Multi-Function Phased Array Radar (MPAR)

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National Weather Center

Norman, Oklahoma

Q) Why Phased Array Radar?

A) To meet NOAA's evolving requirements for radar observations.

- Faster Volume Updates
  - Improved Probability of Detection (POD) and False Alarm Ratio (FAR), increased tornado warning lead-times
  - Data assimilation into numerical weather models (Warn On Forecast)
- Electronic Adaptive Scanning
  - Based on prioritization – Scan when and where needed

These benefits are not possible with the WSR-88D

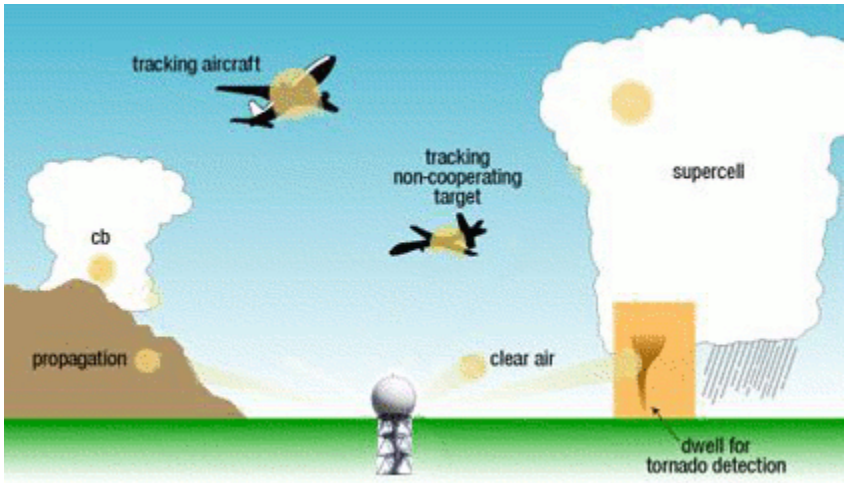
http://wdssii.nssl.noaa.gov/web/wdss2/products/radar/MPAR/par_scan.shtml

Electronic Scanning

Conventional scanning

NEXRAD

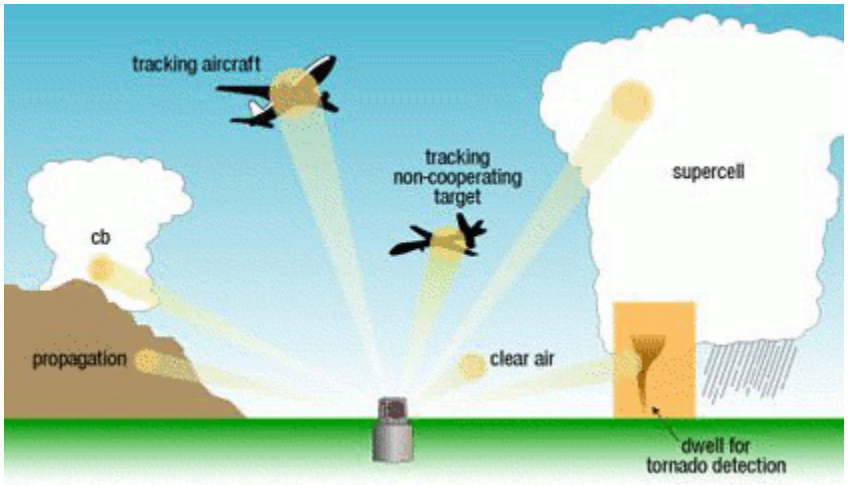
Sequential scanning only (including "clear" air)



