Department of the Air Force

Report to Congressional Committees

Conduct of Weather Reconnaissance in the United States

April 2024

The estimated cost of this report or study for the Department of Defense is approximately $3,410 for the 2024 Fiscal Year. This includes $10 in expenses and $3,400 in DoD labor.


DEPARTMENT OF THE AIR FORCE
UNITED STATES OF AMERICA
MCMXLVII

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, D.C.

Conduct of Weather Reconnaissance in the United States

This report provides an assessment of the resource requirements for weather reconnaissance, emphasizing the Air Force Reserve Command, 403d Wing, 53rd Weather Reconnaissance Squadron's pivotal role in enhancing forecast accuracy for tropical cyclones and winter storms. It notes a 20% increase in tropical cyclone missions and a 606% rise in winter operations over the last five years, highlighting the growing need for precise weather data.

Looking ahead to 2035, projections indicate a consistent rise in operational demands for weather reconnaissance. Despite the impressive contributions of the 53rd Weather Reconnaissance Squadron, the report identifies substantial challenges due to resource constraints. To address these, it advocates for careful management and optimization of mission assets to ensure the squadron continues to effectively contribute to weather forecasting and public safety.

Sincerely,

JOHN P. HEALY
Lieutenant General, USAF
Chief of Air Force Reserve


DEPARTMENT OF THE AIR FORCE
UNITED STATES OF AMERICA
MCMXLVII

Introduction

This report is provided to the congressional defense committees as directed by section 1090 of the National Defense Authorization Act for Fiscal Year 2024.

Not later than 90 days after the date of the enactment of this Act, the Secretary of the Air Force, in consultation with the Administrator of the National Oceanic and Atmospheric Administration, shall perform a resources review of mission capabilities needed for observation to carry out the activities described in subsection (a)(2) and submit to the appropriate committees of Congress a comprehensive report, for the period beginning on the date of the enactment of this Act and ending on December 31, 2035, on—

(i) the resources necessary for the 53rd Weather Reconnaissance Squadron of the Air Force Reserve Command to continue to support—

(I) the National Hurricane Operations Plan;

(II) the National Winter Season Operations Plan;

(III) emerging technologies that offer new, improved, or innovative ways to collect data for improved forecasts of strength and landfall for hurricanes, atmospheric rivers, and winter storms; and

(IV) any other operational requirements relating to weather reconnaissance;

(ii) the resources expended by the National Oceanic and Atmospheric Administration to cover taskings that the 53rd Weather Reconnaissance Squadron of the Air Force Reserve Command is unable to accomplish; and

(iii) the resources expended by the 53rd Weather Reconnaissance Squadron of the Air Force Reserve Command to cover taskings that the National Oceanic and Atmospheric Administration is unable to accomplish.

Executive Summary

This report provides an assessment of the current and future resources required to collect weather observations for tropical cyclones, winter storms (to include atmospheric rivers), and other requirements to support the forecast and warning services of the National Weather Service of the United States (U.S.) and the Department of Defense (DoD). The Air Force Reserve's 53rd Weather Reconnaissance Squadron (53 WRS) provides vital weather data which have increased weather model accuracy by 20%[1], improved the hurricane track forecast by 20%[1], and the hurricane intensity forecast by 10%[2]. In addition to tropical cyclones, the 53 WRS conducts missions to collect data for significant winter storms impacting the US Gulf and East Coasts as well as weather systems transporting excessive moisture called atmospheric rivers. Atmospheric rivers missions alone have been shown to improve weather forecasts 30 - 75%[3] and provided an additional 72-hours lead time for decision makers.

The weather reconnaissance (WR) mission to support the Department of Commerce was established in 1989 with resources to support tropical cyclone reconnaissance. This support was further defined by Congress in 1995 when a requirement was set for 10 aircraft, 20 aircrews and 1,600 flying hours via the Fiscal Year (FY) 1996 National Defense Authorization Act, and in 1998 the annual flying hours were directed to be no less than 3,000. Today these resources have not significantly changed while demand over the last 5 years has increased in both tropical cyclones (20%) and winter season operations (606%).

Operating from Keesler AFB in Biloxi, Mississippi, under the Air Force Reserve Command's 403d Wing, the 53 WRS is equipped with 10 Lockheed Martin WC-130J aircraft and supported by 278 maintenance personnel, 100 aircrew members, and 57 other support staff. These teams are tasked with collecting critical weather data through direct storm reconnaissance and deploying weather sensors and buoys, with real-time data processing and dissemination to the Department of Defense (DoD) and the National Oceanic and Atmospheric Administration (NOAA). Support requirements are defined in the National Hurricane Operations Plan (NHOP) and National Winter Season Operations Plan (NWSOP) and specify the ability to operate out of up to three locations simultaneously.

