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FY 2018 ARM Radar Plan

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ARM
CLIMATE RESEARCH FACILITY

DISCLAIMER

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Acronyms and Abbreviations

ADC	ARM Data Center
AMF	ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
AWARE	ARM West Antarctic Radiation Experiment
CACTI	Cloud, Aerosol, and Complex Terrain Interactions
COMBLE	Cold-Air Outbreaks in the Marine Boundary Layer Experiment
CSAPR	C-band Scanning ARM precipitation Radar
CSU	Colorado State University
DOD	Department of Defense
DOE	U.S. Department of Energy
DQO	Data Quality Office
ENA	Eastern North Atlantic
FY	fiscal year
IEP	Intensive Engineering Period
IOP	intensive operational period
KAZR	Ka-band ARM Zenith profiling Radar
LANL	Los Alamos National Laboratory
MARCUS	Measurements of Aerosols, Radiation, and Clouds over the Southern Ocean
MOSAIC	Multidisciplinary Drifting Observatory for the Study of Arctic Climate
MWACR	Marine W-band ARM Cloud Radar
NSA	North Slope of Alaska
OS	operating system
PNNL	Pacific Northwest National Laboratory
RWP	radar wind profiler
SACR	Scanning ARM Cloud Radar
SDS	Site Data Systems
SGP	Southern Great Plains
SME	subject-matter expert
TWP	Tropical Western Pacific
UPS	uninterruptible power supply
WACR	W-band ARM Cloud Radar
XSAPR	X-band Scanning ARM precipitation Radar

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1.0 Introduction

The fundamental objective of the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility 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. Historically, ARM has operated zenith-profiling cloud radars at millimeter wavelengths at five of its facilities. Since 2010, 16 scanning systems have been added to the radar facility. The ARM radar facility has 33 radars in its possession at three fixed sites and three mobile facilities. A breakdown of the ARM radar assets is given below:

- 8 Scanning ARM Clouds Radar Systems (SACR: two radars on single pedestal; six 1st- and two 2nd- generation)
- 7 Ka-band ARM Zenith profiling Radar (KAZR: five 1st- and two 2nd-generation)
- 5 X-band Scanning ARM precipitation Radar (XSAPR: four 1st- and one 2nd-generation)
- 3 C-band Scanning ARM precipitation Radar (CSAPR: two 1st- and one 2nd-generation)
- 1 W-band ARM Cloud Radar (WACR)
- 1 Marine W-band ARM Cloud Radar (MWACR: configured to be deployed on a stable table or scanning pedestal).

Of these radars, all but six (two SACRs [accounting for four radars], one KAZR, and one 1st-generation CSAPR) have operational assignments. Therefore, the current measurement strategy involves operating 27 radars, not including radar wind profilers (RWPs). This array of instruments represents a combination of scanning and profiling radars at ARM's sites. In addition to the scanning capabilities, the radars at each site differ in operating frequency, technology, and complexity, but all are complex systems. Some of them were custom designed and built specifically for ARM.

Typically, newer systems take a few years to reach operational maturity with adequate characterization, calibration, testing, and quality control. Due to various factors, not all of the radars have achieved an operationally mature status sufficient to provide high-quality data in a research environment. In addition, these radars are often deployed in remote locations and harsh environments to meet science needs. The remoteness of such complex systems is a considerable challenge for continuous operations. Tools needed for a research-level operational radar are not readily available from vendors, and many of the necessary system management tools, both hardware and software, to manage these systems must be developed in-house for such deployments.

Based on experience over the past seven years, including conclusions from the first phase of the radar plan, implemented in mid-2016, it is clear that ARM cannot support the operation of all 27 currently deployed radars and expect to provide research-quality data (including higher-order products) with the current resources. Experience from the first phase of the radar plan has provided a better indication than has been available previously of what size radar network is reasonable. A preliminary proposal for what that radar network could look like is provided here. The plan presented here uses the available resources to best support this proposed network.

