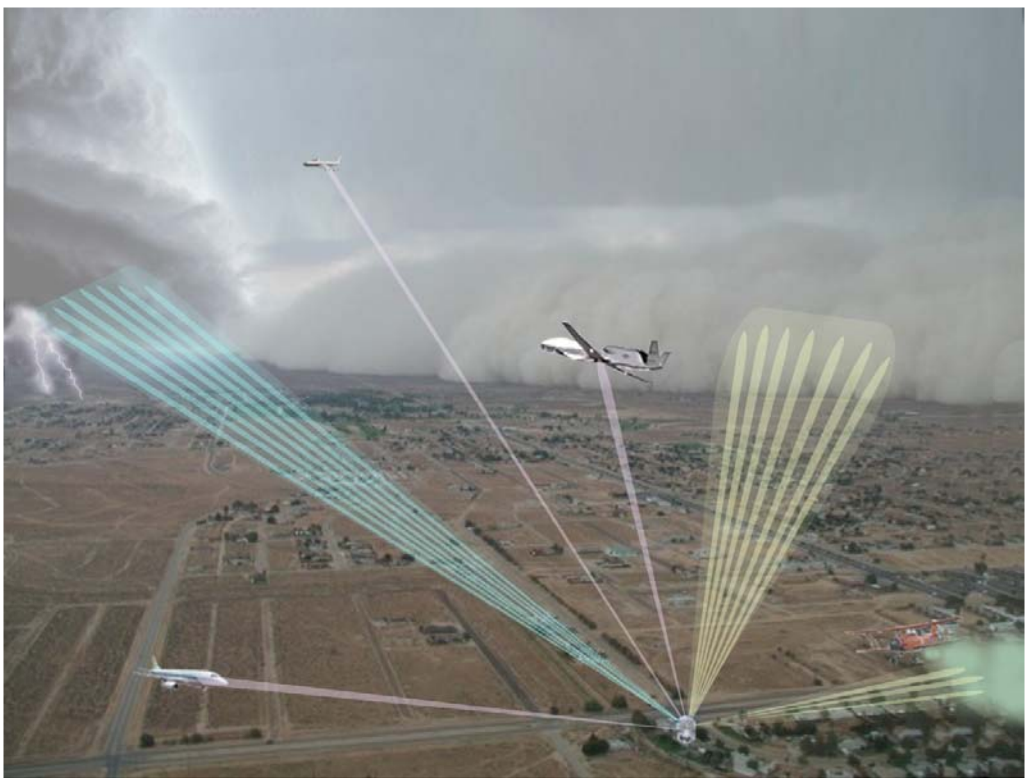
INTERDEPARTMENTAL COMMITTEE FOR
METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

COMMITTEE FOR COOPERATIVE RESEARCH (CCR)

JOINT ACTION GROUP FOR PHASED ARRAY RADAR PROJECT
(JAG/PARP)

Federal Research and Development Needs and Priorities for Phased Array Radar

FCM-R25-2006



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FOREWORD

Weather radar has proven its value to the Nation since the installation of the current weather surveillance network began in 1990. In 2020, the WSR-88D radars forming this NEXRAD network will be 23 to 30 years old. In about the same time frame, most of the Nation's aircraft surveillance radars will be nearing the end of their design life. Decisions on replacing or repairing and upgrading these National radar assets must be made over the next 10 to 15 years.

We are now on the threshold of a revolution in civilian radar capability, enabled by the adaptation of established military radar technology to existing civilian applications, plus new capabilities beyond what current systems can provide. Historically, civilian radars with large rotating antennas like the NEXRAD weather surveillance network and the aircraft surveillance radars used by the Federal Aviation Administration (FAA) evolved from military radar applications. During the past several decades, a new generation of military radars has matured. These electronically scanning phased array radars with no moving parts (rotating antennas) were originally developed to track multiple airborne objects such as aircraft and missiles simultaneously. The unique beam agility, increased resolution, and faster full-volume scan rate of phased array radar can enable a single radar unit to perform multiple weather and atmospheric surveillance tasks and, at the same time, track multiple airborne craft.

