**Multifunction Phased Array Radar (MPAR) Symposium Summary Report**

1. **Purpose:** The purpose of this document is to provide a summary of the MPAR symposium which took place in Norman, Oklahoma, from October 10-12, 2007. The symposium was sponsored by the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) and the U.S. Office of Science and Technology Policy, Committee on Environment and Natural Resources, Subcommittee on Disaster Reduction (SDR). The theme for the symposium was *Leveraging Technology to Build a Next Generation National Radar System*, and the purpose was to forge consensus on a risk-reduction program for MPAR as an enabling technology to replace the Nation's aging fleet of air and weather surveillance radars. The symposium was attended by 181 representatives from the federal government, academia, military laboratories, and radar industry.
2. **Objectives:**
   - Highlight future user PAR requirements and summarize benefits derived from PAR's adaptive scanning capability
   - Explore implementation of R&D priorities laid out in the June 2006 Interagency JAG report *Federal Research and Development Needs and Priorities for Phased Array Radar*, accounting for: (1) work already accomplished (2) items that still need additional focus and (3) potential alternative configurations
   - Gather perspective from the radar industry on the state of the technology, the technological uncertainties, and the challenges of delivering affordable phased array radar systems in the future
   - Develop the way ahead to address MPAR risk-reduction challenges through an implementation strategy and interagency management approach
3. **Special Presentations:** The opening addresses on Wednesday, October 10th, provided a variety of viewpoints highlighting partnerships necessary for a successful MPAR risk-reduction effort and the importance of linking a new sensing technology such as MPAR to societal benefits.
   - **Mr. Joseph Harroz**, Vice President and General Counsel of the University of Oklahoma, representing President Boren. His comments included:
     - Partnerships are critical in advancing our national surveillance capability
     - The University of Oklahoma has a history of supporting collaborative efforts with government and industry, having been instrumental in developing the Doppler weather radar concept that eventually resulted in NEXRAD
     - The University of Oklahoma is committed to becoming the MPAR center of excellence and in promoting the government/industry/academic partnerships necessary to succeed
   - **Dr. Denise Stephenson Hawk**, Director, Societal-Environmental Research and Education Laboratory, National Center for Atmospheric Research. Her comments included:
     - Importance of linking technical advances of MPAR to societal needs and benefits
       - MPAR addresses significant weather events (tornados, flooding, aviation weather) that most directly affect people's lives, livelihoods, and the national economy
     - MPAR cost analysis should address *outcomes* to ensure societal resilience; final product should be a complete analysis delineating the risks, cost, and benefits of MPAR to the Nation

- Future MPAR risk-reduction program needs to cultivate strategic relationships among meteorologists, engineers, economists, social scientists, emergency managers, and broadcast media

- **Mr. Al Mille**r, contractor from Office of the Assistant Secretary of Defense for Homeland Defense. His comments included the following:
  - Threats (both traditional and asymmetric) from the air will require air domain awareness superiority
  - Current air surveillance systems insufficient to provide the level of air domain awareness required for national security from threats, both from general and commercial aviation, as well as from UAVs, cruise missiles, etc.
  - MPAR could contribute to air domain awareness needed for national security
  - Any air surveillance solution will require strong interagency collaboration

