U.S. DEPARTMENT OF ENERGY | Office of Science

DOE/SC-ARM-13-022

Atmospheric Radiation Measurement (ARM) User Facility Management Plan

April 2024

ARM

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How to cite this document:

U.S. Department of Energy. 2024. Atmospheric Radiation Measurement (ARM) User Facility Management Plan. DOE/SC-ARM-13-022.

Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acronyms and Abbreviations

AACT	ARM-ASR Coordination Team
AAF	ARM Aerial Facility
ADC	ARM Data Center
ADO	Associate Director for Operations
ADR	Associate Director for Research
AMF	ARM Mobile Facility
AMSG	Aerosol Measurement and Science Group
ARM	Atmospheric Radiation Measurement
ARS	Access Request System
ASR	Atmospheric System Research
ASST	Architecture and Services Strategy Team
BNF	Bankhead National Forest
CACTI	Cloud, Aerosol, and Complex Terrain Interactions
CDCO	Chief Data and Computing Officer
CPMSG	Cloud and Precipitation Measurements and Science Group
DOE	U.S. Department of Energy
DQM	Data Quality Manager
EESSD	Earth and Environmental Systems Sciences Division
EMSL	Environmental Molecular Sciences Laboratory
ENA	Eastern North Atlantic
G-1	Gulfstream 159 aircraft
HPC	high-performance computing
HPSS	high-performance storage system
IMB	Infrastructure Management Board
LASSO	Large-Eddy Simulation (LES) ARM Symbiotic Simulation and Observation
LES	large-eddy simulation
NetCDF	Network Common Data Form
NSA	North Slope of Alaska
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory
PC	personal computer
PI	principal investigator
PNNL	Pacific Northwest National Laboratory
RH	relative humidity
SGP	Southern Great Plains

T	temperature
TBS	tethered balloon systems
TWP	Tropical Western Pacific
UAS	uncrewed aerial systems
UEC	User Executive Committee
USGCRP	U.S. Global Change Research Program
VAP	value-added product

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1.0 Mission and Vision

Mission and Vision Statements for the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) User Facility

Mission

The ARM user facility, a DOE Office of Science facility managed by the Office of Biological and Environmental Research, provides the climate research community with strategically located atmospheric observatories to improve the understanding and representation in climate and earth system models of clouds and aerosols as well as their interactions with the Earth's surface.

Vision

To provide the research community with the best array of field observations and supporting state-of-the-art data analytics to significantly improve the representation of challenging atmospheric processes in earth system models.

2.0 Introduction

The Atmospheric Radiation Measurement (ARM) user facility is a U.S. Department of Energy (DOE) Office of Science user facility. ARM was created in 1989 to provide an observational basis to improve the understanding of cloud processes and their interaction with radiation and aerosols and to improve the representation of these processes in earth system models and numerical weather prediction models (Stokes and Schwarz 1994). These goals continue to reflect ARM's current mission (Mather and Voyles 2013).

ARM began collecting measurements in 1992 at its longest-operating observatory in Oklahoma. Today, the ARM facility provides measurements of atmospheric properties and properties of the underlying land surface through the continuous operation of approximately 430 ground-based instruments. These instruments are distributed across three fixed-location atmospheric observatories and three mobile facilities that have been deployed to diverse locations ranging from the Arctic to the tropics to Antarctica. The ARM facility also includes aerial platforms that are typically used to augment measurements from the ground-based observatories. The ARM mobile facilities and aerial platforms are deployed on a proposal-driven basis. Data from ARM instruments are automatically collected and transferred to the ARM Data Center where they are processed, archived, and made openly available to the research community through a sophisticated Data Discovery portal.

This unique collection of measurement capabilities and supporting data infrastructure enables high-impact science aligned with the DOE Earth and Environmental Systems Sciences Division (EESSD) as well as with science interests of the broader atmospheric research community. ARM measurements contribute to a wide range of interdisciplinary science in areas such as meteorology, atmospheric aerosols, cloud processes, radiation, hydrology, and biogeochemical cycling and are used for satellite validation and the validation and development of atmospheric processes in earth system models. To facilitate the application of ARM data to earth system models, ARM has developed the Large-Eddy Simulation (LES) ARM

Symbiotic Simulation and Observation (LASSO) framework, which combines high-resolution model simulations with ARM observations. ARM has also developed a wide array of value-added data products, which aid in the application of ARM measurements by providing derived higher-order parameters, sophisticated quality assessment, and merging of parameters across multiple instruments.

The ARM facility is managed and operated by nine DOE laboratories. ARM staff at these laboratories are responsible for day-to-day operations of the ground-based and aerial ARM observatories, engagement with the user community, and the ongoing development of new measurements, data products, and data management capabilities. This document provides a brief description of the components of the ARM facility and the ARM management structure. Additional information can be found at the ARM website (www.arm.gov) and in a monograph that describes many aspects of ARM's first 20 years (Turner and Ellingson, 2017).

3.0 Oversight and Reporting Requirements

Oversight of the ARM user facility is provided by the DOE ARM Program Manager within the DOE Office of Science's Biological and Environmental Research and, through that program, a review panel of scientists, engineers, and program managers are selected to review the structure, interactions, and overall performance of the facility. This review is nominally chartered on a three-year cycle.

As a matter of government policy, all DOE user facilities, including the ARM facility, have several reporting requirements. ARM is required to report to the DOE ARM Program Manager where accountabilities are established by DOE's Office of Science's Biological and Environmental Research, and to the White House Office of Management and Budget (OMB). A primary requirement for ARM is the documentation of unique science users. Scientific users of the ARM facility are categorized as onsite, remote, or data users depending on how they use ARM facility resources for their scientific research.

