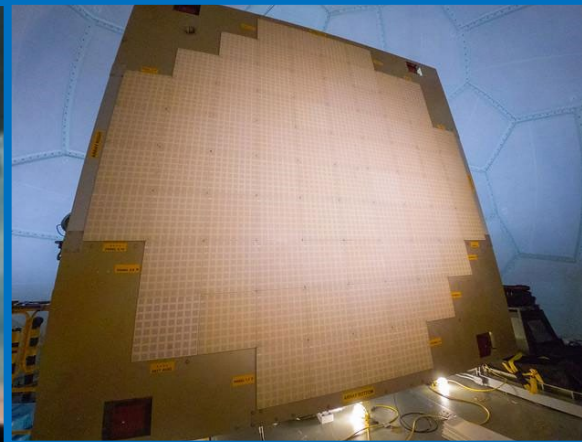


Observations and Understanding Phased Array Radar R&D Overview

Kurt Hondl, NSSL Deputy Director & PAR R&D Manager





PAR Observations Improve Forecasts And Warnings

Grand Challenge to ensure NOAA has the best radar tools available to accomplish its mission

- **Investigation of PAR and its abilities to provide the future weather radar observations requires NSSL to**
 - Develop and evaluate cutting edge radar system technologies
 - Understand their application to weather radar operations
 - Inform NOAA's acquisition decisions for the replacement of the WSR-88D network

OAR Strategic Plan (2020-2026)

GOAL 3

Make Forecasts Better

- Improve predictions
- Save lives and property

3.1 Develop interdisciplinary Earth system models

3.2 Design tools to forecast high-impact weather

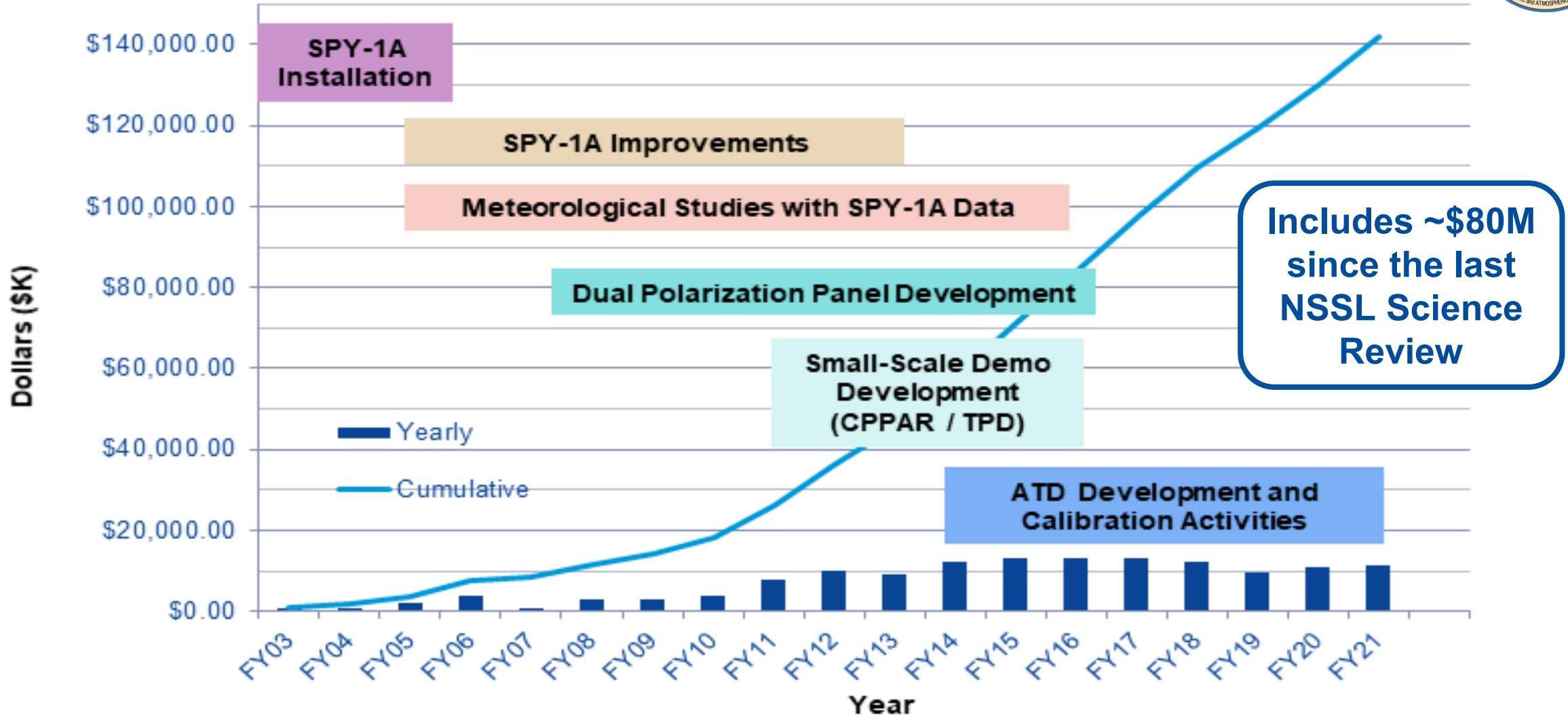
- Increase relevancy of forecasts
- Improve understandability of observations
- Better communicate the uncertainty

