enhanced weather observations of severe winter storms that impact the coastal regions of the United States.

Navigation and Navigable Waters Authorities[124]

The Navigation and Navigable Waters authorities at 33 U.S.C. § 883d authorize NOAA to increase engineering and scientific knowledge by conducting developmental work for the improvement of surveying and cartographic methods, instruments, and equipment; and to conduct investigations and research in geophysical sciences.

Presidential Decision Directive, NSTC-8, National Space Policy

Presidential Decision Directive, NSTC-8, National Space Policy is a broad set of policy guidelines to support a strong, stable and balanced national space program that serves numerous national goals. The directive gives NOAA the lead responsibility for managing federal space-based civil operational Earth observations necessary to meet civil requirements. This includes acquiring data, conducting research and analyses, making required predictions about the Earth's environment and operating Earth observation systems in support of operational monitoring needs.

Tsunami Warning and Education Act[125]

The Tsunami Warning and Education Act authorizes and strengthens the tsunami detection, forecast, warning, and mitigation program of the National Oceanic and Atmospheric Administration. Much of the law is concerned with detection methods and responsibilities; however, tsunami inundation models and maps are required by the law as well. A critical component of the tsunami inundation model is a seamless topographic/bathymetric digital elevation model, which NOAA constructs in part using aerial remote sensing data collected by LIDAR (light detection and ranging) systems and photogrammetry.

U.S. Ocean Action Plan

The U.S Ocean Action Plan outlines the fundamental components which together provide the foundation to advance the next generation of ocean, coastal, and Great Lakes policy. Taken in its entirety, this response engenders responsible use and stewardship of ocean and coastal

124 33 U.S.C. § 883d.
125 33 U.S.C. § 3201 *et seq.*, Pub. L. No. 109-424.

resources for the benefit of all Americans. Management of these resources requires an entire watershed perspective including effects far upstream such as runoff from snow melts and assessments of soil moisture levels.

Charting and Surveying

Coast and Geodetic Survey Act[126]

The Coast & Geodetic Survey Act (CGSA) is the organic authority for NOAA to "...provide charts and related information for the safe navigation of marine and air commerce and to provide basic data for engineering and scientific purposes and for other commercial and industrial needs..." The CGSA authorizes the Secretary of Commerce, and by extension NOAA, to conduct the following activities for safe marine navigation:

a. Hydrographic and topographic surveys;
b. Tide and current observations;
c. Geodetic-control surveys;
d. Field surveys for aeronautical charts; and
e. Geomagnetic, seismological, gravity, and related geophysical measurements and investigations, and observations for the determination of variation in latitude and longitude.

This mandate covers all U.S. territorial waters and the U.S. EEZ which extends 200 nautical miles offshore from the Nation's shoreline. NOAA is designated as the central depository for geomagnetic data, and the Secretary is authorized to collect, correlate and disseminate such data. The Act authorizes the Secretary to conduct developmental work for the improvement of surveying and cartographic methods and instruments and to conduct investigations and research in geophysical sciences. The Secretary is authorized to enter into cooperative agreements with states, Federal agencies, public or private organizations or individuals, for surveying, mapping and publication activities, and to contract with qualified organizations for National Geodetic Survey functions. The Act provides for a permanent authorization of appropriations to perform these functions, as well as to acquire, construct, maintain, and operate ships, stations, equipment, and facilities as needed to meet the mission.

This Act also authorized the Department of Commerce to conduct geodetic control surveys; field surveys for Federal Aviation Administration aeronautical charts; developmental work for the improvement of surveying and cartographic methods, instruments, and equipment; and investigations and research in geophysical sciences, including geodesy and seismology.

The Coast and Geodetic Survey Act (CGSA) provides the authority for coastal seismic and sea level monitoring, including the Pacific Tsunami Warning Center (PTWC). The specific duties of the Coast and Geodetic Survey included operation of the National Geomagnetism Program and Honolulu Geomagnetic Observatory (established 1902) and the U.S. Seismic Sea Wave Warning system established at the Honolulu Observatory (established in 1946). In 1949, the PTWC in Ewa

126 33 U.S.C. § 883a *et seq.*

Beach, Hawaii, was established to provide warnings from tsunamis to most countries in the Pacific Basin, as well as to Hawaii and all other U.S. interests in the Pacific outside of Alaska and the U.S. West Coast. The language in the Act is generally permissive: The Secretary is "authorized" to do various functions. But the statute, passed in 1947, stated as its purpose: "To define the functions and duties of the Coast and Geodetic Survey, and for other purposes." Mapping of coastal areas – observance, analysis, and prediction of tide and current data support tsunami hazard mitigation.

