Phased Array Radar Program Status

Update on New Technology for the Multi-Function Phased Array Radar (MPAR)

ICNS 2 May 2007

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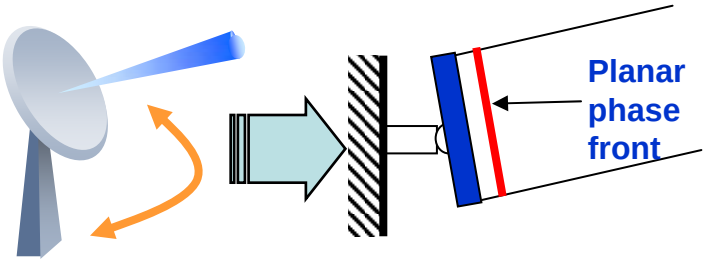
SPY-1D Phased Array Radar aboard DDG-79 USS OSCAR AUSTIN

Overview

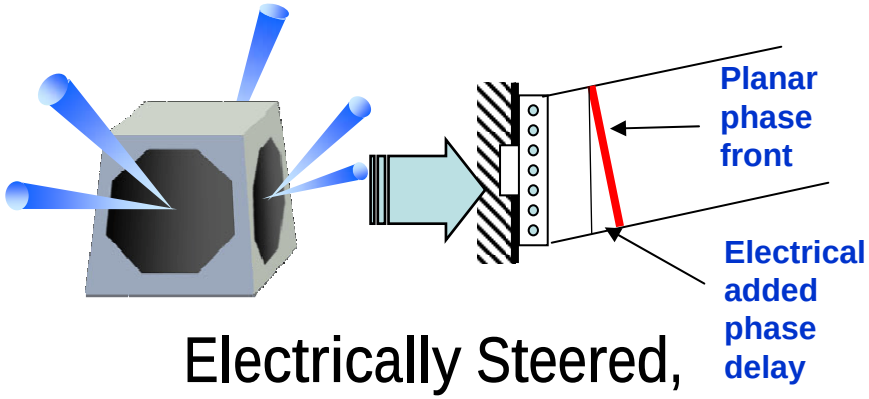
- **Background/History**
- **Benefits**
- **Program Status**
- **Technology Advancements**
- **Future Efforts**
- **Summary**

What is Phased Array Radar?

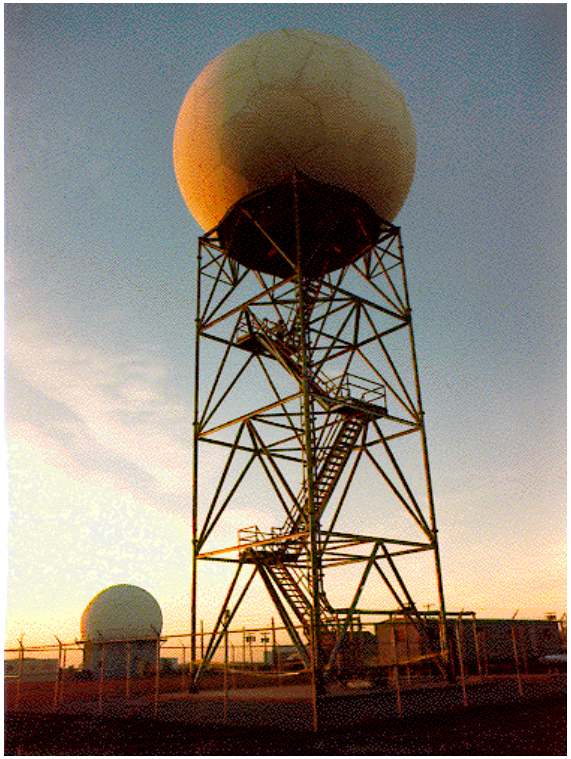


Mechanically Steered,
Rotating Reflector Array

vs

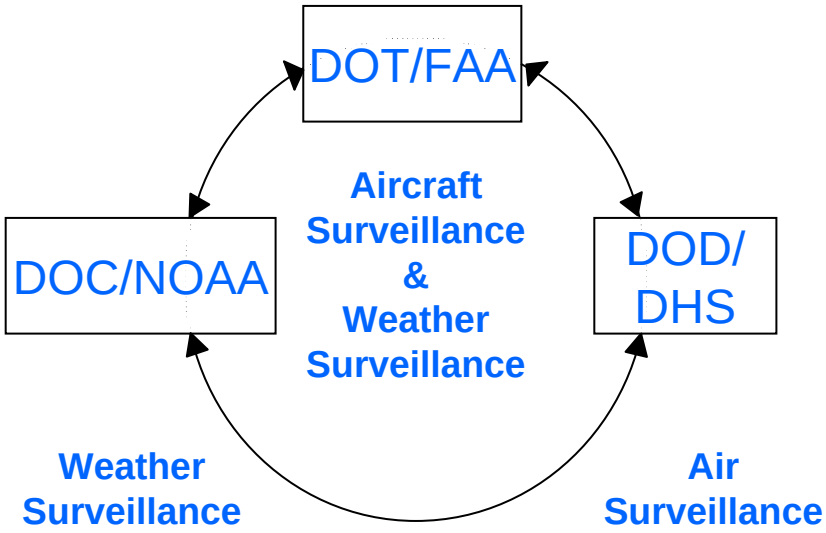


Electrically Steered,
Fixed Phased Array



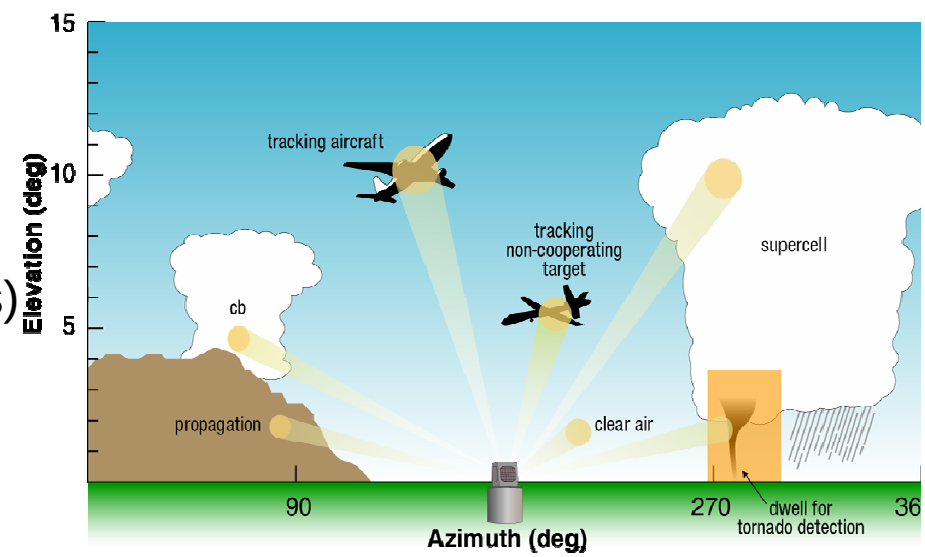
MPAR Program Origin

- In FY 2000 Congress mandated research and development of phased array radar technology to improve aircraft tracking and weather information for civilian use (Tri-Agency: FAA, NOAA, DOD)
- NRC Report *Beyond NEXRAD (2002)*, recommends PAR technology be developed as replacement for legacy weather radars
- In 2004 Federal Committee for Meteorological Services and Supporting Research (FCMSSR) directed an inter-agency Joint Action Group be convened to assess R&D priorities for MPAR