3.3 Transition science that meets users' current and future needs



PAR R&D Funding History

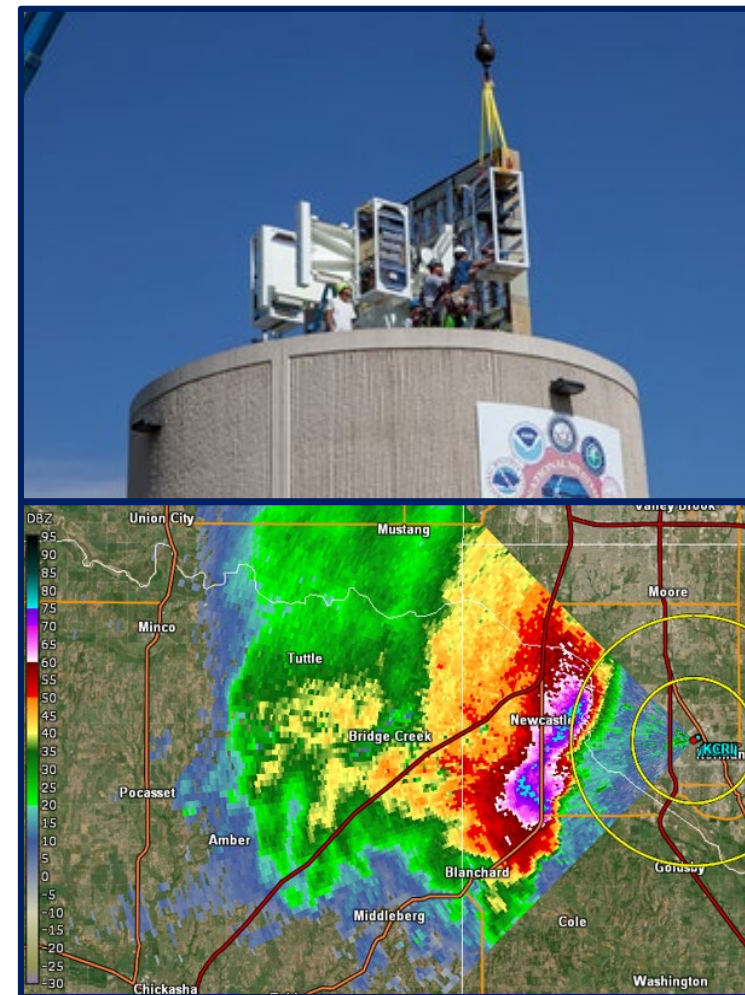
❖ Does not include initial investment of \$24M by non-NOAA entities to establish SPY-1A system in Norman