4.0 Atmospheric Observatories

ARM operates long-term, fixed-location observatories in three different climatic regimes: (1) Southern Great Plains (SGP), (2) North Slope of Alaska (NSA), and (3) Eastern North Atlantic (ENA). Respectively, these sites address a range of climatic conditions: (1) variable midlatitude climate conditions, (2) land and land-sea-ice arctic climate, and (3) marine stratocumulus. In addition, two ARM Mobile Facilities (AMF1 and AMF2) are deployed for short-term field campaigns (approximately one year) at locations around the world. ARM is capable of supporting ground-based or ship-based deployments. A third mobile facility (AMF3) is currently deployed for an extended period in the Bankhead National Forest in Alabama. During 1996-2014, ARM operated instruments at three sites in the Tropical Western Pacific (TWP). While these sites are no longer operating, the data from them are available in the ARM Data Center archive. In addition, ARM includes aerial measurement capabilities that are typically deployed to augment the ground-based observatories. ARM is currently in transition between piloted aerial platforms. The Gulfstream 159 (G-1) aircraft was retired at the end of 2018 and a Challenger 850 (CL850) regional jet was purchased in 2019. The CL850 is expected to be ready for research operations in 2026. The locations of the ARM fixed-location observatories along with mobile and aerial facility deployments are shown in Figure 1. The characteristics of the ARM observatories are summarized below.

Figure 1. Locations of ARM fixed observatories, and the mobile, aerial, and ship-based deployments as of 2024.

Each ARM observatory includes an extensive set of instruments that measure the surface energy balance and the atmospheric properties that impact that balance, with a particular emphasis on cloud and aerosol measurements. Below is a list of core instruments provided at each of the ARM fixed-location observatories and with most mobile facility deployments.

- Surface meteorological sensors (T/RH/wind)
- Balloon-borne sounding system
- Weighing gauge and tipping bucket precipitation sensors
- Broadband solar and terrestrial infrared radiometers (up- and down-looking)
- Microwave radiometer; 2-channel (23/31 GHz) or 3-channel (23/31/90 GHz)
- Atmospheric Emitted Radiance Interferometer (infrared spectral radiances)
- All-sky imager
- In situ aerosol sensors including condensation particle counter and nephelometer
- Ceilometer (range of ~7km)
- Micropulse lidar (dual-polarization, backscatter-only)
- Doppler lidar
- 35 GHz profiling cloud radar
- 915 GHz or 1290 GHz radar wind profiler

Details on the specific nature of these and additional site-specific instrumentation can be found on the ARM website at http://www.arm.gov/instruments/. The ARM instruments page also includes information about instruments deployed on the ARM aerial platforms. These include an extensive array of in situ probes for observing cloud and aerosol properties along with the atmospheric state.

4.1 Southern Great Plains

The SGP observatory is managed by Argonne National Laboratory and consists of in situ and remote-sensing instrument clusters arrayed across north-central Oklahoma. The ARM SGP site is the most extensive climate research field site in the world. The site includes a Central Facility with extensive instrumentation for studying clouds, aerosols, precipitation, and their interaction with the surface energy balance (https://www.arm.gov/capabilities/observatories/sgp). The site also includes a network of ancillary sites that provide spatial information about surface properties, the surface energy balance, boundary-layer structure, and hydrometeor distributions.

Because the SGP observatory contains one of the largest collections of ground-based remote sensors and continuous measurements for atmospheric research in the world, it is an ideal and popular site for field campaigns, which range from hosting individual guest instruments to major collaborative field projects. From 2015 through 2019, measurements at the SGP site were augmented with LES model runs targeting shallow convection (https://www.arm.gov/capabilities/modeling/lasso). These LES runs are coupled with ARM observations with automated diagnostics and facilitate the application of ARM observations to global-scale model evaluation and development.

4.2 North Slope of Alaska

The NSA observatory is managed by Sandia National Laboratories and provides data about cloud and radiative processes at high latitudes. Routinely operating instruments include millimeter-wavelength cloud radar, micropulse lidar, several radiometers, and other instruments for atmospheric profiling and measurements of surface meteorology (https://www.arm.gov/capabilities/observatories/nsa). Data from these instruments are being used to understand cloud processes in the Arctic and to refine models and parameterizations as they relate to arctic climate. The site consists of a facility at Utqiagvik, Alaska, which includes a subset of the instruments available at the SGP Central Facility.

The NSA observatory provides a test bed for studies of climate change at high latitudes. In this region, ice (including snow) is the predominant form of condensed water most of the year, both in the air and on the surface. Ice and snow scatter, transmit, and absorb sunlight and radiant heat much differently than water. There is very little water vapor in the atmosphere, changing the impact of the atmosphere on the propagation of radiant energy, particularly radiant energy propagating upwards from the surface, and on the performance of some atmospheric remote-sensing instruments. The major "pumps" for the global ocean currents are at high latitudes, and there is good reason to believe that those pumps will be affected by climate-related changes in the atmosphere. High-latitude atmospheric processes over both land and sea must be characterized for incorporation into global climate models.

Beginning in August 2022, the NSA observatory now includes a supplemental site located several kilometers inland. This supplemental site provides information about gradients in precipitation and related parameters.

4.3 Eastern North Atlantic

The ENA site is located on Graciosa Island in the Azores archipelago and is managed by Los Alamos National Laboratory. The Azores is in the northeastern Atlantic Ocean, a region characterized by marine stratocumulus clouds. Response of these low clouds to changes in atmospheric greenhouse gases and aerosols is a major source of uncertainty in global climate models. The ENA fixed-site facility is located near the site of a previous ARM Mobile Facility deployment. The previous Azores deployment lasted approximately 20 months beginning in May 2009 and illustrated the scientific importance of measurements in this region (https://www.arm.gov/capabilities/observatories/ena).

4.4 ARM Mobile Facilities

The ARM Mobile Facilities (AMFs) were created to explore science questions beyond those addressed by ARM's current fixed sites. With instrumentation and data systems similar to the fixed sites, the AMFs are deployed to locations around the world for campaigns lasting 6 to 24 months. They are designed to operate in any environment, from the cold of the poles to the heat of the tropics. The AMF1 and AMF2 are deployed on a proposal-driven basis with proposal calls open to the general science community. Proposed deployment sites are logistically reviewed by the ARM Infrastructure Management Board (see section 7.2) and scientifically peer reviewed by the ARM Science Board.

