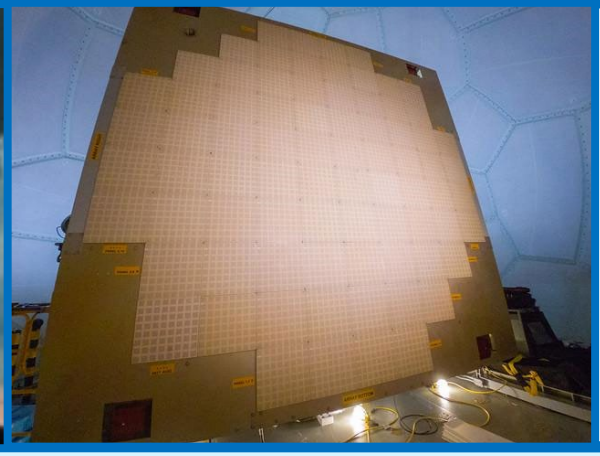
Observations and Understanding

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

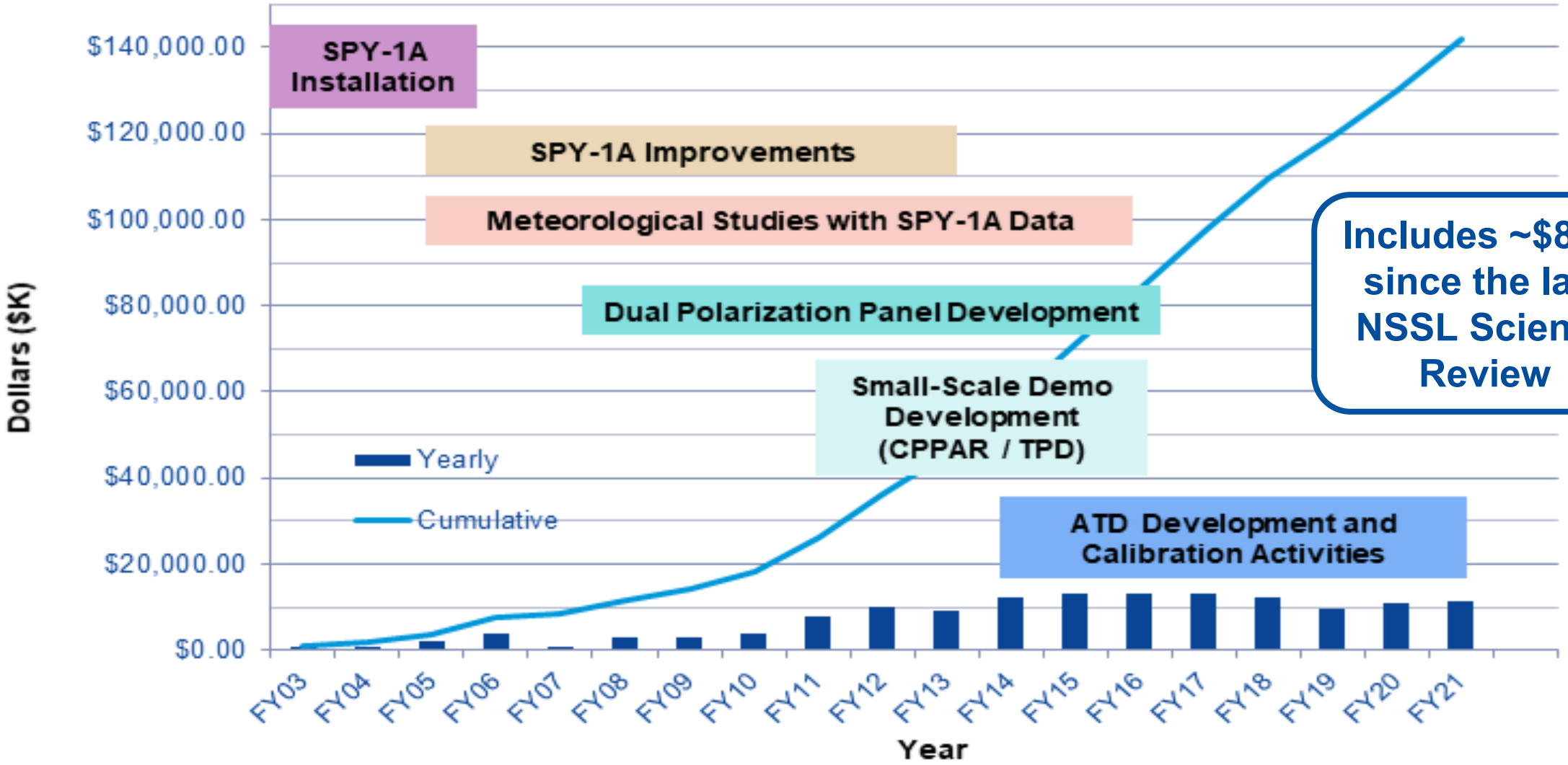
3.2 Design tools to forecast high-impact weather

