14B.4 A REVIEW OF THE SECOND MULTIFUNCTION PHASED ARRAY RADAR (MPAR) SYMPOSIUM

Samuel P. Williamson, Judson E. Stailey*, and Sabrina J. Taijeron
Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM)

ABSTRACT

Multifunction Phased Array Radar (MPAR) is a multiagency initiative to replace seven types of mechanically rotating conventional radars operated by four federal agencies with one type of phased array radar. The plan calls for sharing data from approximately 330 multifunction radars, which would replace about 510 single-purpose radars. For a more comprehensive review of MPAR concepts, see OFCM (2006).

The Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM), in conjunction with the OFCM-sponsored Executive Council for MPAR and Working Group for MPAR, planned and sponsored the Second MPAR Symposium, convened at the National Weather Center in Norman, OK, on November 17-19, 2009. A follow-on to the first symposium, held in October, 2007, Symposium II focused on key risk-reduction efforts undertaken during the last two years. Meeting under the theme *Moving Forward with Risk Reduction for Cost Effective Service Improvements*, 230 participants from government, industry, academia, and other sectors reviewed progress in addressing multifunctionality, potential service improvements (OFCM 2009), and cost reduction. Special presentations included talks by Dr. Randolph Lyon, Commerce Branch Chief in the Office of Management and Budget, and Dr. Karlin Toner, Director of the Secretary of Transportation's NextGen Coordination Staff. Recommended actions resulting from the symposium included completing a preliminary cost-benefit analysis and a mission needs assessment, updating the MPAR R&D Plan, synchronizing the MPAR concept of operations and governance with broader on-going efforts within the integrated surveillance community, leveraging other phased array radar R&D, and addressing radio spectrum allocation issues.

Corresponding author address: Judson E. Stailey, OFCM, 8455 Colesville Road, Suite 1500, Silver Spring, MD 20910; e-mail Judson.stailey@noaa.gov

1. INTRODUCTION AND BACKGROUND

This paper provides a summary of the Second MPAR Symposium, which took place in Norman, Oklahoma, from November 17-19, 2009. The first MPAR Symposium—convened in October, 2007, under the theme *Leveraging Technology to Build a Next-Generation National Radar System*—set the stage for development of a risk reduction strategy and ongoing research and development targeted at implementing that strategy. After two years' work, the community reconvened at MPAR Symposium II under the theme *Moving Forward with Risk Reduction for Cost Effective Service Improvements* to assess progress in executing the risk reduction strategy and to consider next steps.

MPAR Symposium II—with 230 experts from the federal government, academia, and the private sector—was an outstanding opportunity for technical exchange. The objectives of the symposium were as follows:

- Review MPAR risk-reduction implementation strategy
- Discuss MPAR multifunctionality with respect to agency needs, priorities, and principles of operation
- Review the progress of MPAR-related research and development
- Highlight potential service improvements with respect to air surveillance, weather, and other mission enhancement opportunities
- Explore the challenges to delivering a cost-effective phased array radar capability
- Discuss the way ahead and next steps

2. OPENING SESSION

2.1 Opening Remarks

Mr. Samuel P. Williamson, the Federal Coordinator for Meteorological Services and Supporting Research, provided opening remarks and set the stage for the rest of the symposium's activities. He reviewed the action items from the first symposium and the subsequent work to address those items. Additionally, he emphasized that work being accomplished in the air surveillance community, including the Next Generation Air Transportation System (NextGen), is important to the MPAR initiative. This work includes the Integrated Surveillance Concept of Operations (CONOPS) that was recently completed and the efforts to define an Integrated Surveillance Governance. Mr. Williamson stated that it will be important to determine how the MPAR initiative fits within the larger Integrated Surveillance umbrella. He also reviewed some major MPAR-related activities, including the following:

- Publication of MPAR Program Status and Potential Service Improvements
- Publication of the NRC report Evaluation of the Multifunction Phased Array Radar Planning Process
- Major efforts by the key agencies (FAA, NOAA, DoD Army and Navy, and DHS)

He then reviewed the objectives of the symposium (see paragraph 1 above) and the expected outcomes. He closed his remarks by previewing the symposium agenda.