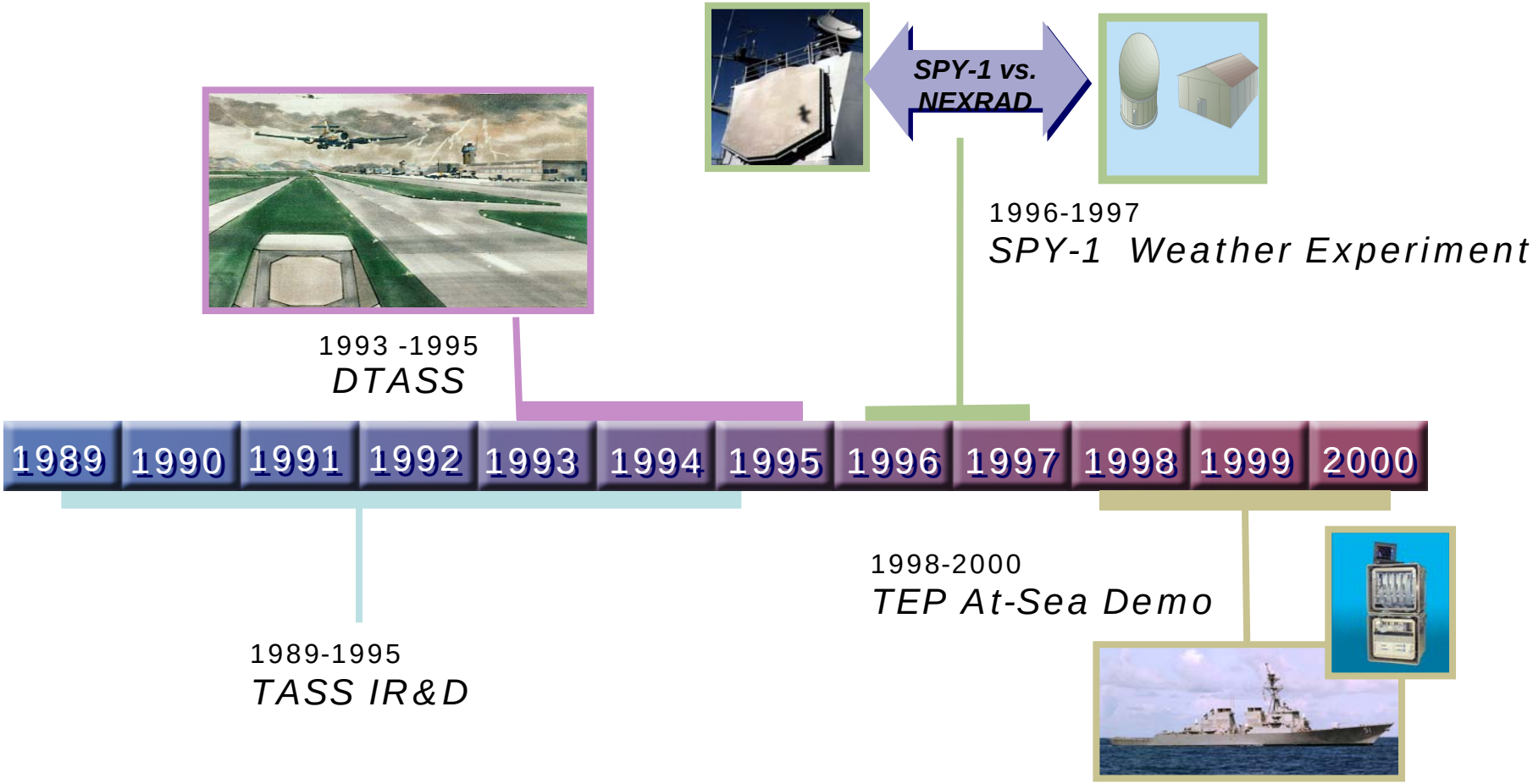


MPAR Program

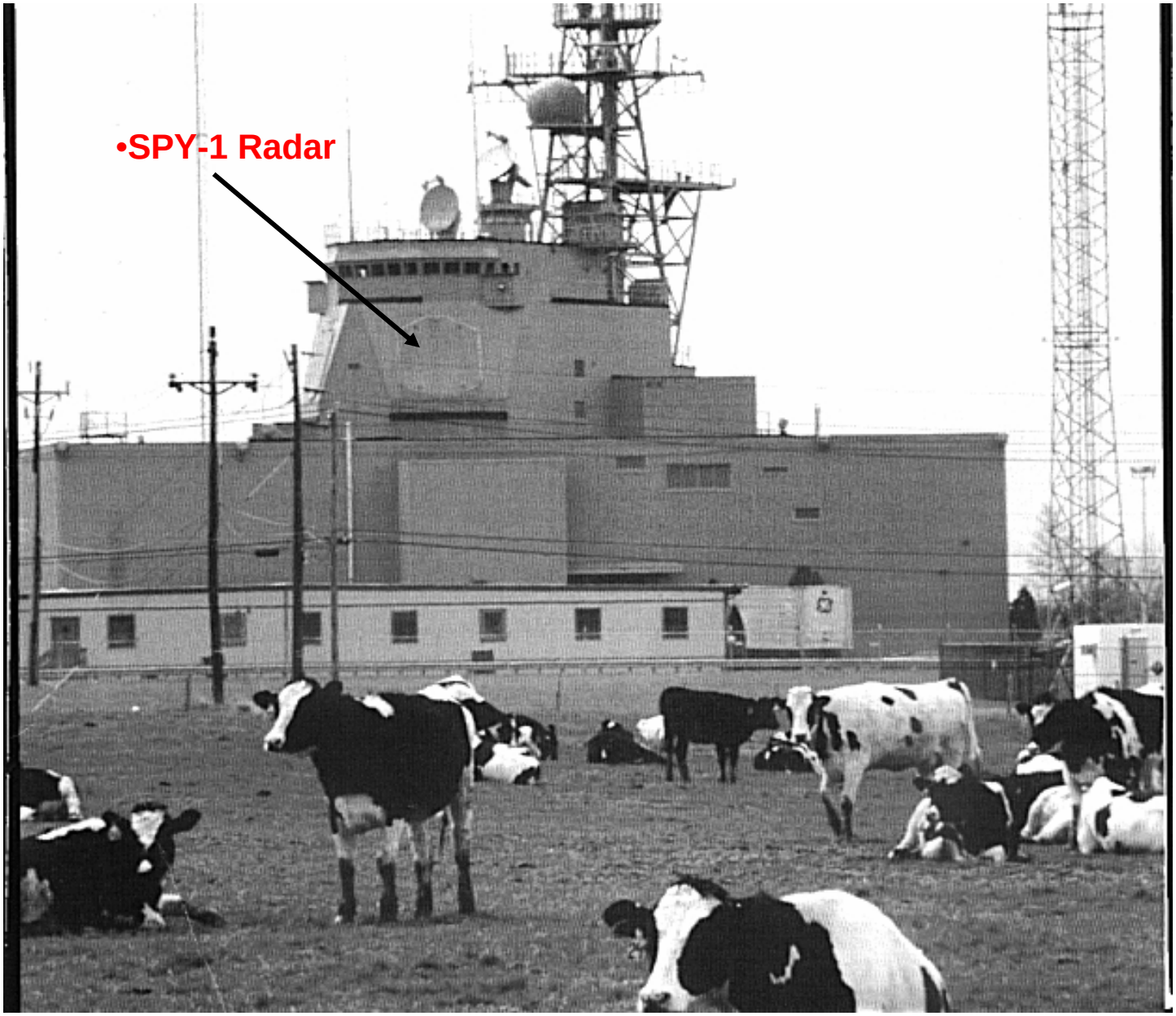
- **Mission**
  - Evaluate new technology and develop the next generation MPAR network
  - Support Joint Planning and Development Office (JPDO) 2025 Vision for the Next Generation Air Transportation System
- **Objective**
  - Develop affordable MPAR network for improved
    - Weather data for aviation safety
    - Numerical weather prediction (modeling)
    - Airport efficiency and capacity
    - Aircraft detection and tracking (cooperative and non-cooperative)
    - Natural disaster warning & response
    - Homeland security (toxic plumes)