The first ARM Mobile Facility (AMF1) was initially developed in 2005 and first deployed to Point Reyes, California. A second mobile facility (AMF2) was first deployed in 2010 to Storm Peak Laboratory near Steamboat Springs, Colorado. A full listing of mobile facility deployments is given in Table 1. The second mobile facility was originally designed to be more modular than the first; however, over time, the two facilities have evolved to be interchangeable. The AMF1 and AMF2 are managed and operated by Los Alamos National Laboratory.

A third mobile facility (AMF3) is intended for intermediate-length deployments of approximately five years. The AMF3 was originally deployed at Oliktok Point, on the North Slope of Alaska, approximately 300 km southeast of Utqiagvik, in 2013. The Oliktok deployment was managed by Sandia National Laboratories, which also manages the ARM observatory at Utqiagvik, Alaska. At Oliktok, the AMF3 provided arctic measurements in a region that experiences higher levels of aerosols due to the adjacent Prudhoe Bay oil fields and enabled development of uncrewed aerial systems and tethered balloon systems capabilities because DOE managed a region of restricted air space over Oliktok as well as an adjacent warning area. In keeping with the mission of intermediate-length deployments for the AMF3, the observatory ended operations at Oliktok in the spring of 2021 and is currently being deployed to the Bankhead National Forest (BNF) in northwestern Alabama. The AMF3 deployment is managed by Argonne National Laboratory The selection of the general southeast United States location was made by DOE management based on science priorities and a 2018 workshop (U.S. Department of Energy, 2019). An AMF3 southeast United States science team was selected based on peer-reviewed proposals to develop a science plan for the AMF3 southeastern U.S. deployment and provide scientific guidance to ARM on site selection, site layout, and instrumentation needs to address science questions.

Table 1. ARM mobile facility deployment campaign names, locations, and dates.

Campaign*	Location	Operation Period
MASRAD	Point Reyes, California	Mar – Sep 2005
RADAGAST	Niamey, Niger	Jan 2006 – Jan 2007
COPS	Heselbach, Germany	Apr – Dec 2007
Aerosol Indirect	Shouxian, China	May – Dec 2008
CAPMBL	Graciosa Island, Azores, Portugal	May – Dec 2009
StormVEx	Steamboat Springs, Colorado	Nov 2010 – Apr 2011
GVAX	Nainital, India	Jun 2011 – Mar 2012
TCAP	Cape Cod, Massachusetts	Jul 2012 – Jun 2013
MAGIC	Eastern Pacific Transects	Oct 2012 – Sep 2013
Oliktok	North Slope of Alaska	Oct 2013 – Jun 2021
BAECC	Hyytialla, Finland	Feb – Sep 2014
GOAmazon	Manaus, Brazil	Jan 2014 – Nov 2015
ACAPEX	Eastern Pacific	Jan – Feb 2015
AWARE	McMurdo/WAIS, Antarctica	Nov 2015 – Jan 2017
LASIC	Ascension Island/South Atlantic	Jun 2016 – Oct 2017
MARCUS	Southern Ocean Transects	Oct 2017 – Apr 2018
CACTI	Sierras de Cordoba, Argentina	Oct 2018 – Apr 2019
COMBLE	Andenes, Norway	Dec 2019 – May 2020
MOSAiC	Central Arctic	Oct 2019 – Oct 2020
TRACER	Houston, Texas	Oct 2021 – Sep 2022
SAIL	Crested Butte, Colorado	Sep 2021 – Jun 2023
EPCAPE	La Jolla, California	Feb 2023 – Feb 2024
BNF	Moulton, Alabama	Mar 2024 – TBD (5+ years)
CAPE-k	Cape Grim, Tasmania, Australia	Apr 2024 – Sep 2025
CoURAGE	Baltimore, Maryland	Dec 2024 – Nov 2025

4.5 ARM Aerial Facility and Tethered Balloon Operations

As an integral measurement capability of the ARM facility, the ARM Aerial Facility (AAF), including piloted aircraft and fixed-wing uncrewed aerial systems (UAS), is managed by Pacific Northwest National Laboratory (PNNL) and provides airborne measurements required to answer science questions proposed by the DOE Atmospheric System Research (ASR) Science Team and the external research community. A G-1 aircraft served as the primary aerial platform for the AAF from 2010 through 2018. During that time, the G-1 flew missions in the United States, Brazil, Portugal, and Argentina. The G-1 was retired at the end of 2018 and a Challenger 850 regional jet has been procured to replace the G-1 as the primary ARM aerial platform. The Challenger 850 is undergoing modifications, equipment integration, and testing over the next few years and is expected to be ready for research flights in 2026.

ARM has experimented with small fixed-wing UAS platforms and currently operates a midsize UAS called the ArcticShark with a payload capacity of approximately 100 pounds. To date, the ArcticShark has operated in clear air conditions over the ARM SGP site.

The ARM facility also includes a tethered balloon system (TBS) managed and operated by Sandia National Laboratories. The TBS provides an efficient, effective mechanism to obtain vertical profiles of atmospheric state, aerosol, and cloud properties over an ARM site. To date, the TBS has operated at Oliktok Point and the Southern Great Plains and as part of mobile facility deployments in Houston and Colorado. Plans are underway to deploy the TBS at other locations including mobile facility deployments in coming years.

Both the fixed-wing platforms and the TBS are deployed on a proposal-driven basis. Over the past few years, a call for proposals for the TBS has been published annually around the start of the calendar year. These calls have included coordination with DOE's Environmental Molecular Sciences Laboratory (EMSL) user facility, which provides detailed chemical analysis of samples collected on the TBS.

The TBS is typically also able to include a few guest instruments. Data obtained from aerial platforms are documented, checked for quality, integrated into the ARM Data Center, and made available in a timely and consistent manner for use by the scientific community.