2.0 Preliminary Plan to Reduce Radar Facility Scope

Feedback from ARM's 2017 triennial review was to carefully manage the overall scope of the ARM facility and the radar network in particular. To that end the Engineering & Operations group and ARM management are working to develop a strategic plan to reduce the scope of radar activities. The main objective of the strategy is to define an operational radar network that is appropriate for available ARM resources and that optimizes the impact of ARM radars on the science community. With this, as well as specific logistics issues, in mind, ARM decided to decommission three radars from operations by the end of fall, 2017. One of the radars was the WACR, previously deployed with the AMF1, which was near its end-of-life with a failing transmitter system and a lack of vendor support. The other two radars were part of the dual-frequency SACR deployed with AMF3 at Oliktok Point, North Slope of Alaska (NSA). The SACR in AMF3 was decommissioned because of logistical difficulties in maintaining a very complex system in Oliktok's harsh and logistically challenging environment. We expect that the AMF3 radar will replace the older SACR in Barrow in late 2018, resulting in a net reduction of two radars. With the decommissioning of these three radars in 2017, ARM has a total of 24 radars that are deployed at fixed sites and mobile facilities from 2018 with a few non-operational radars.

The proposed deployments of these 24 radars is shown in Table 1. With the retirement of the WACR, there are actually 32 ARM radars with of the types listed in the previous section. The eight undeployed radars are as follows:

- Two X-Ka systems (four radars) that were formally part of the Darwin and Manus TWP sites
- One W-Ka Pair (two radars) formerly deployed at AMF3/Oliktok
- One CSAPR system formerly deployed at the Manus TWP site
- One KAZR formerly deployed in the TWP.

With the shutdown of the TWP sites—and with them, two X/Ka-SACRs—the decision to not deploy the Southern Great Plains (SGP) I11/12 SACR sites, and the removal of a W-Ka SACR from Oliktok, there are at least three non-operational SACRs (potentially more depending on AMF status; for example, there will not be an AMF2 SACR deployed until MOSAIC). The working proposal is to work on two of these systems in a rolling fashion to prepare for the next set of AMF deployments and to use a third SACR as a development system to permit the implementation of fixes and upgrades on a non-deployed system prior to being integrated into the operational network. At any given time, the details of this SACR rotation will depend on the frequencies required for current and upcoming deployments. Here is the current status and a summary of proposed actions:

- One X-Ka system is being prepared at Pacific Northwest National Laboratory (PNNL) for CACTI.
- One X-Ka system is currently at Los Alamos National Laboratory (LANL) following the completion of the AMF2 deployment of AWARE. This should come to PNNL later in FY18 to prepare for MOSAIC.
- One W-Ka system is in storage at Oliktok and will be moved to Barrow, Alaska later this year. At that point the Barrow system would be returned to PNNL for overhaul.
- One W-Ka system is en route from Ascension Island. This radar will also need an overhaul. Either this radar or the Barrow radar would be deployed for COMBLE.

- One X-Ka system is in storage at SGP. Either this system or one of the W-Ka systems could be used as the development system.

There is also an unused KAZR from the shutdown of a TWP site and it is proposed to keep that system as a development system.

The CSAPR from TWP-Manus should be kept for spares for the SGP CSAPR or possible future deployment. The SGP CSAPR is currently not functioning and there are no immediate plans for that radar, but it does have the potential to be a robust and useful system. It simply is not among the highest priorities. The current thinking is that the SGP system would cycle into priority and the Manus system would provide spares for that system.

Note that the development system (one SACR, two frequencies) would be managed to be consistent with field systems (just one step ahead) so it could serve as a hot-spare under certain circumstances. Additionally, this system, along with the systems being overhauled, provides good training opportunities and related experience for both the engineering team and the field technicians.

Table 1. Radars fielded by ARM for operations as of October 1, 2017.