Phased Array Radar Evolution

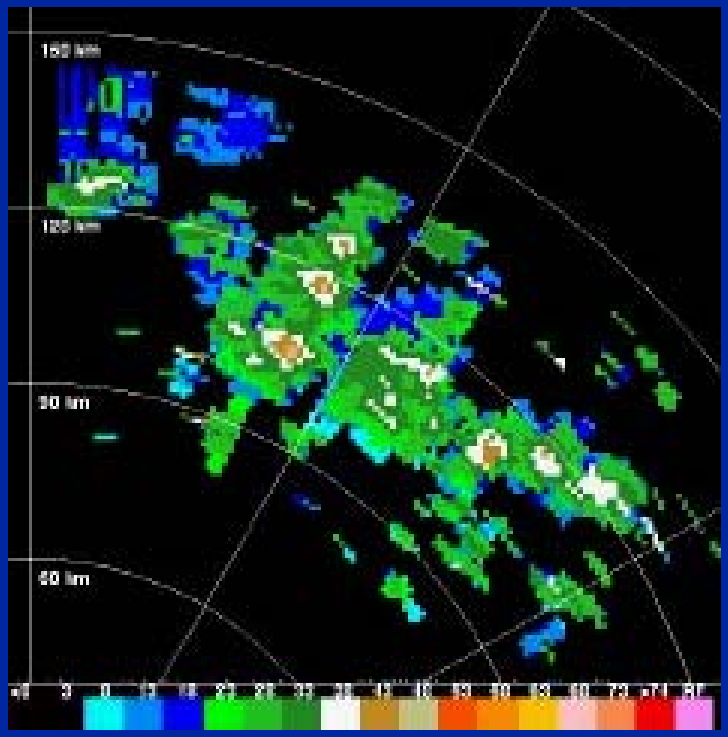


“Radar in the Cornfield” – Moorestown, NJ



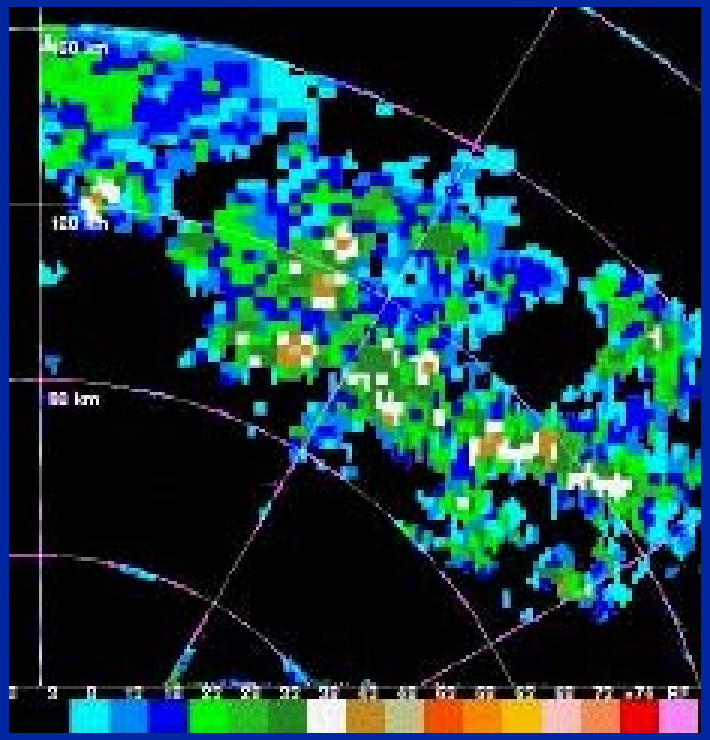
Example of SPY-1 Vs NEXRAD Reflectivity

PAR vs. NEXRAD Composite Reflectivity Hurricane Fran Remnants



SPY-1 (Single -Pulse)

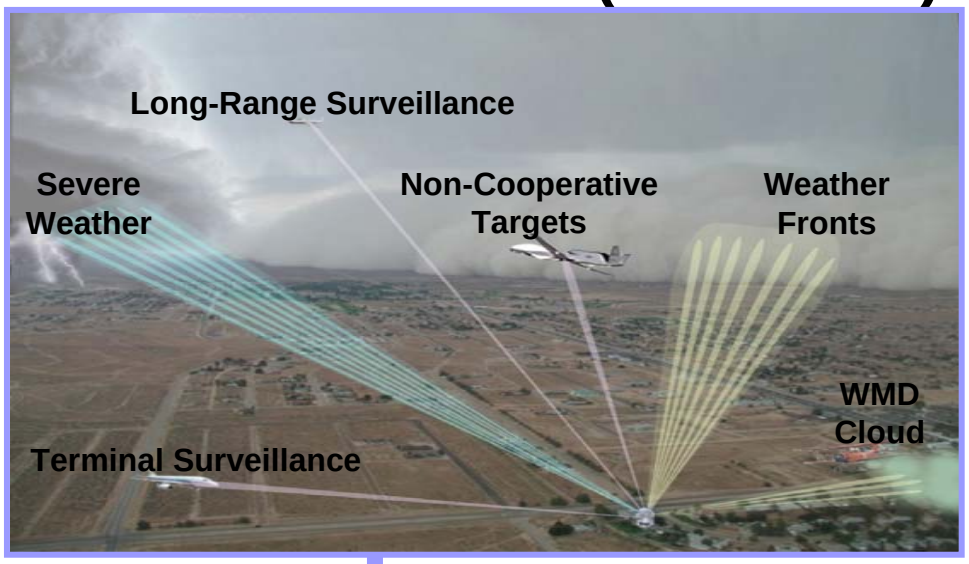
Data Collected on SPY Weather Experiment



NEXRAD (~100-Pulse)

Higher Speed Of Scan Provides Finer Temporal Resolution
No Beam Smearing---Finer Spatial Resolution

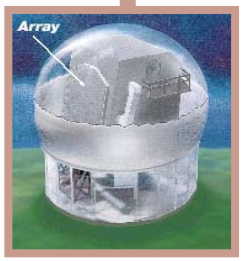
Phased Array Radar Evolution (continued)



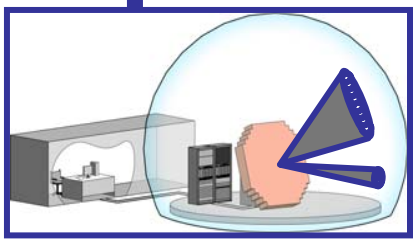
2000-2002
Dual-Use Science & Technology

2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | and beyond...

