Implementation Plan

for the

National Oceanic and Atmospheric Administration's Modernization of the National Volcano Early Warning and Monitoring System Pursuant to the National Defense Authorization of Fiscal Year 2023

Developed pursuant to: The National Defense Authorization Act of Fiscal Year 2023, Public Law 117–263

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THE NATIONAL DEFENSE AUTHORIZATION ACT OF FISCAL YEAR 2023, (PUBLIC LAW 117–263, 136 STAT. 2395 at 3993) INCLUDED THE FOLLOWING LANGUAGE

TITLE CV—VOLCANIC ASH AND FUMES
SEC. 10501. MODIFICATIONS TO NATIONAL VOLCANO EARLY WARNING AND MONITORING SYSTEM.

(f) IMPLEMENTATION PLAN.—

(1) DEVELOPMENT OF PLAN.—Not later than 180 days after the date of the enactment of this Act, the Secretary of Commerce, in consultation with the Secretary of the Interior, shall develop a plan to implement the amendments made by this Act during the 5-year period beginning on the date on which the plan is developed.

(2) ELEMENTS.—The plan developed under paragraph (1) shall include an estimate of the cost and schedule required for the implementation described in such paragraph.

(3) PUBLIC AVAILABILITY.—Upon completion of the plan developed under paragraph (1), the Secretary of Commerce shall make the plan publicly available.

THIS PLAN RESPONDS TO THE ACT'S REQUEST.

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I. EXECUTIVE SUMMARY

This Implementation Plan for the National Oceanic and Atmospheric Administration's (NOAA) Modernization of the National Volcano Early Warning and Monitoring System Pursuant to the National Defense Authorization of Fiscal Year (FY) 2023 outlines current NOAA capabilities related to volcanic hazards. Section V of this document outlines a cost estimate of $90.9 million over five years needed to modernize existing capabilities and add new capabilities required for NOAA's contributions to the National Volcano Early Warning and Monitoring System (System). The plan also outlines recurring annual cost estimates of $12.55 million to sustain these capabilities, should NOAA implement them.

II. INTRODUCTION

The John D. Dingell, Jr., Conservation, Management, and Recreation Act (Public Law 116–9, 133 Stat. 580) Title V, Section 5001 (codified at 43 U.S.C. § 31k) authorized the establishment of the System within the United States Geological Survey (USGS). The National Defense Authorization Act of FY 2023 (Public Law, 136 Stat. 2395 at 3993) Title CV, Volcanic Ash and Fumes (hereinafter referred to as the Act), amended 43 U.S.C. § 31k. Title CV, Section 10501 of the Act outlined the responsibilities assigned to NOAA in regard to modernization activities to support the System.

NOAA collaborated with the USGS to develop an Implementation Plan[1] for the modernization of the System oriented around seven equal priorities, set forth below:

1. Improve service on monitoring and forecasting volcanic smog (vog).
2. Develop/improve an operational plan to warn of volcanic debris flows/lahars from eruptive and non-eruptive events.
3. Improve service on quantifying airborne ash hazards to aviation.
4. Improve service on quantifying ashfall hazards.
5. Improve near-real-time data sharing to improve situational awareness and operational response.
6. Improve service on forecasting volcanogenic tsunamis and submarine eruptions.
7. Improve the efficacy of USGS and NOAA hazard information products.

The modernization efforts outlined by NOAA in this plan will play a critical role in envisioning the future System. NOAA activities augment the System and support its viability and functioning. These efforts will be key to the success of commensurate USGS activities as USGS works to improve the System.

[1] The Fumes Act called for a modernization plan. NOAA interpreted that in order to modernize, the bureau needed to develop an implementation plan to achieve the modernization.

III. BACKGROUND

The United States has approximately 170 volcanoes within its borders that are considered potentially active, with 29 erupting repeatedly between 1980 and 2017.[2] Of these volcanoes, 106 pose at least a moderate threat.[3] Within the U.S. Exclusive Economic Zone (EEZ), there are many unstudied submarine volcanoes that have not been evaluated for their threat potential and are very poorly monitored. Volcanoes do not follow geopolitical boundaries, meaning the effects of an eruption can impact the United States and its interests from a significant distance. Examples can include impacts to air traffic, such as those seen across Europe in 2010 due to the Eyjafjallajökull eruption, as well as volcanic emissions, ash clouds, and volcanogenic tsunamis.