Radars	No. of Radars	No. of Pedestals
SGP		
KAZR	1	0
SACR	2	1
XSAPR	3	3
CSAPR	1	1
NSA		
KAZR	1	0
SACR	2	1
XSAPR	1	1
ENA		
KAZR	1	0
SACR2	2	1
XSAPR2	1	1
AMF1		
KAZR	1	0
SACR2	2	1
AMF2		
KAZR	1	0
MWACR	1	1
SACR	2	1
AMF3		
KAZR	1	0

Radars	No. of Radars	No. of Pedestals
CSAPR2	1	1
Total	24	13

Table 2 and Table 3 lists the preliminary plan to reduce the scope of radar activities. One of the important aspects of the plan is to include significant time to overhaul a radar before it is deployed for a field campaign. It is important to define radar "operating" and "Mentor focus" in the context of this plan:

Intensive Engineering Period (IEP): The radar system is under the mentor's focus area for the intensive engineering period. During the IEP, the radar system is characterized, calibrated, and configured for operations. The radar system's performance and data quality are also analyzed.

Operating: The radar is operational and collecting data. A radar is expected to operate with minimal mentor intervention after the radar has been characterized and calibrated during IEP. It is important to note it is not necessary for a radar system to be in IEP for it to be operating. It is also possible to have a radar operating while it is in IEP.

Table 2. List of ARM radars with operating condition and mentor assignment for FY18. An assignment of '0' indicates false and '1' indicates true.

Radars		# Radars	# Peds.	Operating	IEP	Comments
SGP						
KAZR		1	0	1	0	Propose we operate KAZRs at all sites (or, WACRs in the case of ship deployments).
SACR			1			Operate in vertically pointing mode. Scanning less important at SGP. SACR doesn't see shallow cloud well due to small particles and insects and attenuation in deep convection.
	KaSACR	1		0	0	
	WSACR	1		1	0	
XSAPR						Scanning cm-wavelength radars support convective dynamic study. Could reduce this to 2 at some point. Mentor focus is only for the first FY quarter.
	I4	1	1	1	1	
	I5	1	1	1	1	
	I6	1	1	1	1	

Radars		# Radars	# Peds.	Operating	IEP	Comments
CSAPR		1	1	0		Lower priority than XSAPR network-
NSA						
KAZR		1	0	1	1	High priority
SACR2			1			High priority. Replaced with SACR2 from Oliktok. Supports study of mixed-phase microphysics.
	KaSACR	1		1	0	
	WSACR	1		1	0	
XSAPR		1	1	1	1	Only source of long-range coverage on North Slope of Alaska.
ENA						
KAZR2		1	0	1	0	High priority.
SACR2			1			A lot of effort went into getting this system calibrated and operational. The system shall be left operational for FY18.
	KaSACR	1		1	0	
	WSACR	1		1	0	
XSAPR2		1	1	1	1	Only source of long-range coverage in ENA.
AMF1						Preparation for CACTI.
KAZR		1	0	0	1	
SACR			1			
	XSACR	1		0	1	
	KaSACR	1		0	1	
AMF2						
KAZR		1	0	0	0	
MWACR		1	1	1	0	Deployed for MARCUS.
SACR			1			
	XSACR	1		0	0	
	KaSACR	1		0	0	
AMF3						
KAZR		1	0	1	0	High priority.

Radars		# Radars	# Peds.	Operating	IEP	Comments
CSAPR2		1	1	1	1	Preparation for CACTI.
Total		24	13	16	10	

Table 3. List of ARM radars with operating condition and mentor assignment for FY19. An assignment of '0' indicates false and '1' indicates true.