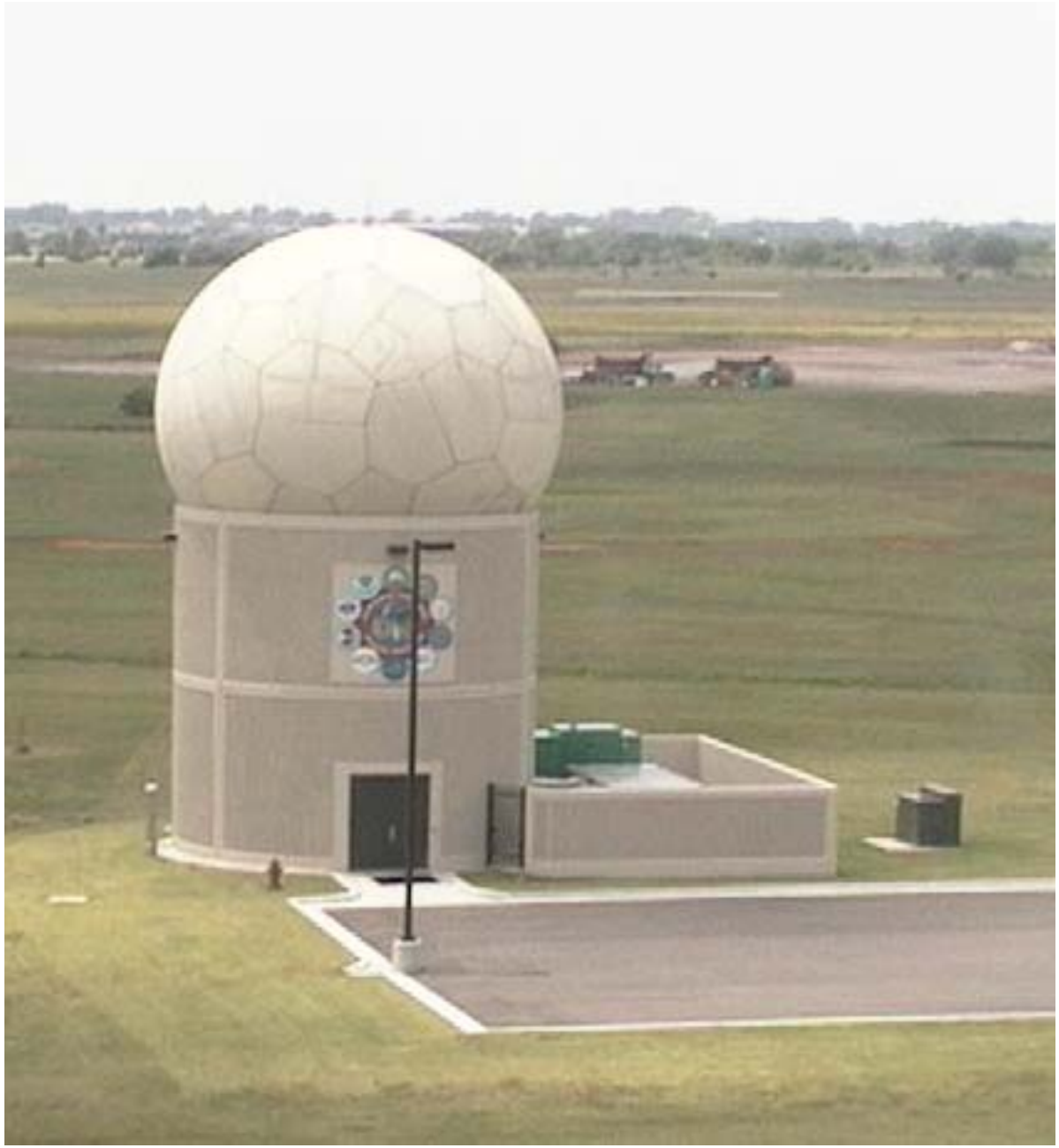
2001-2005+
Nat'l Wx Radar Testbed



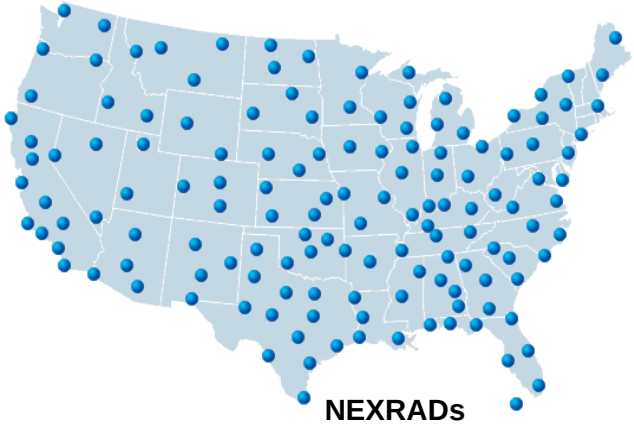
2006 - 2010
MPAR Pre-Prototype



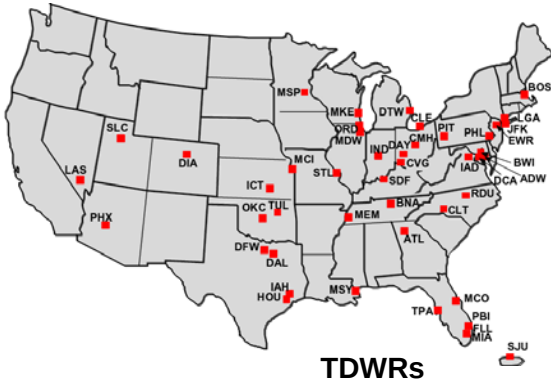
National Weather Radar Testbed – Norman, OK