Thus, a single network of multifunction phased array radar (MPAR) units could provide next-generation expansion of our current weather surveillance network, replace the Nation's aging air traffic surveillance radars, meet homeland security and defense requirements for identifying and tracking non-cooperative craft operating over the U.S. homeland, and become an integral part of achieving National and International goals set for the Global Earth Observation System of Systems (GEOSS).

- MPAR will enable continued improvement of the Nation's severe weather warning system. It can provide adaptive sensing for warnings and nowcasts related to severe convective storms and the locally destructive effects of hurricanes (tropical cyclones) after they make landfall. Among the storm phenomena that could be tracked are tornadoes, strong wind gusts, hail, and locally heavy rains responsible for flash floods and mudslides. The result: more timely and accurate high-impact warnings for our nation's populace.
- The enhanced weather surveillance provided by an MPAR network will provide economic benefits to domestic aviation and surface transportation systems. The agility and specificity of its multitasking beams will provide more detailed weather and atmospheric observations for urban meteorology, air quality nowcasts and forecasts, climate variability monitoring and forecasting, wildland fire monitoring and prediction, and atmospheric transport and diffusion modeling. While research has established the proof-of-principle for new applications of weather radar in these and other areas, the adaptive flexibility of MPAR will be essential in transferring these promising radar techniques to operations.

- The non-cooperative aircraft surveillance capability of an MPAR network would complement the cooperative surveillance strategy planned for the Next Generation Air Transportation System (NGATS), while also addressing new craft tracking requirements of the Departments of Defense and Homeland Security.

Because an MPAR network would replace multiple existing networks, it offers an affordable option to the alternative strategy of continuing with the existing civilian radar capability by repairing and eventually replacing aging units. Due to technology breakthroughs in radio frequency components, fueled by the wireless telephony and digital communications industries, the cost of a key MPAR component—the transmit-receive elements in an MPAR antenna—has dropped by orders of magnitude over the past 5 years, and this trend should continue. For a number of reasons, the operations and maintenance costs for MPAR units appear to be a third area of substantial savings relative to continuing to repair and replace current radar units as they age.

Thus, with respect to both capabilities and cost, MPAR is a promising option for meeting the Nation's future domestic radar surveillance needs. The proposal put forward in this report, however, is not to decide now between MPAR or an alternative approach to meeting those needs. Before we can make this important decision with reasonable confidence, a near-term program of targeted research and development (R&D) is necessary to establish definitive answers to specific technical issues, as well as to validate preliminary cost analyses and network concepts. This report, produced by the Joint Action Group for Phased Array Radar Project, documents the current and future Federal agency needs that can be met with domestic surveillance radar systems, details potential benefits that may be realized from this technology, and proposes an R&D plan to evaluate an MPAR option to meet these needs and realize the benefits.

Working with our partners and stakeholders, we must capitalize on emerging science and technology to enhance public and aviation safety. We must seek to reduce hazardous risks through science and service, with the ultimate goal of saving lives, reducing injuries, and, where possible, protecting property and resources. Therefore, I urge Federal agencies with a stake in any of the applications enabled by surveillance radar to study the report and consider integrating its recommendations into their R&D programs.

