MULTIFUNCTION PHASED ARRAY RADAR

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The 2002 report "Weather radar technology beyond NEXRAD" from the National Research Council (NRC) identified phased array radar as a candidate technology to replace America's aging fleet of weather surveillance radars (National Academies 2002). Prompted by the NRC report, the Office of the Federal Coordinator for Meteorology (OFCM) convened a joint action group to investigate user requirements for this emerging technology. The group's efforts resulted in the June 2006 report "Federal Research and Development Needs and Priorities for Phased Array Radar" (OFCM 2006).

Based on advances in radar technology since the 1980s, the OFCM report recommended consideration of wholesale replacement of America's existing weather and aircraft surveillance radar networks with multifunction phased array radar (MPAR) systems. MPAR is a specialized application of general phased array radar technology, designed to simultaneously fulfill the multiple functions of national air and weather surveillance. The basis for this recommendation is as follows: 1) MPAR observations will enable improved meteorological forecasts and warnings; 2) major existing radar components and facilities infrastructure are projected to become obsolete; 3) MPAR will become increasingly more affordable, while the cost to maintain the existing radar systems will become increasingly more expensive; and 4) there is significant potential to greatly reduce overall acquisition and life-cycle costs by combining meteorological and air surveillance functions into a single system. The OFCM report also laid out a research and development plan of action, culminating in building a full MPAR prototype, to answer questions about capability, concept design, and cost before a final acquisition decision would be made.

Under the theme "Leveraging technology to build a next-generation national radar system," the

MULTIFUNCTION PHASED ARRAY RADAR SYMPOSIUM

WHAT: Upward of 180 experts from the federal government, private industry, and academia met to discuss the requirements, feasibility, and affordability of multifunction phased array radar as a replacement technology for the nation's legacy radar systems.
WHEN: 10–12 October 2007
WHERE: Norman, Oklahoma

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Multifunction Phased Array Radar symposium[1] brought together the principal stakeholder agencies—National Oceanic and Atmospheric Administration (NOAA), the Federal Aviation Administration (FAA), the Department of Homeland Security (DHS), and the Department of Defense (DoD)—to discuss replacing the aging Next Generation Weather Radar (NEXRAD) and FAA radar networks with phased array radar technology.

Objectives of the symposium were to

- highlight future-user MPAR requirements and summarize benefits derived from the phased array radar's adaptive scanning capability;
- explore implementation of research and development (R&D) priorities in the 2006 OFCM report, accounting for 1) work already accomplished, 2) items that still need additional focus, and 3) potential alternative configurations;
- gather perspectives from the radar industry on the state of phased array radar technology, the technological uncertainties, and the challenges of delivering affordable phased array radar systems in the future; and
- develop a plan to address MPAR risk-reduction challenges through an implementation strategy and interagency management approach.

These objectives were addressed through a series of presentations and panel discussions led by senior leaders from the principal stakeholder agencies, private industry, and academia. Senior government leaders gave perspectives on how MPAR could meet the core mission requirements of NOAA, FAA, and DHS, and they highlighted both the partnerships necessary for a successful MPAR risk-reduction effort and the importance of linking new sensing technologies to societal benefits. Each of the six panel discussions argued from a unique perspective its case for establishing an MPAR system.

Summaries of the leader perspectives as well as the panel discussions follow, with a consensus statement of the outcome of the MPAR symposium concluding this meeting summary.

NOAA, FAA, AND DHS PERSPECTIVES. Acting Deputy under Secretary for Oceans and Atmosphere Mary Glackin opened the symposium. Her talk emphasized efforts key to a successful MPAR risk-reduction plan. The primary effort is linking MPAR to NOAA's mission of predicting changes in Earth's environment to protect lives and enhance the economy and transportation. Research endeavors to determine these links must consider radar as part of an overall architecture of observing systems to maximize capability and affordability for our nation. Vital to making MPAR succeed are partnerships forged across government agencies as well as with industry, academia, and even other countries.

Victoria Cox, vice president of Operations Planning within the Air Traffic Organization of the FAA, highlighted near-future FAA challenges and mission requirements, and how MPAR could assist them. First, the increasing stress on the National Air Transport System will require automation and better data to safely reduce aircraft separation. Second, the FAA's satellite-based Automatic Dependence Surveillance-Broadcast (ADS-B) system, the basis for cooperative air surveillance in the coming decade, will require a cost-effective backup strategy entailing ground-based primary radars; MPAR may be the solution. Third, MPAR could assist in achieving key Next Generation Air Transportation System (NextGen) capabilities, such as assimilating weather into decision-making, aircraft trajectory–based, and superdensity operations. The essence of NextGen is to have more aircraft flying safely with reduced separation, both between each other and the weather. Higher-density civil air operations in the future mean that better surveillance will be required. For these reasons, the FAA strongly supports the MPAR risk-reduction effort.