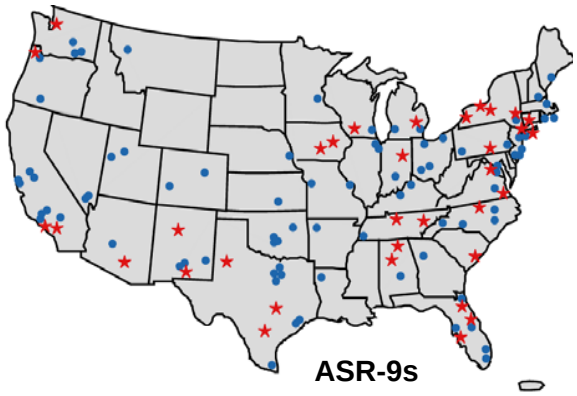
U.S. Surveillance Radar Networks Today



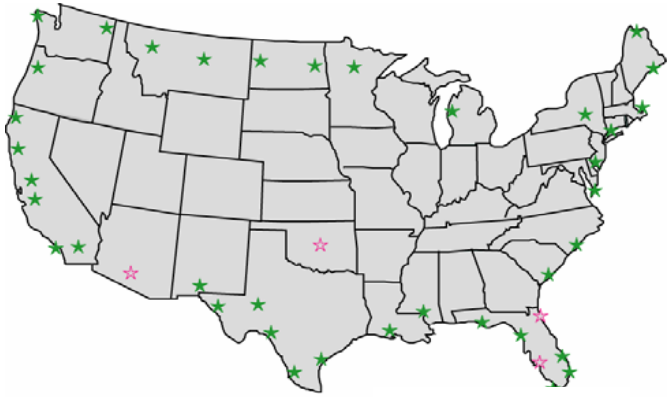
NEXRADs



TDWRs



ASR-9s



ARSR-4s

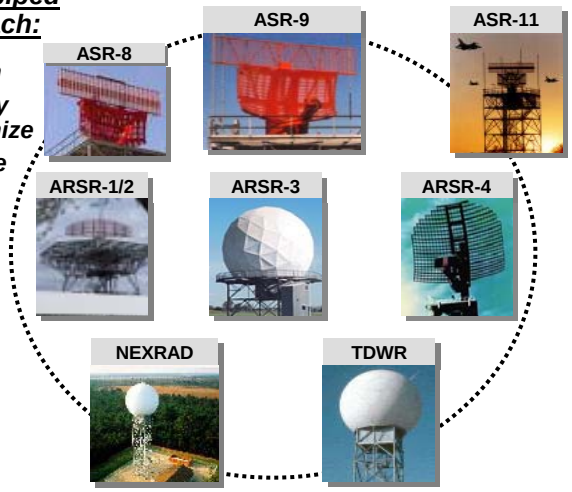
ASR-11s

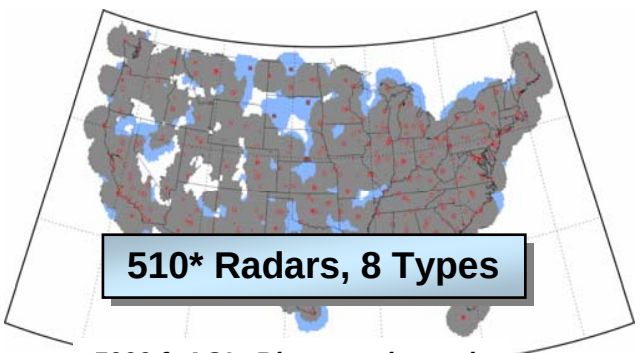
Multi-Mission PAR for Tomorrow

Today

Stove-piped Approach:

- *Sustain*
- *Partially Modernize*
- *Replace*





5000 ft AGL, Blue, weather only

***Includes Operational CONUS radar only**

Joint Agency Group Recommendations

2006:

- **Define concept and R&D roadmap**

Mid 2007-2012:

- **NWRT Proof-of-concept tests**
- **Develop scaled prototype and critical technologies**

2010 - 2016:

- **Full-scale prototype & operational test**

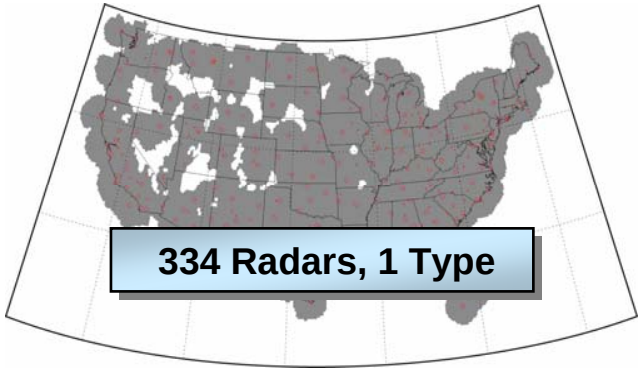
Future Concept

Affordable Multifunction Phased Array Radar (MPAR)

Reduced number of radars

Consolidated maintenance and logistics infrastructure

Enhanced capabilities



Programmatic Benefits

- Investment in R&D is paying dividends for MPAR
  - MPAR is a potential replacement for aging fleet of 510 conventional mechanically scanning radars over next 20 years
  - Consolidation of multiple single-mission radars into MPAR can reduce national radar fleet by > 40%
  - Functionality can provide both air and weather surveillance from a single radar site
  - Design requires no moving parts, lower maintenance costs
  - No single point of failure, multiple transmit/receiver components
  - Air cooled, no expensive water cooling
  - Scalable design of prototype will provide proof of concept for future MPAR

Functional Benefits

- **Weather measurement**
  - Rapid temporal sampling; full volume scan periods < 1 minute
  - Adaptive antenna tilts reduce ground clutter
  - Adaptive dwell times/beam steering; selective target revisit in seconds rather than minutes
  - Split aperture correlation to estimate crossbeam wind component
  - Dual polarization for hydrometeor discrimination
- **Increases safety and capacity in severe weather conditions**
  - Increases lead time for tornado warnings
  - Increases lead time for flood & severe weather warnings
  - Better initializing of national numerical weather prediction models leading to improved forecasting
  - Research other severe storm phenomena

Functional Benefits (continued)

- **Terminal & Enroute surveillance**
  - Significant reduction in false track probability
  - Vertical position measurement Dedicated track modes
  - Sub-second track update rates in terminal area
  - Hazardous weather monitoring
    - Microburst wind shear, gust front/wind shift, wake vortex, convective storms and hydrometeor discrimination
- **Homeland security**
  - Non-cooperative target tracking
  - Wind field mapping for dispersion models
  - Nuclear biological chemical (NBC) tracking…R&D needed
- **Volcanic ash, airborne debris**

Program Status

- **MPAR performance is not an issue**
  - Military PARs have been around for decades
  - Benefits of rapid digital scanning radars are well known
  - Old paradigm – “Only the military can afford PAR”
- **Major cost driver is the active array antenna of a MPAR (i.e. sheer number of T/R modules)**
- **Proposed MPAR ‘active array’ development exploits advances in**
  - Military R&D
  - Civilian industry solid state technologies
- **Results in affordable MPAR for civilian use**

Program Status (continued)

- **Established/implemented multifunction phased array radar (MPAR) pre-prototype technology demonstration program**
  - Explored low-cost technology (e.g., T/R module/Digital beam former)
  - Demonstrated multifunction system concept
  - Verified/Validated new hardware architecture (digital beam former, overlapped sub-arrays, advanced signal processing, etc.)
  - Leveraged commercial technology (e.g., semiconductor materials, fabrication, etc.)
  - Researched advanced surveillance strategies
- **Identified major cost issues and proposed mitigation strategies**

Program Status (continued)

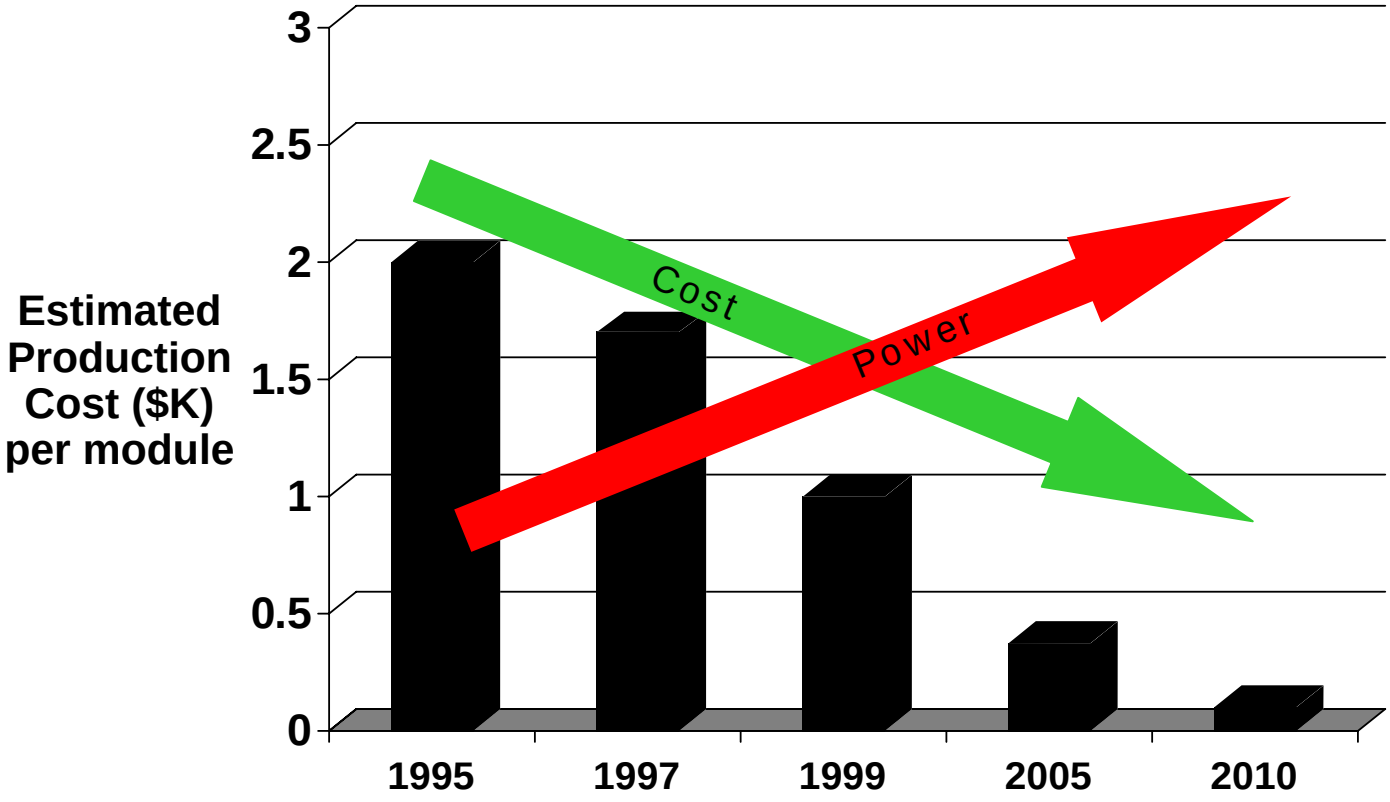
- **Completed initial radar system concept definition (e.g. radar coverage analysis, scaled gap-filler systems)**
- **Established contacts/initiated partnerships with industry leaders in phased array technology**
- **Developed R&D strategy plan in 2006: *"Needs and Priorities for Phased Array Radar"* (PAR Joint Action Group):**