5.0 Science Data Products

Instruments do not typically provide direct measurements of geophysical quantities and sometimes require complex algorithms to retrieve important variables, such as liquid water path, droplet effective radius, or chemical composition of aerosol particles. ARM provides several types of science data products to provide measurements of complex geophysical parameters or to facilitate the use of ARM measurements.

5.1 Value-Added Products

Value-added products (VAPs) are higher-order products that have been analyzed and processed to ease scientists' use of ARM data in atmospheric research and earth system models. VAPs usually combine measurements from multiple instruments and typically provide an enhanced assessment of data quality.

5.2 LASSO Activity

LASSO enhances ARM observations by using LES modeling to provide context and a self-consistent representation of the atmosphere surrounding ARM sites. The initial implementation targeted shallow clouds at ARM's Southern Great Plains atmospheric observatory. LASSO is now expanding to other phenomena and sites, starting with deep convection observed during ARM's Cloud, Aerosol, and Complex Terrain Interactions (CACTI) field campaign in Argentina.

6.0 Data Services

ARM Data Services are managed by Oak Ridge National Laboratory (ORNL) and provide facility-wide leadership, management, and operations of end-to-end data management to make data collected at ARM facilities available and accessible. Data Services staff at Oak Ridge are supported by software developers across the ARM facility. ARM data are processed to a standard Network Common Data Form (NetCDF) format and are available to anyone through the ARM Data Discovery portal. Many ARM data products

are available to the science community within about a day of collection at field sites. Individuals using ARM data and requiring significant computational resources due to large data volume or computational intensity may request access to ARM's high-performance computing (HPC) cluster, known as Cumulus.

The following functional groups ensure that ARM data processes are staying current with modern computational technologies and best practices in earth system data management.

The site data systems team is responsible for the deployment, sustainability, operations, and maintenance of a high-performance, secure, computing and communications environment that bridges measurement collections from instruments to the ARM Data Center (ADC). The site data system also provides onsite processing and early access to preliminary data plots and metrics for special deployments and field campaigns.

The data flow software team is responsible for software and tool development that supports data flow and data flow monitoring, which includes collections, site transfer, and tools.

The ADC team provides overall cyberinfrastructure and the data processing environment for ARM infrastructure and science users. The ADC team also provides data processing and analytical platforms for research users.

The ADC data ingest and processing team is responsible for the timely collection, processing, value-added processing, and delivery of data products from ARM research sites to the ARM archive. These operations and engineering activities are closely coordinated with the ADC archival team and site data system team to optimize data transfer and storage rules, data collection metrics, and overall processing performance.

The ADC archival team is responsible for validation and verification of data released by the ADC data ingest team. After the data are validated, they are sent to deep archive within the ORNL high-performance storage system (HPSS). A backup copy is also sent to the HPSS at Argonne National Laboratory to preserve the archive in case of a catastrophic event. A subset of the data is available on spinning disk for quick access and distribution to end users.

The data reprocessing team is responsible for timely and accurate data product reprocessing to resolve data quality issues, automation of reprocessing workflow, and effective use of ARM high-performance computing resources for large reprocessing tasks.

The metadata workflow and field campaign data management team manages metadata operations for baseline, VAP, principal investigator (PI), evaluation, and field campaign data products. The metadata team is responsible for developing tasks, milestones, and priorities associated with metadata workflow and standards across ARM processes and data products

The database and workflow design team is responsible for providing technical leadership in the design and implementation of database development that improves functionality of ARM databases across ARM processes and data products. This includes mitigating redundancies and improving efficiencies in the metadata workflow. The ADC database development team works with cross-laboratory development teams to understand database needs including ingests and VAPs, website, user services, Data Discovery, data quality, asset management, site operations, field campaigns, and staff and user information.

The instrument management, data and metadata tools team is responsible for developing and operating user web tools related to generation of metadata, metadata management, user registration, operations system status, access requests, data citation, data quality and corrective maintenance reporting tools, Data Discovery, and retrieval.

The ARM Data Services systems and hardware team is responsible for operations and maintenance of ADC hardware, network configuration, deployment of software packages, license management, user account management, adhering to DOE cybersecurity policies and procedures, evaluating and adapting to new storage, computing, network, and software solutions, providing system admin support to data product generation teams and data services teams, interfacing with the site data systems team to support end-to-end data flow and monitoring, interfacing with the Oak Ridge high-performance computing and information technology groups for administration and operations of ARM clusters, and interfacing with Argonne's high-performance storage systems group for offsite backup.

The ADC compute clusters team is responsible for the design, implementation, and operation of the ARM Next-Generation Computing facility, support development, optimization and porting of ARM computational workflows to the HPC environment, and operational support to ARM HPC projects such as the LASSO framework.

7.0 Management Structure

The ARM facility management structure is designed to provide representation of the diverse facility components and representation of the user community (see Figure 2). Components of the facility are managed and operated by nine DOE national laboratories: Argonne, Brookhaven, Lawrence Berkeley, Lawrence Livermore, Los Alamos, National Renewable Energy, Oak Ridge, PNNL, and Sandia. The facility components are managed on a day-to-day basis by the Infrastructure Management Board, with oversight by the DOE ARM Program Manager. The ARM facility serves the broad international climate and atmospheric research community; however, there is a particularly close link between ARM and the Atmospheric System Research (ASR) Program.

7.1 DOE ARM Program Manager

The DOE Program Manager directs and empowers the ARM budgeting, planning, coordination, and management of activities within the ARM structure.