4. **<u>Senior Leader Perspectives:</u>** The following presentations provided senior leader perspectives on how MPAR could meet mission requirements for their particular agencies.
   - **Ms. Mary Glackin,** Acting Deputy Under Secretary for Oceans and Atmosphere. Her comments included:
     - Linking MPAR to NOAA's mission of predicting changes in the Earth's environment to protect lives and enhance the economy and transportation
     - Stating that radar must be considered as part of an overall architecture of observing systems in order to maximize capability and affordability for the Nation
     - Emphasizing importance of beginning research *now* to determine MPAR's capability and affordability as a key component of NOAA's future array of observing systems
     - Partnerships and a sense of urgency are key to making MPAR succeed; partnerships need to be forged across government agencies, and with industry, academia, and even other countries
   - **Ms. Victoria Cox,** Vice President of Operations Planning, Air Traffic Organization, Federal Aviation Administration. Her comments highlighted the following:
     - Increasing stress on the National Air Transport System will require automation and better data to reduce separation safely
     - FAA's satellite-based Automatic Surveillance System-Broadcast (ADS-B), the basis for cooperative air surveillance in the coming decade, will require a backup strategy entailing ground-based primary radars
     - FAA needs cost-effective means to back up ADS-B: MPAR may be the solution
     - MPAR could assist in achieving key NextGen capabilities such as:
       - Assimilating weather into decision-making
       - Aircraft trajectory-based operations
       - Super density operations
     - For these reasons FAA strongly supports the MPAR risk-reduction effort
   - **Mr. Randel Zeller,** Director, Interagency Programs, Science and Technology Directorate, Department of Homeland Security. His comments included the following:
     - National Security Presidential Directive 16 directs 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 out to 2025. The

Joint Program Office managing the current long-range air surveillance radars has undertaken service-life extension programs that allows additional time to develop a follow-on air surveillance capability; among the emerging technologies to consider is MPAR

5. **Symposium Panels:** The six symposium panels are summarized below:

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| **1** | MPAR User Communities of Interest |
| **2** | Current State of Military Investment in Phased Array Radar |
| **3** | Latest Innovations in PAR: An Industry Perspective |
| **4** | Component Technology: What the Future Holds in Cost and Performance |
| **5** | MPAR Alternative Configurations |
| **6** | Way Ahead to Address MPAR Risk Reduction—Implementation Strategy and Interagency Management Approach |

- **MPAR User Communities of Interest.** This panel, consisting of senior leaders from NOAA's National Weather Service, NOAA's Office of Atmospheric and Oceanic Research, the Federal Aviation Administration, the Department of Homeland Security, the U.S. Air Force, and the U.S. Navy was devoted to determining the mission needs and capability gaps within various federal agencies that MPAR could address. Several common themes expressed by the panel were:
  - The long lead time required for acquisition of any new operation system makes it imperative to begin MPAR risk reduction sooner rather than later
  - Societal pressures and demands of weather forecasts to become both more accurate and of finer scale drive a need for progressively finer-scale weather observing systems
  - Past technologies (such as NEXRAD) have had demonstrable effects on improving forecast accuracy and warning lead times; the business case for MPAR must show similar impact on somewhat stagnant severe weather and flooding lead-time statistics
  - New systems such as MPAR must show both improvement in capability, and reduction in overall life cycle costs to be viable candidates for acquisition
  - Both for weather and aircraft surveillance, a national primary radar network is going to be needed into the foreseeable future
  - The Nation (both civilian and military) can endure no gaps or retrogression in air and weather surveillance coverage in the course of transition to a new technology
  - Any new technology implies some risk; the Nation must become risk tolerant to exploit new technology to realize its full benefit
  - The Nation must get ahead of the obsolescence curve of its legacy radar systems by investing in aggressive R&D on replacement technologies such as MPAR
  - Growth curve of the NAS, like lead times on severe weather, have flattened out in recent years—we need a technological breakthrough to move us out of stagnation
  - MPAR R&D efforts must be anchored to solid requirements from the user community
- **Current State of Military Investment in Phased Array Radar.** The military, both historically and at present, is heavily invested in cutting-edge phased array research. This

panel, consisting of representatives from several military research labs and sponsoring organizations, reinforced the strong military investment in PAR, explaining how military-specific PAR research actually converges on a number of R&D goals of MPAR, namely:

- Military phased array research is concerned with cost as well as performance; historically, this has not always been the case with military systems
- Using commoditized parts and exploiting economies of volume production are the key to driving down cost of MPAR from historic norms of high-cost military PAR
- Military PAR systems are increasingly based on open architectures, drawing upon commercial off-the-shelf (COTS) versus very high-priced mil-spec parts
- The goal is to have a scalable system with reusable parts and modules; technical improvements should require little to no retro-engineering
- Military pushing industry to produce PAR modules of progressively lighter weight, higher efficiency, smaller size, and lower cost
- Military investment has driven PAR evolution from passive arrays to active arrays, and to all-digital radars
- In general, size restrictions have driven military to higher-power radar components than civil MPAR would need, there is still much overlap and potentially useful technology
- Life-cycle costs (supportability) needs to be factored into a radar acquisition program at the beginning, not the end
- Overall, the panel identified a great deal of military PAR research that has direct relevance to MPAR R&D efforts

- **Latest Innovations in PAR: An Industry Perspective.** This panel drew together representatives from the major radar integrators: Northrup Grumman, Raytheon, Lockheed Martin, and Harris Corp. The following conclusions emerged:
  - After decades of military use for sector air defense, weather is essentially a new mission for PAR
  - 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 technology
  - A major issue to be determined is ***cost***; while ultimate cost of a national MPAR system is still yet to be determined, building an architecture around open systems and building in scalability will both serve to drive down future costs
  - Current downward trends in T/R module costs is encouraging, but lowering cost of PAR antennas alone will not be the whole solution; more efficient data processing through enhanced software and other "back-end" breakthroughs are also essential ingredients in the overall cost issue
  - Many user "requirements" are not requirements at all, but simply the upper performance level of legacy systems; users must not confuse what they really need with what they have had to settle with in the past
  - Solid user requirements are essential for risk-reduction R&D efforts
- **Component Technology: What the Future Holds in Cost and Performance.** This panel drew together spokespersons from principal manufacturers of phased array radar components: the major cost driver in PAR technology. Several common themes emerged from the panel:

- Sheer volume of a national MPAR acquisition, of any configuration, would tend to drive down cost of T/R modules through economies of scale
- Integration of more functions on to same chip lowers cost and increases reliability because fewer high-cost RF interconnects needed on surface mounted chips
- New semiconductor materials provide much higher efficiency, allowing low-cost air cooling for heat dissipation, rather than complex, high-cost liquid cooling
- Component manufacturers look to exploit dual use (same components for military and civil applications) as key to affordability
- Important to build flexibility into the system so it can grow to accommodate future missions with minimum of retro-engineering

- **MPAR Alternative Configurations.** This panel, drawing upon representatives from the National Weather Testbed, the center for Collaborative Adaptive Sensing of the Atmosphere, MIT Lincoln Laboratory, and the National Center for Atmospheric Research 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 would exploit the optimum capability of phased array radar technology. The common themes included:
  - Weather will be the principal radar resource driver in any phased array system of the future; 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; a likely solution will be separate frequencies for tracking aircraft and weather from the same aperture
  - MPARs should be considered, not as free-standing radars, but as "nodes on a network;" only by designing an MPAR system as a distributed network will true power of phased array radar surveillance be exploited
  - Legacy radar requirements need to be completely redefined for MPAR: for example, equivalent resolution achieved by narrow beam width in mechanically scanning radars may be achieved by a wider beam width for MPAR. This is engineering work to be done
  - Gaps in low-level (boundary layer) coverage inherited from legacy radars need to be addressed by any follow-on radar system; Earth curvature and topographic blockage create blind spots in current radar coverage that are important both from meteorological and air defense perspectives. Blanket coverage may not be feasible, rather coverage may be "grown" on the network over high-priority areas
  - Demand for extremely high-resolution radar coverage, especially in urban areas, will drive requirements for both siting and design/configuration of MPAR system
  - Engineering challenge will be to provide visualization tools for effective use of MPAR data by human agents; given the shear volume of this data, providing effective automated tools will be essential
- **Way Ahead to Address MPAR Risk Reduction.** This panel recapped themes from previous five panels, linking consensus on user needs and technological maturity of PAR to future steps toward eventual MPAR risk reduction and implementation. Overall conclusion of the panel was that the symposium had demonstrated solid consensus on both the desirability and feasibility of MPAR to meet national surveillance requirements, both for weather and aircraft, but that developing an effective interagency management structure for MPAR risk reduction will prove challenging. Specific findings included:

- NEXRAD interagency management model may prove an effective precedent for MPAR
- Must engage the four principal agencies involved: NOAA, FAA, DoD, and DHS
- Air surveillance and weather have been demonstrated independently with PAR; need to demonstrate the capability to prosecute both missions simultaneously
- Engaging agency support for risk reduction will depend on building compelling business case; the need for more robust DoD involvement was highlighted
- Follow-on technical interchange meetings between government and industry is required to assess true state of commercial capability to deliver affordable PAR technology that is able to meet user requirements
- Most urgent requirement is to develop a risk-reduction implementation strategy, which includes the building and field-testing of a prototype with modern active phased array radar technology that will actually demonstrate simultaneous multifunction capability

**6. <u>Summary of Symposium Results:</u>**

- **Overarching Surveillance Radar Requirements.** The overarching surveillance radar requirements are there can be no gaps to the current weather and aircraft surveillance capability; the Nation needs improved forecasts and lead time; the next-generation aircraft surveillance radar will (1) be a backup to the future FAA cooperative aircraft surveillance plans and (2) be needed for tracking of noncooperative aircraft; and life-cycle costs of current weather and aircraft surveillance systems need to be reduced.
  - The detailed requirements are documented in the report, *Federal Research and Development Needs and Priorities for Phased Array Radar*. The OFCM-sponsored Working group for Multifunction Phased Array Radar (WG/MPAR) will continue to refine and update the requirements.
- **Fundamental Message/Outcome.** The fundamental message/outcome from the symposium is that 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: (1) legacy surveillance radars are nearing the end of their life cycle; (2) society demands greater protection of life and property, more timely warnings of hazardous weather events, and increased accuracy, spatial resolution and lead times for severe weather warnings; (3) the need for enhanced capability to track non-cooperative aircraft and other airborne threats to safety and security is paramount; (4) the multifunction capability of MPAR leads to reduced life-cycle costs; and (5) a risk-reduction implementation strategy will reduce uncertainties and produce cost-effective alternatives, which will lead to a sound business case.
- **Actions and Way Ahead:** The actions stemming from the symposium were:
  - Place all presentation materials on symposium website for maximum accessibility
  - Develop an interagency management approach for the MPAR risk-reduction activities, considering the management approach used for the NEXRAD program and also other options.
  - The OFCM-sponsored Working Group for Multifunction Phased Array Radar (WG/MPAR) needs to develop a risk-reduction implementation strategy. The strategy should:
    - Leverage military R&D (e.g., Space and Naval Warfare Systems Center, San Diego; AFRL, ONR, NRL)
    - Reach out to critics

- Enhance outreach and education efforts, including opportunities to:
    - Participate and/or present at meetings / workshops (e.g., AMS, IEEE, AAAS, AGU, ATA, AOPA, RTCA, WGA, WMO, ICAO)
    - Be included in magazines / publications
    - Link with other communities, like the wildland fire community
    - Conduct additional MPAR workshops / symposia
    - Reach out to potential industry partners
    - Conduct technology interchange meetings
    - Inform/update agency senior leadership, and OMB and OSTP representatives
- Involve both federal laboratories and industry
    - Federal laboratories roles and missions: labs are in the position, due to their expertise, to make recommendations on risks and areas of research and development; also able to perform some R&D (advanced development)
        - Conduct technology demonstration projects
    - Industry potential roles and missions
        - Develop alternative system design approach (cost effective alternative(s))
        - Production feasibility study (results evaluated by government)
        - Acquisition and logistics / maintenance (life cycle costs)
        - Tests required to evaluate capability; tests need to be clearly identified
        - Future trade-off studies regarding uncertainties
        - Site surveys and geographical coverage of MPAR
        - Facilities analysis / requirements (towers, etc.)
        - Frequency allocation analysis
        - Acquisition approach alternatives; best course of action to acquire system (four phases? two phases?)