Volcanoes create a wide range of destructive processes, including lava flows, ash falls, airborne ash plumes, debris flows/lahars, submarine landslides, tsunamis, toxic gases, and powerful explosions. Unlike earthquakes, eruptions of *most well-monitored* volcanoes can be forecast well before their occurrence, and their locations are well-known beforehand. Advance warning allows for preparation, which often can mitigate the worst effects of an eruption. Timely and accurate eruption forecasts require high-quality monitoring data from ground, aerial, submarine, and space-based instruments accompanied by expert scientific analysis and interpretation, both of which depend on solid and reliable infrastructure.

NOAA maintains several activities related to volcanic hazards that are listed in Section IV, below. To coordinate these activities with USGS and determine how they should be modernized under the Act, NOAA and USGS staff began to meet regularly in FY 2023. The scope and authority for these meetings is set forth in a memorandum of understanding (MOU) between NOAA and the USGS signed in 2022.[4] The agencies developed the priorities listed in the introduction of this plan, and from these priorities, determined appropriate and feasible areas of modernization across NOAA Line Offices and programs in conjunction with support from USGS.

NOAA should consider establishing an overarching bureau lead for volcanic services. This person should lead the NOAA volcano services program, which crosscuts the Line Offices. In this capacity, the bureau lead will serve as the project manager for the modernization activities under the Act, including the development of a Statement of Work (SOW) for this modernization effort that includes a governance structure, membership, timeline, tempo, and overarching objectives.

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[2] Ewert, J.W., Diefenbach, A.K., and Ramsey, D.W., 2018, 2018 update to the U.S. Geological Survey national volcanic threat assessment: U.S. Geological Survey Scientific Investigations Report 2018–5140, 40 p., accessed at https://doi.org/10.3133/sir20185140.

[3] Natural Hazards Review, Volume 8, Issue 4.

[4] Coordination and Cooperation in Activities Involving Physical and Biological Sciences and Environmental Studies, USGS, NOAA (2022).

IV. CURRENT NOAA ACTIVITIES RELATED TO VOLCANIC HAZARDS

NOAA provides services derived from observations of volcanic activity and eruptions. NOAA operates key operational offices, which provide forecasts, warnings, advisories, and Impact-Based Decision Support Services (IDSS) related to volcanic hazards. NOAA also operates a robust satellite surveillance capability to observe volcanic hazards. NOAA's portfolio also provides a research-to-operations (R2O) capability to enhance its operational science capabilities.

A. U.S. Volcanic Ash Advisory Centers (VAAC)

NOAA operates two U.S. Volcanic Ash Advisory Centers (VAACs) out of nine global VAACs: in College Park, MD, and Anchorage, AK. The VAACs were established in 1998 under International Civil Aviation Organization (ICAO) Annex 3 Amendment (Amd) 71 to provide volcanic ash advisory information "regarding the extent and forecast movement of the volcanic ash 'cloud'" to meet standards in ICAO Annex 3 Amd 80 (see Section 3.5).[5]

By November 2025, the U.S. VAACs will begin issuing Quantitative Volcanic Ash (QVA), a modernized information stream of probabilistic volcanic ash forecasts, based on the upcoming standards per ICAO Annex 3 Amd 81 recommendations. Related to ICAO Amd 81, in calendar year 2023 the Federal Aviation Administration (FAA), as the U.S. Meteorological Authority under the ICAO, issued letters to NOAA instructing both U.S. VAACs to be compliant with QVA product issuance by November 26, 2026. These QVA activities will overlap with the modernization efforts outlined in this plan but will be implemented separately due to ICAO recommendations and standards.

Additionally, under ICAO Annex 3, NOAA operates three Meteorological Watch Offices (MWO) that are responsible for issuing Volcanic Ash SIGnificant METeorological Information (SIGMET) products to warn the aviation community of any volcanic activity that produces volcanic ash emissions. These offices use the forecast position information available from advisories provided by the VAACs. The three U.S. MWOs are located at:

- The Alaska Aviation Weather Unit (AAWU) in Anchorage, AK,
- The Aviation Weather Center (AWC) in Kansas City, MO, and
- The Honolulu, HI Weather Forecast Office (WFO HFO).

[5] ICAO Documents are available online for purchase through the ICAO Store.