Despite these resources, the squadron faces substantial operational challenges, including the limited availability of aircraft due to maintenance requirements and upgrades, as well as staffing constraints that impact the squadron's ability to meet the growing demand for weather reconnaissance services.

[1] Sippel, J., X. Wu, S.D. Ditchek, V. Tallapragada, D.T. Kleist, 2022: Impacts of Assimilating Additional Reconnaissance Data on Operational GFS Tropical Cyclone Forecasts. J. Weather and Forecasting. https://journals.ametsoc.org/view/journals/wefo/37/9/WAF-D-22-0058.1.xml

[2] Tong, M., and Coauthors, 2018: Impact of Assimilating Aircraft Reconnaissance Observations on Tropical Cyclone Initialization and Prediction Using Operational HWRF and GSI Ensemble–Variational Hybrid Data Assimilation. Mon. Wea. Rev., 146, 4155–4177, https://doi.org/10.1175/MWR-D-17-0380.1.

[3] Zheng, M., Delle Monache, L., Cornuelle, B. D., Ralph, F. M., Tallapragada, V. S., Subramanian, A., et al. (2021). Improved Forecast Skill through the Assimilation of Dropsonde Observations from the Atmospheric River Reconnaissance Program. Journal of Geophysical Research: Atmospheres, 126, e2021JD034967. https://doi.org/10.1029/2021JD034967

Report

Resources Needed to Support the National Hurricane Operations Plan

Current resources allocated to conduct weather reconnaissance (WR) operations include 278 maintenance positions, 100 aircrew positions, 57 other support positions, and 10 Lockheed Martin WC-130Js. Of these personnel, approximately 33% are employed in a full-time status (Air Reserve Technicians or Active Guard and Reserve), and 69% are employed part-time as traditional reservists. These resources are funded through the "Weather Services" program element which has maintained an average annual budget of $60 million for operations and maintenance (O&M) and $15 million for reserve personnel appropriations (RPA). Of the $15 million RPA budget, $2-3 million per year is allocated to pay personnel to conduct operations with the remainder to provide indirect unit support and training. These resources are intended to support year-round weather reconnaissance operations to include the National Hurricane Operations Plan (NHOP).

NHOP operations are considered defense support to civil authorities (DSCA) under the Chairman of the Joint Chiefs of Staff Execution Order for DSCA Support[4] (CJCS DSCA EXORD) and requirements are pre-communicated and coordinated via the NHOP. Within the NHOP paragraph 5.2.1, U.S. Air Force WR forces provide 24/7 coverage of current or potential tropical cyclones that threaten the U.S. or its interests within the Atlantic, Caribbean, Gulf of Mexico, Eastern and Central Pacific basins[5]. Additionally, there is a requirement to provide WR support from up to three different locations simultaneously[5]. To provide 24-hour coverage for one storm as outlined in the NHOP, the minimum force package consists of three aircraft, 54 maintenance personnel, 18 aircrew members, and 23 support personnel. As storms get closer to a U.S. mainland landfall, the resources increase by one aircraft, thirteen aircrew members, and three support personnel to increase persistence of coverage. Based on these factors, there is a need for 10 operational and available aircraft, 164 maintenance personnel, 67 aircrew members, and 72 support personnel available to conduct operations at any given time from June 1st through November 30th.

Since 2018, the rolling three-year average of operational flying hours in support of the NHOP has trended up by 18% or 152 hours. Contributing factors to this increase include the need to identify tropical cyclones earlier in their development, the need for more persistent coverage to identify changes in storm track and intensity, and advances in weather model capability to integrate WR data. These advances and changes in the utilization of WR capabilities have resulted in a 20%[6] increase in weather model accuracy, improved hurricane track forecast by 15%[6] and improved hurricane intensity forecast by 10%[7].

The squadron faces significant challenges in meeting NHOP's demands due to limitations in maintenance personnel, aircraft availability, and funding constraints. The 53 WRS is currently postured to fully support two of the three storm package requirements,

[4] Chairman, Joint Chiefs of Staff, DSCA Execution Order (EXORD) Modification 1, (2020)
[5] National Hurricane Operations Plan, FCM-P12. (2023).
https://www.weather.gov/media/nws/IHC2023/2023_nhop.pdf
[6] See supra, Impacts of Assimilating Additional Reconnaissance Data, at note 1
[7] See supra, Impact of Assimilating Aircraft Reconnaissance Observations, at note 2

primarily due to manning shortfalls in maintenance personnel and aircraft availability rates. The unit is only authorized 110 maintenance personnel for mission generation while the C-130J standard is 54 personnel to support three aircraft at each location. Even if all authorizations were filled, the unit would only have enough personnel for two locations. The unit has averaged just above 50% available manning due to position vacancies, members in training, and members not medically available. Additionally, at any given time there is at least one aircraft in long-term depot maintenance away from Keesler and another in short-term scheduled maintenance at Keesler, leaving only eight total aircraft. This is only sufficient for two locations to operate. Also, with these aircraft being the oldest J-model C-130s in the Air Force inventory (ranging 20-30 years old), the average aircraft availability rate is 65% due to scheduled and unscheduled maintenance.