- 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

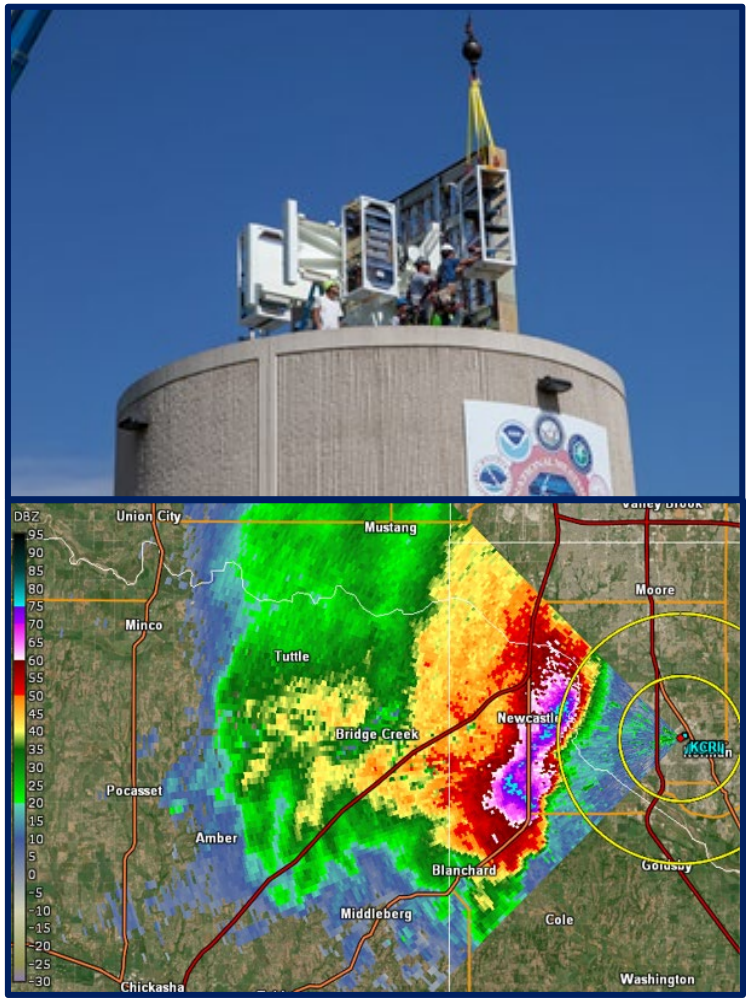
❖Does not include initial investment of $24M by non-NOAA entities to establish SPY-1A system in Norman