Electronic Adaptive scanning

Phased Array Radar

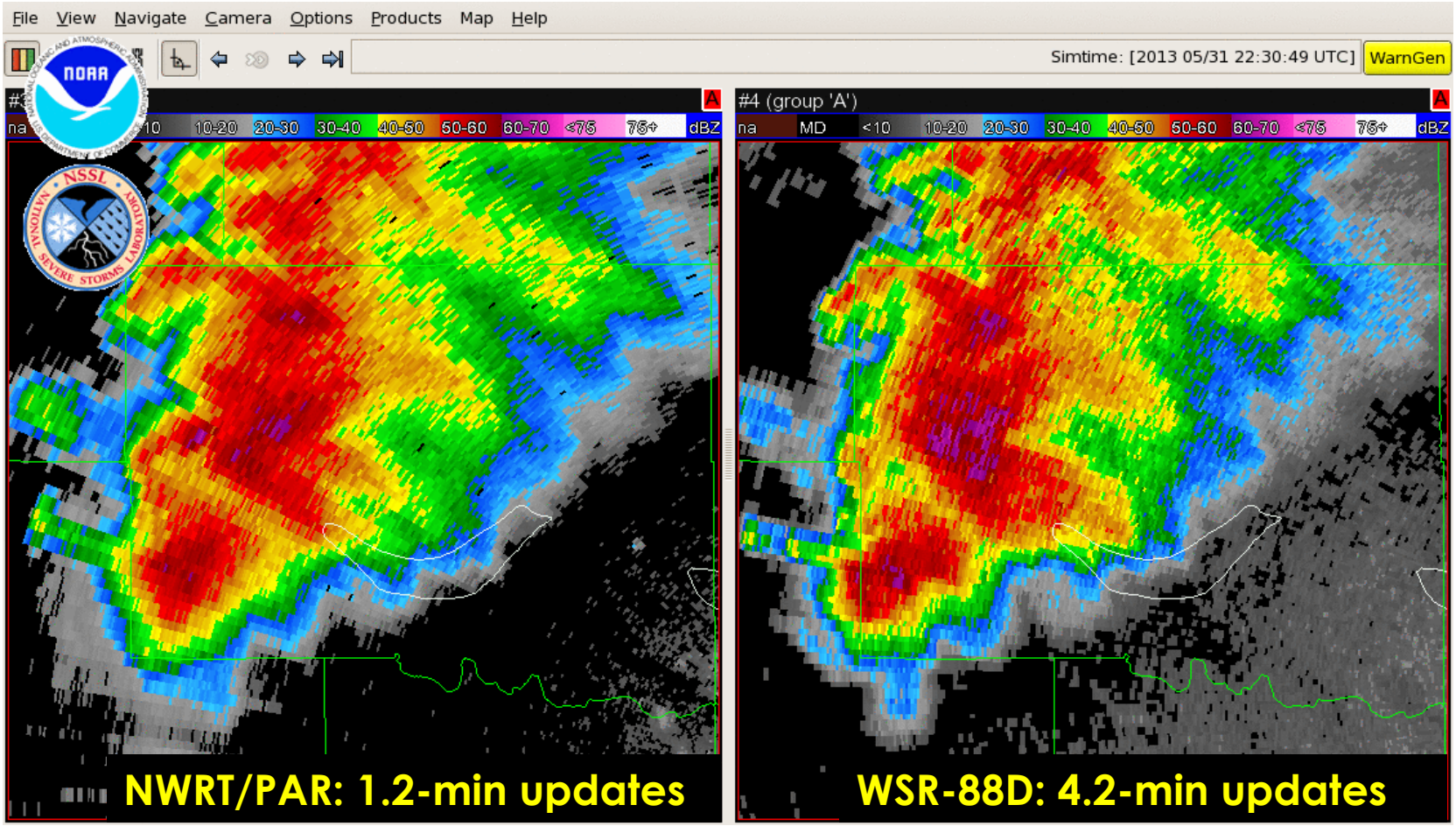
Concentrates radar only on areas of concern



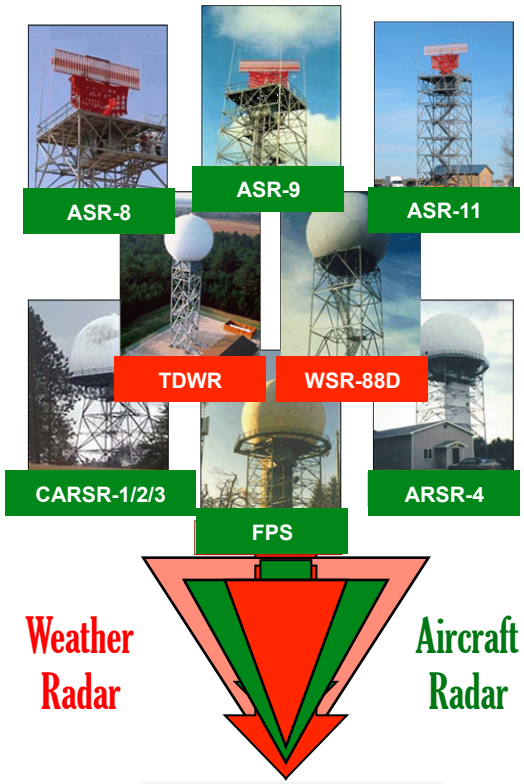
El Reno EF3 Tornado 31 May 2013

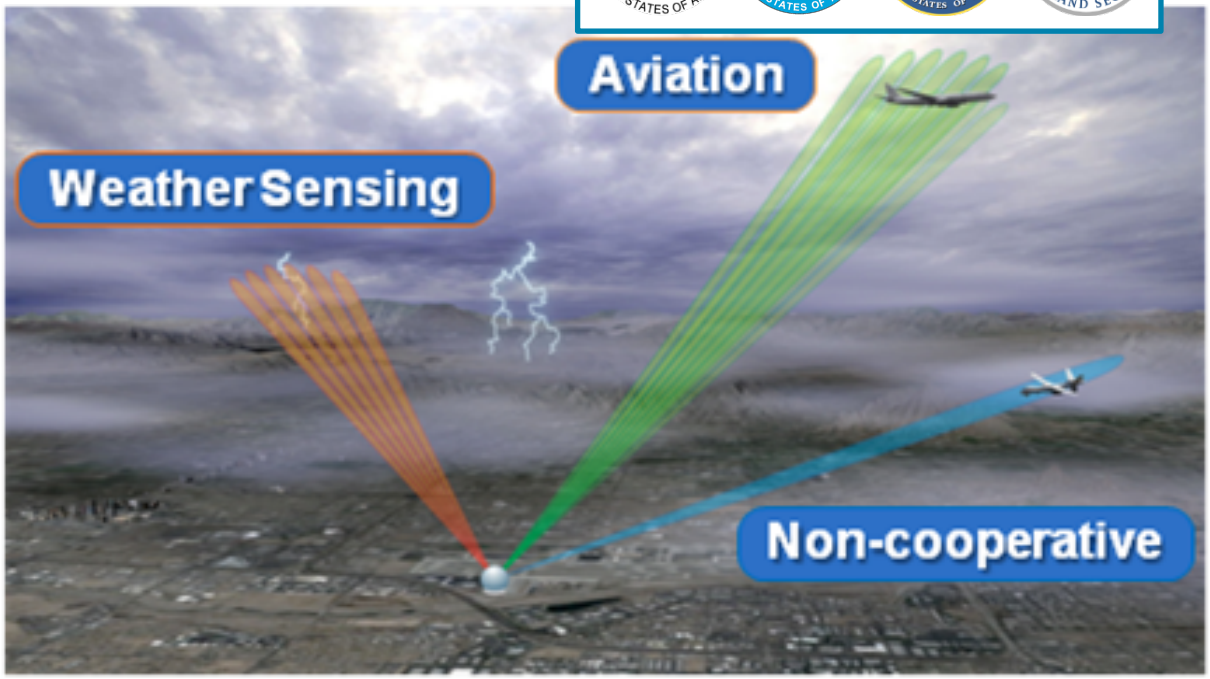
http://wdssii.nssl.noaa.gov/web/wdss2/products/radar/MPAR/NWRT/ELReno_NWRTPAR.gif