B. Weather Forecast Offices (WFO)

NOAA operates 122 WFOs across the United States and its Territories as well as a Weather Service Office (WSO) in American Samoa. These offices perform the following functions related to volcanic activity:

- Include Volcanic Ash in Terminal Aerodrome Forecast (TAF) products whenever volcanic ashfall is occurring or expected within five statute miles of an airport served by an NWS TAF.
- Issue Ashfall Warning and Advisory products whenever ashfall to the surface over land areas is expected or occurring for Public Health and surface transportation partners. Alaska WFOs also issue Special Weather Statements in these circumstances.
- Issue Special Marine Warnings and Marine Weather Statements to warn mariners of volcanic hazards.
- Issue Flash Flood Warnings for lahar and debris flow events.
- Issue Flood Warnings for mainstem river flooding related to glacial/snow melt and river blockages due to volcanic activity.
- Relay Volcano Warning and other Non-Weather Emergency messages at the request of local Emergency Management.

C. Center Weather Service Units (CWSU)

NOAA operates 21 Center Weather Service Units (CWSU) across the United States and its territories. These CWSUs brief air traffic controllers at their associated Air Route Traffic Control Center (ARTCC), as well as controllers at affiliated towers and Terminal Radar Approach Control Facilities (TRACON), of the impacts of volcanic activity on aviation.

D. Volcanic Cloud Analysis Toolkit (VOLCAT)

Volcanic Cloud Analysis Toolkit (VOLCAT) enables VAACs to analyze thousands of new satellite images acquired each day and ensure ash cloud forecast models are initialized with high-quality observations. Using near real-time processing of geostationary and low-earth orbit satellites covering the globe, VOLCAT automatically detects new volcanic eruptions, tracks volcanic ash clouds, and provides quantitative estimates of ash loading and height. Cited in over 12,000 volcanic ash advisories since 2016 (when tracking citations in volcanic ash advisories started), VOLCAT supports the timely issuance of new advisories and is needed to generate calibrated QVA products. In addition, VOLCAT is used by volcano observatories, including those operated by the

USGS, to monitor changes in ground temperature near volcanoes, allowing for a more complete assessment of changes in volcanic activity.

E. Modeling

NOAA conducts the following modeling efforts in support of the volcanic hazards program:

- NOAA maintains and develops the HYSPLIT model, which is utilized to support the VAACs. HYSPLIT uses information from NOAA's numerical weather prediction (NWP) models to produce forecasts of dispersion and transport of volcanic plumes. HYSPLIT was recently updated to utilize the Global Ensemble Forecast System (GEFS) to create a 31-member dispersion ensemble to support probabilistic forecasting. Methods for incorporating satellite data into the modeling system are planned to be transferred into operations starting in 2025. The updates include the capability of estimating volcanic emissions.
- Several NOAA NWP models now incorporate aerosols and could utilize emissions estimates of sulfur dioxide (SO2). Volcanic ash may also be incorporated into these models in the future.
- NOAA provides scientific updates to the National Air Quality Forecast Capability (NAQFC) for NWS to implement operationally. This capability provides operational air quality forecast guidance. Current operational predictions include ozone, fine particulate matter, smoke, and dust. The program is a partnership between NOAA, the Environmental Protection Agency (EPA), and state and local air quality forecasters. Vog could be added to this capability.

F. Monitoring and Measuring

NOAA conducts research on submarine volcanic activity, ocean chemistry, and tsunami generation and propagation, including:

- Bathymetric mapping of volcanic regions within the U.S. EEZ in the Pacific to identify submarine volcanoes.
- Water column physical and chemical studies to identify submarine volcanoes with active hydrothermal systems to indicate magmatic heat and potential volcanic activity.
- Acoustic data collection by moored hydrophones to record volcanic seismicity and locate sources.
- Research to improve tsunami modeling and tsunami detection systems.
- Research on monitoring submarine volcanoes and predicting their eruptions.
- Studies of submarine lava flows, landslides, turbidite flows, dissolved and particulate volcanic products injected into the water column, and effects of eruptions on the seafloor.

- Aerosol particle collection and chemical analysis.
- Collection and chemical analysis of seawater samples impacted by deposition of ash and other volcanogenic products.