Based upon a best fit regression analysis on historical demand, adjusted to account for outside operational factors (e.g., the National Hurricane Center increasing outlooks from 5 to 7 days resulting in the need for more reconnaissance), we anticipate the increase in WR utilization to continue with a steady increase in demand from the current 15-16 storms flown per year to 18 storms flown per year by 2035. The NHOP budget is projected to increase from $18.15M in FY 2025 to $24.56M in FY 2035, with allocations for both the Atlantic and Pacific regions. The Atlantic region will see its total costs rise from $14.2M to $19.3M, while the Pacific region's expenses are expected to grow from $3.95M to $5.26M over the same period. This reflects a consistent increase in costs across flying hours, personnel, and dropsondes for both regions. Given current challenges and compounded by the anticipated future growth in demand, we are not positioned to be able to fully support NHOP requirements.

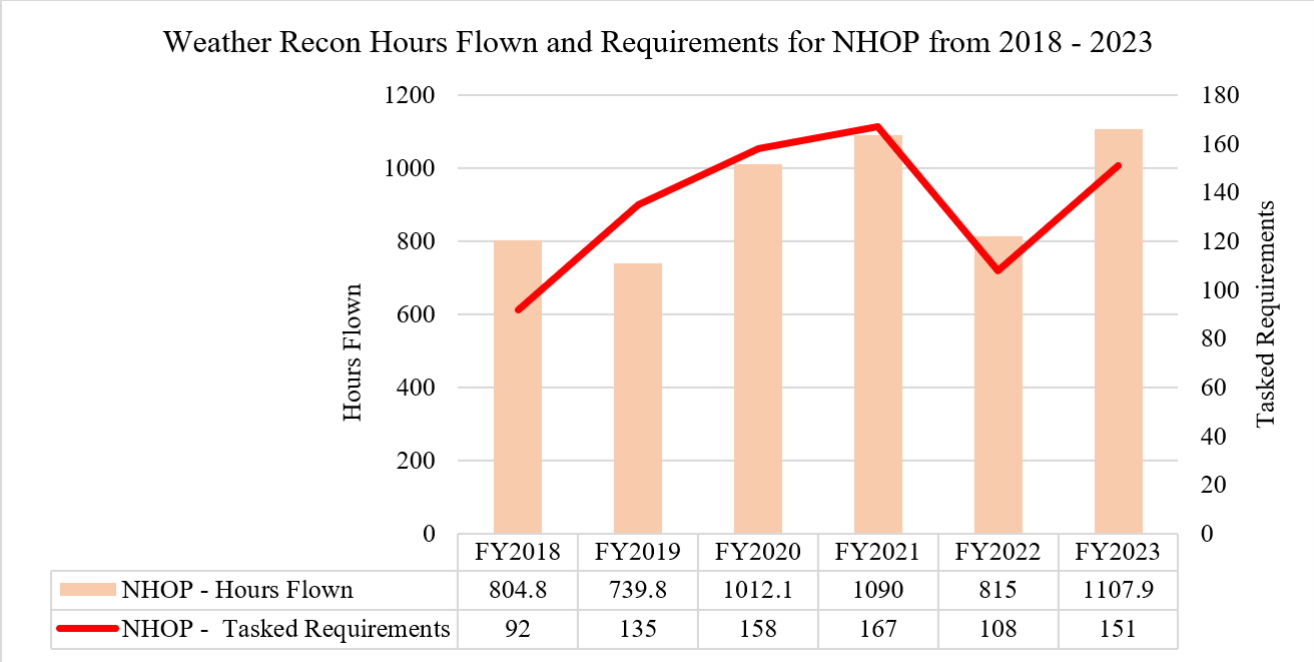


Figure 1 Air Force WC-130J hours flown in support of the NHOP from 2018-2023

			FY25 Total	FY30 Total	FY35 Total
NHOP	Atlantic	Flying Hours	$9.5M	$10.8M	$13.2M
		Personnel	$3.2M	$3.6M	$4.4M
		Dropsondes	1.5M	$1.5M	$1.7M
		Total Cost	***$14.2M***	***$15.9M***	***$19.3M***
	Pacific	Flying Hours	$2.8M	***$3.3M***	$3.8M
		Personnel	$1M	$1.1M	$1.3M
		Dropsondes	$150,000	$155,000	$161,000
		Total Cost	***$3.95M***	***$4.55M***	***$5.26M***
	Total		***$ 18.15M***	***$ 20.45M***	***$24.56M***