Leading the Way: Dual Polarization PAR

- **Developed the most sophisticated S-band, dual polarization PAR Advanced Technology Demonstrator (ATD)**
 - Design and development: 2015-2018
 - Installation begun: July 2018
 - First RF test: November 2018
 - Testing & Evaluation: 2019-2020
 - Preliminary calibration report: November 2020
 - Completed Systems Operational Test: April 2021
- **Many research activities being done for the first time**
 - Pioneering dual polarization calibration processes



Calibration Infrastructure

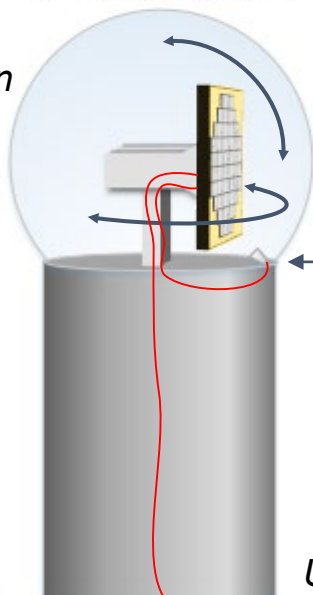
Challenge: The most significant risk for dual-pol phased array radar is in calibration tolerances.

Strategy: Build in as many tools as possible to take measurements. Our main tool is the **calibration tower**.



