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ARM FY2022 Radar Plan

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ARM

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Acronyms and Abbreviations

AMF	ARM Mobile Facility
ANL	Argonne National Laboratory
ARM	Atmospheric Radiation Measurement
ARSCL	Active Remote Sensing of Clouds
CMAC2.0	Corrected Moments in Antenna Coordinates
COMBLE	Cold-Air Outbreaks in the Marine Boundary Layer Experiment
CSAPR2	C-Band Scanning ARM Precipitation Radar (2nd generation)
CSU	Colorado State University
CY	calendar year
DOE	U.S. Department of Energy
DQ	Data Quality
EIKA	extended interaction klystron amplifier
ENA	Eastern North Atlantic
EPCAPE	Eastern Pacific Cloud Aerosol Precipitation Experiment
FY	financial year
IOP	Intensive Operational Period
KAZR	Ka-band zenith radar
MICROBASE	Cloud Microbase-KAZR Profiles (KA) Value-Added Product
MICROBASEKAPLUS	Improved MICROBASE Product with Uncertainties
MMCG	Mapped Moments to a Cartesian Grid
MOSAiC	Multidisciplinary Drifting Observatory for the Study of Arctic Climate
NSA	North Slope of Alaska
PI	principal investigator
PNNL	Pacific Northwest National Laboratory
Py-ART	Python-ARM Radar Toolkit
QVP	Quasi-Vertical Profiles
RF	radio frequency
SACR	Scanning ARM Cloud Radar
SACRGRID	gridded SACR value-added products
SAIL	Surface Atmosphere Integrated Field Laboratory
SAPR	Scanning ARM Precipitation Radar
SFA	science focus area
SGP	Southern Great Plains
TRACER	Tracking Aerosol Convection Interactions Experiment
VAD	velocity azimuth display
VAP	value-added product

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Mentor team: Andrei Lindenmaier, Timothy Wendler, Vagner Castro, Alyssa Matthews, Karen Johnson
Translators: Scott Collis, Scott Giangrande
Contributors: Adam Theisen, Jennifer Comstock, Jim Mather

1.0 Introduction

The fundamental objective of the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) radar facility is to provide high-quality radar observations to the scientific user community with an overarching goal of improving the treatment of clouds and precipitation in climate models. ARM has a complement of 32 radars, including scanning and zenith pointing varieties (Table 1). The effort to maintain and operate these radars is significant and requires a large, distributed staffing commitment. However, at available staffing levels, ARM's experience dictates that it is not feasible to ensure the continuous, high-level operations expected by the ARM user community for all radars at all locations at all times. Therefore, priorities must be established to routinely manage select radar operations every fiscal year. These priorities for FY22 are listed herein.

Table 1. Inventory of ARM radars, including frequency, at each site. Frequencies are approximate and can be slightly different in the field.

	Radars	Frequency
SGP	3 - X-Band Scanning ARM Precipitation Radars (XSAPR) 1 - C-Band Scanning ARM Precipitation Radar (CSAPR) 1 - Ka/W-Band Scanning ARM Cloud Radar (Ka/W SACR) 1 - Ka-Band zenith radar (KAZR)	9.35 GHz 6.25 GHz 35.3/94.0 GHz 35 GHz
NSA	1 - X-Band Scanning ARM Precipitation Radar 1 - Ka/W-Band Scanning ARM Cloud Radar (2nd Generation) 1 - Ka-Band zenith radar	9.35 GHz 35.3/94.0 GHz 35 GHz
ENA	1 - X-Band Scanning ARM Precipitation Radar (2nd Generation) 1 - Ka/W-Band Scanning ARM Cloud Radar (2nd Generation) 1 - Ka-Band zenith radar (2nd generation)	9.5 GHz 35.3/94.0 GHz 35 GHz
AMF1 AMF2	2 - Ka-Band zenith radar 1 - W-Band Marine ARM Cloud Radar 1 - Ka/W-Band Scanning ARM Cloud Radar (Rotational) 1 - Ka/X-Band Scanning ARM Cloud Radar (Rotational)	35 GHz 95 GHz 35.3/94.0 GHz 35.3/9.71 GHz
AMF3	1 - Ka-Band zenith radar (2nd generation)	35 GHz
Other	1 - C-Band Scanning ARM Precipitation Radar (1st generation) 1 - C-Band Scanning ARM Precipitation Radar (2nd generation) 1 - Ka-Band Zenith Radar (Spares) 2 - Ka/X-Band Scanning ARM Cloud Radar (Rotational/spares) 1 - Ka/W-Band Scanning ARM Cloud Radar (SGP)	6.25 GHz 5.7 GHz 35 GHz 35.3/9.71 GHz 35.3/94.0 GHz

2.0 Radar Support Team

A broad group of mentors, technicians, developers, scientists, and data quality analysts support ARM's radars. This group has expanded over time but generally consists of the radar mentor team, radar engineers, radar technicians, and the radar data and value-added products team.