Table 1 Projected Air Force Weather Reconnaissance operational costs to support the NHOP through 2035

Resources needed to Support the National Winter Season Operations Plan

The resources detailed previously for the NHOP, including 278 maintenance positions, 100 aircrew positions, 57 support roles, and 10 Lockheed Martin WC-130Js, are also designated for the National Winter Season Operations Plan (NWSOP). Likewise, the NWSOP mission also utilizes the same 'Weather Services' program average annual budget of $60 million for O&M and $15 million for RPA. This shared allocation underlines the need for careful resource management and optimization, as the same budget and personnel are utilized to fulfill the requirements of year-round weather reconnaissance activities, covering both hurricane season and winter weather challenges.

NWSOP operations are considered DSCA under the CJCS DSCA EXORD[8] and requirements are pre-communicated and coordinated via the NWSOP. Within the NWSOP, U.S. Air Force WR forces provide 24/7 coverage of potential environmental threats to the U.S. or its interests within the Atlantic, Gulf of Mexico, Eastern and Central Pacific basins[9]. Additionally, the NWSOP para 2.2.1 requires the DoD to provide WR support from up to three different locations simultaneously. To provide the coverage necessary to support NOAA operations, the minimum force package consists of three aircraft, 54 maintainers, 18 aircrew members, and 23 support personnel. Based on these factors alone, there is a requirement to have nine aircraft, 162 maintenance personnel, 54 aircrew members, and 69 support personnel available to conduct NWSOP operations at any given time from November 1st through March 31st.

From 2018-2023, a rolling three-year average of NWSOP requirements and operational flying hours have increased over 600%. The trend continued into FY 2024 with October 2023 through January 2024, receiving 82% more requirements and 64% more flying hours completed than the previous historical maximum. During the month of January 2024, the 53 WRS flew missions spanning nearly half the northern hemisphere including the Gulf of Mexico and the Eastern, Central, and Western Pacific. Contributing factors to the increase in taskings include identification of new threats to the U.S. mainland such as atmospheric

[8] See supra, DSCA Execution Order (EXORD) Modification, at note 4
[9] National Winter Season Operations Plan, FCM-P13. (2023). https://www.icams-portal.gov/resources/ofcm/nwsop/2023_nwsop.pdf

rivers, new applications of WR techniques to increase the value of the data collected, and advances in weather model capability to integrate WR data. These advances and changes in the utilization of WR capabilities have resulted in as much as a 20% increase on average in weather model accuracy, which translates into an additional 72 hours' notice of extreme weather events to DoD and civilian decision makers along the US West Coast[10].

Today's demand provides support challenges based on the tempo of operations. Over the last several years we have seen historically busy hurricane seasons run later in the year (extending as late as November). We are also seeing the need for additional WR requirements earlier in the winter season (beginning in November). Transitioning from a busy hurricane season to a busy winter season creates issues with personnel reconstitution and aircraft maintenance cycles. This, in turn, creates a downstream impact on aircraft availability and up-time in the following operational season. From 2015 to 2018, the 53 WRS was able to meet an average of 89% of the requirements levied, but as the requirements have significantly increased, the 53 WRS has only been able to fully accomplish 60% of the requirements levied.

Based upon a best fit regression analysis on historical demand, adjusted to account for outside operational factors (e.g., the adoption of customized data collection in the Atlantic and Gulf of Mexico basins driving increased utilization), we anticipate the increase in WR utilization for winter season operations to continue as improved WR utilization techniques are adopted in the Gulf of Mexico, Atlantic, and Pacific basins. This increase brings today's approximate 50 winter storm flights to 65-70 flights by 2035. The projected costs for NWSOP operations indicate an increase in total expenses from $6M to $7.7M, with the Pacific region experiencing a higher cost growth compared to the Atlantic. Specifically, the Atlantic region's total costs are anticipated to rise from $1.2M to $1.9M, while the Pacific sees a more significant increase from $4.8M to $5.8M. This reflects a consistent increase in costs across flying hours, personnel, and dropsondes for both regions. Given current challenges and anticipated future growth in demand, we are not positioned to be able to fully support NWSOP requirements.