- Transition to tornadic storm seen earlier and more clearly by Phased Array Radar
- Direction of tornado path captured better by Phased Array Radar



MPAR Concept

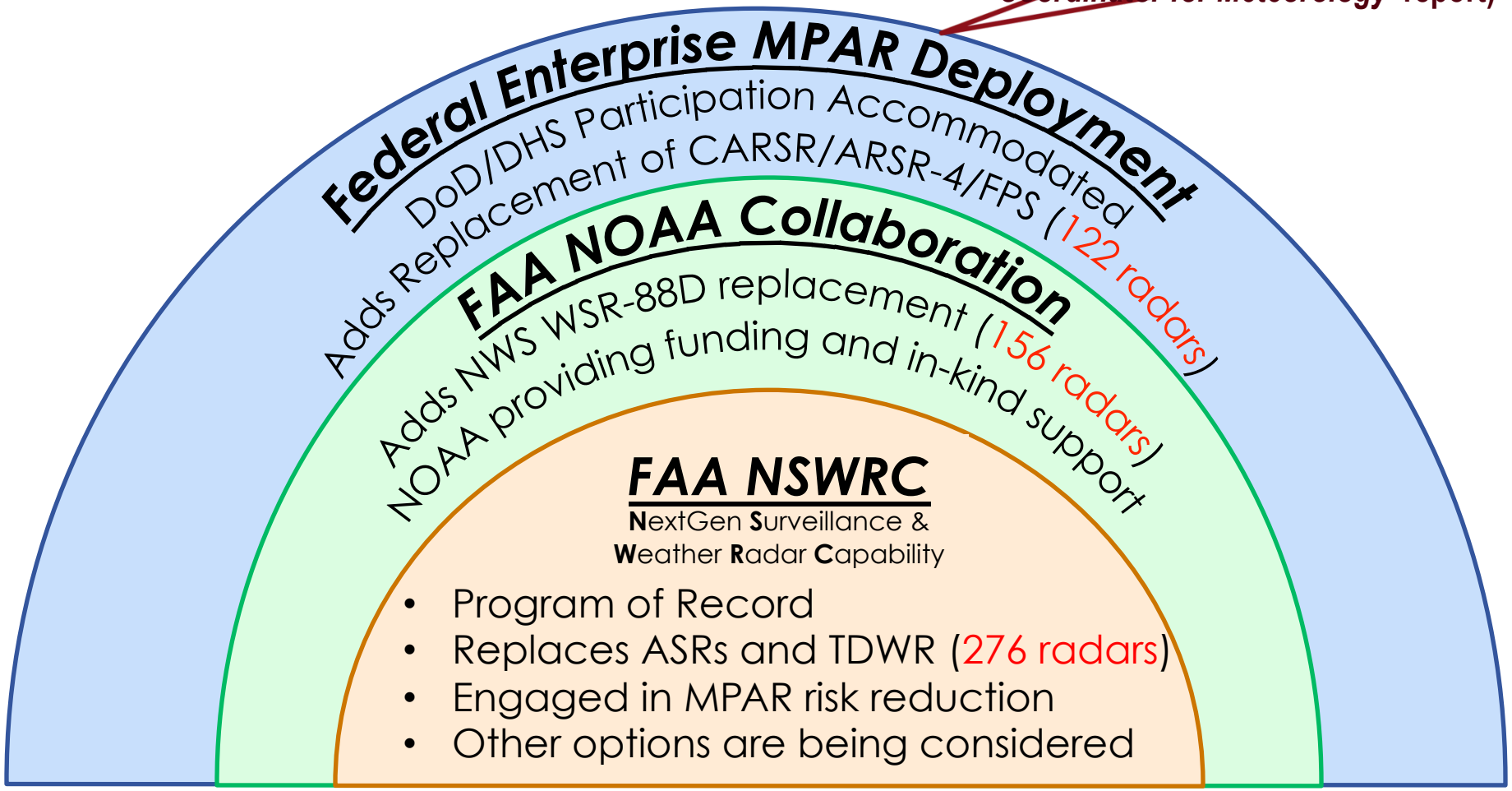




Eight System Types	→	Single System
Single Mission	→	Multi-Mission
Legacy Requirements	→	Legacy & Emerging Requirements
Non-Scalable	→	Scalable to Mission Needs
Mechanically Rotating	→	Electronically Steered
Multiple Maintenance, Logistic and Training Programs	→	Consolidated Maintenance, Logistic and Training Programs