Samuel P. Williamson
Federal Coordinator for Meteorological Services
and Supporting Research

MEMORANDUM FOR: Mr. Samuel P. Williamson
Federal Coordinator for Meteorology

FROM: Cochairpersons. Joint Action Group for Phased Array Radar Project (JAG/PARP)

SUBJECT: Report on Federal Research and Development Needs and Priorities for Phased Array Radar

The JAG/PARP has completed its assigned tasks to: (a) determine the specific needs of Federal agencies that could be met by surveillance radar, (b) show the benefits of phased array radar capability in meeting these needs, and (c) explore opportunities for expanded participation in the Phased Array Weather Radar Project (FCMSSR Action Item 2002-4.1). We are pleased to provide the subject report, titled: *Federal Research and Development Needs and Priorities for Phased Array Radar.*

Col Mark P. Weadon, Cochairperson
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Dr. James J. Kimpel, Cochairperson
Director, National Severe Storms Lab
U.S. Department of Commerce

CONCURRENCES:

The undersigned concur that the report, *Federal Research and Development Needs and Priorities for Phased Array Radar,* meets the tasks assigned to the JAG/PARP under FCMSSR Action Item 2002-4.1.

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TABLE OF CONTENTS

Appendices

TABLES

FIGURES

EXECUTIVE SUMMARY

All current civilian radar systems for weather surveillance and aircraft surveillance use a rotating antenna. The transmitted beam is shaped and directed by the antenna's reflective surface. The continuous physical rotation of the antenna around a vertical axis causes this beam to sweep a volume of space surrounding the radar unit. In a phased array radar, by contrast, the beam emanates from a stationary surface and is shaped and steered electronically; there is no rotating antenna. This capability to form and steer a radar beam permits multiple radar functions to be performed with the same radar unit: a *multifunction* phased array radar, or MPAR. Phased array radar technology has been used operationally by the U.S. military since the 1970s. For civilian aircraft and weather surveillance, MPAR can greatly improve capability while reducing life-cycle costs because multiple radar applications can be performed with the same radar unit. The electronically scanning array panels of an MPAR can accomplish diverse surveillance tasks much more quickly, flexibly, and at higher resolution than can the mission-specific, rotating antenna systems in use today.

In 2002, the Federal Committee for Meteorological Services and Supporting Research (FCMSSR) directed the Federal Coordinator for Meteorological Services and Supporting Research to (a) determine the specific needs of Federal agencies that could be met by surveillance radar, (b) show the benefits of phased array radar capability in meeting these needs, and (c) explore opportunities for expanded participation in the Phased Array Weather Radar Project (FCMSSR Action Item 2002-4.1). Initial work on these tasks led to the formation in late 2004 of the Joint Action Group for Phased Array Weather Radar Project. When this group established the feasibility of a single phased array radar unit performing both aircraft surveillance and weather surveillance functions, it was renamed the Joint Action Group for Phased Array Radar Project (JAG/PARP). This report presents the detailed response from the JAG/PARP to the original FCMSSR Action Item.

> **Multiple Federal agencies currently rely on radar networks to provide essential services to the Nation. The principal current uses are for weather surveillance and other atmospheric observations and for aircraft surveillance.**

Agencies whose mission areas already are or could be impacted by improved radar capabilities for weather surveillance include the National Oceanic and Atmospheric Administration (NOAA) and NOAA's National Weather Service (NOAA/NWS), the Federal Aviation Administration (FAA), Federal Highway Administration, National Aeronautics and Space Administration, the Department of Agriculture (including the U.S. Forest Service), the Department of the Interior (National Park Service, Bureau of Land Management, and the U.S. Geological Survey), the Department of Homeland Security (Federal Emergency Management Agency, U.S. Fire Administration, and U.S. Coast Guard), Department of Defense (Air Force, Navy, and Army for domestic and homeland defense operations), and the U.S. Environmental Protection Agency.

With respect to aircraft surveillance, the FAA plans to transition from ground-based radar for civilian aircraft surveillance to the Automated Dependent Surveillance–Broadcast (ADS-B) system, in which cooperating aircraft will transmit identification and position data to air traffic controllers. Even with ADS-B, radar surveillance of the National Airspace System (NAS) will continue to be essential for detecting, identifying, tracking, and—if necessary—interdicting non-cooperative aircraft. MPAR also provides confirmation of ADS-B positions, as well as a backup system for identifying and tracking cooperative aircraft. Radar surveillance thus complements the planned cooperative surveillance strategy.