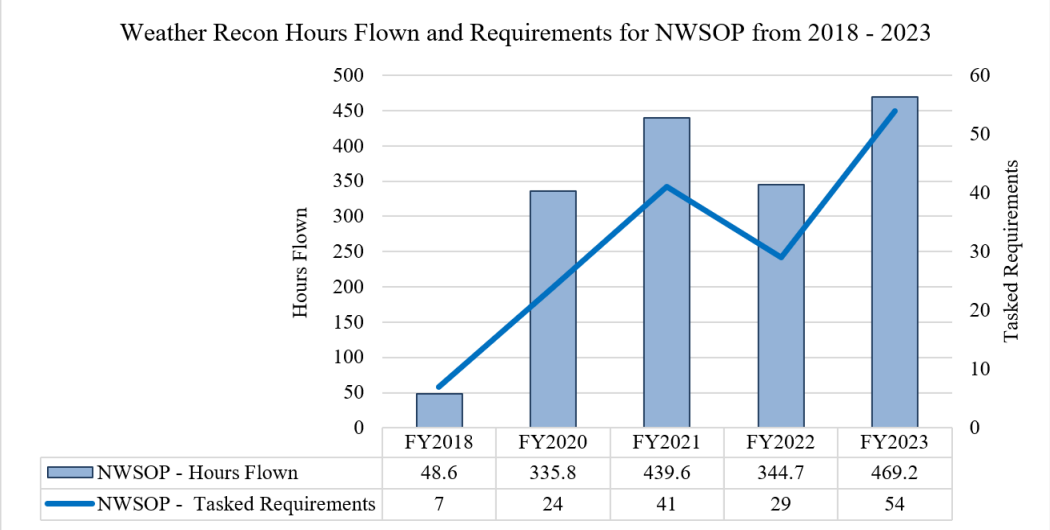


Figure 2 Air Force WC-130J hours flown in support of the NWSOP from 2018-2023

[10] See supra, Improved Forecast Skill through the Assimilation of Dropsonde Observations, at note 3

			FY25 Total	FY30 Total	FY35 Total
NWSOP	**Atlantic**	Flying Hours	$493,000	$739,000	$833,000
		Personnel	$386,000	$579,000	$652,000
		Dropsondes	303,000	$404,000	$411,000
		Total Cost	***$ 1.2M***	***$ 1.7M***	***$ 1.9M***
	Pacific	Flying Hours	$1.9M	$2.3M	$2.6M
		Personnel	$1.7M	$1.8M	$1.8M
		Dropsondes	$1.2M	$1.4M	$1.4M
		Total Cost	***$ 4.8M***	***$ 5.5M***	***$ 5.8M***
	Total NWSOP Projected Cost		***$ 6M***	***$ 7.2M***	***$ 7.7M***

Table 2 Projected Air Force Weather Reconnaissance operational costs to support the NWSOP through 2035