2.2 Welcome

Dr. Kelvin Droegemeier, Vice President for Research, University of Oklahoma, represented President Boren. His comments included:

- This event represented a gathering of government, industry, and academia sharing a common vision of doing things very differently.
- The differences in how we will do things allow fundamental changes in weather operations that impact society:
  - Providing severe weather warning based on forecasts rather than observations
  - Making new air traffic management paradigms possible in NextGen
  - Intelligent use of resources—sharing data, sharing systems, adaptive scanning, etc.
- This symposium is exciting because we get to work on the details of how to make this happen.

2.3 Keynote Address

Dr. Randolph M. Lyon, Chief, Commerce Branch—Housing, Treasury and Commerce Division; Office of Management and Budget, opened his comments by reminding the participants that budgets are very tight, so programs must show good value. He observed that MPAR appears to be that type of program, and then address a number of important factors that should be taken into considerations as MPAR moves forward:

- You must make the cost case (consider benefits of saving lives and improving on-time airline performance; factor in alternative investments and allied investments (NOAA weather radio, modeling; insure that cost projections are comprehensive)
- Consider the spectrum intensity of the system—RF spectrum that is used is a cost because it cannot be sold or leased by the government
- Make use of the Small Business Innovative Research program
- Exploit the synergies associated with Regional Innovation Clusters
- Building the right interagency framework is key—OMB can help
- Expect and plan for funding to be competitive, merit-based

2.4 Senior Leader Perspectives

Senior leaders from the key agencies associated with MPAR were asked to speak about important mission areas and programs that drive radar requirements, the strength their agencies bring to an interagency program like MPAR, how existing partnerships can enhance the potential for MPAR success, and what could be done better to make progress reducing risk and improving cooperation.

2.4.1 Dr. Richard Spinrad, Assistant Administrator of NOAA for Oceanic and Atmospheric Research.

Dr. Spinrad represented the Department of Commerce. His remarks included:

- Radar is a basic observing system that crosses all NOAA mission goals, but to make it a reality agencies must work together; working together we must
  - Demonstrate effectiveness (including cost-effectiveness)
  - Make MPAR a priority
  - Craft a clear, concise message about what MPAR can do
  - Inform policy makers
  - Communicate with internal stakeholders

- There is a role for all of us—the challenges are big, but the payoffs are extraordinary

2.4.2 Mr. James Williams, Director of Systems Engineering and Safety, Federal Aviation Administration.

Mr. Williams represented the Department of Transportation. His remarks included:

- The near-disaster involving a state governor's aircraft illustrated the need for better integration in our surveillance systems
- The work of the Integrated Surveillance Study Team initiated the current effort to address the surveillance gaps and deficiencies
- Under the auspices of the Joint Planning and Development Office (JPDO), an Integrated Surveillance (IS) Concept of Operations (CONOPS) was completed in June 2009
- An IS Enterprise Architecture had been developed within JPDO and is under agency review
- An effort to define an interagency governance scheme is underway
- The move to Automatic Dependent Surveillance—Broadcast under NextGen does not eliminate FAA's need for radar
- MPAR is a potential solution to the need to replace FAA radar systems stipulated in FAA's Enterprise Architecture Roadmap

2.4.3 Mr. Kevin "Spanky" Kirsch, Director, Science and Technology Special Programs, Department of Homeland Security.

Mr. Kirsch's remarks included:

- Interactions between the deputy secretaries of DHS and DoD regarding the status of surveillance and proposals to address deficiencies
- Related national-level activities:
  - Air Domain Surveillance and Intelligence Integration in response to NSPD-47/HSPD-16
  - DHS hosting Air Domain Awareness summit in January 2010
  - NextGen actions
  - Secretary Napolitano "committed to integrated air surveillance"
  - C2 Gap Filler Joint Capability Technology Demonstration
  - Over-the-Horizon Radar Technology Risk Reduction Initiative Study
  - Wind Turbine Modeling Study
- Multifunction Phased Array Radar could provide
  - An effective complement to the FAA GPS system
  - Improved weather surveillance
  - Improved surveillance of U.S. airspace for potential threats
  - Wind turbine effects mitigation
  - Mitigation of L-Band GPS signal interference

2.4.4 Dr. John Stubstad, Director, Space and Sensor Systems, Defense Research and Engineering, Office of the Secretary of Defense.