7.2 Infrastructure Management Board

The Infrastructure Management Board (IMB) consists of the Director, Associate Director for Operations, the Associate Director for Research, Chief Data and Computing Officer, Instrument Operations Manager, Aerial Facility Manager, and the Site Managers for each of the ARM observatories. These positions are described below. The members of the IMB are responsible to DOE management for their respective ARM facility components and serve as the primary points of contact for their respective areas. The IMB meets weekly with the DOE Program Manager (usually via videoconference) to discuss a broad range of matters pertaining to the management of the ARM facility. The IMB is responsible for the overall ARM budget that is proposed to the DOE Program Manager for review and approval. The IMB assesses the impacts of

all requests for use of the ARM facility and screens science requests for use of the ARM facility prior to consideration by the Science Board. It also provides information regarding the feasibility, cost, and facility impact associated with each request. The IMB works with DOE management on strategic planning using input from the user community as guidance for how to best configure the facility to serve research needs.

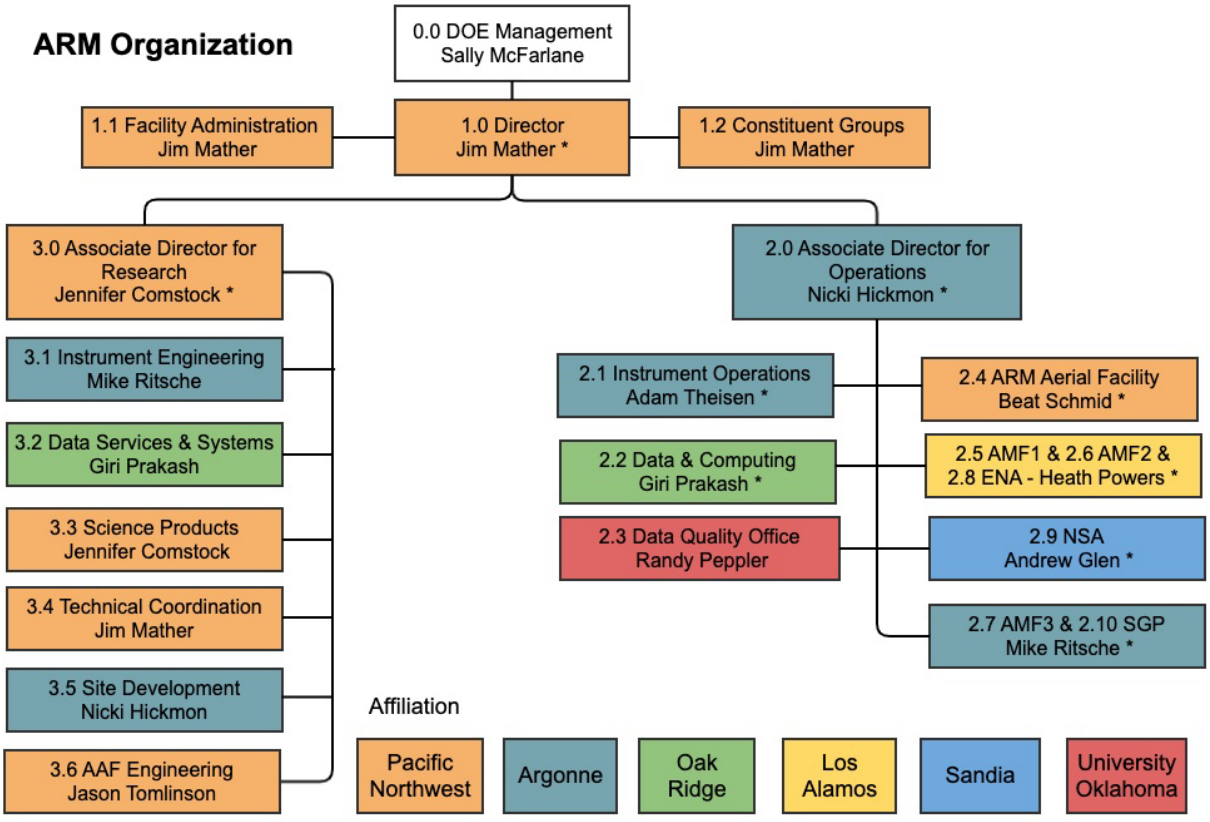

Figure 2. ARM user facility management structure. Asterisks (*) represent roles that are members of the Infrastructure Management Board. Box colors indicate institution affiliation.

7.2.1 Director

The Director is the chair of the IMB, reports directly to the DOE ARM Program Manager, and is responsible for ARM day-to-day technical activities, strategic planning, budgeting, engineering development, contracting, property management, and interactions with the science community. The Director provides scientific leadership and is responsible for leading the development of the ARM vision and the strategy to achieve that vision. The Director oversees the implementation of user requirements with the Associate Director Operations for the operation and enhancement of the facility. The Director coordinates with the Associate Director for Research for the implementation of engineering services required for the operation and enhancement of the facility. Responses to review committees are coordinated through this office. The Director works with the DOE Program Manager to coordinate, plan, and implement communications with the science community, and ensures DOE user facility policies and reporting requirements are followed. To develop and advance the ARM vision, the Director oversees the

ARM User Executive Committee (UEC), participates on the ARM-ASR Coordination Team (AACT), and engages with the user community through a variety of forums. The Director is the primary point of contact for ARM.

7.2.2 Associate Director for Operations

The ARM Associate Director for Operations (ADO) is responsible for ensuring efficient, effective, and continuous operation of instruments and data systems. The ADO reports to the ARM Director. The ADO is responsible for coordinating the overall field campaign screening process within the IMB and for resolving user issues that might arise regarding external science projects conducted at the ARM facility. The ADO serves as the communication link between the ARM IMB and the ARM Science Board. The ADO works with the Director to promote the use of the ARM facility by the external scientific community. The ADO works with the Director to develop and implement the facility operational strategy.

7.2.3 Associate Director for Research

The Associate Director for Research (ADR) is responsible for the oversight of all ARM engineering tasks. The ADR reports directly to the Director and is responsible for developing priorities within and across the engineering areas and communicating priorities to each of the engineering area leads. The ADR is responsible for tracking the progress of engineering tasks and communicating progress to the Director. The ADR works with the leaders of each of the engineering areas to establish and track performance metrics that measure progress of tasks toward goals and provide a mechanism to feed improvements back into the engineering system. The ADR also works to define and refine engineering workflows for the facility and makes sure that the fundamentals of the engineering process are consistently applied across the facility.