NSWRC and MPAR

Potential savings of $1.8B in acquisition costs by reducing the total number of radars from 554 to ~365
(2006 *Office of the Federal Coordinator for Meteorology* report)



MPAR R&D Focus Areas

Acceptable Cost

- Exploit Commercial Technology
- Fewer Systems Overall
- Economies of Scale
- Graceful Degradation
- Single Logistics & Maintenance System

Multi-Functionality

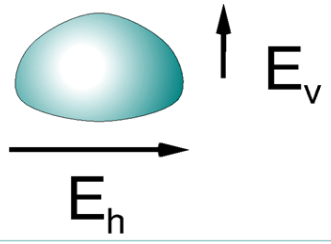
- Resource Management
- One System that Meets Multiple Needs
- Data Sharing and Operational Flexibility

Dual Polarization Capability

- Unique Weather Requirement of WSR-88D
- Improved Clutter Rejection & Aircraft Detection

Differential Reflectivity

Larger drops -- Diameter ~ 4.0 mm

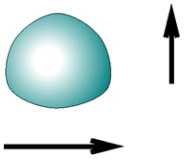


$Z_h > Z_v$

$Z_{DR} = Z_h - Z_v > 0$ dB

Larger rain drops are oblate

Smaller drops -- Diameter ~ 0.5 mm



$Z_h \approx Z_v$

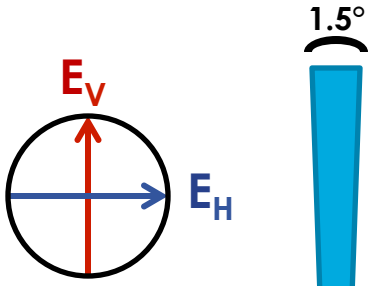
$Z_{DR} \approx 0$ dB

Smaller rain drops are more spherical

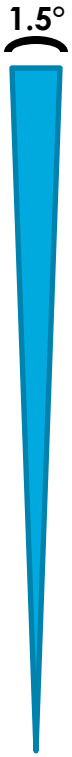
Z_H needs to be parallel to the earth at all viewing angles to effectively capture the aspect ratio of the rain drop.

Electronic Scanning

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

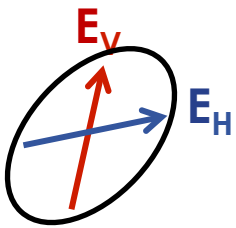


Beam is circular in shape and H is parallel to the surface of the earth



Phased Array Antenna

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



Beam is elliptical in shape and H is not parallel to the surface of the earth

Phased Array Antenna

MPAR Activities

National Weather Radar Testbed / Phased Array Radar (2003-2014)

Meteorological phenomena studies, Adaptive scanning, Warning decision-making process, Multi-function demonstration

MPAR-Sponsored Studies (2010-2014)

Siting study, Spectrum analysis, Preliminary cost study, Microburst / Windshear assessment, Backend analysis

NOAA/FAA Activities

Industry Engagement

Request for Information (2012)

Industry Day (2012)

Sponsored Industry Studies

Phased Array Radar Dual Polarization Engineering Approaches (2012)

Antenna Design and Life Cycle Cost Estimation (2013)

Industry Activities

Cylindrical Polarized Phased Array Radar (2011-2105)

OU/ARRC proof of concept demonstrator, CPPAR Design study

10-Panel Dual Polarization Demonstrator Development (2012-2015)

MIT/LL Gen 2+ panel technology, OU transceivers, Final assembly in progress

Advanced Technology Demonstrator (ATD) Design (2014-2015)

Preparing for evaluation prior to FAA/NSWRC Initial Investment Decision (IID)

Technology Development Activities

Cylindrical Polarized PAR (CPPAR)

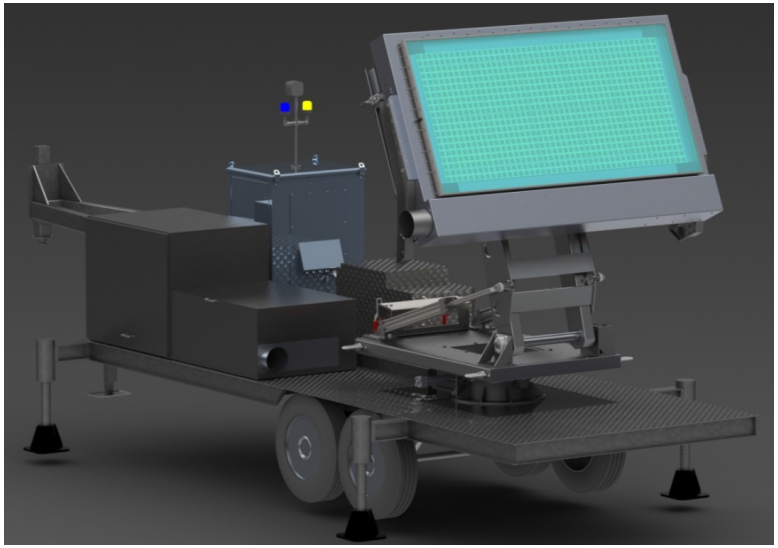
Developed by OU Advanced Radar Research Center (ARRC)