  http://www.ofcm.gov/r25-mpar/fcm-r25.htm
- **Instituted follow-up on MPAR Working Group (WG/MPAR) to develop a risk-reduction implementation strategy to address key findings and recommended next steps**

Technology Advancements

- **Leverage research in semiconductors for PAR**
  - Increased power density
  - Increased power efficiency
  - Improved thermal management
- **Leverage Defense Advanced Research Projects Agency (DARPA) wide bandgap Gallium Nitride (GaN) effort**
  - Awards Total $144.5M over five years (began in March 2005)
  - Wide bandgap semiconductor (WBGS) for radar application
    - Q band Solid State Power Amplifiers(Northrop Grumman/Emcore)
    - X band T/R module (Raytheon/Cree)
    - Wide band High Power Amplifier (Lockheed Martin/TriQuint)

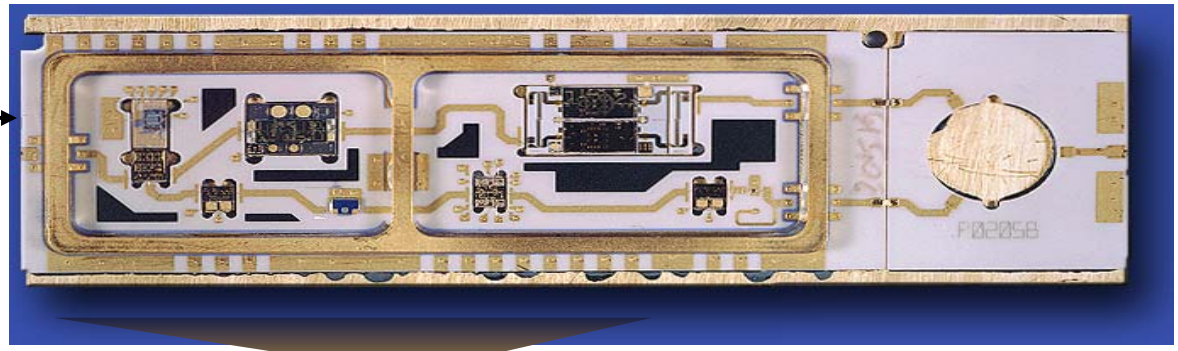
RF Solid-State T/R Module Trends



System costs substantially reduced & operation costs lower every year

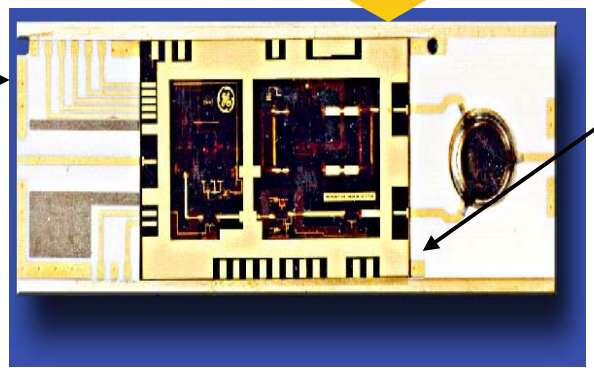
T/R Module Designs

Today's Technology



Leads To

Future Technology



Advanced MMIC Design

Ceramic HDI

SMALLER, HIGHER POWER, MORE EFFICIENCY

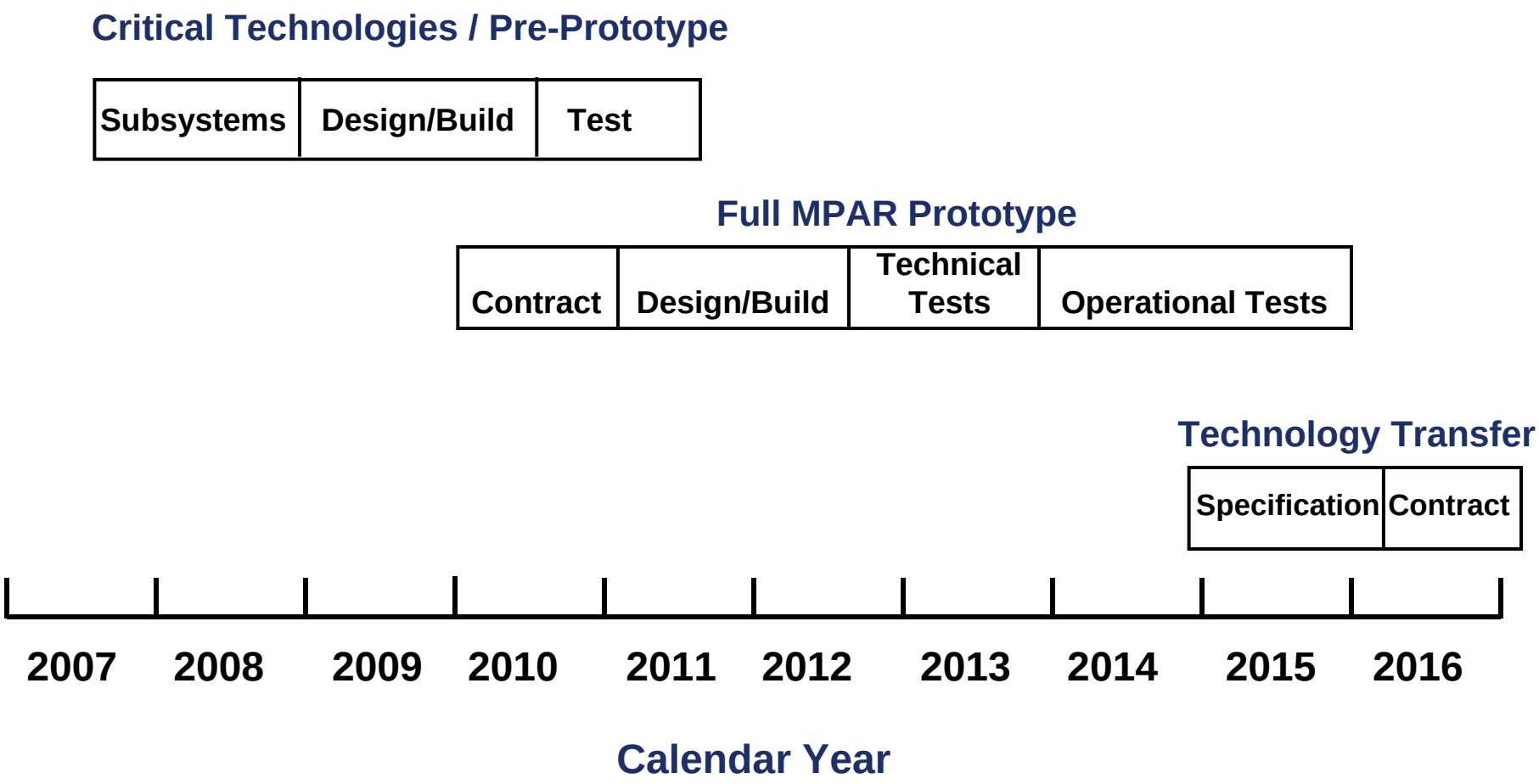
Future Efforts

- **Continue development of low cost, critical component technologies:**
  - Transmit-receive modules (<<$100 per module)
  - Digital transceivers
  - RF interconnects
  - Analog and digital beam forming architectures
  - Efficient processing algorithms
  - Advanced signal processing techniques