Dr. Stubstad represented the Department of Defense. His remarks included:

- A review of the DoD Radar Joint Analysis Team (JAT)
  - Tasked to develop a coordinated, defense enterprise roadmap for radar technology, radar development and radar procurement
  - Completed work December 2008
  - Designated specific "special interest" radar acquisition programs
  - Directed establishment of a radar-focused Open Systems Architecture Defense Support Team
- A review of current DoD-level radar related activities
  - Radar Roadmap
  - Radar Spectrum Working Group
  - Radar Open System Architecture Working Group
  - Radar Synchronization Panel Reviews
- The goal must be to lower radar lifecycle costs through increased collaboration with the services and Joint Staff on requirements/capabilities

2.5 Special Presentations

2.4.1 Dr. Karlin Toner, Director, NextGen Coordination Staff to the Secretary and Senior Policy Committee, U.S. Department of Transportation.

Dr. Toner discussed NextGen and potential MPAR involvement in initiative. Her remarks included:

- Flight delays cost the US economy $41 billion in 2007
- Adverse weather accounts for nearly 70% of delays
- MPAR shows potential to support NextGen in two ways:
  - To replace existing FAA air surveillance radars as a back-up to ADS-B
  - To help reduce weather impacts by providing more precise location and rapid updates for hazardous weather
- MPAR requires aligning agency need, priorities, and operating principles—this is challenging
  - At a recent meeting NextGen Senior Policy Committee members (key department secretaries) all demonstrated a willingness to tackle the challenges of aligning policies and resources
- The potential of MPAR fits with the national strategic direction

2.4.2 Dr. Paul Smith, Chair—NRC Committee on the Evaluation of the MPAR Planning Process, Evaluation of the MPAR Planning Process.

Dr. Smith reviewed the make-up of the NRC committee and its processes, and discussed the results of the study (NRC 2008):

- The overarching recommendation of the committee: The MPAR Research and Development (R&D) program be continued with the objective of evaluating the degree to which a deployable MPAR system can satisfy the national weather and air surveillance needs cost-effectively.
- Principal findings:
  - Phased Array technology can offer some significant technical advantages.
  - Significant technical questions for weather surveillance remain
  - Implementation of a network of ~350 MPAR radars could replace 510 existing NWS and FAA radars
  - Replacement of existing systems alone cannot meet all agency mission requirements
  - JAG Report "preliminary cost evaluation" is embryonic; does not consider cost-benefit prospects of the legacy systems or of other (non-PAR) alternatives, does not consider the cost-benefit status of the MPAR risk reduction plan, and does not include an independent analysis

2.4.3 Mr. Jud Stailey, Senior Staff Meteorologist, Office of the Federal Coordinator for Meteorology.

Mr. Stailey reviewed the MPAR Risk-Reduction Strategy developed by the Working Group for MPAR in response to an action item from the first MPAR Symposium. He then presented the following:

- A review of key risk-reduction issues—multifunctionality, cost, and service improvements
- A review of efforts to establish weather and air surveillance service improvements derived from phased array radar
- Goals for updating the MPAR Risk-Reduction Strategy

Session #	Subject
1	Multifunctionality—Agency Needs, Priorities, and Principles of Operation
2	Underpinning for Service Improvements: Technology Innovation and Development—Laboratory Update
3	Underpinning for Service Improvements: Technology Innovation and Development—Industry Update
4	Potential Service Improvements for Air Surveillance and Weather—Part 1
5	Potential Service Improvements for Air Surveillance and Weather—Part 2
6	Addressing the Risk Reduction Challenges
7	Moving Forward with Risk Reduction

Figure 1. The seven MPAR Symposium II sessions focused on key risk reduction issues—multifunctionality, service improvements, and cost reduction.