2.1 Radar Mentors

Radar mentors are ARM's instrument experts for the radar systems. They are responsible for directing and performing engineering activities, including calibration, with ARM's radars as well as ensuring that the radars produce high-quality data during deployments. All engineering and data processing tasks were previously performed by the same mentor team. In order to manage the radars more effectively, the mentorship will have both a radar engineering team and a radar data team. The engineering team will be responsible for preparing and maintaining ARM radar assets while the radar data team will be responsible for overseeing the processing of radar data to a well-characterized state, including developing, maintaining, and documenting the process for data processing, analyzing radar data and identifying anomalous behavior, and developing procedures for anomaly detection while working closely with the Data Quality (DQ) Office and others across ARM.

2.2 Radar Engineers and Technicians

In order to support the radar hardware in the field, ARM has a team of radar engineers and technicians that are tasked by the mentor team. Radar engineers have background and experience with microwave technologies. Radar technicians have good electronics skills but not as much experience with microwave technology as radar engineers. Additionally, ARM has site technicians that lack formal radar training but can work on tasks with oversight and guidance from the mentor team.

2.3 ARM Infrastructure

The radar mentor team also has broad support from various other groups in the ARM infrastructure, including the translator and value-added-product (VAP) developers and the DQ Office. The VAP group has been actively involved in the data processing to produce calibrated b1-level files and the DQ Office actively monitors operational radars for data quality problems.

2.4 External Partners

To supplement ARM's radar team, (mentors, engineers, technicians, and infrastructure), ARM has engaged with external partners (vendors and universities) to provide support (software and hardware) and even for the deployment of non-ARM radar assets in the field to support ARM scientific objectives.

As of October 1, 2021, the radar engineering team will consist of two mentors, two radar engineers, and three radar technicians. The radar data team will include two and a half mentors and a part-time developer. Throughout FY22, ARM will coordinate between all groups, including the rest of ARM infrastructure, to ensure that they can contribute to the success of ARM's radars.

3.0 Fiscal Year 2022 Priorities

ARM has recently engaged with DOE to develop an overarching radar strategy to guide radar-related activities. The implementation of this strategy will start in FY22, and priorities and those assigned to work on them may change. As part of this strategy, ARM will work on mechanisms to better

communicate the priorities and radar status on a routine basis. Additionally, ARM will develop a *Roadmap to Operations* plan for each radar that is further defined below.

In general, radar priorities have focused on ARM Mobile Facility (AMF) deployments and FY22 is no different. Priorities include the ongoing deployments in Houston, Texas (Tracking Aerosol Convection Interactions Experiment [TRACER]) and Gothic, Colorado (Surface Atmosphere Integrated Field Laboratory [SAIL]), along with preparations for the upcoming campaigns in La Jolla, California (Eastern Pacific Cloud Aerosol Precipitation Experiment [EPCAPE]) and the AMF3 relocation to the Southeast U.S. A summary of these activities and the rest of the planned FY22 activities listed in Table 2 are described below.

Table 2. Timeline of FY22 radar activities.

			October-2021	November-2021	December-2021	January-2022	February-2022	March-2022	April-2022	May-2022	June-2022	July-2022	August-2022	September-2022
Maintain KAZR Operations	1/1/21	10/1/24												
Assessment of ARM Radar Systems	10/1/21	9/30/22												
TRACER Campaign Operations (AMF1)	10/1/21	9/30/22												
CSAPR2 Operations	9/1/20	9/30/22												
Cell Tracking Operations	6/1/22	9/30/22												
Ka/X SACR Operations	10/1/20	9/30/22												
SAIL Campaign Operations (AMF2)	9/1/21	6/15/23												
CSU X-Band	10/1/20	12/31/23												
EPCAPE Radar Preparations	1/1/22	3/31/22												
AMF3 (Southeast U.S.)	3/1/23	3/1/28												
SACR	1/1/22	3/31/22												
CSAPR2 Preparations and Operations	1/1/22	3/1/23												
Deployable CSAPR	1/1/22	12/31/24												
EIKA Tube Maintenance Plan	3/1/22	1/1/24												