Dual-pol calibration using stratiform rain

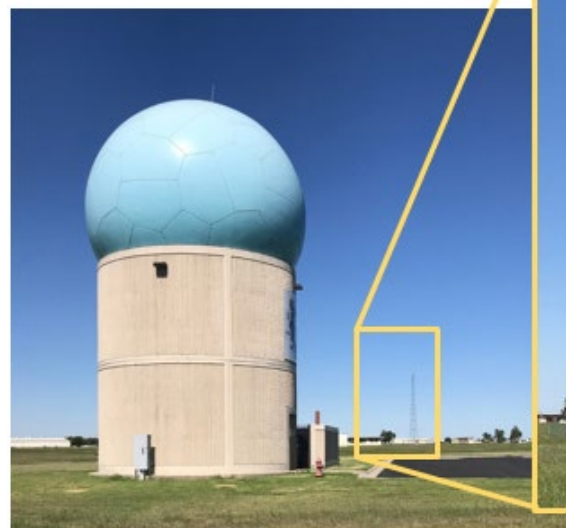
Rotates in azimuth,
Tilts in elevation



Remote probe

Calibration tower can receive, transmit, or even simulate a far-away target

Underground fiber communication & RF



Cal tower



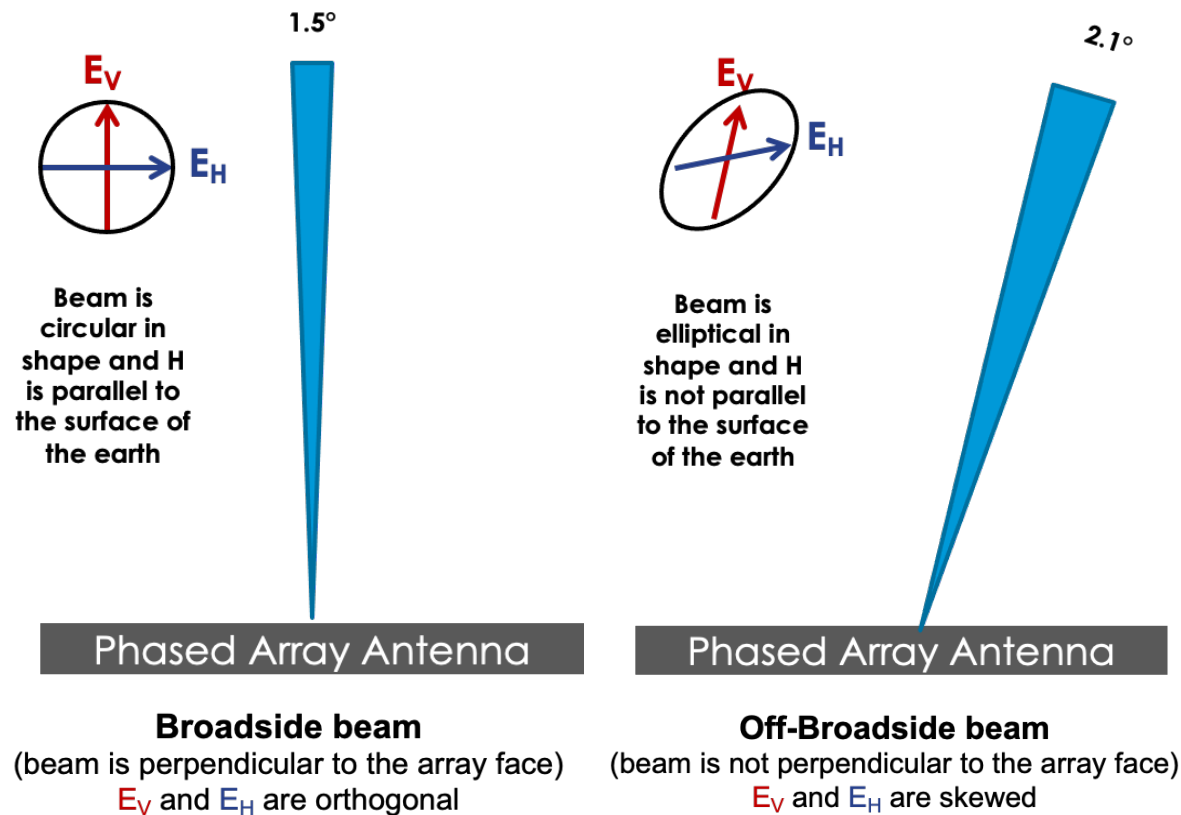
The Challenge of PAR Calibration

Polarimetric radars require precise characterization of radar beams

- The quality of weather observations depends on our ability to account for the radar system