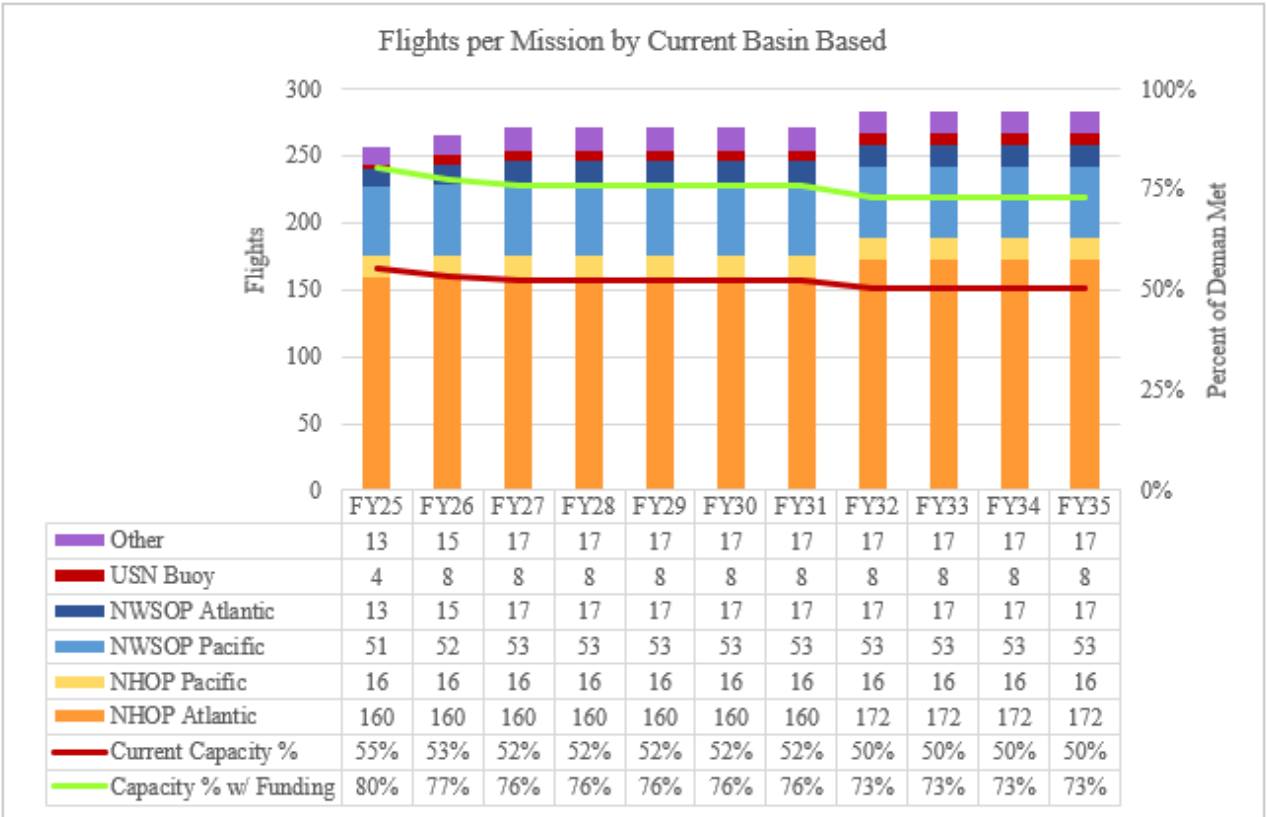
Dropsonde Usage in NHOP and NWSOP

Both NHOP and NWSOP missions rely on dropsondes for atmospheric data collection. These instruments, launched from aircraft to measure various atmospheric parameters, are pivotal for data gathering. With increasing atmospheric rivers data collection demands, dropsonde usage has surged, significantly impacting operational costs. In FY 2024, the 53 WRS deployed 868 dropsondes in support of the NWSOP and a total of 928 in support of 2023 NHOP operations, contributing to an annual expense of approximately $4 million when including training.

Beginning in FY 2020, Congress has provided program increases for atmospheric rivers research, with a portion of that funding allocated to cover the cost of dropsondes for NWSOP (Table 3). In FY 2024, a total of $2.5 million in funding was added directly to the Air Force Reserve O&M appropriation to cover the cost of additional dropsondes associated with the increase in atmospheric rivers requirements. Without such funding increases, our missions would achieve only about 55% of the targeted data collection coverage for both operational plans and associated training. An estimated increase of $3 million annually in dropsonde funding would boost our mission fulfillment rate to 80%, significantly enhancing both our operational capacity and the accuracy of weather forecasts.

Fiscal Year	Additional Congressional Budgetary Amount ($ million)
2020	$1.0
2021	$1.4
2022	$0.6
2023	$2.5
2024	$2.5

Table 1 Budgetary additions for dropsondes supporting Atmospheric River operations



	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35
Other	13	15	17	17	17	17	17	17	17	17	17
USN Buoy	4	8	8	8	8	8	8	8	8	8	8
NWSOP Atlantic	13	15	17	17	17	17	17	17	17	17	17
NWSOP Pacific	51	52	53	53	53	53	53	53	53	53	53
NHOP Pacific	16	16	16	16	16	16	16	16	16	16	16
NHOP Atlantic	160	160	160	160	160	160	160	172	172	172	172
Current Capacity %	55%	53%	52%	52%	52%	52%	52%	50%	50%	50%	50%
Capacity % w/ Funding	80%	77%	76%	76%	76%	76%	76%	73%	73%	73%	73%

Figure 3 USAF capacity to meet demand with and without additional dropsonde funding

Resources Needed to Support Emerging Technologies

The recognition of the WC-130Js' growing technological obsolescence in 2018 catalyzed a collaborative effort among the Air Force, NOAA, and the Office of the Federal Coordinator for Meteorology (OFCM), leading to the formation of the Aerial Reconnaissance Equipment Working Group (ARE-WG). This interagency group aims to foresee and bridge the technology gaps over the next 3-10 years, ensuring the WC-130J fleet remains at the forefront of weather reconnaissance capabilities. The group also established a vetting and on-boarding process for evaluating emerging technologies and migrating them from test and evaluation to operational utilization.