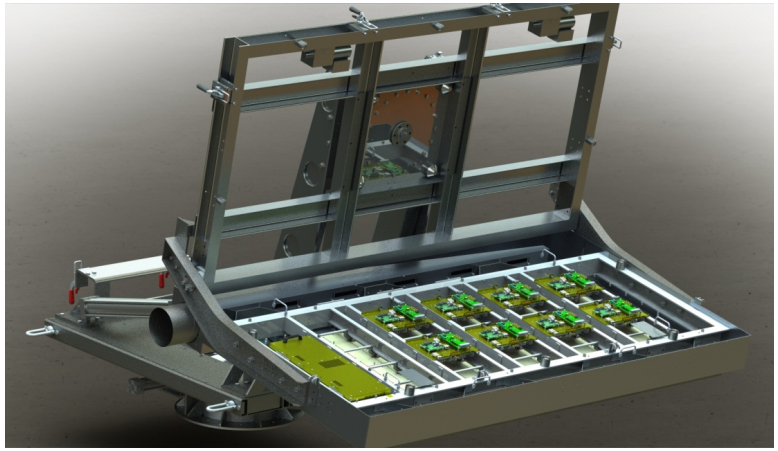
- **CPPAR Objectives**
  - Demonstrate properties of cylindrical arrays
    - Scan strategies
    - Dual polarization performance
    - Calibration concept
  - Gain understanding of cylindrical array benefits and limitations
  - Joint NSSL & ARRC full-scale CPPAR design study 2013-2014
    - Included all-digital radar architecture
- **Initiated all-digital array design (fall 2014)**

10-Panel Dual Pol Demonstrator

Developed by MIT/Lincoln Laboratory

- **Dual Polarization Panels**
  - Successive generations of design starting in 2007
    - Previous funding provided by FAA, and USAF. Demonstrator funded by NOAA.
- **10-Panel Demonstrator Objectives**
  - Demonstrate sufficient progress towards identified risk areas
    - Dual polarization performance
    - Calibration concept
    - Thermal management
  - Testing at NSSL during spring 2015
    - Evaluation for FAA Investment Analysis Readiness Decision (IARD, Dec 2015)
    - ***Is the MPAR concept mature enough to be included in the analysis of alternatives?***