PAR electronic steering changes radar beams

- Pointing direction, beam shape, polarization orientation



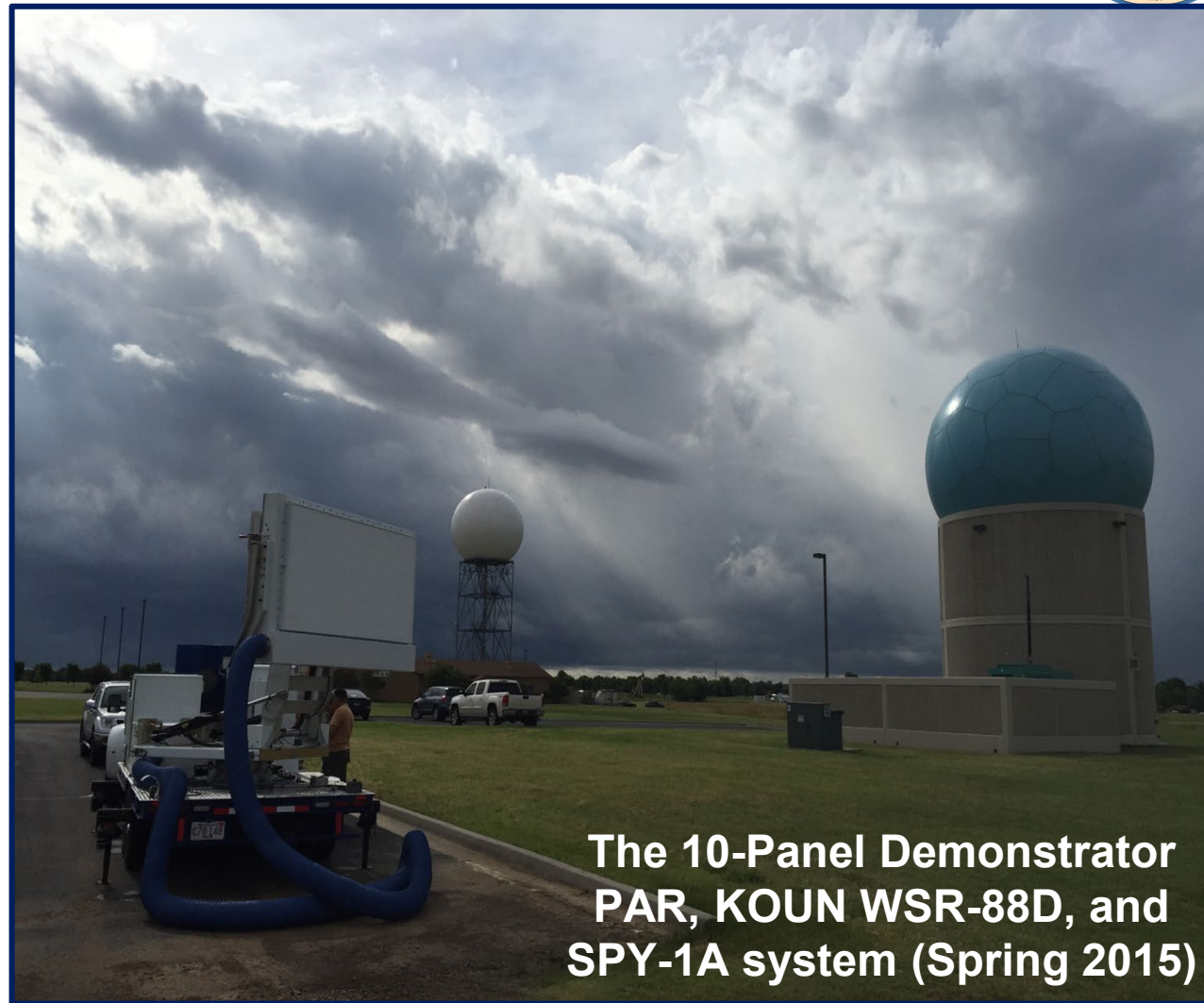
Calibration of a dish antenna = characterize 1 beam
 Calibration of a PAR antenna = characterize 1,000s of beams





Research Documentation (2015-2021)

- **4 Congressional Reports**
 - Numerous briefings
- **44 formal publications concerning “phased array”**
- 25** • Technical applications or performance
- 7** • Phenomenon studies
- 6** • Forecaster use and evaluations
- 4** • Programmatic or overview
- 2** • Modeling applications
- **9 NSSL technical reports**
 - Sharing information with collaborators





Forecaster Use and Evaluation Studies Of Rapid-Update PAR Data

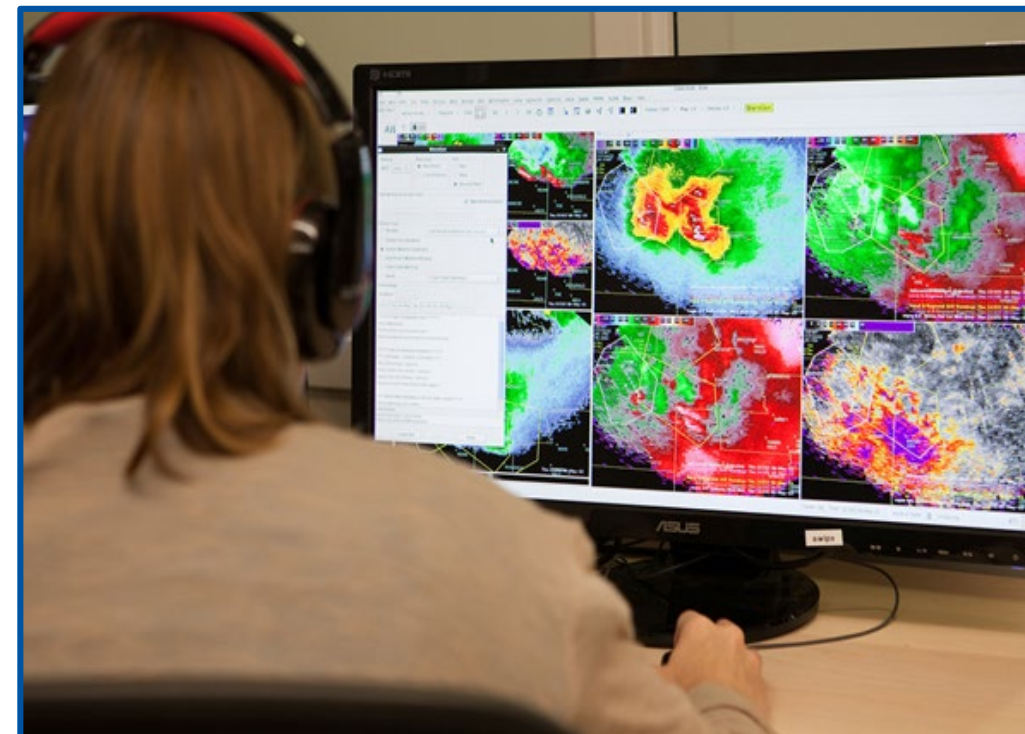
Does radar update time matter?