V. NOAA VOLCANIC SERVICES GAPS, MODERNIZATION, AND ASSOCIATED COST ESTIMATES

Based on the parameters in the Act, NOAA has developed cost estimates to meet the Act's intent for modernization. These NOAA cost estimates were developed within priority areas developed in collaboration with the USGS. These cost estimates emphasize the strong collaboration between the USGS and NOAA and account for important partnerships, both internal and external, to leverage resources from the Act. Table 1 presents the cost estimates produced by NOAA for these service gaps and modernization activities.

Table 1 - Overall NOAA Cost Estimates for Modernization and Service Gaps (in millions)[6]

	FY2024 Enacted	Year 1	Year 2	Year 3	Year 4	Year 5	Recurring Costs/O&M
Priority 1	$0.11	$1.91	$1.87	$1.91	$1.82	$1.84	$0.33
Priority 2	$0	$0.58	$0.60	$0.61	$0.63	$0.65	$0
Priority 3	$0.78	$4.64	$4.72	$5.60	$5.13	$5.09	$3.73
Priority 4	$0	$2.09	$3.43	$3.72	$3.17	$3.16	$0.05
Priority 5	$0	$2.27	$1.29	$3.23	$3.20	$3.93	$2.99
Priority 6	$0	$1.03	$0.88	$6.35	$6.15	$7.54	$5.45
Priority 7	$0	$0.22	$0.49	$0.44	$0.60	$0.11	$0
TOTAL NOAA	**$0.89**	**$12.74**	**$13.28**	**$21.86**	**$20.70**	**$22.32**	**$12.55**
TOTAL NOAA MODERNIZATION COSTS YEARS 1-5						**$90.90**	
RECURRING COSTS						**$12.55**	

[6] Years 1-5 include additions for modernization, beyond the existing expenditures reflected in the FY2024 Enacted column. The "Recurring Costs/O&M" column reflects the combined total of existing FY2024 costs, and new O&M funds needed to sustain new efforts produced by modernization beyond Year 5.

NOAA allocated **$0.89 million** of the FY 2024 enacted appropriation to produce its existing suite of volcanic services. For modernization efforts, NOAA produced cost estimates of **$90.9 million over 5 years** to complete specific activities, as detailed below in subsections A through G. Once these modernization deliverables are completed, NOAA estimates it would need recurring **annual funds of $12.55 million,** inclusive of its current expenditure of $0.89 million for existing services, to sustain those activities beyond the fifth year of implementation.

A. Priority #1: Improve service on monitoring and forecasting volcanic smog (vog)

Vog reduces air quality and is a hazard to human health. It is a persistent problem in Hawaii, and the Hawaii Interagency Vog information dashboard has been a highly successful effort to provide vog information and forecasts to the public. Within the information dashboard, vog forecasts are provided by the Vog Measurement and Prediction project (VMAP) run by the University of Hawaii. The forecasts use NOAA's HYSPLIT model coupled to an ensemble of model runs and utilize emissions estimates from the USGS.

The NAQFC system does not include predictions for vog. With the implementation of this plan, NOAA will support projects to bring vog elements to NWS forecast operations across its entire service area as vog can be an issue for locations other than Hawaii, including the Commonwealth of the Northern Mariana Islands (CNMI) and American Samoa. NOAA will work to transition vog modeling efforts at the University of Hawaii into NWS operations. Additional work will be done to strengthen NOAA's partnerships with other federal agencies (e.g., EPA), state agencies (e.g., Hawaii Department of Health), and other regional, Tribal, and local agencies, as appropriate, which support NOAA's work to improve air quality and vog decision support services.

The requested National Environmental Satellite, Data, and Information Service (NESDIS) resources would allow NESDIS to develop satellite products optimized for detecting, tracking, and characterizing vog as needed to accurately forecast air quality. Under this plan, NESDIS is fulfilling new requirements to identify vog and support vog forecasting workflows. Without customized satellite products, there will be a critical gap in vog observational capabilities.

B. Priority #2: Develop/improve operational plan to warn of volcanic debris flows/lahars from eruptive and non-eruptive events

Modernization activities within this priority focus on enhanced Impact-Based Decision Support Services (IDSS) provided by the NWS and equipment to better monitor river flooding. The NWS is developing new technology to track and provide IDSS. This software will modernize NWS's capabilities to track messaging and warnings provided to communities in the path of volcanic debris flows and lahars. Cost estimates portray the

amount necessary to add these capabilities to the new software. NWS will also work with the USGS as they investigate modernizing river gauge networks in Alaska.