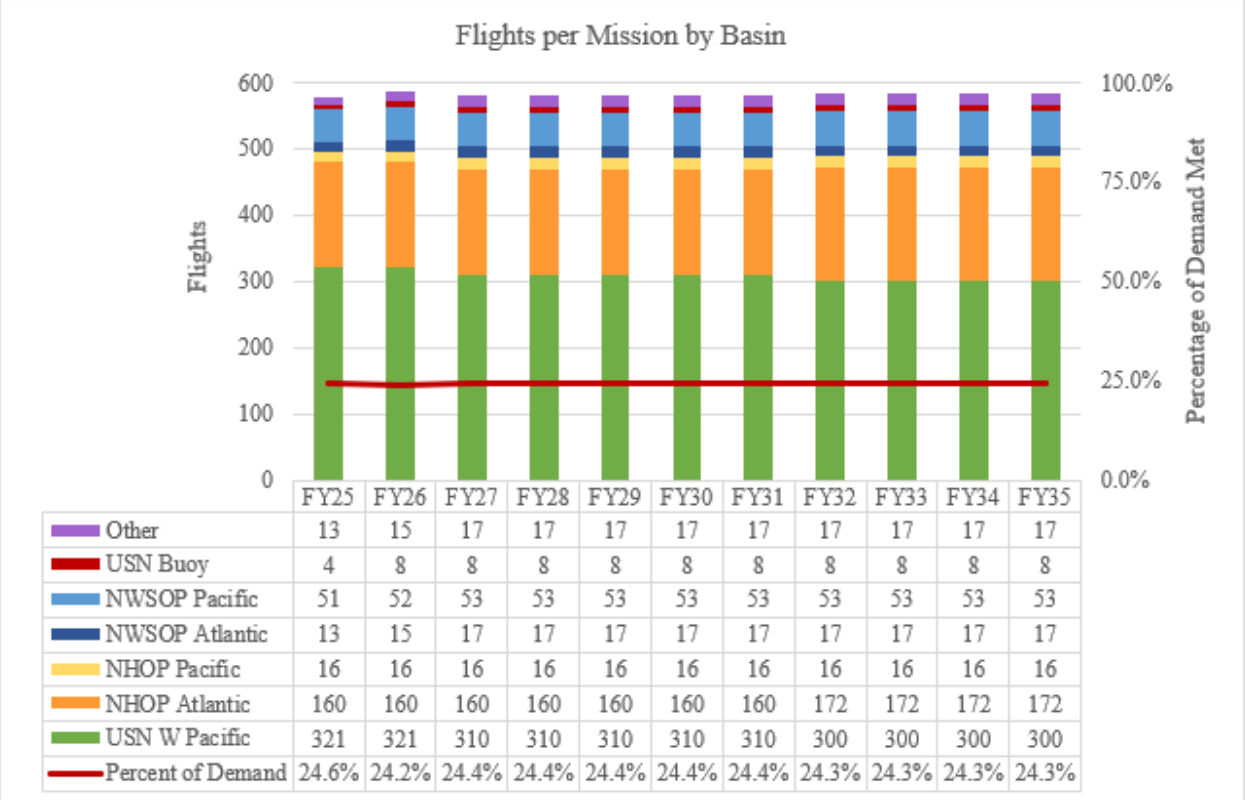
ARE-WG's efforts have led to the identification of essential sensor upgrades for the WC-130J aircraft. However, before these sensors can come online, several other steps need to take place. First, an update of WC-130J mission systems require an infrastructure upgrade to facilitate reduced maintenance costs, increase platform flexibility, and a redesign of the internal workstation networking and data transmission bandwidth. To address this, we are leveraging common parts across workstations and systems to reduce costs and supply chain complexity, we are in the process of installing sensor pods to build agility and allow us to change out sensors to meet current mission needs, and we are redesigning workstation connectivity to allow for networked workstations to share computing power as demand dictates while increasing our bandwidth to transmit data from the aircraft via commercial wideband satellite connectivity. As mission system infrastructure is being addressed, we are also in the process of updating current WC-130J capabilities. Efforts here include everything from a recent upgrade of dropsonde models to computer and sensor processor upgrades. As

the infrastructure and funding allows, we will be working closely with our mission partners to analyze and integrate the new technologies identified by the ARE-WG.

Resources Needed to Support Other Operational Requirements

Within other operational requirements, Air Force WR forces provide support to other organizations in the DoD. Since 2019, AF WC-130s have deployed buoys for the U.S. Navy's Naval Oceanographic Office (NAVOCEANO). These operations have supported larger efforts such as United States European Command's (USEUCOM) European Deterrence Initiative among other U.S. Navy operations. Although these operations have historically been manageable within existing training allocations, the demand for WR support across the DoD spectrum is on the rise.

United States Indo-Pacific Command (USINDOPACOM) and the Joint Typhoon Warning Center (JTWC) has requested future WR support within their area of operations to supplement and back up existing weather data collection methods critical to the forecasting of typhoons. Like NHOP, there is a need to support multiple storms simultaneously. Tropical cyclones can occur year-round across the Pacific Ocean and have been identified as the most significant environmental threat across the USINDOPACOM area of operations, but the time frame for peak activity is July through December. This timing overlaps with both the NHOP and NWSOP and would drive a significant increase to the demand already placed on the mission. Based on the currently limited resources of the 53 WRS (aircraft, flying hours, personnel and dropsondes), if these requirements were added, the mission capability would drop to approximately 25%.