  - Enhanced scanning capabilities
- **Focus on additional MPAR research**
  - Continue exploring improved solid state technologies
  - Continue research to improve multiple missions/functions (weather and surveillance)
  - For both NRT and pre-prototype systems

Future Efforts (continued)

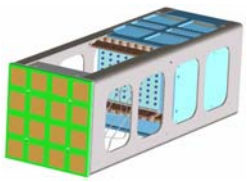
- **Solidify key technical requirements for objective system**
  - Number of independent channels
  - Number of concurrent beams per channel
- **Develop a technology demonstration program**
  - Analyze critical technologies
  - Develop a pre-prototype
  - Develop full MPAR prototype
- **Demonstrate affordability**
- **Test MPAR in an operational environment**

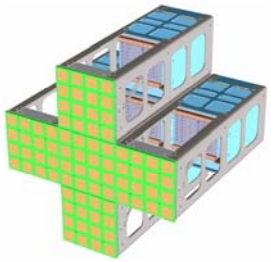
Timeline MPAR Development

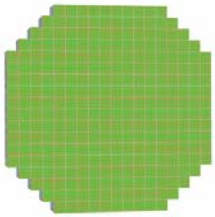


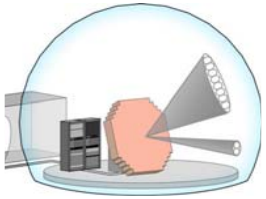
MPAR Pre-prototype Development Schedule

Year 1	Year 2	Year 3	Year 4
PDR	CDR	Testing CDR	
Concept Development, Design, and Subsystem Prototyping		System Fabrication and Assembly	Experimental Testing and Evaluation
Brick	Sub array	Array	Data Collection









Hardware:

- 16 Element Brick
- Transceiver
- 80 Element Sub array
- DBF Dev
- 4544 Element Array
- 16 Channel DBF
- Collect Multimode Data

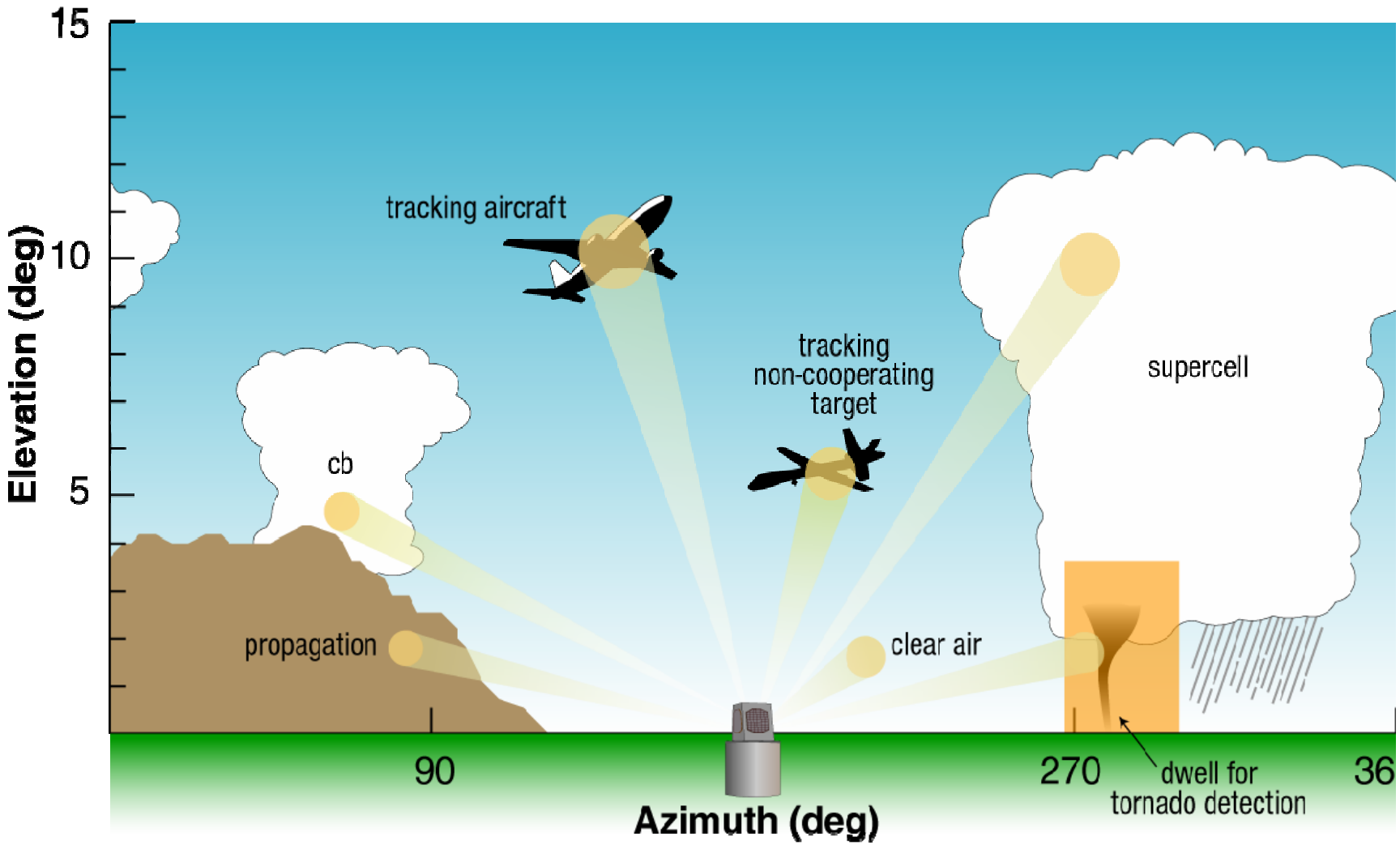
Systems & Signal Processing:

- Waveform Design
- Systems Analysis
- Algorithm Dev
- System Simulation
- System Simulation
- Test Planning
- Process Data
- Report Results