C. Priority #3: Improve service on quantifying airborne ash hazards to aviation

This plan identifies cost estimates for the Alaska Direct Broadcast satellite downlink capability. This facility provides low latency satellite data that is critical to Anchorage VAAC operations and USGS volcano monitoring and cannot be obtained faster via other means. Similarly, Direct Broadcast antennas across the NWS Pacific Region provide polar-satellite data and products essential for the delivery of the NWS volcanic mission in that area. Near-real-time data from the Alaska and Pacific Region antenna systems offset the current polar satellite latency, which can exceed 50 minutes when obtained from other sources. There is no sustainable funding source to support these facilities long term. This data is critical to the VAACs for timely warning issuances and also important to volcano products and services issued by other NWS offices listed in Section IV.

NOAA will modernize satellite product support for volcano monitoring and aviation services via the VOLCAT tool. Additional VOLCAT capabilities, including eruption source parameters, are needed for NOAA VAACs to provide reliable Quantitative Volcanic Ash (QVA) products, as will be required by the International Civil Aviation Organization (ICAO) and to meet the objectives outlined in the FUMES Act. Funds will support the maintenance and sustainment of the new VOLCAT products. Web capability and Advanced Weather Interactive Processing System (AWIPS) modernization will be undertaken in support of QVA deployment. NOAA will continue development of data fusion and other modeling techniques in support of QVA and other volcanic emissions applications (HYSPLIT group).

D. Priority #4: Improve service on quantifying ashfall hazards

Development, transition to operations, and operations and maintenance of modeling systems are key modernization outcomes. NOAA will incorporate satellite information and other observations into the system, provide probabilistic forecasts of ashfall amounts and air quality information through the use of ensembles, and provide evaluation and verification metrics on the same platform where airborne ash information is available. This will also include elements of priorities 5 and 7.

USGS has capabilities to provide ashfall forecasts through a web application, while NOAA's airborne ash forecasting capability can be adapted to provide ashfall forecasts by using particle size distributions developed by USGS. Improvements to current systems to modernize volcanic hazard services will include: development of probabilistic forecasts; incorporation of relevant satellite and ground observations into modeling systems; increased data sharing and development between USGS and NOAA; shared platforms; implementation of polygon alerting for NWS products including Ashfall Advisory and

Warning; and observation systems for reporting ashfall accumulations on the ground. NOAA will use social, behavioral, and economic sciences (SBES) to study messaging and best practices for updating NWS impact statements and Call to Action statements for NWS Ashfall Advisories and Warnings.

E. Priority #5: Improve near-real-time data sharing to improve situational awareness and operational response

Operations in the U.S. VAACs are the key NOAA asset in monitoring, production, and dissemination of volcanic ash products. Products include the Volcanic Ash Advisory (VAA), Volcanic Ash Graphic (VAG), and eventually QVA. Full-time staffing needs at the VAACs are a major gap for NOAA in fulfilling this priority. Both the Anchorage and Washington VAACs cover very large areas of responsibility (AOR), often requiring VAAC staff to respond to multiple but separate volcanic events at the same time. Staffing levels at both VAACs are not adequate to support upcoming ICAO VAAC requirements related to QVA. These requirements will significantly increase workload, which is at historic levels of volcanic-related product issuances. Implementation of this plan will increase U.S. VAAC staffing by five additional Full Time Equivalent (FTE) at the Washington VAAC and six additional FTE at the Anchorage VAAC. FTE costs are captured below using current projections. Additional staffing would allow NOAA to fulfill the Act mandates, emerging volcanic ash needs, and other future requirements. Costs to address gaps in the VAACs critical infrastructure, training, and outreach are included in this plan.

The VAACs also require development, transition to operations, and operations and maintenance of capabilities to detect ash clouds, forecast ash cloud concentrations, and create and distribute hazard information. This includes:

- Staffing to allow for a meteorologist dedicated to monitoring and responding to volcanic eruptions at the AAWU.
- Upgrades to satellite products and services and user training that are critical for meeting ICAO QVA requirements. Upgrades would include a satellite image tile service supporting government-wide volcano monitoring.
- Ensuring that modeling systems incorporate satellite information and other observations into the system, provide probabilistic forecasts of airborne ash concentrations through the use of ensembles, produce emissions estimates and provide evaluation and verification metrics.
- VOLCAT development and maintenance.