4.0 Primary Activities

4.1 Maintain KAZR Operations

Timeframe: Continuous
Mentor Staffing: Tim Wendler, Andrei Lindenmaier, Ya-Chien Feng, Alyssa Mathews, Karen Johnson

The KAZRs are a workhorse for ARM's radar measurements and are a continued high priority at all ARM sites (fixed and AMF deployments). As travel and time permit, the KAZR receivers will undergo periodic calibration. See *Routine b1-Level Processing* section below for further information on data processing efforts for ARM's radars.

4.2 Assessment of ARM Radars

Timeframe: 10/1/2021 – 9/30/2022
Mentor Staffing: Adam Theisen. Andrei Lindenmaier, Ya-Chien Feng, Alyssa Mathews, Karen Johnson

To properly assess effort and options to maintain radar operations, ARM will perform an in-depth review of ARM radars to ensure that the requirements and effort needed to bring them into an operational state and keep them operational and producing high-quality data are known and documented. This will allow ARM and the mentor team to assess those requirements and determine paths forward to improve operational uptime. Initially, a *Roadmap to Operations* will be created for each radar that will include:

- Scientific scope each radar is best poised to address and optimal seasonality to do so.
- Requirements to get each radar to an operational state and who can perform the tasks to do so. This can include, but is not limited to, the mentor team, radar engineering team, site operations, and/or vendors.
- Requirements and processes necessary to keep the radars operational and producing high-quality data along with who can perform the corresponding tasks.
- Inventory of available ARM data products to ensure that ARM has the products available to maximize the scientific impact of our operational radars.

4.3 TRACER Campaign Operations (AMF1)

Timeframe: 10/1/2021 – 9/30/2022

The CSAPR2, SACR, and KAZR will be operational for TRACER. Since a primary TRACER science emphasis is on deep convective clouds, the scanning precipitation radars in particular will play a central role in achieving the science goals for this campaign. Notably, the scanning radars will require additional effort during the Intensive Operational Period (IOP) from June 1, 2022 to September 30, 2022. During this time, the CSAPR2 cell tracking (described below) will be an operational priority. The SACR scan strategy during TRACER will be reviewed periodically with ARM staff and campaign principal investigators (PIs), and potentially revised as is necessary.

4.3.1 TRACER CSAPR2 Operations

Timeframe: 9/1/2020 – 9/30/2022
Mentor Staffing: Andrei Lindenmaier, Tim Wendler, Ya-Chien Feng, Alyssa Mathews, Precipitation Radar Translator Team, DQ Office

The CSAPR2 is installed in Houston, Texas for the start of TRACER on October 1, 2021. To enable the steering of the CSAPR2 from external inputs, servers with upgraded software will be installed during the campaign, prior to the IOP. Testing of the system along with the cell tracking software will be coordinated with the PI to limit impact to the science. A vendor service contract will be implemented during TRACER to support radar operations and troubleshooting in the field. The data mentor, along with the precipitation radar translator team and DQ Office, will monitor and assess data, with calibrated data products and VAPs being made available at the end of the campaign.

4.3.2 TRACER Cell Tracking Operations

Timeframe: 6/1/2022 – 9/30/2022
Staffing: Pavlos Kollias, Ed Luke, Mariko Oue, Bernat Puigdomenech

The development of automated adaptive scanning will be a major upgrade to the CSAPR2. Coordination between the mentor team, vendor, adaptive scanning software team led by Pavlos Kollias of Brookhaven National Laboratory, and others will be vital to ensure the successful implementation of this capability for the TRACER campaign. Initial testing of this capability will be carried out after the installation of the aforementioned servers, with routine operation of these capabilities to occur during the IOP.