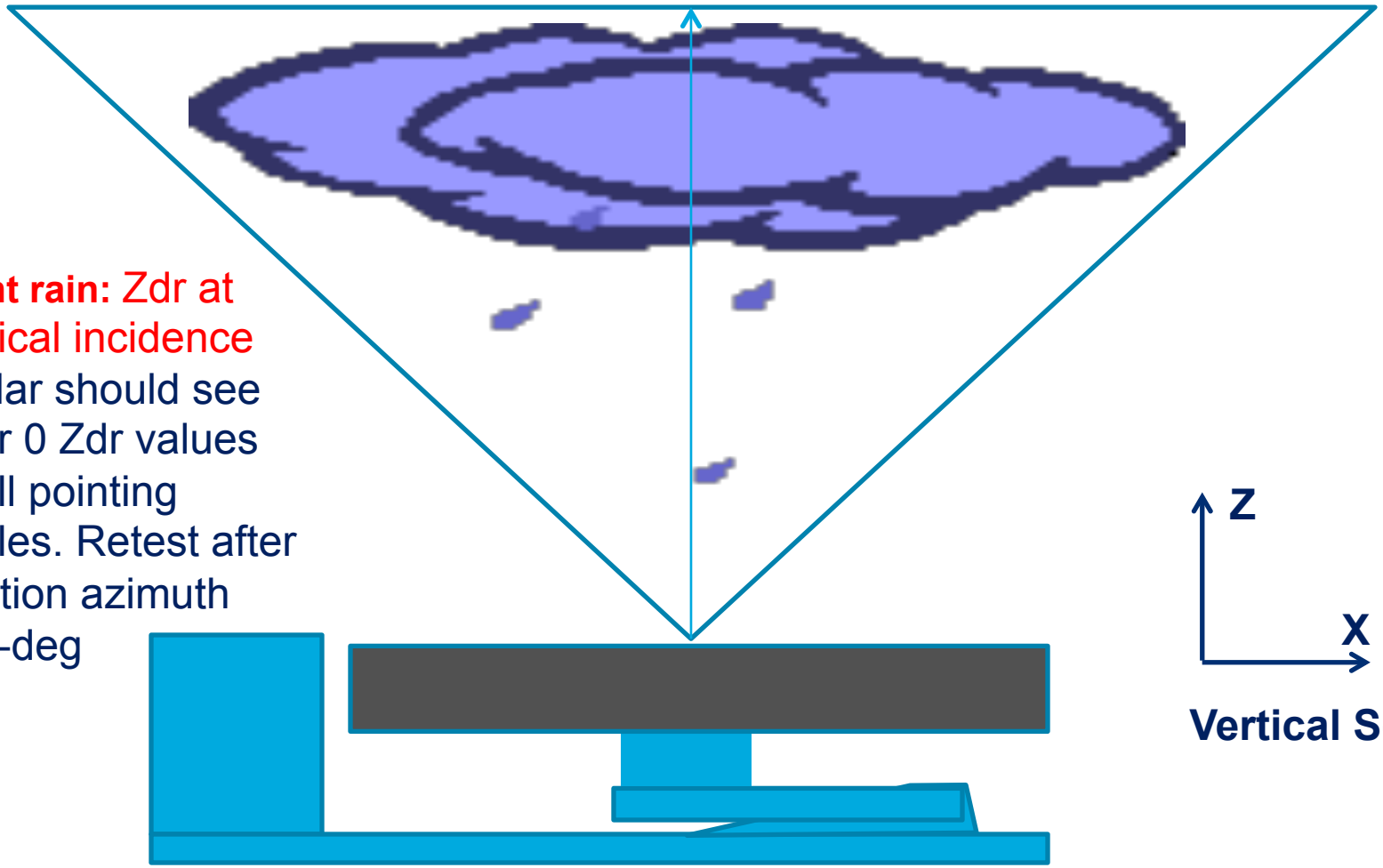




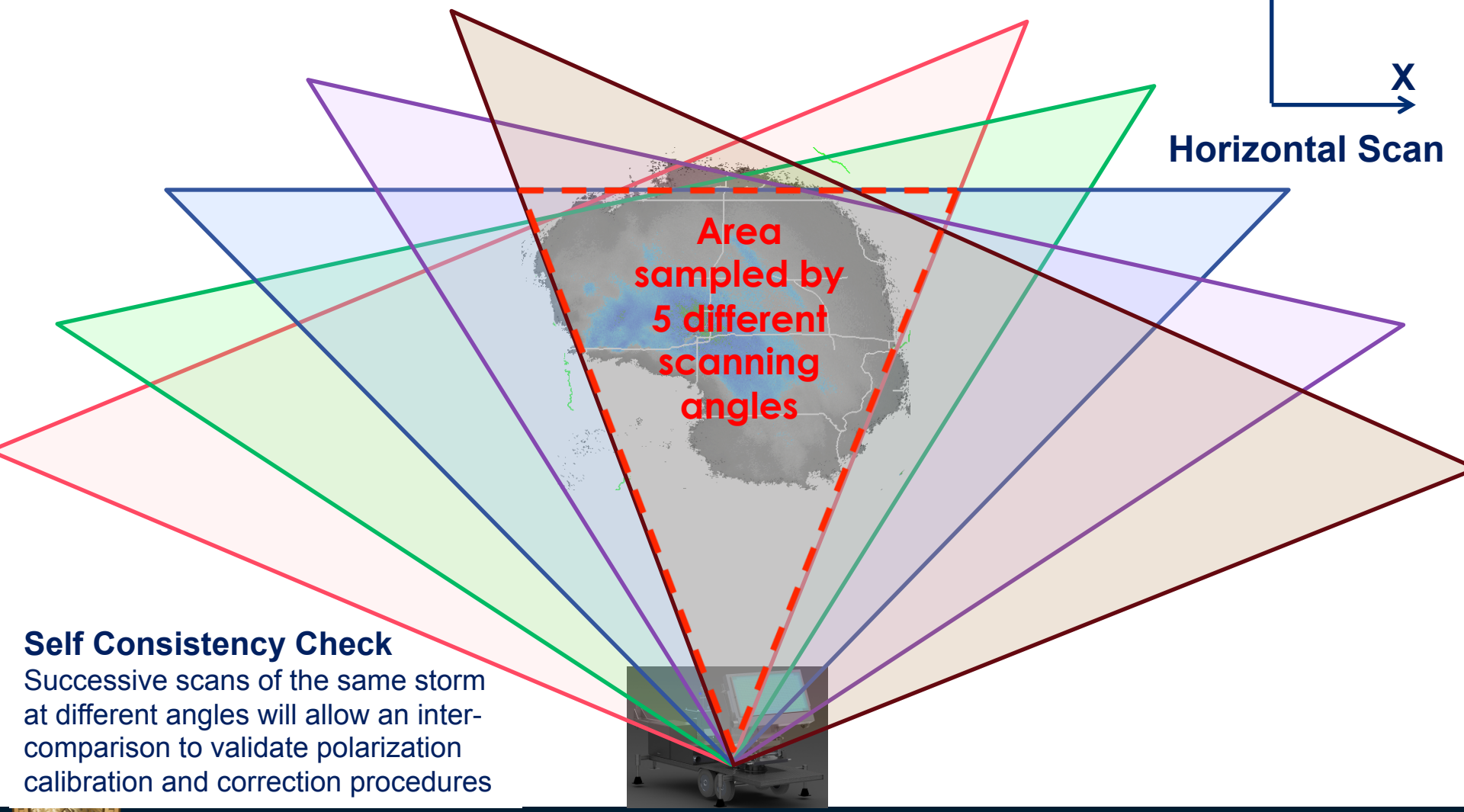
Dual Polarization Evaluation

Light rain: Zdr at vertical incidence

Radar should see near 0 Zdr values at all pointing angles. Retest after rotation azimuth ±90-deg