3. SYMPOSIUM SESSIONS

The core program at the symposium comprised seven sessions (Figure 1) revolving around the key risk reduction challenges (multifunctionality, service improvement, and cost reduction). A brief summary of each session follows:

3.1 Session 1: Multifunctionality—Agency Needs, Priorities, and Principles of Operation

This panel—consisting of senior leaders from NOAA's National Weather Service, the Federal Aviation Administration, the Department of Homeland Security, and the Department of Defense—was moderated by **Dr. Fred Lewis**, Air Force Director of Weather. Dr. Lewis reminded participants that in both weather and surveillance MPAR would be one system in a system of systems, and would not have to do the whole job. We need to work on getting the "big S" in surveillance and the "big W" in weather. **Mr. Jim Williams** (FAA) reviewed FAA's various practical research efforts that help define the agency's potential use of MPAR, including showing that MPAR could back up ADS-B, demonstrating that the rapid update capabilities of MPAR improve the accuracy of the Corridor Integrated Weather System (CWIS) over accuracy provided by the WSR-88D, and investigating the potential for a PAR to perform mode S surveillance. **Mr. Spanky Kirsch** (DHS) reviewed air surveillance needs and options, showing the role MPAR could play. **Mr. Don Berchoff** (NWS) presented the service's goals for 2025, which would be supported by an integrated observation/analysis system of which MPAR would be a part. The NWS vision requiring improved radar observations includes up to 60 minute warnings for tornados based on forecasts rather than observations, flash flood lead times of 2-4 hours, 30-60 minutes forecasts for initiation of convection to support aviation. **Dr. John Stubstad** (DoD) departed from the needs/priorities message to discuss new DoD procurement requirements. Using the Risk-Reduction Strategy from Mr. Stailey's earlier briefing, he referred to the depiction of the Joint Capabilities Integration and Development System (JCIDS) to highlight some of the challenges facing procurements under the revised DoD system.

3.2 Session 2: Underpinning for Service Improvements: Technology Innovation and Development—Laboratory Update

This panel, comprising representatives of laboratories and research centers, was moderated by **Dr. Joe Friday**, professor emeritus at the OU School of Meteorology. Dr. Friday reminded the participants of the on-going issue of determining when to draw the line and implement a new technology rather than wait for further developments and improvements. We're not at that point yet with MPAR, but will likely face that decision within the next decade. **Mr. Rob Sexton**, of the Naval Surface Warfare Center, represented the Office of Naval Research and discussed Navy phased array R&D. Primary Navy research and development activities centered on S-band phased arrays for volume surveillance applications from surface combatants. Near term S&T is driven by Air and Missile Defense while longer term S&T is driven by affordable volume surveillance radar concepts to replace aging systems. The strategy includes pushing open architecture into the radar itself, not just at the radar/combat system interface. Within this context, Mr. Sexton briefed on digital array radar development, the Affordable Common Radar Architecture Program, and the points of synergy between Navy developmental programs and MPAR. **Dr. David Pepyne,** University of Massachusetts, briefed on progress with the Collaborative Adaptive Sensing of the Atmosphere (CASA) initiative, which is investigating the concept of deploying 10,000 short wavelength/range radars at about 30 km spacing across the US to provide 100% coverage at 300m elevation. An array of 4 rotating radars deployed in Oklahoma has demonstrated the ability of the radars to collaborate to produce high -temporal and spatial resolution products. Plans call for field testing of a phased array that horizontally scans electronically and vertically scans mechanically next year, and field deployment of two phased array panels in 2012. **Mr. Larry Bovino**—US Army Communication-Electronics Research, Development, and Engineering Center (CERDEC)—briefed on radar development activities at CERDEC and antenna technology development work within the Army Research Labs. Drivers and constraints for the work include system requirements that flow down from operational requirements, mobility/transportability, reliability and maintainability that emphasized modularity and minimizing single points of failure, and unit and life-cycle cost. His discussion of radars under development at CERDEC included information on a cylindrical array architecture that could be of interest in addressing dual polarization concerns (see Zrnic in Session 6) and the Enhanced Multi-mission radar, which has been proposed as a platform for MPAR prototyping. **Mr. Doug Forsyth**, Chief of Radar R&D at NSSL, reviewed accomplishments with the National Weather Radar Testbed since the last MPAR symposium. These include study of design criteria for a dual polarized sub-array, activation of a monopulse port, installation and integration of a multichannel receiver suite, modification of the real time controller to support adaptive scanning, and several initiatives to improve data quality, upgrade the signal processor, enhance the user interface, and provide wind retrievals. In addition, the capability to perform adaptive scanning was implemented and tested, and several examples of results were presented.