> **A single MPAR network with the capabilities described in this report could perform all of the existing civilian radar functions. In addition, other existing and emerging needs not being adequately met by existing systems could be met with this same MPAR network.**

The beneficial uses for radar observations of atmospheric phenomena are expanding to new applications with substantial value for increased safety and National economic growth. Radar can be used to detect precipitation type and quantify precipitation rate on the spatial and temporal scales necessary for advanced applications in quantitative precipitation forecasting and flash-flood nowcasting. Wind and turbulence phenomena observable by new radar techniques can improve warning times for tornadoes and severe thunderstorms; for wind shear, wind gusts and shifts, and microbursts; and for the local spin-off effects of cyclonic storms interacting with terrain.

These advanced radar observing capabilities, coupled with the improvements in numerical weather prediction (NWP) modeling that advanced radar data make possible, have application to downstream needs as diverse as fire weather and wildland fire management, debris flow prediction, spaceflight launch and recovery, and "ground truth" for calibrating and validating new generations of satellite-borne remote-observing instruments. Radar can also aid in detecting natural hazards to aviation not caused by atmospheric conditions alone, such as bird flocks and volcanic ash plumes.

A comprehensive list of Federal departments and agencies that would benefit from expanded radar surveillance capability—particularly if the multifunction, agile-beam capabilities of an MPAR network were available—includes all of those listed above plus the Department of Energy, the National Interagency Fire Center and the Fish and Wildlife Service of the Department of the Interior, and the Centers for Disease Control and Prevention. Even longer is the list of State and local partners who work with these Federal entities in providing the Nation with emergency preparedness and response, air quality monitoring and enforcement, and safe and efficient transportation systems and infrastructure.

> **The timing is right to conduct a thorough evaluation now of MPAR as an alternative to conventional radar for the full range of current and emerging applications described in this report. The aging of our existing domestic**

> **radar networks for weather and aircraft surveillance will require substantial commitments of Federal resources to either maintain or replace them.**

Seven of these aging, single-function conventional radar networks could in principle be replaced by a single network of MPAR units, with each unit capable of performing multiple functions. A shift in National strategy from multiple networks of mechanically rotating conventional radars to one MPAR network could provide all the capability of the existing systems while also enabling many new observing capabilities for the growing number of downstream applications summarized above and discussed in chapter 2.

When MPAR capabilities are compared with those of conventional radar technology, as chapter 3 of this report does in detail, the technical advantages of MPAR are overwhelming. However, before a decision is made between continuing with conventional single-function radars or an MPAR network, some specific technical issues, discussed in chapter 4, need further testing and demonstration to ensure that the necessary MPAR technology is mature enough to proceed with this major shift in strategy.

> **A preliminary cost evaluation shows that one MPAR network designed to meet multiple national needs can be developed, implemented, and maintained at a lower cost, on a life-cycle basis, than would be required to sustain the existing conventional radar networks through required maintenance and incremental upgrades.**

An MPAR network using today's technology is likely to be a cost-effective option, and technology trends provide opportunities for further cost reductions. Rapid advances in technology and manufacturing economies of scale, driven by the commercial wireless telecommunications industry, have decreased costs substantially and will continue to do so. In a preliminary study of required radar coverage, analysts from MIT Lincoln Laboratory concluded that a network of about 334 MPAR units could replace the roughly 510 units in the seven aging, disparate networks—a 35 percent reduction in radar units. Replacing current networks with 176 fewer radars with an average cost of $10 million each could yield a $1.8 billion savings just in initial acquisition costs. The preliminary cost analysis estimates a further $3 billion savings in operations and maintenance (O&M) costs over the 30-year lifespan of an MPAR network, if aggressively implemented, compared with the total O&M cost to continue with the legacy systems. These preliminary studies need to be refined and validated before a decision on National domestic radar strategy is made.