7.2.4 Chief Data and Computing Officer

The Chief Data and Computing Officer (CDCO) provides management and leadership for the ARM computing environment, product delivery, facility user account database, and process and science user interaction. This includes the end-to-end definition and operational execution of collection, processing, and delivery of quality-assured measurement data products from our research sites to the ARM Data Center and discovery and distribution to the scientific user community.

The CDCO leads the Architecture and Services Strategy Team (ASST; see section 8.2).

7.2.5 Aerial Facility Manager

The ARM Aerial Facility (AAF) Manager is responsible for the safe and effective operation of aerial measurements including crewed and uncrewed fixed-wing aircraft and associated measurement systems as well as coordination with ARM management, ASR science, and the general science community to define and adapt aerial measurement strategies for approved field campaigns and advance the aerial facility to meet the needs of ARM facility users. Responsibilities also include the timely processing, quality assessment, and delivery of aerial measurements data to the science community.

7.2.6 ENA, AMF1, and AMF2 Site Manager

The ENA, AMF1, and AMF2 Site Manager is responsible for the safe and effective management of the ENA, AMF1, and AMF2 research facility assets. This includes the instrumentation, data systems, facilities, and personnel, as well as ground-based and aerial support for ARM field campaign activities. An important responsibility is the cooperative relationship with local and regional stakeholders.

7.2.7 NSA Site and TBS Manager

The NSA Site Manager is responsible for the safe and effective management of the Utqiagvik research facility and TBS deployments. This includes the instrumentation, data systems, facilities, and personnel, as well as ground-based and aerial support for field campaign activities. An important responsibility is the cooperative relationship with local and regional stakeholders.

7.2.8 SGP and AMF3 Site Manager

The SGP and AMF3 Site Manager is responsible for the safe and effective management of the SGP and AMF3 research facilities and assets. This includes instrumentation, data systems, facilities, and personnel, as well as ground-based and aerial support for field campaign activities. An important responsibility is the cooperative relationship with local and regional stakeholders.

7.2.9 Instrument Operations Manager

The Instrument Operations Manager is responsible for the effective planning and mentorship of ARM instrumentation. Such efforts include management of mentorship activities, development of the ARM instrument plan, including specific plans for aerosol and radar instrumentation, coordination of new instruments with engineering, and effective tracking of instrument information.

7.3 IMB Support

A range of specialists support ARM's IMB in the performance of its various functions. These roles are described below.

7.3.1 Technical Administrator

The ARM Technical Administrator has a variety of responsibilities supporting the operation of the ARM Director's Office. The Technical Administrator is responsible for communications through the Director's Office, maintaining facility records in the PNNL electronic records database, and managing travel and other logistics for members of the Director's Office. The Technical Administrator reports to the Director.

7.3.2 Field Campaign Administrator

The ARM Field Campaign Administrator is responsible for coordinating the overall field campaign screening process within the IMB. This is the communication link between ARM and the field campaign PI and the IMB and the Science Board. The ARM Field Campaign Administration works with the IMB to

promote the use of the ARM facility by the external scientific community and to resolve user issues that might arise regarding external science projects conducted at ARM. The Field Campaign Administrator reports to the Associate Director for Operations.

7.3.3 Financial Coordinator

The financial coordinator maintains the integrated budget, develops and maintains routine and special financial reports, and manages funding flow for ARM subcontracts. The financial coordinator reports to the Director.

7.3.4 Contracting and Procurements Manager

The contracting and procurements manager is responsible for managing the contracting process for procurements and service contracts placed through the ARM Director's office. These include all capital procurements, instruments, and computers outside the ARM Data Center. They also include a variety of service contracts including inter-laboratory contracts. Responsibilities include maintaining regular contact with PNNL contracting staff to ensure continued progress on contracts from the request for proposals through to contract close-out, maintaining tracking documentation for contracting actions, and working with the director and the IMB to ensure consistency between the integrated budget and contracting actions. The contracting and procurements manager reports to the Director.

7.3.5 Property Manager

The Property Manager is responsible for tagging new equipment as it comes into the ARM facility and maintaining records for ARM property in the PNNL property database and the ARM Asset Management system. The Property Manager coordinates with mentors and staff at the observation facilities to ensure that property information in Asset Management is up to date. The Property Manager reports to the Director.

7.3.6 People Database Affiliations Manager

The People Database Affiliations Manager is the primary point of contact managing the roles, group leads, email lists, and email list managers in the People Database. These People Database metadata are used for populating web pages and routing internal communications. The People Database Affiliations Manager reports to the Director.

7.4 ARM-ASR Coordination Team (AACT)

As a user facility, ARM serves the broad climate research community. However, ARM has a particularly close relationship with ASR, a partner program within the DOE Office of Science's Biological and Environmental Research (https://www.energy.gov/science/ber/biological-and-environmental-research). The ASR program supports basic research related to clouds, aerosols, and precipitation interactions based on observations from the ARM facility, laboratory experiments, and process modeling (https://asr.science.energy.gov).

DOE has established the AACT (https://www.arm.gov/connect-with-arm/organization/aact), which includes members from ARM and ASR leadership, to foster communication between ARM leadership and users, ASR scientists, and DOE program managers.

A key role of the AACT is to help plan the annual Joint ARM User Facility/ASR Principal Investigator Meeting.

8.0 Additional ARM Facility Roles

The ARM user facility spans the full range of activities associated with atmospheric observations from the operation of instruments at field sites to the distribution of processed data. Functions associated with the ARM facility are carried out at nine DOE laboratories and a variety of collaborating institutions. The high-level organization was summarized in Figure 2. There are too many roles to describe in this document, but a subset of roles that are particularly important for engagement with external stakeholders are described in this section.