Coast Guard Navigation Safety Regulations[127]

Coast Guard Navigation Safety Regulations require that self-propelled vessel of 1,600 or more gross tons and/or foreign vessels operating in the navigable waters of the United States must have current, updated nautical charts produced by NOAA, as well as the NOAA Coast Pilot and NOAA tide and current tables. The requirement derived from the regulations is for NOAA to produce and update said materials with shoreline and hydrographic data for navigation safety use.

Hydrographic Services Improvement Acts (HSIA)[128]

The Hydrographic Services Improvement Acts also reiterate NOAA's responsibilities "...to fulfill the data gathering and dissemination duties... [of] acquiring and disseminating hydrographic data, promulgate standards for hydrographic data..." and the authority to "operate vessels, equipment, and technologies necessary to ensure safe navigation and maintain operational expertise in hydrographic data acquisition and hydrographic services." The 2002 HSIA also authorizes NOAA to "...carry out activities authorized under this title that enhance homeland security, including...hydrographic surveys..."

Interagency Agreement between NOAA National Geodetic Survey and Federal Aviation Administration[129]

Under the Interagency Agreement between NOAA and the Federal Aviation Administration, NOAA's National Geodetic Survey is required to furnish necessary products and services in support of the Aeronautical Surveys Program. Those products and services include runway obstruction field surveys, aerial photography for airports, and digital Airport Obstruction Charts, which depend upon aircraft operations to deliver.

Tsunami Hazard Mitigation Implementation Plan

Tsunami Hazard Mitigation Implementation Plan, 1996 provides a plan for reducing the tsunami risks to coastal residents. Under the Plan, developed in response to Senate Appropriations Committee direction, NOAA is building high-resolution digital elevation models (DEM) for select U.S. coastal regions in support of tsunami forecasting and modeling. These combined

127 33 C.F.R. § 164.33.

128 33 U.S.C. § 892 *et seq.*

129 Interagency Agreement No. DTFAWA-08-X-80002, April 2008.

bathymetric-topographic DEM are part of the tsunami forecast system currently being developed for the NOAA Tsunami Warning Centers, and are used to simulate tsunami generation, propagation, and inundation.

Emergency Response

Executive Order 12656, Assignment of Emergency Preparedness Responsibilities[130]

Executive Order (E.O.) 12656, Assignment of Emergency Preparedness Responsibilities, assigns national security emergency preparedness responsibilities to federal departments and agencies. Under this order, agencies are required to have capabilities to meet essential defense and civilian needs during any national security emergency. The head of each agency shall provide for: 1) succession to office and emergency delegation of authority in accordance with applicable law; 2) safekeeping of essential resources, facilities, and records; and 3) establishment of emergency operating facilities. In addition, this E.O. assigns the Department of Commerce the lead responsibility for developing plans to provide meteorological, hydrologic, marine weather, geodetic, hydrographic, climatic, seismic, and oceanographic data and services to Federal, state, and local agencies, as appropriate, and developing overall plans and programs for the fishing industry's continued production during an emergency.

Homeland Security Act of 2002[131]

The Homeland Security Act of 2002 established the Department of Homeland Security (DHS). It establishes the primary mission of the DHS to prevent terrorist attacks within the United States; reduce the vulnerability of the United States to terrorism; to minimize the damage, and to assist in the recovery, from terrorist attacks that do occur within the United States. NOAA supports DHS in its functions through information sharing, complying with Continuity of Operations guidance, and providing response and recovery assistance.

Homeland Security Presidential Directive #5, Management of Domestic Incidents[132]

Homeland Security Presidential Directive (HSPD) #5, Management of Domestic Incidents, tasks the Secretary of Department of Homeland Security to develop a comprehensive National Incident Management System (NIMS) and the National Response Plan (NRP) which integrates Federal Government domestic prevention, preparedness, response, and recovery plans into one all-discipline, all-hazards plan. All Federal departments and agencies, including the Department of Commerce and NOAA, are required to adopt the NIMS and assist and support with the development of the NRP.