Radars		# Radars	# Peds.	Operating	Mentor Focus	Comments
SGP						
KAZR		1	0	1	1	Propose we operate KAZRs at all sites (or, WACRs in the case of ship deployments).
SACR			1			Operate in vertically pointing mode. Scanning less important at SGP. SACR doesn't see shallow cloud well due to small particles and insects and attenuation in deep convection.
	KaSACR	1		0	0	
	WSACR	1		1	0	
XSAPR						Scanning cm-wavelength radars support convective dynamic study. Could reduce this to 2 at some point.
	I4	1	1	1	0	
	I5	1	1	1	0	
	I6	1	1	1	0	
CSAPR		1	1	0		Lower priority than XSAPR network.
NSA						
KAZR		1	0	1	0	High priority.
SACR2			1			High priority. Replaced with SACR2 from Oliktok. Supports study of mixed-phase microphysics.
	KaSACR	1		1	0	
	WSACR	1		1	0	
XSAPR		1	1	1	0	Long-range coverage in Arctic that does not exist.

Radars		# Radars	# Peds.	Operating	Mentor Focus	Comments
ENA						
KAZR2		1	0	1	0	High priority.
SACR2			1			Given emphasis on low liquid-only clouds, operate with single wavelength only. W-band is not sensitive enough.
	KaSACR	1		1	0	
	WSACR	1		0	0	
XSAPR2		1	1	1	0	Long-range coverage in ENA that does not exist.
AMF1						
KAZR		1	0	1	0	CACTI deployment.
SACR			1			CACTI deployment.
	XSACR	1		1	1	
	KaSACR	1		1	1	
AMF2						
KAZR		1	0	0	1	Preparations for MOSAIC.
MWACR		1	1	0	1	Preparations for MOSAIC.
SACR			1			Preparations for MOSAIC.
	XSACR	1		0	1	
	KaSACR	1		0	1	
AMF3						
KAZR		1	0	1	0	High priority.
CSAPR2		1	1	1	1	CACTI deployment.
Total		24	13	17	8	

3.0 Assumptions

ARM is a user facility with a complex organization spread across multiple national laboratories. Several assumptions have been made in the plan for its implementation, as follow:

- The radar facility operates with several temporal logistic challenges, including, shipping, repairs, and part procurement. These factors vary depending on the site and/or vendor. The dates for packing and shipping the radars are based on the best estimate dates.
- The field engineers, Todd Houchens and Peter Argay, shall visit PNNL frequently to work on the radars with guidance from mentors.
- There is no radar technician at ARM sites with the exception of SGP.
- Often reanalysis of the radar data has to be performed to address questions raised by end-users. Significant time is needed when mentors have to perform extensive reanalysis of the large volumes of data and metadata to resolve data quality issues. Significant time is required to develop software patches in order to reprocess large volumes of data. Radar group shall inform ARM management of instances when significant time is necessary to reprocess data. Given ARM's limited resources, ARM management shall deliberate allocating resources for reprocessing and reanalysis of the data. ARM shall consider scientific impact and relative priority compared to ongoing activities. One important consideration is that resource usage from the radar mentor team for reanalysis and reprocessing can alter or hinder the FY18 work plan. If the radar mentor team is reassigned to perform reanalysis, then one or more tasks in the FY18 work plan will be deferred and discussed in FY19.
- The radar mentors will not be maintaining production software long-term. The software will be released like other ingests. There will be a manual component to the b1-level processing in which data will be reviewed and calibration updates will be incorporated into configuration files to produce those b1-level files. It is possible that in addition to calibration changes there could be other corrections applied in the b1 processing that amount to offsets or scale factors. Mentors shall provide correction files that will be applied as part of the b1-level processing for off-normal corrections. General software maintenance and routine reprocessing will be in the hands of the ARM Data Center (ADC), as it is for other datastreams.

4.0 Work Plan

The radar group will be undertaking various projects to provide data for the community, as well as improve the radars, improve data quality, and ensure operational stability. The list of projects was derived from a number of factors such as available resources to support operations, field campaigns, and mission-critical and science objectives. The brief description of the FY projects is given in Table 4. The details of the projects shall be tracked on the ARM ServiceNow website.

Table 4. FY2018 radar projects.