Includes ~$80M since the last NSSL Science Review

Leading the Way: Dual Polarization PAR

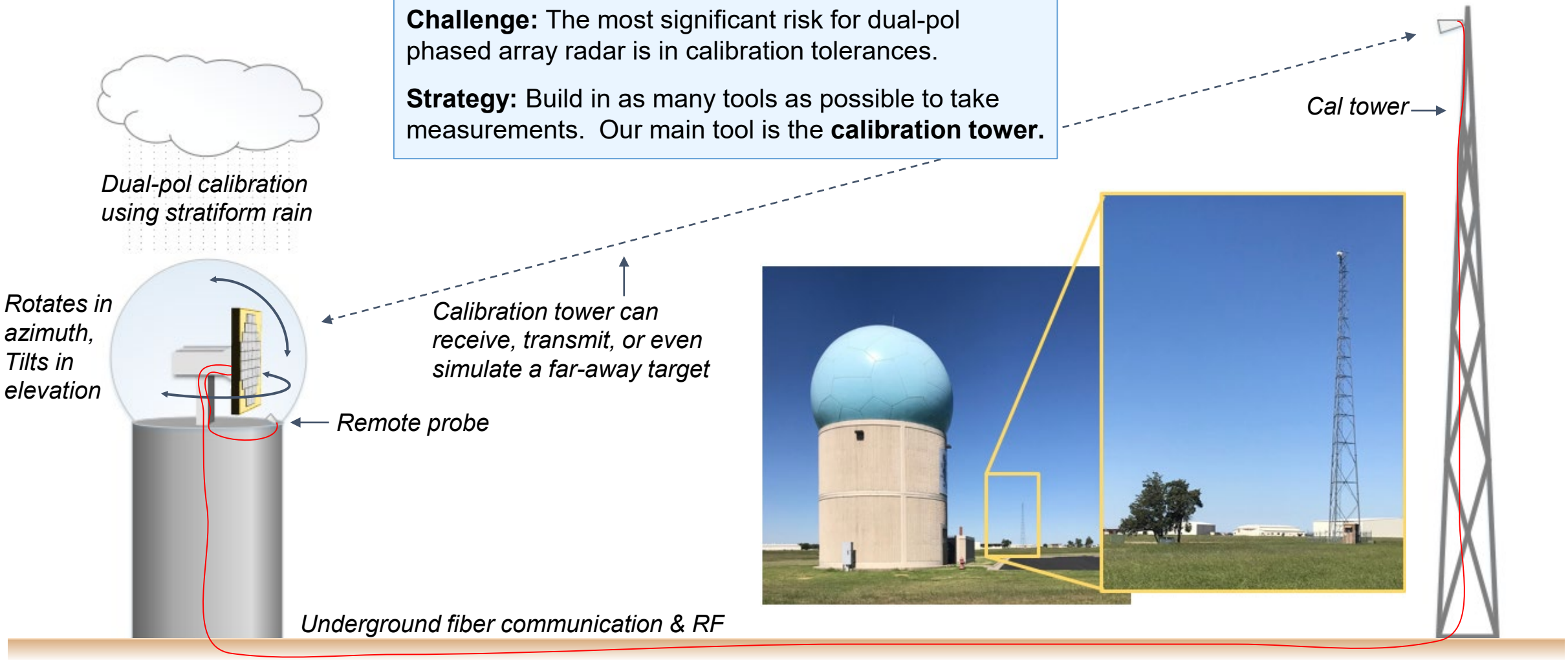
- **Developed the most sophisticated S-band, dual polarization PAR Advanced Technology Demonstrator (ATD)**
  - Design and development: 2015-2018
  - Installation begun: July 2018
  - First RF test: November 2018
  - Testing & Evaluation: 2019-2020
  - Preliminary calibration report: November 2020
  - 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.**