3.3 Session 3: Underpinning for Service Improvements: Technology Innovation and Development—Industry Update

Mr. Mike Sarcione, Sr. Principal Engineering Fellow at Raytheon, addressed how the interplay between performance pull and technology push can work to result in successful development of weather/surveillance capabilities. He stated that most necessary technologies already exist but must be leveraged from commercial and defense industries. After reviewing several key technologies, he discussed Raytheon's contributions to MPAR technology. **Dr. Doug Reep**, Director of Airborne Early Warning Radar and Advanced Programs for Lockheed Martin, discussed current trends in phased array radar technology, key enabling technologies, and present status of maturity of PAR technologies before proposing research thrusts for MPAR. The maturity of key technologies varied from fielded (GaAs MMICs) to basic research (clutter rejection), with several areas still in applied research. He closed by pointing out that MPAR can leverage DoD phased array technology and commercial packaging, but investment in MPAR-specific technical areas will be needed. **Mr. Jay Kralovec**, Chief of Antenna Technologist/Space Systems for Harris Corporation, concurred that key technologies required to support an MPAR implementation exist, but affordability will require improved produceability. He pointed out that more rapid results are possible with improved development infrastructure. In particular, efficient design and analysis tools can improve first pass success. **Mr. Frank Walker** Director of Surveillance and Fire Control Systems at Northrop Grumman, highlighted the trends in active electronic scanned array technology, the operational results of those trends, and the way the technology is evolving to support multifunction systems. He highlighted the key technology challenges for MPAR and assessed the current state of the technology and/or the associated cost, noting that affordability ends up being the key in most cases. He closed by encouraging the MPAR community to engage industry, suggesting a focus on system concept definition, establishing system level performance requirements, and targeted risk reduction. **Dr. Jeff Barner**, Program Manager for Foundry Services at Cree Inc, provided an overview of wide bandgap device technology, reviewing the status of GaN (gallium nitride) technology. Pointing out that next generation MPAR T/R modules must use COTS components and processes to achieve lowest cost, he highlighted the cost and performance benefits of GaN technology: ultra-high efficiency, high power density, and higher voltage operation—all supporting a wider trade-space for systems optimization. He closed by detailing areas for additional R&D—switch-mode device and circuit optimization, power/cost/thermal optimization, and module packaging and interconnects. **Mr. Steve Nelson**, VP MMIC for Operations at Cobham, listed the requirements for a low-cost phased array supplier—highly integrated custom MMICs, low cost packaging approaches, innovative antenna technologies (including dual polarization designs), high volume manufacturing capability, open architecture, and scalable design. He discussed how X-band expertise can be leveraged for S-band development, and provided a detailed look into a variety of issues that drive cost, articulating challenges and suggesting possible solutions.