No.	Title	Assigned To	
1	Radar Engineering and Operations Management	N. Bharadwaj	Manage the projects in FY18, radar operations and engineering procurements, radar operational planning and reviews for ARM campaigns and operations, radar property management, and operational plans for field campaigns.
2	CSAPR2 at SGP	N. Bharadwaj	Oversee installation of radome, engineering evaluation of radar operational performance, calibration, configuration, and data quality assessment.

No.	Title	Assigned To	
3	KAZR Calibration Setup	N. Bharadwaj	Develop operator-usable software tool for generating filters and calibration constants. This is to be used by field engineers to generate new filters once a month at the minimum.
		K. Johnson	Production implementation of b1 files for KAZR/KAZR2. This includes KAZR data before implementation of DOD superset for ARM radars.
		A. Matthews	Production implementation of calibration comparison of KAZR modes. This is to track the calibration offset between the modes in KAZR/KAZR2.
4	AML/AMF1 SACR	B. Isom	XSACR: overhaul, engineering evaluation of system, calibration, configuration, and data quality assessment.
		N. Bharadwaj	KaSACR: overhaul, engineering evaluation of system, calibration, configuration, and data quality assessment.
		A. Lindenmaier	XSACR: bench testing of TWTA and provide recommendation for operational use.
		T. Houchens P. Argay B. Isom, N. Bharadwaj	Overhaul of AL-4018 pedestal, complete SACR server upgrade with rugged server and Jessie. Overhaul of SACR container, RF enclosures, UPS, chillers, dry-air system, camera, tools, spare parts, inventory, and pack up. The mentor's role for this task is to provide oversight and guidance as appropriate.
5	KAZR at AML and AMF1	N. Bharadwaj P. Argay, T. Houchens	Overhaul, engineering evaluation of system, calibration, configuration, and data quality assessment. Overhaul of RF enclosures, UPS, dehydrator, tools, spare parts, inventory, and pack up.
6	ACE-ENA SACR	B. Isom	Configuration changes as needed.
		P. Argay	Maintain operations, manage daily rounds, calibration measurements.
7	Impact of Wind Farm in SGP	B. Isom	Analysis and characterization of wind farm echoes, characterization of the impact on radar observations (added uncertainty due to wind turbine contamination). This is to address the usability of scanning radars at SGP.
8	XSAPR2 at ENA	J. Hardin	Engineering evaluation of system, calibration, configuration, and data quality assessment.
		P. Argay	Maintain operations, manage daily rounds, calibration measurements.
9	X-band/C-band Radar Data Characterization	J. Hardin N. Bharadwaj	Data quality assessment using derived products with models. This is to be used for operational assessment of data in near-real time where X-band and C-band radar deployed (ENA, CACTI, and SGP).
10	Radar Data Flow	J. Hardin	Finalize the common DOD superset, reader for XSAPR2/CSAPR2, design implementation architecture for b1 file generation, coordination effort on the data flow project.
		K. Gaustad	Software development with ADI for production release of "raw to a1" for all.