8.1 Instrument Mentors

ARM currently operates more than 430 instrument systems that provide ground-based observations of the atmospheric column. To keep ARM at the forefront of climate observations, the ARM infrastructure depends heavily on instrument scientists and engineers, known as instrument mentors (http://www.arm.gov/instruments/contacts). Lead mentors must have an excellent working knowledge of their instrument systems as well as an understanding of instrument applications to studying relevant processes to ensure research-quality instrument performance. Instrument mentors report to the Instrument Operations Manager.

8.2 Architecture and Services Strategy Team

The Architecture and Services Strategy Team (ASST) provides facility-wide vision, strategy, and leadership for the ARM computing environment to provide a flexible and extensible computing architecture and resources for high volume, high processing rates, and complex relationships between data elements.

The ARM software development and operations team is distributed across all nine DOE laboratories associated with the ARM facility. The ASST is responsible for representation of and communication with the software development and operations team members. The ARM CDCO is tasked to effectively coordinate the participation and contributions of ASST.

8.3 Data Quality Office

The Data Quality Manager (DQM) and the making up the Data Quality Office guide and manage a program to ensure the data collected at the ARM facility sites meet the data quality objectives and tolerances as defined by the science user community and ARM (http://www.arm.gov/data/quality).

8.4 Translators

The ARM science translators are liaisons between the ARM science community and the ARM infrastructure and are responsible for understanding community needs related to value-added products. The primary responsibility of the translators is to work with scientists and software developers to implement scientific algorithms to create robust data products that can be routinely applied to ARM data. ARM translators develop project plans that follow the VAP workflow, use ARM standards for each data development project, are required to host design reviews, and report progress to the Lead Translator. Translators report to the ADR.

8.5 Data Analysts

The ARM data analysts work to enhance data utility. This work could involve development of data products that addresses capability gaps, improves the use of ARM data, or supports modeling community activities. They will also engage in data characterization that helps describe the applicability of ARM measurements and derived geophysical parameters, provides metadata to add spatial context to ARM measurements and epochs, and helps to quantify measurement and data product uncertainty. ARM data analysts report to the ADR.

9.0 Constituent Groups

Beginning with the radar science and operations group in 2012, several groups have been formed over the past few years to facilitate communications between ARM and its user community. Two of these groups focus on particular measurement areas (clouds and precipitation and aerosol) while the User Executive Committee includes representation that is intended to span the range of science user areas of interest. In each case, the group reports to the ARM Director with the expectation of providing feedback to improve the ARM facility and its service to the user community.

9.1 User Executive Committee

The User Executive Committee (UEC or Committee) is an independent body charged with providing objective, timely advice and recommendations to the leadership of the ARM user facility with respect to the user experience. The Committee reports directly to the Director in his/her capacity as chair of the ARM Infrastructure Management Board (IMB) and serves as the official voice of the user community in its interactions with ARM management. This charter defines the membership, responsibilities, and structure of the UEC.

9.2 Cloud and Precipitation Measurement and Science Group

The ARM Cloud and Precipitation Measurements and Science Group (CPMSG) brings together members of the ARM instrument operations, engineering, and translator teams with the ARM science community to improve the performance and science impact of ARM's measurements of clouds and precipitation. The members of the CPMSG work toward this goal by confronting science needs from the broader research community with operational constraints of the ARM facility.

A driving consideration for the group should be how resources can best be applied to measurements of cloud and precipitation properties and the development of associated data products to increase the scientific impact of these measurements.

The CPMSG, reporting directly to the ARM Director, provides constructive recommendations regarding the operation, characterization, and development of instruments yielding cloud and precipitation measurements along with the development of data products derived from these instruments and the identification of measurement gaps.

9.3 Aerosol Measurement and Science Group

The Aerosol Measurement and Science Group (AMSG) leads the identification of scientific performance goals, objective task prioritization, measurement gaps, data products, data processing algorithms, approaches to quality assessment, and metrics necessary to couple measurement products to the needs of the climate science community and for reporting progress toward these goals and objectives to DOE ARM and ASR management. The AMSG will be responsible for working with the ASR and ARM science communities to identify the measured parameters and the architecture of these parameters required at the ARM user facility to improve understanding of the impact of aerosol and trace gases on climate processes that affect climate and related model simulations and forecasts. The role of the AMSG is not to set scientific priorities or objectives in aerosol research, but to provide expertise on the measurements and processes required to best meet the aerosol science objectives of the ARM facility and ASR program.

10.0 Logistics for Users

The ARM facility is managed as a DOE user facility despite its geographic displacement from major DOE installations. DOE guidelines for visitors and access are followed in all cases. Formal procedures are used to accommodate users at the ARM sites. Activities at the ARM facility fall under DOE's safety and security policies. Therefore, requests for visits and data accounts on user data systems by foreign nationals require substantial lead-time for approval.

Users conduct several major types of activities, including:

- A request for data from the ARM Data Center (data users)
- A visit to a site (on-site users), including conducting an ARM field campaign
- Remote access to ARM computing facilities at the ADC, including the HPC cluster, or one of the ARM sites (remote users).

All user requests are managed through the unified user registration process. The user registration form collects information that is required for ARM to effectively engage with users and that is required by DOE. This required information includes name, contact information, home institution, citizenship, project title, primary source of support, and type of project (proprietary or non-proprietary).

10.1 Requests for Archived Data

Any scientist can request data from the ARM Data Center. The request process includes the creation of an "ARM user account" using the interface available on the ARM website. This account creation provides ARM with information about how to contact the user (email, phone number, etc.) and their affiliation (educational status, institutional status, etc.), area of research, and a few other details. The ARM Data Center keeps detailed records about data requests that enable future reports about "who uses how much of which data types from where and what time periods." Data from both routine and field campaign measurements are accessible, and data access is monitored by ADC operations.