3.4 Session 4: Potential Service Improvements for Air Surveillance and Weather—Part 1

Dr. John Cho, MIT Lincoln Laboratory, opened this session with a review of MPAR characteristics and potential service improvements that follow from those characteristics. The MPAR concept involves replacing over 500 aging, mechanically scanned radars of 8 unique types with about 330 copies of one type of state-of-the-art radar that would meet the requirements of 4 different missions. The intent would be to streamline to one type of radar, taking advantage of modularity and scalability. Anticipated service improvements would derive from rapid and adaptive scanning, elevation angle space resolution and coverage, multiple spaced received beams, polarimetry, and high bandwidth and pulse repetition frequency. He closed by cautioning that the MPAR resource in the energy/time/frequency domain is finite, so not all potential service improvements will be realized. **Lt Col Bryan Miller**, USAF, from NORAD Operations, provided NORAD's perspective on aircraft surveillance. NORAD shares sensors with the FAA and DHS to defend North American airspace against cooperative and non-cooperative manned aircraft, unmanned aircraft systems (UAS), cruise missiles, etc. Service improvements anticipated with future systems include improved detection and processing capability, improved threat assessment, increased air domain coverage, and target quality guidance capability. MPAR is considered one of systems needed to help meet these needs. **Mr. Gary Andrews** of DeTect Inc briefed on MPAR technology and the potential for aircraft birdstrike risk management, highlighting the magnitude of the birdstrike problem and some of the more noteworthy incidents resulting in aircraft mishaps. Most birdstrikes cause no damage, and many occur during flight regimes that do allow for evasive maneuvering. He reviewed the limited actions being taken today to minimize the birdstrike hazard, and suggested that MPAR could significantly reduce risk through increased capability and coverage, and especially with dual polarization to separate birds from insects and estimate the size of birds. Human factor considerations suggest that hazard advisories should be provided directly from system to cockpit, bypassing task-saturated controllers. **Dr. David Schneider**, from USGS Alaska Volcano Observatory, discussed radar applications in responding to the risks presented by volcanic ash, starting with a review of the nature and magnitude of the problem. There have been 120 reports of aircraft encounters with volcanic ash since 1973, the most dramatic occurring as a result of the 1989 Mt. Redoubt eruption when an airliner lost all four engines and suffered $80 million in damage. He reviewed how radar is being used at present to detect and track volcanic ash, then suggested how MPAR might provide improved service. Polarization and the ability to provide faster vertical cross-sections are key system capabilities, while support to both science and operations could include providing information on the role of ice and water in the eruption column, identifying secondary maxima of fall deposits, determining mass loading, and eruption model testing. He closed by suggesting baseline and optimal requirements for volcanic ash operations. **Mr. Andy James**, of the Oklahoma Department of Forestry, discussed the use of radar in fire detection and smoke management. He reviewed the nature of the wildfire problem in southeastern Oklahoma, listed the radar resources available to support his work, and showed examples of smoke returns on radar. He closed by discussing how he uses radar on a daily basis to detect fires that have not yet been reported and track their status remotely.

3.5 Session 5: Potential Service Improvements for Air Surveillance and Weather—Part 2

Mr. Tim Maese, Basic Commerce and Industries, briefed on extracting weather data from phased array radars. The Navy has developed the capability to passively (i.e., with no impact on other radar functionality) process surveillance radar data to extract weather echoes from the SPS-48E and the SPY-1 systems. After formal military utility assessment of the SPS-48E extractor (called Hazardous Weather Detection and Display Capability (HWDDC)), the Navy is deploying it on large deck ships. The capability provides composite reflectivity, wind fields, storm track and prediction, echo tops, and refractivity from clutter (RFC). Potential benefits to MPAR include R&D lessons learned (extracting high-quality weather data from air surveillance scan strategies and waveforms), open system architectures and modular processing software, and detection and characterization of propagation conditions. **Dr. Pam Heinselman**, National Severe Storms Laboratory spoke on the early detection of severe storms using phased array radar based on experience with the National Weather Radar Testbed. She cited several cases of service improvements based on high resolution, rapid refresh data and adaptive scanning. Her studies included the participation of operational forecasters from NWS field offices, and allowed her to conclude that high temporal resolution provided better continuity of significant features, making them easier to identify. This led to greater confidence on the part of forecasters and resulted in earlier warnings with longer lead times. **Dr. David Stensrud**, NSSL Division Chief for Forecasting R&D, briefed on storm-scale

NWP models and initialization using PAR data. He made the case that forecasters have perhaps too much data to assimilate and apply during the severe weather forecasting process, and suggested that the data should be synthesized into a single 3D analysis that can be used to initialize an NWP model. The consensus that NWP initialization should be based on 8-10 volumetric scans results in an observation period of about 40 minutes with the WSR-88D. This can be significantly compressed with MPAR, resulting in more timely and/or more accurate forecasts. He illustrated this by comparing model outputs based on 20 minutes of data (20 volumes for the NWRT versus 5 for the 88D) to observed radar data. He closed by citing the challenges faced in improving on the present laboratory capability and transitioning it to operations. **Dr. Robert Palmer**, University of Oklahoma, briefed on other weather applications (besides severe weather forecasting) for phased array radar systems. He illustrated the ability of a PAR to exploit beam agility to perform beam multiplexing, and showed the practical results of applying that technique. He also highlighted the ability of adaptive arrays to mitigate ground clutter, perform spaced antenna interferometry to measure cross-beam winds directly, and measure moisture fields. Dr. Walter Bach, US Army, addressed potential PAR use for boundary layer and dispersion applications. He cited a series of reports and studies that address boundary layer forecasting issues, highlighting an "observation gap" between data taken for large scale (mesoscale, synoptic, global) and very fine scale numerical weather prediction. He went on to point out that radar can provide boundary layer data to fill some of that gap, and ended by presenting the key challenges to fine-scale planetary boundary layer modeling.

