Raytheon

Weather Radar Technology
Principles, Today, and Tomorrow

Nicolas S. Powell
Principal Systems Engineer
April 26, 2018

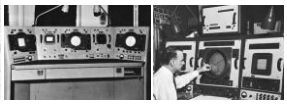
Copyright © 2018, Raytheon Company. All rights reserved.

This document does not contain Technology or Technical Data controlled under the U.S. International Traffic in Arms Regulations or the U.S. Export Administration Regulations.

AMS A Short History

Raytheon Intelligence, Information and Services

- World War 2 and earlier technology used extensively in US into the 80s
- Early weather radar efforts begin with use of AN/APQ-13 bombing/navigation radar
- AN/CPS-9 and WSR-57 first true weather radars
- WSR-88D provides dual pol capability



Whiton, R.C., P.L. Smith, S.G. Bigler, K.E. Wilk, and A.C. Harbuck, 1998: History of Operational Use of Weather Radar by U.S. Weather Services. Part I: The Pre-NEXRAD Era. Wea. Forecasting, 13, 219–243

Wings for Combat
USAAF Publication
Ullman Co, 1943.

AMS Weather Research and Forecasting Innovation Act of 2017

Raytheon Intelligence, Information and Services

Sec. 414. "Study on Gaps in NEXRAD Coverage and Recommendations to Address Such Gaps"

- Directs Secretary of Commerce to complete NEXRAD Coverage Gap study NLT 180 days of enactment
- Specifies Study Elements
  - Identify areas in the US where limited or no NEXRAD coverage has affected weather warnings and forecast quality
  - Identify key weather effects where radar could improve predictions
  - Identify additional high impact weather observation sources: TDWR, FAA Air Surveillance Radars, X-Band radars, and cooperative observer networks
  - Assess feasibility of using non-NOAA radar networks (FAA, DoD, State, and other non-federal operated) – Technical, cost, and schedule
- NLT 90 days after study completion Secretary of Commerce submits hazardous weather detection and forecasting coverage improvement recommendations for areas of limited/no NEXRAD coverave
- Secretary of Commerce may seek 3rd party reviews of recommendations

AMS Weather Radar Principles (1/2)

Raytheon Intelligence, Information and Services

- Essential for Severe Weather Detection and Warning
- NWS NEXRAD – Ranked 2nd in US Tier 1 Observing Systems[1]
- Meteorological and biological target backscattered radio frequency power and Doppler motion measurements provide 6 base parameters
  - Reflectivity (Z)
  - Radial Velocity (V)
  - Spectrum Width (σ)
  - Differential Reflectivity (Z_{DR})
  - Correlation Coefficient (ρ_{hv})
  - Differential Phase (ϕ_{DP})
- Base Parameter processing creates derived products (e.g. Melting level, Hydrometeor classification, Tornado vortex signature, Precipitation rate, Mesocyclone, etc.)

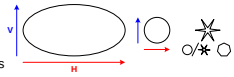
[1] National Science and Technology Council, 2014: National Plan for Civil Earth Observations

AMS Weather Radar Principles (2/2)

Raytheon Intelligence, Information and Services

- Dual Polarization (H and V electric field vectors) required for accurate precipitation rate estimates, intensity, and hydrometeor classification (Rain, hail, wet/dry snow, drizzle, etc.), smoke, tornadic debris, and bio-target identification
- Returned power depends on target size and dieletric constant

Large Drops: Higher H than V Pol power return
Small Drops: H and Pol Returns nearly the same
Non-liquid water, mixed phase, and hail: Different dielectric constant and power return than water drops



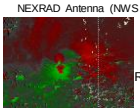
- Wavelength (S-, C-, and X-Band) strengths/weaknesses
  - S-Band: 2.7-3.0 GHz (10 cm), C-Band: 5.6-5.65 GHz (5 cm), X-Band: 9.3-9.5 MHz (3 cm)
  - Longer Wavelengths: Longer Range, less attenuation, larger antenna, lower resolution
  - Shorter Wavelengths: Higher resolution, smaller antenna, shorter range, greater attenuation

AMS Radar Today

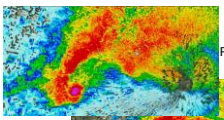
Raytheon Intelligence, Information and Services

- NWS NEXRAD Dual Polarization Doppler Weather Radar
  - Tightly coupled with AWIPS and Warning Generation software
  - 460 km max range, 1 deg Az/250m range resolution
  - 154 S-Band Radars support Weather Enterprise in US, Guam, PR, AK, HI
- FAA Terminal Doppler Weather Radar (TDWR)
  - 460 km max range, 0.5 deg Az/150 m range resolution
  - 45 C-Band aviation hazard single polarization radars - associated with airports
- FAA Air Surveillance Radar – Basic weather detection for aviation

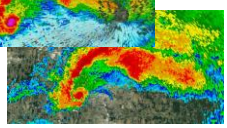
NEXRAD Antenna (NWS Images)



NEXRAD Radial Velocity



NEXRAD Reflectivity



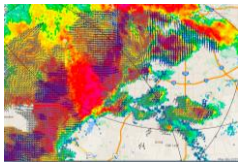
TDWR Reflectivity

AMS Tomorrow's Radar Potential

Raytheon Intelligence, Information and Services

- Active Electronically Scanned Array (AESA) deployment
- Electronic Steering and Adaptive Scanning – Disruptive Technology
  - Faster Update Cycle (~6 min NEXRAD volume scan to < 1 min)
  - More complete volume coverage
  - Constant Height vs Elevation Angle data collection
- 3-D data fields from merged, netted radars for MRMS, high resolution, model and decision support tool input

National Weather Radar Testbed (NWRT) Phased Array Antenna
NOAA/NSSL Image



Netted Radar Reflectivity and Wind Vectors From CASA radar network
Courtesy U Mass and CASA program

7

AMS Questions?

Raytheon Intelligence, Information and Services