F. Priority #6: Improve service on forecasting volcanogenic tsunami and submarine eruptions

NOAA conducts research on submarine volcanoes, but there is no operational program within NOAA to monitor submarine volcanism, predict submarine eruptions, or issue

warnings related to submarine and subaerial volcanic activity for potential volcanogenic tsunami threats. In addition, there is no program to document the impacts of submarine and subaerial eruptions on ocean chemistry and biology. NOAA and partners have collected data over decades and generated base maps of submarine volcanoes in the western Pacific, including the Mariana Arc, and have detected and studied multiple submarine eruptions. With additional data and analysis, NOAA will identify magmatically and hydrothermally active volcanoes, monitor them with hydrophones to detect activity, repeat bathymetric surveys to quantify changes due to eruptions and landslides, and track hydrothermal plume and vent chemistry for indications of changes in magmatic and hydrothermal systems. Using expertise within NOAA to identify shallow submarine and subaerial volcanoes with eruption potential or tsunamigenic threat and set up monitoring systems will improve the readiness and tsunami warnings and forecasts for local populations (e.g., in the Guam/Mariana Islands region and around American Samoa, the Aleutian islands, the U.S. Virgin Islands, and Puerto Rico). Finally, NOAA expertise will be used to examine the impacts of eruptions on ocean chemistry, geochemical cycles, and biology throughout the Pacific Ocean. Cost estimates identified for modernization work in this area include new coordination, collaboration, and potential joint work agreements with the USGS to develop capabilities within ocean chemistry, and to study the impact of Alaska volcanoes on ocean biogeochemical modeling. These work agreements would help NOAA and USGS maximize opportunities and prevent duplication of efforts.

Improving models of tsunami generation and propagation around island arcs, combined with better tsunami detection systems, has the potential to save lives. NOAA will improve tsunami detection, forecasts, and warnings for volcanogenic tsunamis using existing tsunami modeling and detection expertise and operational tsunami warning capabilities. With the decommissioning of the U.S. Navy hydrophone array formerly used for research at NOAA, there are few submarine hydrophones with real-time data to detect submarine volcanic and seismic activity. This greatly limits the ability to identify volcanic activity prior to a significant eruption. Satellite data can detect sea surface effects from active eruptions, but early warning capability depends on the installation of submarine detection systems. Cost estimates cover needed resources for the development, transition to operations, and operations and maintenance of submarine monitoring and modeling systems to predict and detect submarine eruptions in real time.

NOAA modernization efforts include the expansion of software capabilities to enhance IDSS for volcanogenic tsunamis and submarine eruptions, so that NOAA can capture partner requirements in this area and adequately support deployment of personnel to respond to volcanic events. In addition, investment in the NWS Operations Proving Ground (OPG) will facilitate R2O transition activities in support of these needs.

G. Priority #7: Improve efficacy of USGS and NOAA hazard information products

Cost estimates for volcanic hazards modernization efforts will support SBES studies focused on identifying and documenting value chains associated with hazard information products from USGS and NOAA. Each value chain will focus on a single use case, identifying the users and the decisions that are informed by these products. These value chains will serve as a foundation for future studies to quantify the societal value of new and enhanced products.

VI SUMMARY

Cost estimates developed for modernization activities and known gaps for NOAA's support of the System represent the resources needed to allow NOAA to modernize its volcanic hazards program and fully support USGS's priorities for volcanic hazards. The USGS will rely on the modernization of NOAA's capabilities to improve volcanic services, as NOAA capabilities are a key component to their envisioned future state of the System.

While modernization cost estimates are critical to ensuring that NOAA can complete these activities, NOAA also recognizes that this modernized state will require additional resources to develop, sustain, and execute them into the future. Cost estimates for operations and maintenance of the investments in modernization also play a critical role in considering the modernization of NOAA's capabilities.

NOAA and USGS will continue close collaboration to ensure completion of the identified priorities, depending on availability of resources. The priorities were developed by a diverse group of over 50 NOAA technical, scientific, operational, and budgetary experts working in close collaboration with USGS counterparts (see Appendix B for a detailed list of contributing NOAA offices). NOAA is eager to modernize its science and service suite in order to work closely with the USGS to provide better volcanic hazard information to the American public.