- Involved participation of 30 NWS forecasters
- Forecasters saw various update times
 - 1, 2, or 5-min of single-pol data
- Warnings issued for severe weather hazards (tornado, hail, high winds)

Answer == Yes!

- Improved all tornado warning metrics
 - Lead time, Probability of Detection, False Alarm Ratio
- Increased confidence in warning decision

Now looking at rapid update dual polarization data from KOUN & ATD



Forecaster working a supercell case during the *Phased Array Radar Innovative Sensing Experiment (PARISE)* to evaluate warning performance based on 1-minute, 2-minute, or 5-minute volume update rates.



The Challenge of PAR System Design

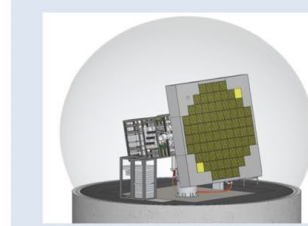
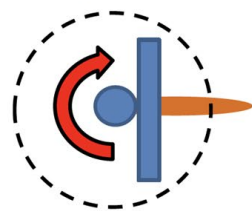
PARs come in many *flavors*

- **Architecture** and **form factor** are key characteristics
- Each have their own benefits based on their technical capabilities and risks or complexities

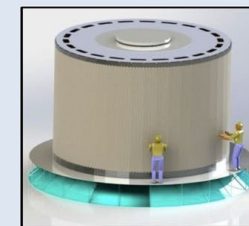
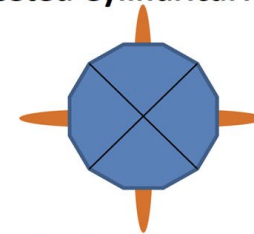
Spent much of the last 15 years looking at a Multifunction PAR

- Dual-use presented additional technical difficulties and increased costs
- A rotating array was not compatible with multi-agency concept of operations

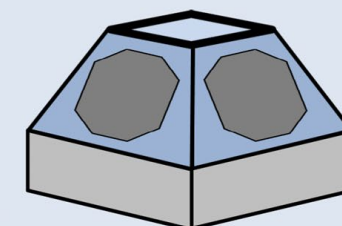
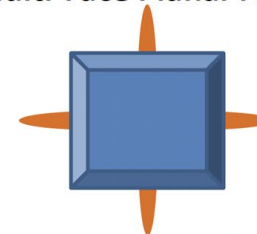
Rotating Planar Array