Dual Polarization Evaluation



Self Consistency Check

Successive scans of the same storm at different angles will allow an inter-comparison to validate polarization calibration and correction procedures

Advanced Technology Demonstrator

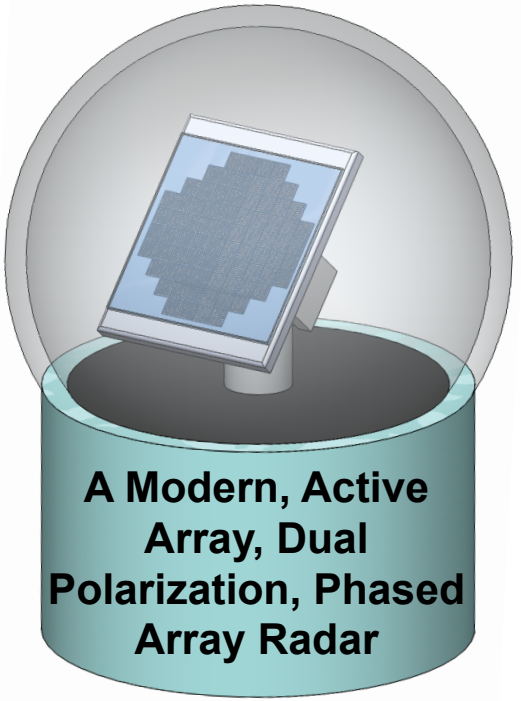
Plan to build a new phased array radar with mature, available components

- MIT/LL dual polarization panel technology
- DOD-developed receivers, exciters, and beamformers
- Using a combination of NSSL-developed and DOD-developed software

To demonstrate MPAR-like technology prior to FAA Initial Investment Decision

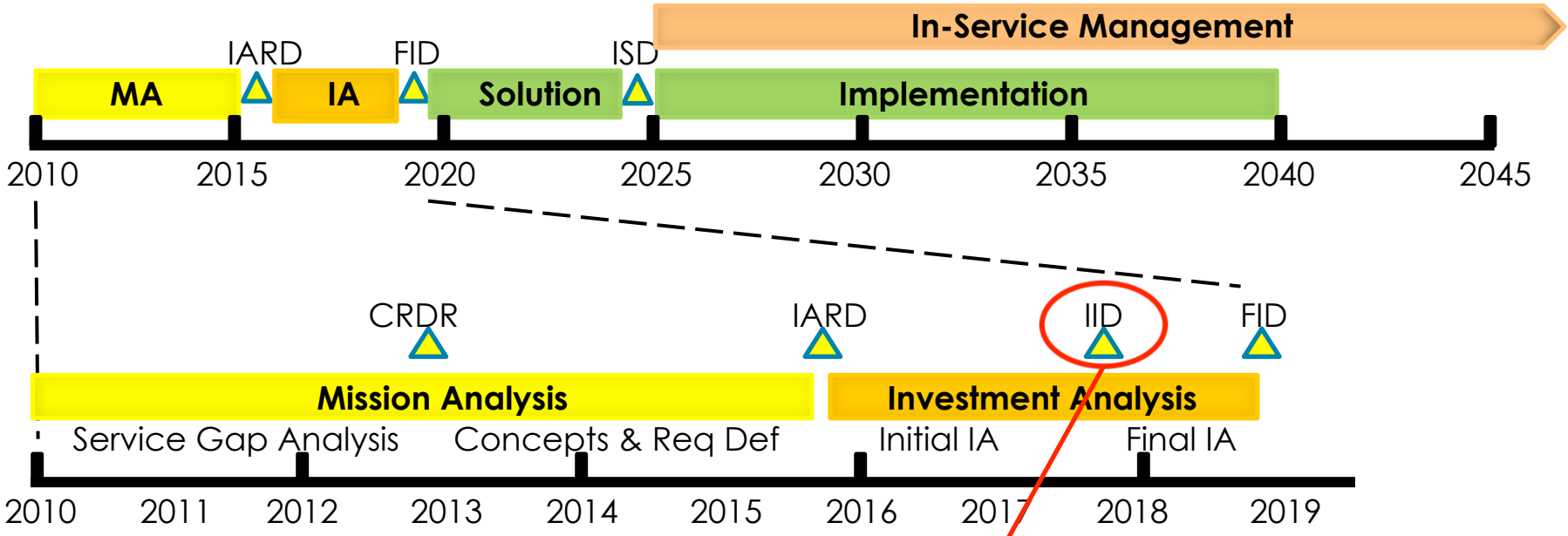
- Will have capabilities that cannot be demonstrated on the NWRT/PAR