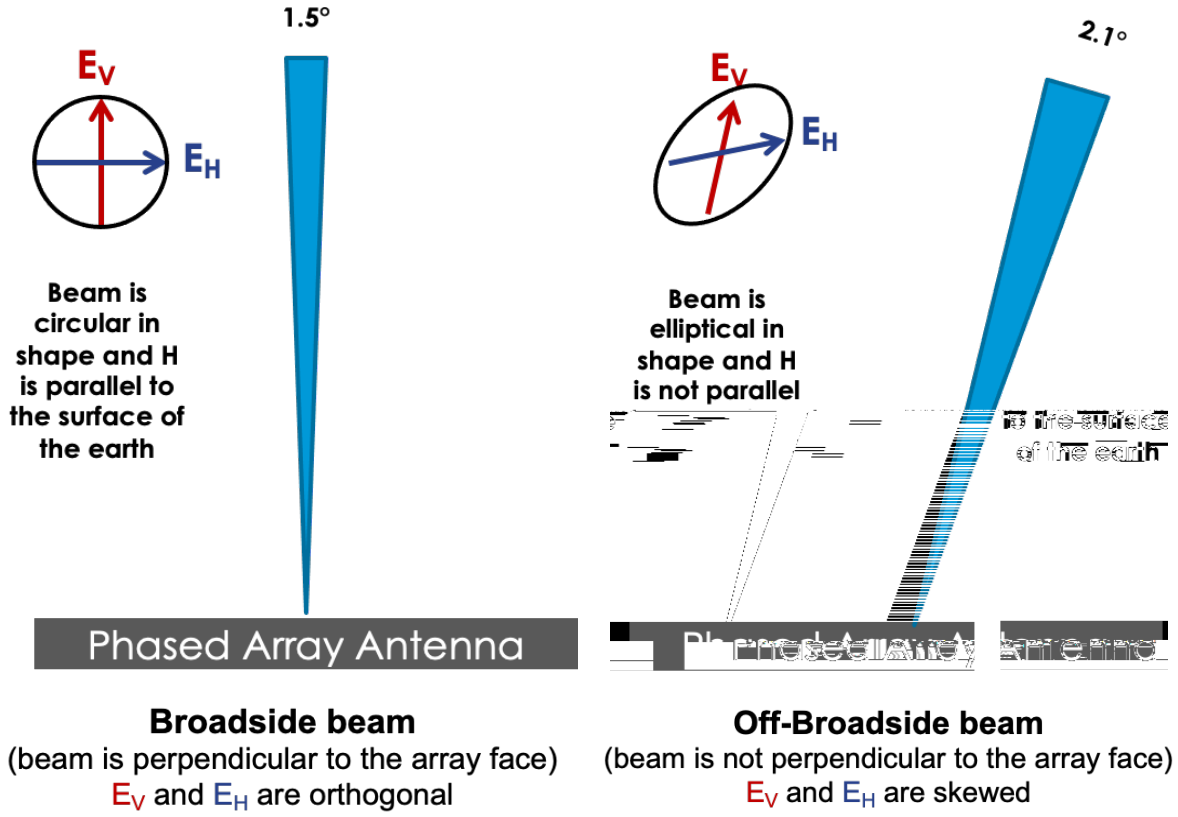
The Challenge of PAR Calibration

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



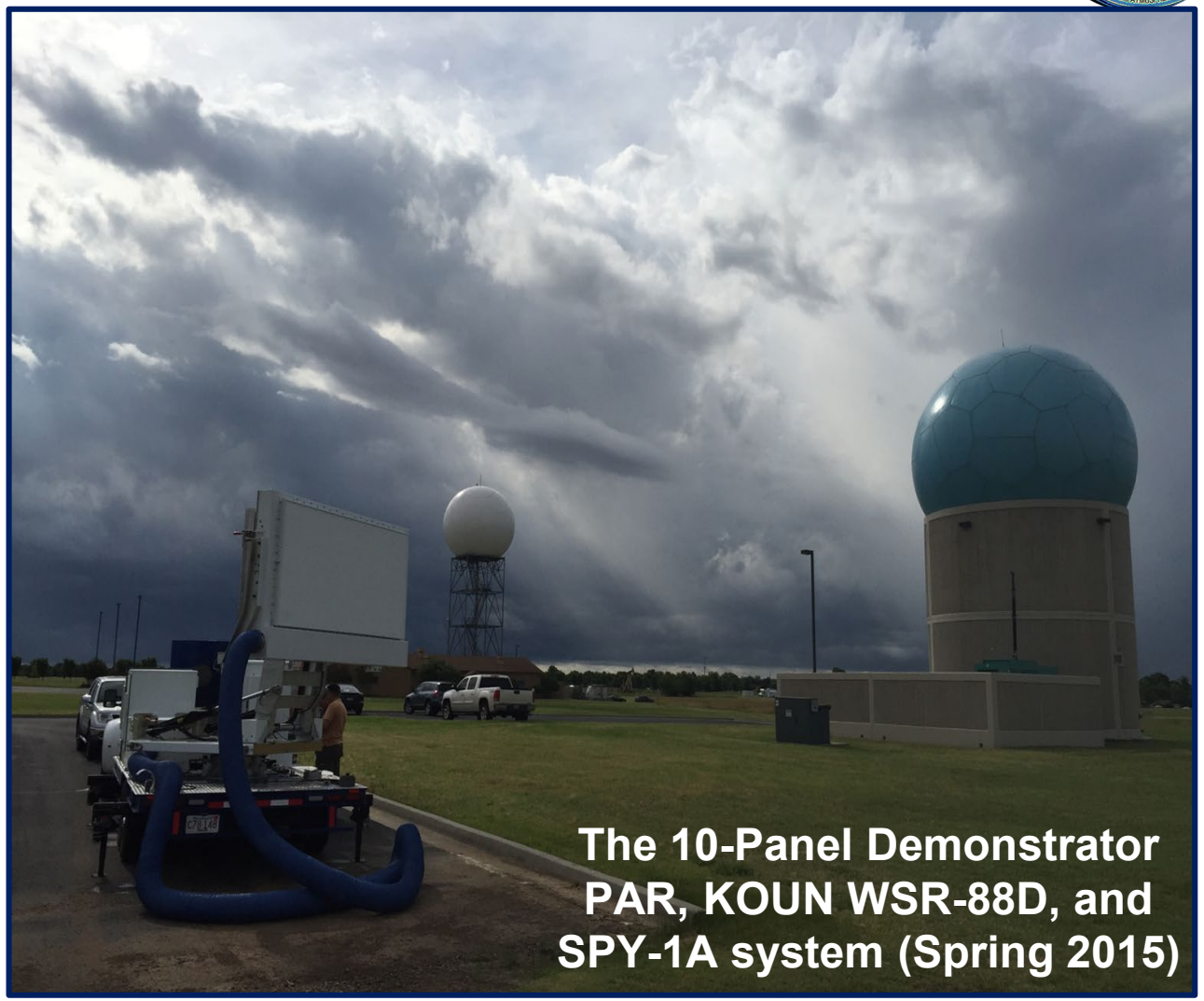
Broadside beam
(beam is perpendicular to the array face)
E_V and E_H are orthogonal

Off-Broadside beam
(beam is not perpendicular to the array face)
E_V and E_H are skewed

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



The 10-Panel Demonstrator PAR, KOUN WSR-88D, and SPY-1A system (Spring 2015)