Faceted Cylindrical Array



Multi-Face Planar Array



PAR designs must consider trade-offs between cost and capabilities

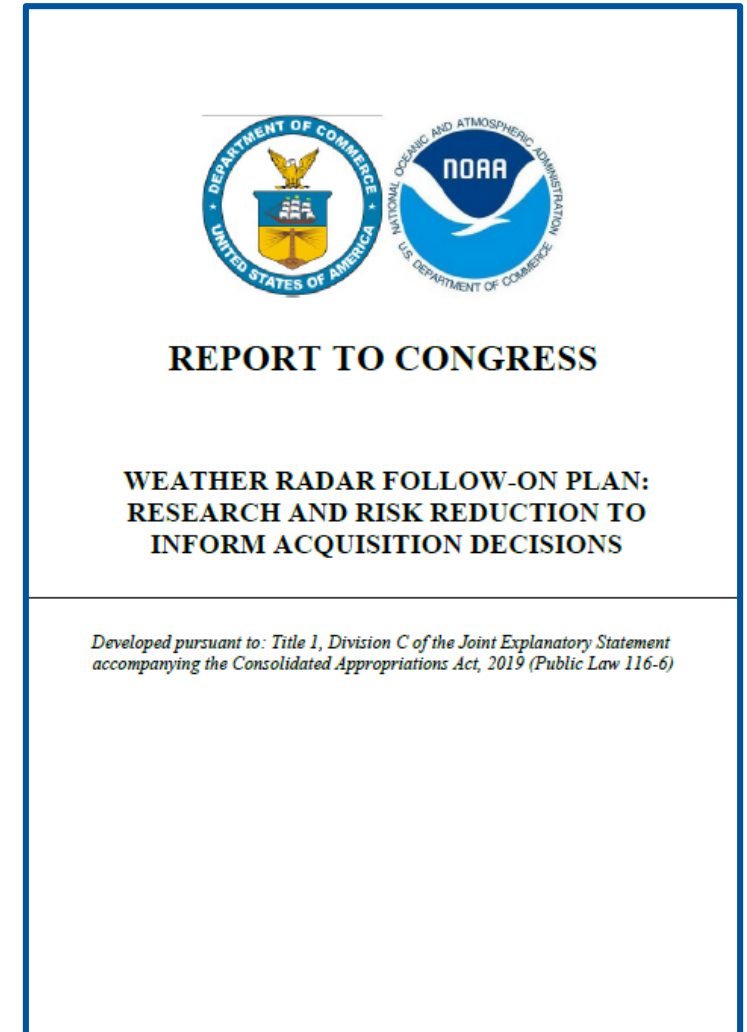
- Any *concept of operations* meeting NWS requirements must be compatible with the capabilities/performance of the radar system



Weather Radar Follow-On Plan



- Consolidated Appropriations Act of 2019 requested NOAA's weather radar follow-on transition-to-operations plan
- Key Elements ...
 - Sustain and enhance NEXRAD through current expected service life (2035)
 - Conduct PAR R&D to reduce technical risk and inform future acquisition
 - Protect NEXRAD spectrum
 - Organize for success

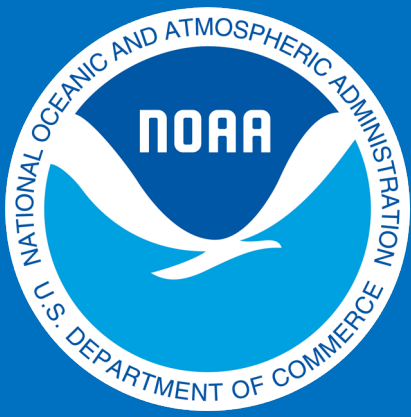




PAR R&D Next Steps

- **Gain knowledge from ATD research**
 - Development of calibration tools suitable for an operational platform
 - Meteorological studies of rapid update dual polarization observations
- **Gain information from other technology demonstrators**
 - Funded all-digital PAR development at OU Advanced Radar Research Center (ARRC) and Massachusetts Institute of Technology Lincoln Laboratory (MIT/LL)
- **Continue research as outlined in *Weather Radar Follow-On Plan ...***
 - Develop additional technology demonstrators to further reduce risk
 - Work with NWS to establish collaborative R&D and acquisition planning





Kurt Hondl



Charles Kuster



Terry Schuur



Sebastian Torres



Danny Wasielewski



Dusan Zrnica

Questions for the PAR panel?