Summary

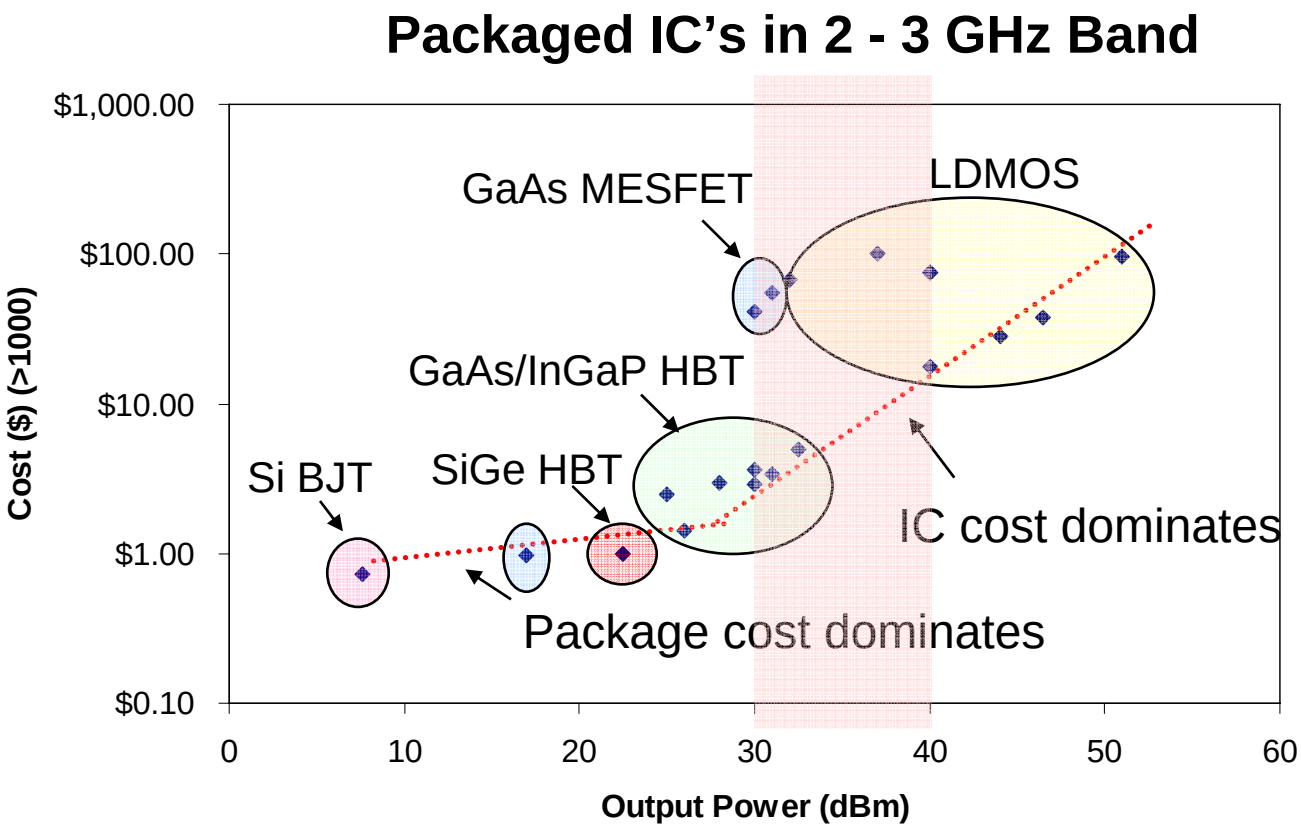
- Low-risk technology development can facilitate a national, multifunction phased array radar (MPAR) network capable of duplicating today's airspace coverage with 35 to 40% fewer radars
- Significant capability enhancements are realized for both weather and aircraft surveillance
- Research & development is the key to developing an MPAR architecture to meet the requirements of the future
- Leveraging government and industry investments is fundamental to success
- MPAR acquisition cost-competitive with legacy mechanically scanned surveillance radars using today's technology
- Life-cycle cost analysis indicates significant cost-savings for NGATS could exceed $5B
- A seven- to ten-year R&D program will be required

Questions


15
10
5
Elevation (deg)
tracking aircraft
tracking
non-cooperating
target
supercell
cb
propagation
clear air
90
270
36
dwell for
tornado detection
Azimuth (deg)

BACKUP SLIDES

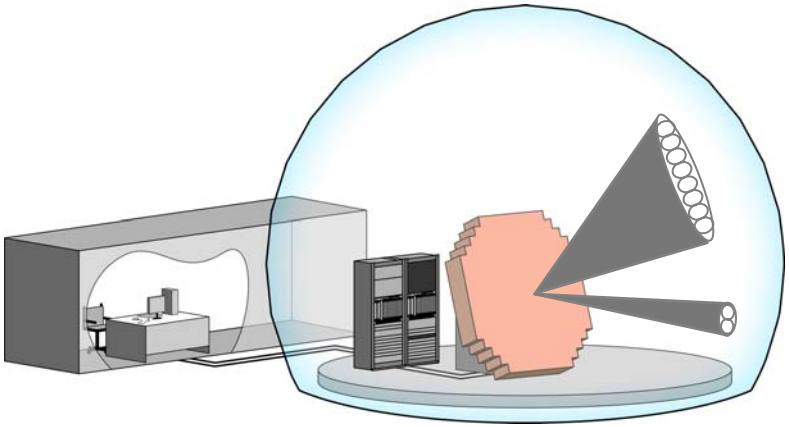
S-band Power Amp Cost by Output Power

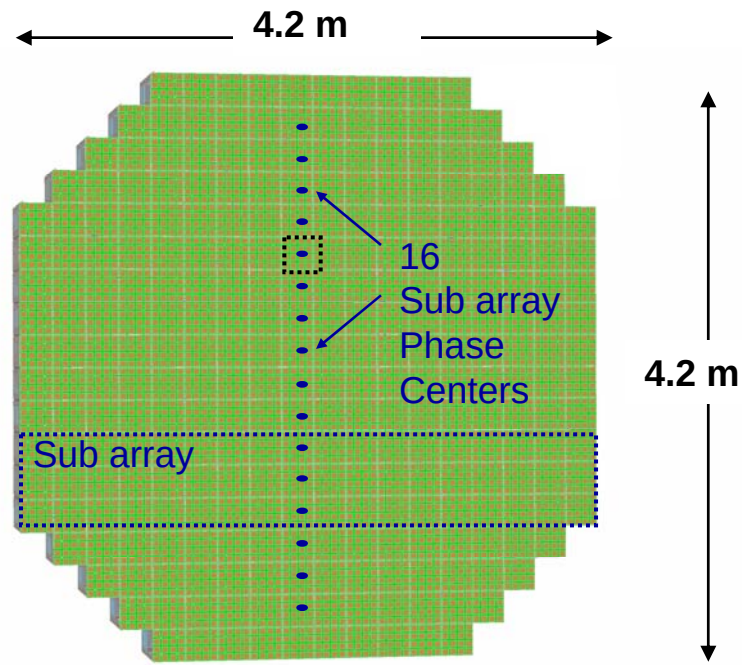


Manufacturers
APT
Analog Devices
Cree
Eudyna
Hittite
Infineon
Motorola
M/A Com
RF MicroDevices
Triquint

- **Optimal choice of HPA cost vs power is in 1W – 10W range**

MPAR Pre-Prototype Demo System





- **Pre-Prototype radar demonstrates two simultaneous modes**
  - Beam width: ~ 2º az by 2º el (broadside)
  - Two independent beam clusters
    - Electronic steering ±45º az, ±40º el
    - Up to 8 beams in each 1D cluster
  - Provides terminal area coverage to ~210 km
    - @10 W per element

= element
= brick
= subarray center

4544 elements
284 bricks
16 subarrays
8 X 1 beam cluster