Forecaster Use and Evaluation Studies
Of Rapid-Update PAR Data

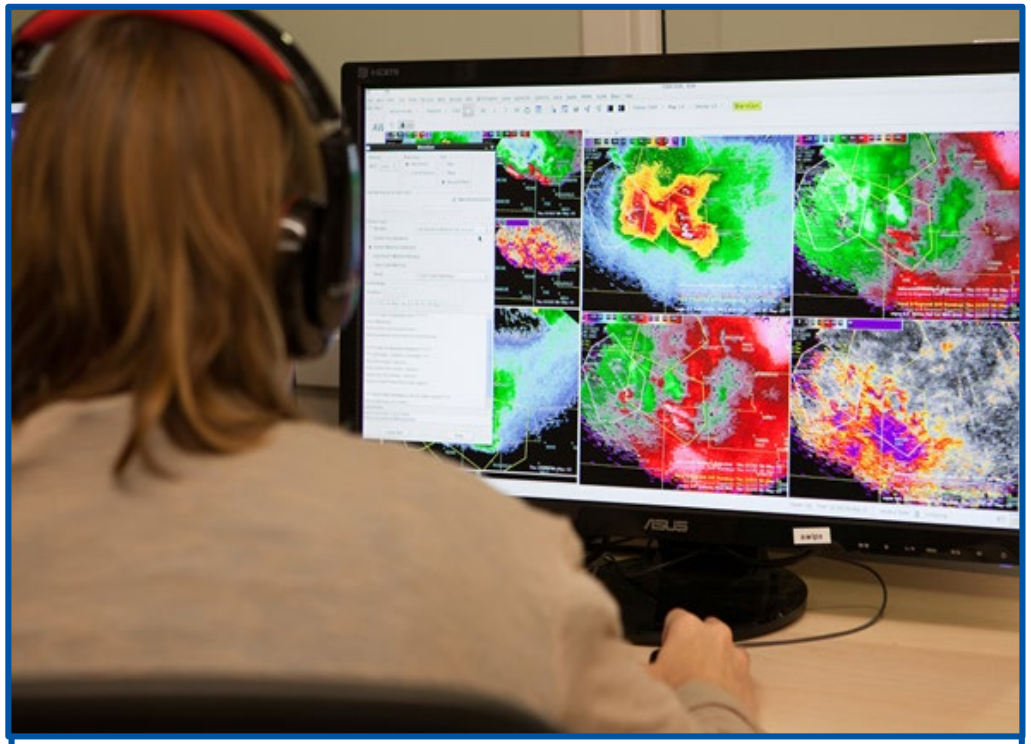
Does radar update time matter?

- 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.

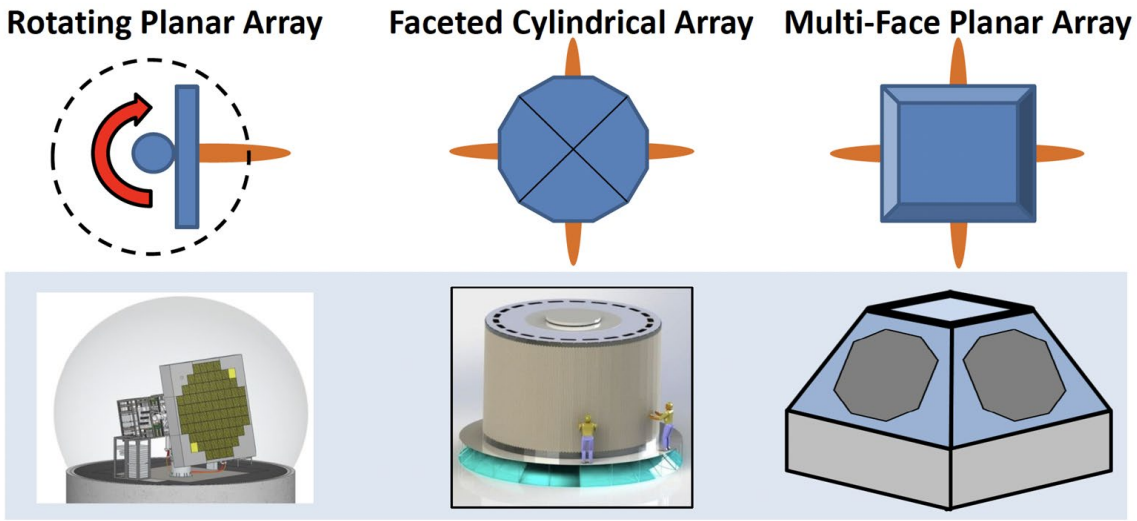
The Challenge of PAR System Design

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



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

REPORT TO CONGRESS

WEATHER RADAR FOLLOW-ON PLAN: RESEARCH AND RISK REDUCTION TO INFORM ACQUISITION DECISIONS

Developed pursuant to: Title 1, Division C of the Joint Explanatory Statement accompanying the Consolidated Appropriations Act, 2019 (Public Law 116-6)

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 Zrnic

Questions for the PAR panel?