Homeland Security Presidential Directive #7, Critical Infrastructure Identification, Prioritization and Protection[133]

130 Exec. Order No. 12,656, 53 Fed. Reg. 47,491 (Nov. 18, 1988).
131 6 U.S.C. § 101, Pub. L. No. 107-296.
132 Homeland Security Presidential Directive (HSPD) #5, Management of Domestic Incidents, February 28, 2003.
133 Homeland Security Presidential Directive (HSPD) #7, Critical Infrastructure Identification, Prioritization and Protection, December 17, 2003.

HSPD #7, Critical Infrastructure Identification, Prioritization and Protection, establishes a national policy for federal departments and agencies to identify and prioritize United States critical infrastructure and key resources and to protect them from terrorist attacks.

Homeland Security Presidential Directive #8, National Preparedness[134]

HSPD #8, National Preparedness, establishes policies to strengthen the preparedness of the United States to prevent and respond to threatened or actual domestic terrorist attacks, major disasters, and other emergencies by requiring a national domestic all-hazards preparedness goal, establishing mechanisms for improved delivery of Federal preparedness assistance to state and local governments, and outlining actions to strengthen preparedness capabilities of federal, state, and local entities.

National Security Presidential Security Directive #51/Homeland Security Presidential Directive #20, National Continuity Policy[135]

NSPD #51/#20, National Continuity Policy, establishes a comprehensive national policy on the continuity of federal government structures and operations and a single National Continuity Coordinator responsible for coordinating the development and implementation of federal continuity policies. This policy establishes "National Essential Functions," prescribes continuity requirements for all executive departments and agencies, "...in order to ensure a comprehensive and integrated national continuity program that will enhance the credibility of our national security posture and enable a more rapid and effective response to and recovery from a national emergency."

134 Homeland Security Presidential Directive (HSPD) #8, National Preparedness.

135 National Security Presidential Directive (HSPD) #51, Homeland Security Presidential Directive (HSPD) #20, National Continuity Policy.

APPENDIX H
UAS MISSION REQUIREMENTS

National Marine Fisheries Service (NMFS)

- Terrestrial, stream channel, floodplain, estuary, lagoon mapping for anadromous fish research and monitoring
- Pinniped surveys with small UAS
- Marine mammal stranding and disaster response
- Shallow water benthic habitat mapping
- Sustainable fisheries
- Large whales: photogrammetry, blow sampling, real time documenting of entanglement, photo ID of individuals, behavioral studies
- Pinniped ecology and assessment
- Sea turtle detection/tagging
- Hawaiian monk seal applications
- Cetacean Surveys, health assessment, abundance, and group size
- CPS surveys off west coast
- Pinniped photogrammetry/Small and large scale pinniped census
- Endurance exceeding 30 minutes for VTOL UAS
- Pinniped health and abundance assessment
- Distribution, abundance and habitat studies of ringed seals in shore fast ice
- Survey for ice-associated seals
- Long-range, beyond LOS Steller sea lion abundance surveys
- Habitat mapping and debris detection
- Marine mammal entanglement and
- stranding Response
- Marine mammal oil spill response
- Marine mammal stranding and disaster response

National Ocean Service (NOS)

- Coastal mapping
- Natural resource damage assessment
- Oil mapping/surveillance overflights
- Sensitive or remote small area marine debris surveys. Assessing and quantifying the presence in sensitive or remote shoreline or nearshore areas.
- Marine monitoring
- Emergency response
- Hydrographic operations

Office of Atmospheric Research (OAR)

- Harmful algal bloom detection
- Climate studies

- GOA2HEAD
- Hurricane surveillance and PBL studies to improve HWRF
- Boundary layer measurements
- Climate monitoring
- Atmospheric aerosol and air quality studies
- Hurricane Reconnaissance (Atlantic and EPAC)
- Harmful algal bloom detection and mapping
- Atmospheric Boundary Layer and Surface Applications of Small UAS Technologies
- Aircore descent from stratosphere
- Hurricane reconnaissance (Atlantic and EPAC)
- Mission to evaluate options for UAS profiling of the lower atmosphere with applications for severe weather
- Quantitative value of mass and wind information from instruments on the Global Hawk to improve forecast skill of high impact weather events, through OSEs and OSSEs
- COYOTE UAS
- Studying atmospheric composition through the boundary layer, especially in the Arctic

National Weather Service (NWS)

- Assessment of impacts after hazardous weather events
- Atmospheric sampling

National Environmental Satellite, Data, and Information Service (NESDIS)

- NOAA Satellite data validation
- Numerical weather prediction model validation

University of California, Santa Barbara (UCSB)

- HF radar antenna calibration