3.6 Session 6: Addressing the Risk Reduction Challenges

Mr. Tracy Wallace, Georgia Tech Research Institute, provided a look at the preliminary results of an effort funded by FAA to define the technical issues associated with MPAR. He reviewed some of the basic considerations related to the following challenges: dual polarization, calibration for polarization characteristics and sensitivity, development, production and sustainment costs, radome selection, cooling, and requirements creep. The final results of this work will be used to define issues addressed with the Technical Assessment Program (see Garth Torok presentation below). **Dr. Dusan Zrnic**, National Severe Storms Laboratory, discussed one of the most challenging issues for MPAR—dual polarization. He reviewed the options for implementing dual polarization on a PAR and discussed the implications of each. He then proposed using a cylindrical rather than a flat array and pointed out that polarization issues with a cylindrical array are essentially the same as those for a parabolic antenna. This solution could provide all the advantages of phased array without compromising the expected capability of the WSR-88D to take polarimetric measurements. **Dr. Jeff Herd**, MIT Lincoln Lab, described on-going work with contractor M/A COM Technology Solutions to develop a low-cost dual polarized phased array panel. The prototype panel, a 64-element array which is currently being assembled, will provide critical assessment data on panel costs (fabrication, assembly and test), dual polarization performance, calibration techniques, and multiple mode functionality. Preliminary information suggests that T/R units can be built for about $20 each, based on actual bills of material from multiple vendors. **Mr. Garth Torok**, from the William J. Hughes Technical Center (FAA) described FAA's program plan for radar replacement, which features consideration of MPAR as an option to replace their Terminal Doppler Weather Radars and Air Surveillance Radars. FAA, working in conjunction with NOAA, is planning a Technical Assessment Program (TAP), the goals of which are to engage industry in demonstrating phased array dual polarization capability, affordable technology performance, and multifunctionality. TAP involves competitive selection of vendors to develop a white paper describing technical solutions to MPAR issues and subsequent down-selection based on the white papers for vendors to design, develop, and test a sub-array based on the solutions laid out in the white paper. The intent is to address as many of the MPAR technical challenges as possible with sub-arrays and lay a firm foundation for proceeding with prototype development. **Dr. Yasser Al-Rashid**, Principal Engineer for Lockheed Martin, briefed on potential opportunities to leverage DoD radar assets to demonstrate PAR dual polarization capability and multifunctionality. One option would be to use an existing DoD radar "backend" to support a new active array antenna, which could be mounted on the back side of the NWRT. The other option would be to modify an Army EQ-36 radar for dual polarization. In addition to dual polarization, both options would support investigation of service improvements and multifunctionality. **Dr. Bill Chappell** from Purdue University described his work on a digital array radar for the Army and potential applications to MPAR. After defining digital array radar he described the prototype 16-element array they have designed and built, and the follow-on 8-element dual polarization array. Key to the work was the successful demonstration of “digital at every element” capability, which, along with massive integration and high power plastic operation employing SiGe and GaN technology, respectively, could help lower MPAR production costs.