Randel Zeller, director of interagency programs within the Science and Technology Directorate of the Department of Homeland Security, commented on mission requirements for aircraft detection. National Security Presidential Directive 16 stipulates that the nation must maximize capability to detect all aircraft within or approaching U.S. airspace. Within the Joint Planning and Development Office, an Integrated Surveillance Study Team has been deputized to develop air surveillance requirements spanning to 2025. The Joint Program Office managing the current long-range air surveillance radars has undertaken service-life extension programs that allow additional time to develop a follow-on air surveillance capability. MPAR is one of several emerging technologies under consideration.

THE PANELS. After the senior-level opening presentations, six panels of experts in MPAR func-

[1] The MPAR Symposium was jointly sponsored by OFCM and the U.S. Office of Science and Technology Policy's Committee on Environment and Natural Resources Subcommittee on Disaster Reduction.

tionality and application discussed the following topics: 1) MPAR User Communities of Interest, 2) Current State of Military Investment in Phased Array Radar, 3) Latest Innovations in Phased Array Radar: An Industry Perspective, 4) Component Technology: What the Future Holds in Cost and Performance, 5) MPAR Alternative Configurations, and 6) Ways Ahead to Address MPAR Risk Reduction—Implementation Strategy and Interagency Management Approach.

The MPAR User Communities of Interest panel—consisting of senior leaders from NOAA's Office of Atmospheric and Oceanic Research, NWS, FAA, DHS, U.S. Air Force, and U.S. Navy—was devoted to determining the mission's needs and capability gaps within various federal agencies that MPAR could address. The panel expressed several common themes. Both for weather and aircraft surveillance, a national primary radar network will be needed well into the foreseeable future. Societal pressures and demands for weather forecasts to become more accurate and of a finer scale drive the need for progressively finer-scale weather observing systems. Panel members stressed that the nation must stay ahead of the obsolescence curve of its legacy radar systems by investing now in aggressive R&D on replacement technologies such as MPAR. The long lead time required for acquisition of any new operational sensing system makes it imperative to begin MPAR risk reduction sooner rather than later, the panel concluded. Past technologies, such as NEXRAD, had demonstrable effects on improving forecast accuracy and warning lead times; hence, panelists insisted that the business case for MPAR must show similar impact on somewhat stagnant severe weather and flooding lead-time statistics. They also felt that MPAR should show improvement in capability and a reduction in overall life-cycle costs to be a viable candidate for acquisition. Like lead times on severe weather, the growth curve of the National Airspace System (NAS) has flattened out in recent years—a technological breakthrough is seen as necessary to move out of stagnation. The panelists were adamant that Americans (both civilian and military) would not tolerate gaps or retrogression in air and weather surveillance coverage during transition to a new technology. Because any new technology implies some risk, tolerance for it is viewed as imperative to exploit such new technology and to realize its full benefit.

Representatives from military research laboratories comprised the panel on the Current State of Military Investment in Phased Array Radar. The panelists confirmed that the military will continue to be heavily invested in the most advanced phased array research, as it has been for the past 40 years or so. Military investment has driven phased array radar evolution from passive, or single-frequency, to active arrays, which transmit multiple frequencies, and on to all-digital radars, which can transmit an unlimited number of frequencies. Overall, the panel identified substantial military research to improve the design and reduce the cost of its phased array radars, having direct relevance to civilian MPAR R&D efforts. A primary goal is to have a scalable system with reusable parts and modules such that technical improvements require little to no retro-engineering. Military phased array radar systems are increasingly based on open architectures, drawing upon commercial off-the-shelf versus very high-priced "mil-spec" parts. Keys to driving down the cost of MPAR from historic norms, the panel concluded, will be utilizing commoditized parts and exploiting economies-of-volume production. Currently, the military is pushing industry to produce phased array radar modules of progressively lighter weight, higher efficiency, smaller size, and much lower cost. Although size restrictions aboard aircraft, ships, and vehicles have driven the military sector to utilize higher-power radar components than the fixed civil MPAR would need, there is still much overlap and potentially useful technology.

The Latest Innovations in Phased Array Radar: An Industry Perspective panel drew together representatives from the major radar integrators: Northrup Grumman, Raytheon, Lockheed Martin, and Harris Corp. The conclusions that emerged from this panel concentrated on user requirements and the design and cost of MPAR. Radar industry leaders agreed that although weather surveillance is a new application for phased array radar, the technology to build MPAR for civil surveillance applications exists now; there is not anything MPAR is programmed to do for weather or civil air surveillance that exceeds the capability of current phased array radar technology. A major issue to be determined is cost; while the ultimate cost of a national MPAR system is yet to be determined, building architecture around open systems and scalability will serve to drive down future costs. Lowering the cost of phased array radar antennas alone will not be the whole solution, although the current downward trend in transmit/receive (T/R) module costs is encouraging. More efficient data processing through enhanced software and other "back-end" breakthroughs are reasoned to be essential ingredients in the overall cost issue. In addition, an essential aspect of radar design and risk-

reduction R&D efforts is user requirements. Many user requirements are not "requirements" at all but simply the upper performance level of legacy systems. Thus, members of this panel agreed that users must clearly state what they really need rather than restate what they have had to settle with in the past.