No.	Title	Assigned To	
		K. Johnson	Finalize the spectra ingest. Responsible for the production processing of b1 files released every three months.
		A. Matthews	Write test programs to validate contents of a1, b1 files. The validation is for completeness, accuracy, and usability of the metadata.
11	WARNO	E. Schuman	Integration of XSAPR2/CSAPR2, bug fixes, implementation of feature requests, optimizing database implementation and handling for remote (ship) deployments.
		J. Hardin	Architecture design and guidance for new features (warn on detect, etc.)
12	SGP XSAPR Characterization	A. Lindenmaier	Engineering oversight on PO with CSU, experiments to collect measurements from sub-systems to characterize the radar, facilitate data collection for signal statistics and quality.
13	XSAPR Upgrade at SGP	A. Lindenmaier	Complete the RCP8 integration in SGP. The integration will be completed in November. However, issues with sector scans have been identified. Investigate the limits of sector scan operations and potential solutions in IRIS software.
14	NSA XSAPR Upgrade	A. Lindenmaier	Integrate RCP8 into the existing radar, characterize and calibrate the radar.
		T. Houchens	Overhaul of NSA XSAPR, provide engineering support for upgrade, installation and testing of hardware, maintain operations.
15	KAZR at NSA	A. Lindenmaier	Characterization and calibration, evaluation of polarizer/feed horn.
		T. Houchens	Upgrade of OS to Jessie, routine monthly calibration, overhaul of system, maintain operations.
16	SACR2 at NSA	A. Lindenmaier	Engineering evaluation of system, calibration, configuration, and data quality assessment.
		T. Houchens	Routine monthly calibration, overhaul of system, maintain operations.
17	Installation of SACR2 at NSA	T. Houchens	Principal engineer for uninstalling SACR and installing SACR2 in NSA. Change shelter configuration for including dry-air system, change in electrical panels, change in shelter equipment rack, overhaul corner reflector on the taller tower.
18	AMF3 KAZR2 Operations	T. Houchens	Maintain operations, manage daily rounds, calibration measurements.
19	Installation of radar for CACTI	P. Argay T. Houchens	Principal engineer for installing SACR, KAZR, and CSAPR2 in AMF1 for CACTI. The expectation is minimal involvement from the mentors for the physical install. Provide oversight and guidance for CSAPR2 radome installation so the ARM radar, LANL, and DOE requirements are met. Document the installation process for CSAPR2.
20	SACR2/KAZR2 Operations at ENA	P. Argay	Maintain operations, manage daily rounds, calibration measurements.
21	Data user interaction	A. Matthews	Host monthly user interaction teleconference, maintain updates on radar status, moderate discussions for field campaigns, IOP, and general data-related discussion.

No.	Title	Assigned To	
			Prepare data users handbook for SACR, KAZR, and SAPRs.
22	Operational setup for CACTI	N. Bharadwaj B. Isom A. Lindenmaier J. Hardin	Perform pre-campaign radar performance checks, configure systems for campaign-specific operating modes, calibration checks, data flow and products generation checks, quicklook & visualization checks, etc.
23	AML SACR for MOSAIC	D. Nelson N. Bharadwaj P. Argay T. Houchens	Design and fabrication of base for Al-4034. Installation of SACR with AL4034 pedestal for overhaul at AML.

5.0 Schedule

The projects for radar engineering and operations are scheduled to end in FY18 (September 30, 2018). The schedule is shown in Figure 1.