4.3.3 TRACER Ka/X SACR Operations

Timeframe: 10/1/2020 – 9/30/2022
Mentor Staffing: Andrei Lindenmaier, Tim Wendler, Ya-Chien Feng, Alyssa Mathews, Karen Johnson, DQ Office

The Ka/X SACR will be deployed for the entire TRACER campaign. Scan strategies for the IOP will be defined prior to the IOP start and the strategy used will be regularly assessed and changed, depending on forecast conditions. Data will be monitored and assessed by the data mentor team and DQ Office with calibrated data products and VAPs produced at the end of the campaign.

4.4 SAIL Campaign Operations

Timeframe: 9/1/2021 – 6/15/2023

The AMF2 will be deployed for an extended period in Colorado for the SAIL campaign (September 1, 2021 – June 15, 2023). The KAZR will be deployed as part of the standard AMF complement of sensors, while Colorado State University (CSU) will deploy its X-Band radar for ARM in place of an ARM scanning cloud radar system.

4.4.1 SAIL CSU X-Band Radar

Timeframe: 10/1/2020 – 12/31/2023
Staffing: Dr. Chandrasekar, Precipitation Radar Translator Team, DQ Office

A scanning cloud radar was not included in the AMF2 call for proposals. To support the science objectives of SAIL, a scanning, polarimetric, X-Band radar from CSU was contracted to provide radar measurements for the entire campaign. This radar will be deployed on Crested Butte Mountain. Data will be collected from the system and near-real-time displays of the data will be provided to the general public. The precipitation radar translator team along with the DQ Office will coordinate efforts to routinely monitor and assess the quality of the radar data in addition to that provided by the CSU team. The radar data is not expected to be ingested but will be processed using ARM's precipitation VAPs.

4.5 EPCAPE Radar Preparations

Timeframe: 1/1/2022 – 3/31/2022
Staffing: Andrei Lindenmaier, Tim Wendler, Vagner Castro

A KAZR and Ka/W SACR will be prepared to support EPCAPE. Campaign operations are expected from February 1, 2023 to January 31, 2024. The KAZR is planned to be deployed on the Scripps Pier in La Jolla, California and the SACR on Mt. Soledad. Preparations for these radars will begin in 2022.

4.6 AMF3 Radar Activities to Support the Southeast U.S.

Timeframe: 1/1/2021 Onward
Mentor Staffing: Andrei Lindenmaier

To prepare for the AMF3 operational start date in early 2023, preparations for the anticipated radars and needs thereof will need to occur in FY22. The CSAPR2 will be deployed but the exact location and configuration (tower versus standard deployment) will be determined based on final siting location. The AMF3 KAZR is planned to be deployed to the AMF3 main site, while the deployment of a SACR is under discussion and contingent on eventual Southeastern U.S. siting options. Operations for the AMF3 will begin under a phased approach starting in FY23, with baseline instrumentation at the main site and advanced instruments (including scanning radar) to follow.

4.7 Deployable CSAPR

Timeframe: 1/1/2022 – 12/31/2024
Mentor Staffing: Andrei Lindenmaier

The CSAPR2 will be deploying with the AMF3 to the Southeast U.S., leaving a gap in C-band radar capabilities for other campaigns. Some initial information has been gathered, but the mentor team and ARM management will review the options and timeline to develop a deployable CSAPR asset that will be available to AMFs. Depending on the final decision and timelines for procurement or refurbishment, this deadline may need to be adjusted accordingly.

4.8 EIKA Tube Maintenance Plan

Timeframe: 3/1/2022 – Onward
Mentor Staffing: Andrei Lindenmaier, Tim Wendler

ARM has roughly 40 extended interaction klystron amplifier (EIKA) tubes for the SACRs and KAZRs. Over time these EIKAs can output less power, reducing the sensitivity of the radars. Each EIKA can be refurbished once, which is significantly cheaper than a new EIKA. The mentor team will evaluate the inventory of EIKAs and identify ones for refurbishment.

5.0 Secondary Activities

ARM will review resources in the *Roadmap to Operations* early in FY22 and determine how best to support radars at fixed sites. As noted earlier, ARM will also review who is able to perform many of these activities and the proposed staffing can change. Efforts to support more remote radars such as those deployed to the Eastern North Atlantic (ENA) and North Slope of Alaska (NSA) sites will depend on travel restrictions and onsite conditions. This information will be factored in when setting plans and priorities for fixed-site radar activities.