NWRT/ATD



NOAA and FAA sharing development costs of ATD

FAA NSWRC Timeline



FAA Milestones

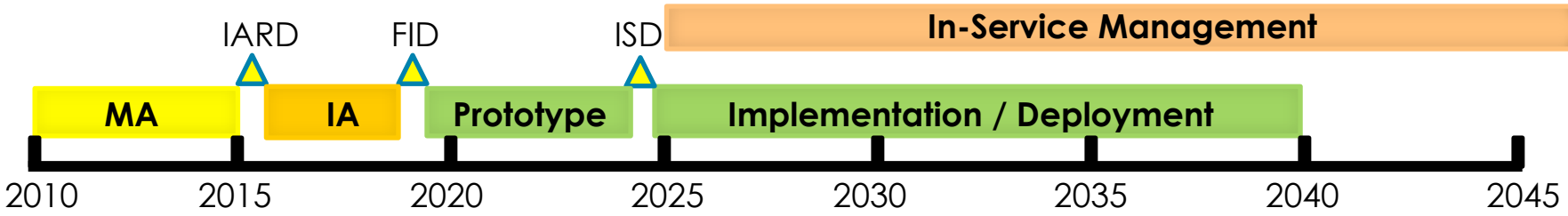
CRDR	Concepts Requirements Definition Readiness
IARD	Investment Analysis Readiness Decision
IID	Initial Investment Decision
FID	Final Investment Decision
ISD	In Service Decision

- Preliminary Requirements
- Analysis of Alternatives
- Cost/Benefit Estimate

- Update Requirements
- Select Preferred Alternative
- Define Business Case

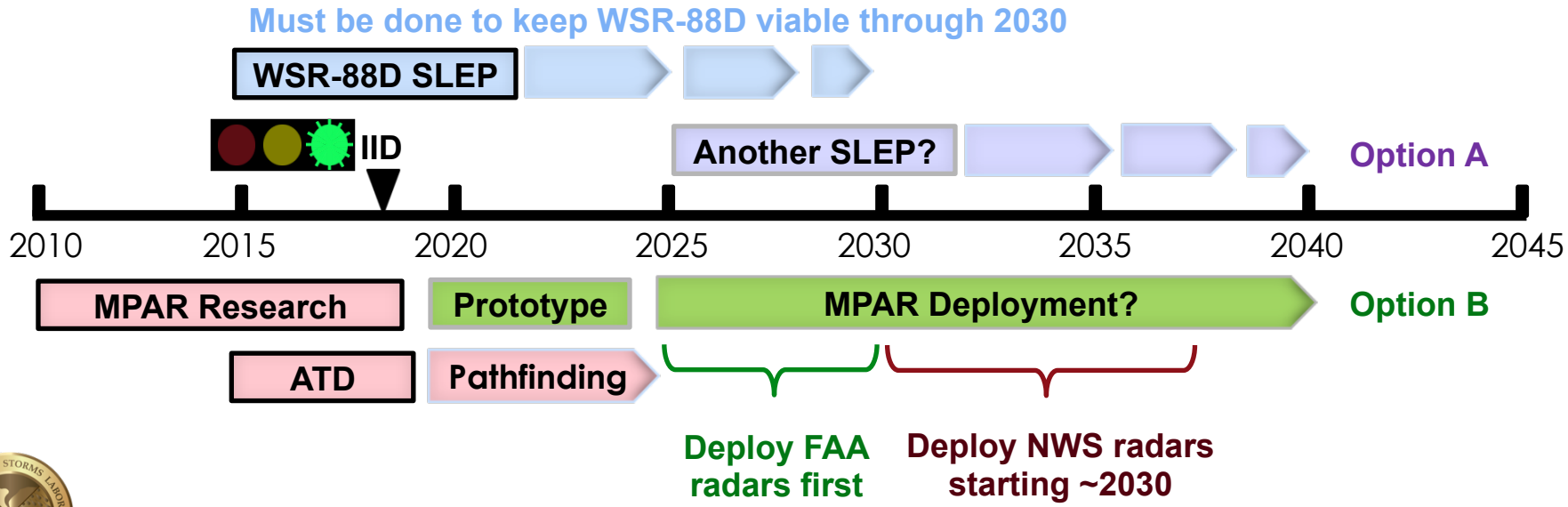
- Finalize Requirements
- Solicit/ Evaluate Offers
- Finalize Business Case

FAA NSWRC Timeline



NOAA Timeline

SLEP = Service Life Extension Program



MPAR Summary

- Phased array radar technology may be necessary to meet evolving NWS requirements
  - Simultaneous multi-function (weather and aircraft) operation only viable via phased array radar
- NWRT/PAR has been a very valuable tool for MPAR R&D
  - The Advanced Technology Demonstrator (ATD) is needed to perform additional MPAR R&D
- MPAR R&D partnership with FAA is very strong
  - Working together to build the ATD
  - ATD offers an opportunity to initiate closer collaboration with the air surveillance components of DOD and DHS
- FAA Initial Investment Decision is rapidly approaching
  - NOAA will have a decision to make in December 2017

MPAR Collaborators

Mark Benner, Rodger Brown, Richard Doviak, Pam Heinselman, Michael Jain, Michael Shattuck, Arthur Witt, Vincent Wood, Allen Zahrai, Dusan Zrnic

Ric Adams, Katie Bowden, Don Burgess, Chris Curtis, Eddie Forren, Douglas Forsyth, Igor Ivic, Charles Kuster, Valery Melnikov, Djordje Mirkovic, David Priegnitz, Mike Schmidt, Robin Tanamachi, John Thompson, Sebastian Torres, Daniel Wasielewski

Thank You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