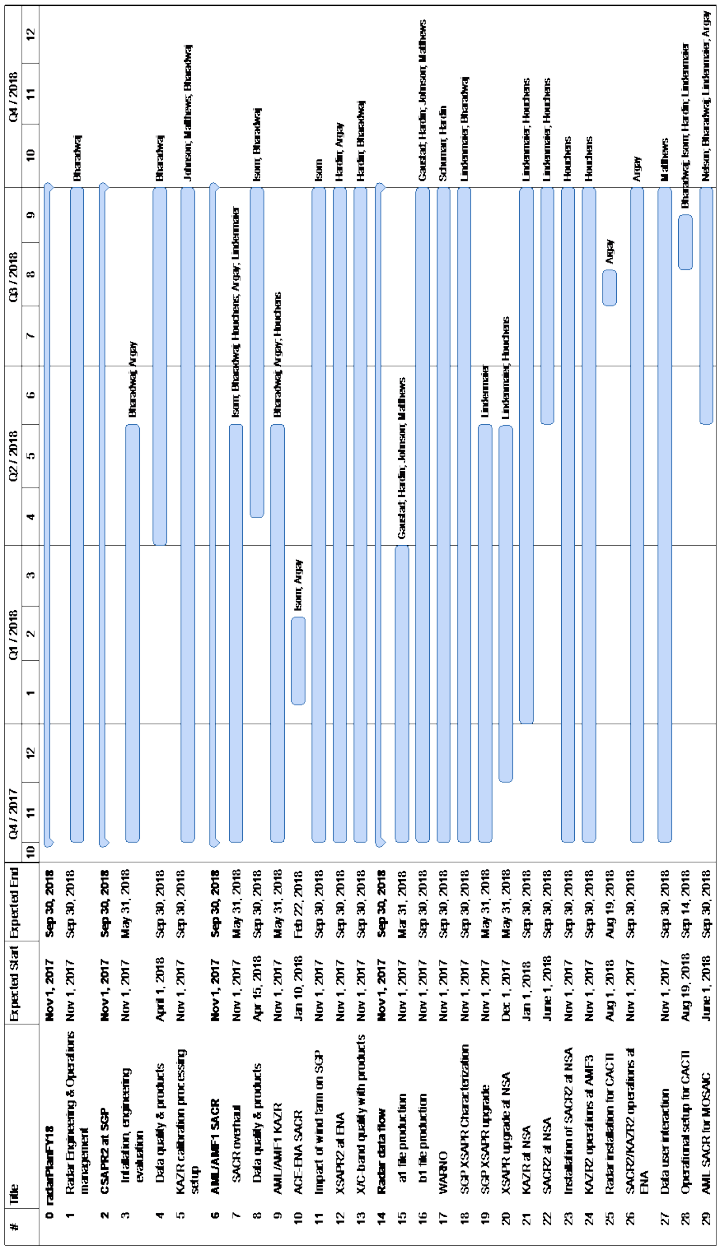

Figure 1. FY18 radar engineering and operations schedule.

6.0 Reporting

The progress and status of the radar activities will be reported in a phased manner. The following mechanism shall be used to communicate the status of the projects:

1. ServiceNow updates: The projects will be tracked on ARM's ServiceNow project management tool. Updates shall be posted on a monthly basis (end of the month).
2. Radar webpage: Updates on the status of the radars shall be posted on the radar webpage on a weekly basis.

3. Quarterly review: A teleconference with ARM management and advisory committees shall be conducted.
4. ARM website: Newsletters with updates shall be posted on the ARM website.

7.0 Risk Management

The ARM radar facility has several complex radar systems deployed at its fixed and mobile sites. Some projects in the proposed plan depend on the functionality of the radar hardware while others do not necessarily require a functioning radar. The following table lists some but not all risks and associated strategy.

Table 5. Some ARM radar deployment risks and mitigation strategies.

No.	Risk	Strategy
1	System failure that cannot be fixed within the stipulated time frame to complete project.	The identified project shall be stopped and cancelled. The systems use shall be discussed and resources assigned for next FY if necessary. No new project shall be assigned as a substitute. The personnel shall use remainder of their time on the already assigned projects.
2	Sub-system/component failures that need new parts but with longer lead times from vendors.	The sub-system/components shall be used from radar not deployed for operations. The removed sub-system/component shall be replaced with newer units.
3	Field engineer unavailable to visit site due to schedule conflicts.	The radar engineering and operations group shall use field engineers across all its sites as needed.
4	MWACR transmitter failure during MARCUS.	The MWACR transmitters (including spare) was retuned and tested to be working properly. In the event of a transmitter failure the mentor shall visit Hobart, Australia to install the spare. The transmitter is not a line replaceable unit and replacing requires SME.

8.0 Key Personnel

The core team for radar engineering and operations is listed below. In addition to the personnel listed below, team members from site operations, Site Data Systems (SDS), DQO, ADC, and translators actively work with the radar group.

Table 6. Core ARM radar team personnel.

Name	Role
Nitin Bharadwaj	Radar Mentor and Radar Group Manager
Andrei Lindenmaier	Radar Mentor
Bradley Isom	Radar Mentor
Joseph Hardin	Radar Mentor
Todd Houchens	Radar Field Engineer
Peter Argay	Radar Field Engineer
TBD	Radar Field Engineer
Karen Johnson	Radar Data Mentor

Name	Role
Alyssa Matthews	Radar Liaison
Krista Gaustad	Software Developer
Eddie Schuman	Software Developer
Danny Nelson	Engineering Support


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