The panel on Component Technology: What the Future Holds in Costs and Performance drew together principal manufacturers of phased array radar components. As with the panel on Latest Innovations in Phased Array Radar: An Industry Perspective, themes emerging from this panel focused on the cost and design of MPAR. Component manufacturers look to exploit dual-use capability (same components for military and civil applications) as a key to affordability. They also emphasized the importance of building flexibility into the system so it can grow to accommodate future missions with a minimum of retro-engineering. Through the economies of scale, the sheer volume of a national MPAR acquisition will drive down the cost of T/R modules. The integration of more functions onto the same chip also lowers cost and increases reliability because fewer high-cost RF interconnects are needed on surface-mounted chips. Additionally, new semiconductor materials provide much higher efficiency, allowing low-cost air cooling for heat dissipation rather than complex, high-cost liquid cooling.

The MPAR Alternative Configurations panel, drawing upon representatives from the National Weather Testbed, the Center for Collaborative Adaptive Sensing of the Atmosphere, Massachusetts Institute of Technology's Lincoln Laboratory, and the National Center for Atmospheric Research (NCAR), challenged the symposium to think broadly about MPAR capabilities without settling prematurely on a single engineering solution. Alternative configurations for an eventual national MPAR system, panel members noted, would exploit the optimum capability of phased array radar technology. Panel members also pointed out that radar performance requirements must be completely redefined for phased array versus mechanically scanning radars. Rather than simply carrying requirements over from legacy systems, phased array radar technologies would likely achieve equivalent results in quite different ways. For example, the equivalent to using a narrow beamwidth in mechanically scanning radars to determine spatial resolution could be achieved using a wider beam width of a phased array radar antenna. In any phased array system of the future, weather—rather than air surveillance—will be the principal radar resource driver. In other words, if MPAR can meet weather requirements (in particular, for clear air reflectivity), it can almost certainly meet any air surveillance requirements that will be levied against it.

To exploit the true power of phased array radar surveillance, the panel determined that MPARs should be considered "nodes on a network" rather than free-standing radars. Demand for extremely high-resolution radar coverage, especially in urban areas, will drive requirements for citing, design, and configuration of the MPAR system. Gaps in low-level (boundary layer) coverage inherited from legacy radars need to be addressed by any follow-on radar systems. Earth curvature and topographic blockage create blind spots in current radar coverage that are important both from meteorological and air-defense perspectives. Although blanket coverage over the entire United States may not be economically feasible, radar coverage can be designed to be denser over high-priority areas. The group agreed that to take full advantage of MPAR data, meteorologists will require the development of effective visualization and automation tools, due to the sheer volume of the data.

The panel titled Ways Ahead to Address MPAR Risk Reduction recapped themes from the previous five panels, linking consensus on user needs and technological maturity of phased array radar to future steps toward eventual MPAR risk reduction and implementation. The overall conclusion of the panel was that the symposium had demonstrated solid consensus on both the desirability and feasibility of MPAR as a candidate technology to meet national surveillance requirements, for weather and aircraft, but that developing an effective interagency management structure for MPAR risk reduction will prove challenging. Some panelists suggested that the NEXRAD interagency management model may prove an effective precedent for MPAR management. Regardless of the management strategy chosen, risk-reduction efforts must engage the four principal agencies involved: NOAA, FAA, DoD, and DHS. Engaging agency support for risk reduction will depend on building a compelling business case; with this in mind, the need for more robust DoD involvement was highlighted. The risk-reduction implementation strategy must include building and field testing a prototype phased array radar with modern active array technology that will actually demonstrate simultaneous multifunction capability, including simultaneous execution of air surveillance and weather missions. The panelists concluded that follow-on technical interchange meetings between government and industry are required to assess the

true state of the commercial capability to deliver affordable phased array radar technology that is able to meet user requirements.

OUTCOME. The fundamental message from the symposium was clear: now is the time to begin the evaluation of MPAR. To do this, a risk-reduction implementation strategy needs to be developed. Items driving the urgency are that 1) legacy surveillance radars are nearing the end of their life cycle; 2) society demands greater protection of life and property through more timely warnings of hazardous weather events, and increased accuracy, spatial resolution, and lead times for severe weather warnings; 3) the need for an enhanced capability to track noncooperative aircraft and other airborne threats to safety and security is paramount; (4) the multifunction capability of MPAR leads to reduced life-cycle costs of a combined national radar system; and (5) a risk-reduction implementation strategy will reduce uncertainties and produce cost-effective alternatives, which will provide the information that decision makers need to develop a sound business case for the future of our national radar network.

Additional information on the symposium, including presentations and a summary report, can be found at www.ofcm.gov/mpar-symposium/index.htm.

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