5.1 NSA SACR and SAPR

Timeframe: Summer 2022
Mentor Staffing: Tim Wendler, Todd Houchens

The NSA SACR components will be repaired and calibrated at Pacific Northwest National Laboratory (PNNL) in CY21. These components will be reinstalled when the site conditions allow. Additionally, the X Band Scanning ARM Precipitation Radar (XSAPR) is operating at NSA and it will need to be characterized and calibrated to provide b1-level data.

5.2 ENA SACR and SAPR

Timeframe: Summer/Fall 2022
Mentor Staffing: Andrei Lindenmaier, Tim Wendler

The SACR radio frequency (RF) units and their auxiliary parts were shipped to PNNL for repair and calibration, which will be completed in CY21. These parts will then be shipped back to ENA for installation by site technicians. Both the SACR and SAPR will require a site visit by the mentor for end-to-end characterization and calibration. Travel policies will dictate the timeline for this site visit.

5.3 SGP XSAPR Magnetrons

Timeframe: Fall/Winter 2021-2022
Mentor Staffing: Andrei Lindenmaier

The Southern Great Plains (SGP) site XSAPRs have been down for an extended period due to closing in on the end of life for the magnetrons. The first of the new magnetrons have been received and will be tuned with the transmitters and installed as time permits. Field calibration of the XSAPRs will be postponed until after TRACER or until a field campaign requires it.

6.0 Translator and Data Product Activities

6.1 Routine b1-Level Processing

Timeframe: Ongoing
Staff: Data Mentor, Alyssa Matthews, Karen Johnson, Cloud and Precipitation Radar Translator Teams, Eddie Schuman

Calibrated b1-level data for the Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE) and Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC) cloud radar deployments (KAZR, SACR) should be available in early FY22. Additionally, the radar data mentor team will monitor and prioritize the data collected during the FY22 AMF1 and AMF2 deployments as previously noted, but the standard expectation is that b1-level data will not be available until after AMF campaigns. The data mentor team will work with ARM's DQ Office to implement tools and processes to better monitor the radar data during campaigns. The data mentor team will work to develop the mechanisms to routinely provide calibrated b1-level data for all of ARM's KAZRs.

6.2 Community Radar Software Support

Timeframe: Ongoing
Staff: Zachary Sherman, Jason Hemedinger, Scott Collis

Support and further development of the Python-ARM Radar Toolkit (Py-ART) will continue. Py-ART is used by internal and external stakeholders and is specifically engineered to work with ARM radar data. Py-ART has supported well over 100 publications and is used across academia, government, and industry. Py-ART is also the main tool used for VAP development on the precipitation radars, and acts as a conduit to get science codes back into infrastructure.

6.3 Precipitation Radar Advanced Products

Timeframe: Ongoing
Staff: Robert Jackson, Zachary Sherman, Jason Hemedinger, Scott Collis

The precipitation radar advanced products team will provide product support for the CSAPR2 deployment to TRACER. Products will include Corrected Moments in Antenna Coordinates (CMAC2.0), Mapped Moments to a Cartesian Grid (MMCG), Velocity Azimuth Display (SAPRVAD), and Quasi-Vertical Profiles (SAPRQVP), along with new development of a moving-frame-of-reference MMCG to support cell-tracking activities.

This team will coordinate closely with the CSU X-Band radar team to ensure that useful products for the SAIL campaign, including maps of quantitative precipitation estimates. This will include analyzing data from the radar, comparison to external measurements (e.g., disdrometer) where needed, rainfall retrievals, and updating delivered data to ensure it conforms to ARM standards. There is also a likely role for outreach and ensuring that the ARM SAIL community (which includes new ARM users from the

Watersheds SFA) knows the data exist and how to apply them to achieve DOE science objectives. ARM standard data products are expected to be produced.

6.4 Cloud Radar Advanced Products

Timeframe: Ongoing
Staff: Lynn Ma, Karen Johnson, Meng Wang, Scott Giangrande

The cloud radar advanced products team has been working with the mentor team to produce calibrated b1-level data sets for the KAZR and SACR AMF deployments. The standard Active Remote Sensing of Clouds (ARSCL) and Gridded SACR products (SACRGRID) will be performed on the available a/b-level data during TRACER and SAIL to help with the data quality monitoring of the KAZR/SACR, respectively. Additional microphysical-retrieval value-added products that benefit from these radars (e.g., Improved MICROBASE Product with Uncertainties [MICROBASEKaPLUS]) are also anticipated from several translator-led activities.

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