	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35
Other	13	15	17	17	17	17	17	17	17	17	17
USN Buoy	4	8	8	8	8	8	8	8	8	8	8
NWSOP Pacific	51	52	53	53	53	53	53	53	53	53	53
NWSOP Atlantic	13	15	17	17	17	17	17	17	17	17	17
NHOP Pacific	16	16	16	16	16	16	16	16	16	16	16
NHOP Atlantic	160	160	160	160	160	160	160	172	172	172	172
USN W Pacific	321	321	310	310	310	310	310	300	300	300	300
Percent of Demand	24.6%	24.2%	24.4%	24.4%	24.4%	24.4%	24.4%	24.3%	24.3%	24.3%	24.3%

Figure 4 USAF capacity to meet DSCA and West Pacific demand

In addition to operational missions, the 53 WRS faces the ongoing necessity of maintaining proficiency and readiness of aircraft and crews through regular training. To fulfill these essential training requirements, approximately 1,100 flying hours, amounting to $10 million in O&M costs, and an additional $40 million in parts and maintenance costs are required annually.

Resources Expended by NOAA and 53 WRS to Cover Taskings

The collaboration between NOAA and the 53 WRS highlights a shared commitment to delivering critical weather reconnaissance. Despite a well-coordinated effort, there are occasions, albeit infrequent, when NOAA is called upon to cover operational taskings initially assigned to the 53 WRS.

When a need for WR is identified by the National Hurricane Center, the Central Pacific Hurricane Center, or the National Centers for Environmental Prediction's Senior Duty Meteorologists, a request for assistance is submitted to the Chief, Aerial Reconnaissance Coordination, All Hurricanes (CARCAH). The CARCAH coordinates with the 403d Wing to determine the availability of Air Force resources. The 53 WRS primarily undertakes these operational missions, with the requirements they can fulfill reported back to the CARCAH. If additional needs arise that the Air Force cannot meet, but which are deemed high priority by NOAA, CARCAH engages with the NOAA Aircraft Operations Center (AOC) to assess their capability to undertake these missions. The finalized task assignments are documented in the Plan of the Day (POD), which formalizes the requests for assistance and tasks the 53rd WRS accordingly.

The 53 WRS predominantly handles operational missions and the NOAA AOC is typically tasked with research-oriented flights. However, the NOAA AOC may undertake operational missions in instances where the 53 WRS is unable to do so due to high priority needs or operational constraints, such as maintenance issues or lack of available aircraft. These situations are rare and have historically occurred fewer than five times per year.

While the resource implications for NOAA in these instances are minimal, each occurrence necessitates careful coordination and consideration of operational priorities and capabilities. The continued collaboration and communication between NOAA and the 53 WRS are crucial in maintaining the integrity and effectiveness of weather reconnaissance efforts.

Similarly, the 53 WRS may, on rare occasions, fly taskings originally designated in the POD to NOAA AOC, also historically less than five times annually. This reciprocal support mirrors the challenges faced when NOAA AOC covers for the 53rd WRS, including differences in operational locations and the specific nature of the missions.

Of note, NOAA AOC's fleet, designed for research and development, is equipped with specialized sensors used for research and development. The 53 WRS WC-130Js are not currently configured to employ these same specialized sensors, nor is the program structured or funded to undertake research and development-oriented tasks.

Conclusion

In 2022, the United States faced 18 weather and climate disasters with losses surpassing $1 billion each, marking it as the third costliest year on record[11]. The invaluable data from WR operations has significantly enhanced weather model and hurricane intensity forecast accuracy. Since the FY 1996 National Defense Authorization Act mandated a fleet of 10 aircraft to support tropical cyclone reconnaissance, there has been an expansion in the scope of WR missions to include winter season operations and atmospheric rivers. However, despite these expanded responsibilities and significant extension of the operational season, the number of aircraft in the 53 WRS has remained constant, challenging their ability to cover these diverse and increasing demands.

As the frequency and severity of weather-related disasters rise, alongside the growing global strategic concerns, the demand for reliable weather data, especially in data-sparse regions has never been more critical. The continued effectiveness and expansion of WR missions are paramount to ensuring that military and civil leaders have the timely, accurate information needed to make informed decisions in an increasingly unpredictable global climate.

[11] Smith, A. B. (2023, January 10). *2022 U.S. billion-dollar weather and climate disasters in historical context*. Climate.gov. https://www.climate.gov/news-features/blogs/beyond-data/2022-us-billion-dollar-weather-and-climate-disasters-historical

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