MPAR enables a 35% reduction in radar surveillance units to provide weather and aircraft surveillance coverage of current domestic surveillance radar assets.

PLUS

MPAR can save $1.8 billion in replacement acquisition costs.

PLUS

MPAR can save an additional $3 billion in life-cycle costs over 30 years.

The JAG/PARP proposes a risk-reduction research and development (R&D) plan that, for a modest investment, will provide a sound technical and cost basis for a National decision between MPAR implementation versus continued maintenance and upgrade of the aging, existing radar systems. The estimated total cost for this risk reduction plan is $215 million.

The technical, cost, and programmatic risks associated with an MPAR network strategy can be reduced substantially by a targeted R&D program, to be completed prior to the time that substantial resource commitments must be made to sustain current radar coverage and capability. This R&D program comprises three components.

1. A technology development and test program will lead to construction of a prototype MPAR unit.
2. Proof of MPAR operational concepts will be conducted initially using the phased array radar of the National Weather Radar Testbed (NWRT), then using the MPAR prototype.
3. The provisional MPAR network concept will be refined using the NWRT, several research radars with appropriate transmission bands, and analysis of data from the legacy radar systems.

On the basis of these findings, the JAG/PARP makes four recommendations to the FCMSSR for actions that will take the next steps toward a coordinated, rational decision on a National strategy to provide domestic radar capability for the next 30 years.

Recommendation 1. The FCMSSR should endorse the concept of an MPAR risk-reduction R&D program that substantially incorporates the objectives and the three components of the plan outlined in chapter 6 of this report.

Recommendation 2. The FCMSSR should consider organizational options to foster collaborative and joint R&D on the MPAR risk reduction activities by establishing a joint entity, such as a Joint National Center for Advanced Radar Research and Development, to manage agencies' contributions to the risk reduction program outlined in this report.

Recommendation 3. For the period prior to operational standup of a joint management entity, the FCMSSR should direct OFCM to form an interagency MPAR Working Group (WG/MPAR) within the OFCM infrastructure to coordinate and report on the R&D activities of participating agencies in implementing an MPAR risk-reduction program. Activities of the WG/MPAR should include, but not be limited to:

- Identification of agency contributions to the first phase of risk-reduction activities in each component prong of the program.
- Establish a cost basis for near-term agency contributions, sufficient to allow incorporation into agency budget submissions.

- Explore options to foster interagency cooperation and collaboration on MPAR risk-reduction activities.
- Develop a set of specific program progress metrics against which annual progress toward risk-reduction goals and objectives can be assessed.
- Prepare and publish an annual statement of the next-year objectives and activities for the risk-reduction program. This annual statement should include a review of progress in the current year and connections to out-year activities and objectives, to show how each year's activities contribute toward achieving the overall risk-reduction goals. As guidance to the participating agencies, the report should include an estimate of budget resources needed for the next-year activities and a summary of prior-year funding by agency. Progress toward goals and objectives, using the program metrics, should be reported each year, with an analysis of areas of shortfall and of substantial progress.
- Identify opportunities for review of program plans and progress by appropriate boards or study committees of the National Academies' National Research Council (NRC).
- Prepare and publish an MPAR Education and Outreach Plan to build understanding of and garner support for a National surveillance radar strategy decision within all the potentially affected Federal agencies, Congress, State and local governmental entities, the private sector, and the public. This plan should involve the academic community and the media and include dissemination of results from the NRC studies suggested above. A series of workshops, coordinated through the National Center for Atmospheric Research (NCAR), should be considered for engaging the academic research community.

Recommendation 4. The FCMSSR should direct that, in conjunction with the MPAR risk-reduction program, a cost-benefit analysis be undertaken to establish the cost-effectiveness of the MPAR option and competing domestic radar strategies. The basis for MPAR acquisition and life-cycle costs should include results from the technology development and test activities and the MPAR network refinement, as appropriate.