APPENDIX A - LIST OF ABBREVIATIONS

AAWU	Alaska Aviation Weather Unit
ANILCA	Alaska National Interest Lands Conservation Act
ANSS	Advanced National Seismic System
ARRA	American Recovery and Reinvestment Act
AVO	Alaska Volcano Observatory
A-VAAC	Anchorage Volcanic Ash Advisory Center
AWC	Aviation Weather Center
BLM	Bureau of Land Management
CalVO	California Volcano Observatory
CNMI	Commonwealth of the Northern Mariana Islands
CVO	Cascades Volcano Observatory
CWSU	Center Weather Service Unit
EEZ	Exclusive Economic Zone
FAA	Federal Aviation Administration
FISMA	Federal Information Security Modernization Act of 2014
FWS	U.S. Fish and Wildlife Service
FY	Fiscal Year
GPS	Global Positioning System
HVO	Hawaiian Volcano Observatory
IMW	Intermountain West
IRIS	Incorporated Research Institutions for Seismology
IT	information technology
MOU	Memorandum of Understanding
NAQFC	National Air Quality Forecast Capability
NASA	National Aeronautics and Space Administration
NEIC	National Earthquake Information Center
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NSF	National Science Foundation
NTIA	National Telecommunications and Information Administration
NVDC	National Volcano Data Center
NVEWS	National Volcano Early Warning System
QVA	Quantitative Volcanic Ash
R&D	Research and Development
RFP	Request for Proposals
STAR	NESDIS Center for Satellite Applications and Research
UNAVCO	University NAVSTAR Consortium
USFS	U.S. Forest Service
USGS	U.S. Geological Survey

VA	Volcanic Ash
VAA	Volcanic Ash Advisory
VAG	Volcanic Ash Graphic
VHP	Volcano Hazards Program
VSC	Volcano Science Center
VWO	Volcano Watch Office
WFO	Weather Forecast Office
W-VAAC	Washington Volcanic Ash Advisory Center
YVO	Yellowstone Volcano Observatory

APPENDIX B: COST ESTIMATE GROUP REPRESENTATION

In FY 2023, NWS Headquarters assembled a group of subject matter experts across NOAA line offices to develop an implementation plan with estimated costs to improve volcanic early warning and monitoring.

This 50+ member group consisted of technical, scientific, operational, and budgetary experts from the following groups across NOAA:

- OAR/Office of the Chief Financial Officer (CFO)/Formulation and Congressional Analysis/Formulation and Performance Management Branch
- OAR Air Resources Laboratory (ARL)
- OAR/Pacific Marine Environmental Laboratory (PMEL)
- NESDIS Washington Volcanic Ash Advisory Center (W-VAAC)
- NESDIS/Center for Satellite Applications and Research (STAR)
- NESDIS/Office of the Chief Financial Officer/Chief Administrative Officer (OCFO/CAO)/Program Analysis Branch
- NESDIS/Office of the Chief Financial Officer/Chief Administrative Officer (OCFO/CAO)/Budget Information Branch
- NWS Anchorage Volcanic Ash Advisory Center (A-VAAC)
- NWS/Office of the Chief Financial Officer (CFO)
- NWS Headquarters Analyze, Forecast, and Support Office (AFSO):
    - Severe, Fire, Public, and Winter Services Branch (AFS21)
    - Aviation and Space Weather Services Branch (AFS24)
    - Decision Support Integration Branch (AFS12)
    - Marine, Tropical, Tsunami Services Branch (AFS26)
    - Forecast Services Division (AFS2)
- NWS Alaska, Pacific, Central, and Western Region Headquarters
- NWS Aviation Weather Center
- NWS Congressional Affairs
- NWS/National Centers for Environmental Prediction (NCEP)/Environmental Modeling Center (EMC)
- NWS/STI/Social, Behavioral Sciences Program
- NOAA/Office of General Counsel (OGC), Weather, Satellites, and Research Section

The focus of this group was to collect a list of needed improvement projects for volcanic event monitoring and warning to be further refined via increased coordination with the USGS. This is due to similarities between the USGS and NOAA concerning volcanic warning and monitoring, determining priorities, limiting duplication, and identifying efficiencies.

APPENDIX C: REFERENCES

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