10.2 Site Visits (Real or Virtual)

A request for a site visit or an account on a site data system is submitted using the Access Request System (ARS; https://armcrf.servicenowservices.com/nav_to.do?uri=%2Fhome.do). The ARS provides advance notice of onsite visits to site managers to coordinate support. The system also provides the means for applicants to request and for administrators to manage access to onsite and offsite computer facilities (virtual access). Submitting an ARS request allows users to easily communicate their needs to ARM site managers and operations staff for site support and network or remote access. It also provides a method of continuing communications with ARM personnel if requirements change or if unforeseen complications or issues arise. Several types of site and computer access requests can be made. All forms are found on the ARM website and should be submitted online.

10.2.1 Physical Onsite Visit Request

A physical request submission (ARS form) is required to visit an ARM site. Advance notice of a site visit through this form is necessary to meet DOE requirements, ensure the safety of onsite visitors, help provide whatever support is needed during the visit, and make the experience of the visitor as productive and pleasant as possible. This form also is necessary for scheduling the activities of site staff.

10.2.2 Request to Connect a Visiting (Onsite) Device (PC or Instrument) to an ARM Observatory

A special form is used for requesting access to an ARM network. An ARS form is also used for requesting permission to connect a PC (personal computer), instrument, or other device to an ARM site network whether the requester will be present at the site or not.

10.2.3 Remote (Offsite) Network Access to any Instrument or Computer System at an ARM Observatory

This type of submission should be used to request network access to a system located on an ARM facility from a location outside the facility. This might be done to access ARM data or data from a guest instrument in near-real time during a field campaign.

10.3 Field Campaign

A field campaign is a research activity that is proposed, planned, and implemented at one or more research sites. ARM field campaigns involve an augmentation or change in the routine data acquisition operation of a site. Field campaigns range from small activities, such as deployment of guest instrumentation at an observatory, changes in instrument sampling strategies, or extra radiosonde launches, to major activities, such as an aircraft or TBS campaign or deployment of an ARM Mobile Facility.

10.3.1 Field Campaign Proposals

Field campaigns may be proposed by any member of the scientific community. Information and guidelines about proposing field campaigns can be found at https://www.arm.gov/research/campaigns. All field campaign proposals require submission of a preproposal. The IMB is responsible for reviewing preproposals and related facility infrastructure needs, assessing the feasibility and costs associated with the preproposal, determining whether the proposed activities fit within ARM's mission, and making recommendations on whether a full proposal should be requested. Preproposals are categorized based on the level of logistical and financial support requested and the extent to which the request might impact ongoing scientific activities.

Activities with minimal cost and impact to ARM may be approved by the IMB based on the preproposal. Campaigns that exceed a certain cost threshold, including AMF and AAF deployments, require submission of a full proposal and are reviewed by the ARM Science Board. The Science Board is an ad hoc review panel that is convened each year by the DOE Program Manager to review proposals for use of the ARM facility. Panel members consist of both DOE-funded scientists and members of the broader scientific community and are chosen to cover the broad range of scientific research areas supported by ARM. Intermediate-level campaigns such as TBS campaigns may require an abbreviated proposal and be subject to peer review. The lead scientist on a preproposal is notified several weeks after submitting the preproposal as to whether a full or abbreviated proposal will be requested. Full and abbreviated proposals are peer-reviewed, with criteria including scientific and technical merit of the proposed project and appropriateness of the proposed method or approach.

10.3.2 User Responsibilities

The PI, or lead scientist, of an accepted field campaign is required to provide an abstract for the ARM website. The PI of an AMF or AAF deployment or smaller field campaign with a higher-than-normal level of complexity is required to provide a campaign science plan that defines experiment goals, participant roles, critical measurements, and other campaign details. Typically, a field campaign results in the generation of one or more new data sets beyond the standard ARM data sets. If the non-standard data set is generated by the PI (for example, from a guest instrument), the PI is required to submit the data to the ARM Data Center. The PI is also required to submit a final report within six months of the completion of the campaign. The level of detail expected in final reports depends on the complexity of the campaign but should describe what occurred and summarize the campaign outcomes, including the degree to which objectives were achieved.

10.4 User Account Request

A user account is required to access ARM data, observatories, and computing resources. Field campaigns sometimes require near-real-time access to ARM datastreams, thereby requiring access to a site research system. Access to ARM sites' research systems or networks is intended to provide local onsite support for visiting scientists and engineers using the facilities for scientific research, for ARM infrastructure staff, or for users requiring access to local instruments. These accounts are approved for a limited time.

11.0 Data Policies

DOE has established a policy for data management that emphasizes the importance of data management for scientific discovery. The policy underlines the importance of sharing and preserving data. All scientific data and data products that result from ARM-supported research are archived (with appropriate documentation) in the ARM Data Center. ARM-supported data are required to be submitted and are maintained as part of the permanent ARM Data Archive. All ARM data, including data originating from ARM-supported field campaigns, are available on a free-and-open basis and are publishable on receipt with acknowledgement of ARM as the source. ARM's data policy was originally derived from the data policies established by the U.S. Global Change Research Program (USGCRP) in 1991, which encourage "full-and-open" access to data and research results (http://www.gcrio.org/USGCRP/DataPolicy.html).

12.0 Communications and Outreach

The ARM facility supports outreach efforts to the science community, communities located near its research sites, and to the general public. The ARM communications team is responsible for managing the ARM website, publishing ARM documents, and raising awareness in the community of ARM activities and of the ARM facility, and for relaying scientific results and successes to the scientific community and DOE management. The communications team regularly updates the ARM website to include current events and activities at ARM observatories, new research results, and a compilation of summaries of published ARM research results or other significant ARM accomplishments. The communications team facilitates prompt and comprehensive responses to inquiries and information requests from scientists and agency personnel and publicizes successful ARM research stories in appropriate venues. Communication specialists develop materials that provide up-to-date information on instrumentation, data, and project results from ongoing science at the ARM observatories. The communications team makes presentation materials available for ARM users to use at meetings and other scientific venues. The communications team also engages in local outreach at each of its extended deployments (fixed sites and mobile facility deployments). The mission of local outreach is to raise awareness in the local community of ARM and its purpose for deploying in a particular area.

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