3.7 Session 7: Moving Forward with Risk Reduction

Moderator **Dr. Paul Try** (Science and Technology Corporation) introduced this session by pointing to the completed initial MPAR studies and documentation in the context of the Risk-Reduction Strategy. **Dr. Jeff Kimpel**, Director of the National Severe Storms Laboratory, pointed out that while cross-agency coordination could be improved, progress has been made in addressing the NRC report recommendations and potential service improvements have been identified. He recommended the establishment of a multi-agency Program Council for MPAR to oversee development of a CONOPS, requirements, cost-benefit analysis, and other programmatic necessities. He closed by pointing out that tracking aircraft with PAR is easy, but at this point the weather issues remain challenging. **Mr. James Williams**, Director of Systems Engineering, FAA, provided several specific suggestions for moving forward with MPAR, including development of a unified R&D plan, updating the Risk Reduction Strategy, starting the process of developing a business case for MPAR, addressing governance (perhaps in the context of broader integrated surveillance initiatives), and starting work on spectrum allocation challenges. He concluded by reminding the participants that the driving issue for MPAR is cost-effectiveness. **Mr. Ted Hom**, US Army Product Manager for Radars, reviewed the technical capabilities of the Army’s EQ-36 radar, which has received attention as a potential platform for modification into a dual pol demonstrator for MPAR. He pointed out that there may be sufficient overlap between MPAR and Army technologies to warrant cooperation and that potential exists to use an EQ-36 radar or its prototype (the Enhanced Multi-mission Radar) to support both MPAR and Army R&D. **Lt Col Bryan Miller**, USAF, from NORAD Operations, described a NORAD-NORTHCOM effort to reduce risk associated with an over-the-horizon radar initiative that was not moving forward due to the lack of readiness in some technologies. Pending funding, the two-phase initiative will extend through FY12 or 13 and demonstrate technology readiness to develop a full-power prototype system. **CAPT Michael Angove**, representing the Navy Oceanographic enterprise (NOe), pointed out that protecting the Fleet from destructive weather is the NOe’s top priority, and highlighted the MPAR capabilities that could enhance resource protection (faster volumetric scans, adaptive sampling to focus on severe weather, better tornado and hail prediction, and longer hazardous weather warning lead times). He pointed out, however, that in the US the Navy is heavily dependent on the National Weather Service for support in meeting resource protection requirements. The Navy remains engaged in the MPAR initiative, focusing on leveraging Navy R&D and technology. He closed with several recommendations, including avoiding mission creep, focusing R&D on requirements, leveraging lessons learned from the Navy’s HWDDC program (see Maese presentation in Session 5), exploiting COTS/GOTS technology, and establishing and documenting the costs and benefits of the program.

4. Review of Action Items and Closing Remarks

Mr. Samuel P. Williamson, Federal Coordinator for Meteorological Services and Supporting Research, began the closing remarks by providing overarching symposium comments, including important points covered in the presentations given by Dr. Lyon and Dr. Toner. He then reviewed the symposium objectives and expected outcomes, expressing satisfaction that the participants had met the objectives and fulfilled the expectations. Also, Mr. Williamson reviewed the near-term follow-up actions, including an upcoming December 14, 2009, meeting of the Executive Council for MPAR that will address results of the symposium. He then presented the longer term action items (Figure 2).

Finally, Mr. Williamson requested feedback from symposium participants, thanked the many organizations and people who made MPAR Symposium II possible, and adjourned the symposium.

MPAR Symposium II Action Items
• Complete a preliminary cost-benefit analysis • Complete a mission needs assessment, identifying current radar-related shortfalls and needed improvements, and considering both technology/equipment and services • Identify technical challenges and develop unified R&D plan • Investigate the MPAR relationship to the JPDO-coordinated Integrated Surveillance CONOPS • Nail down the MPAR management approach option and its tie to JPDO-recommended integrated surveillance governance process • Exploit leveraging opportunities • Address spectrum allocation issues

Figure 2. MPAR Symposium II action items address largely programmatic and management issues..

5. SUMMARY

The Second MPAR Symposium brought together 230 experts from the phased array radar community under the theme *Moving Forward with Risk Reduction for Cost Effective Service Improvements*. In addition to hearing special presentations by key government leaders, participants considered the three key risk-reduction initiatives: multifunctionality, service improvement, and cost reduction. As a result of the interactions at the symposium, participants recommended several programmatic, management, and technical actions.

Acknowledgments. The authors would like to thank Mr. Mark Welshinger for his thorough and insightful review of the manuscript.

<u>REFERENCES</u>

NRC 2008: *Evaluation of the Multifunction Phased Array Radar Planning Process,* Committee on the Evaluation of the Multifunction Phased Array Radar Planning Process, National Research Council, National Academies Press, Washington D.C.

OFCM 2006: *Federal Research and Development Needs and Priorities for Phased Array Radar*, Report No. FCM-R25-2006. Available in PDF at http://www.ofcm.gov/r25-mpar/fcm-r25.htm

OFCM 2008: Multifunction Phased Array Radar Program Status and Potential Service Improvements. Available in PDF at http://www.ofcm.noaa.gov/wg-mpar/references/PDM%20Paper%20v2.1.pdf