14.5 NEXRAD Product Improvement - Expanding Science Horizons

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1. INTRODUCTION

The Departments of Commerce (National Weather Service), Defense (Air Force Weather Agency), and Transportation (Federal Aviation Administration) initiated the Next Generation Weather Radar (NEXRAD) program to upgrade the weather radar mission support capabilities required by the three agencies. Under NEXRAD, 158 radars, termed the Weather Surveillance Radar – 1988 Doppler (WSR-88D), have been installed at operational locations in the United States and selected overseas sites. The organizations (NEXRAD tri-agencies) have since established the NEXRAD Product Improvement (NPI) Program as a long-term activity to steadily improve WSR-88D science and technology [1]. The NPI program has ongoing efforts to replace the Radar Data Acquisition (RDA) and Radar Product Generation (RPG) subsystems with open systems compliant software and hardware (ORDA, ORPG). These system upgrades will enable the operational implementation of new scientific applications and signal processing techniques to improve the radar data quality. Further, the NPI program is currently working on the potential implementation of dual polarization, and on integration of weather data from several FAA radar systems. An additional NPI effort is focused on developing tools to improve the process of developing, testing, implementing and maintaining the software involved with functional enhancements to the WSR-88D. This paper describes the status of NPI ongoing projects and explores the expanding opportunities for development and implementation of new radar science and techniques intended for the WSR-88D.

2. DEVELOPMENT STATUS

2.1 *ORPG Status*

The ORPG deployment has been completed. Initial indications from NWS sites are that the new systems far exceed the capability and reliability of the legacy RPG [2]. As deployment of the ORPG began, design and development of the first set of capability enhancements were already underway [3]. The first of these enhancements were released even before the initial ORPG deployment was finished. These enhancements included data array products that provide the highest resolution data for both reflectivity (255 data levels, 1 km range resolution) and velocity (255 data levels, 1/4 km range resolution). These products had immediate impact on NWS tornado warning operations for storms in Iowa and Missouri. Figures 1 and 2 depict high resolution velocity images for these two tornadoes.

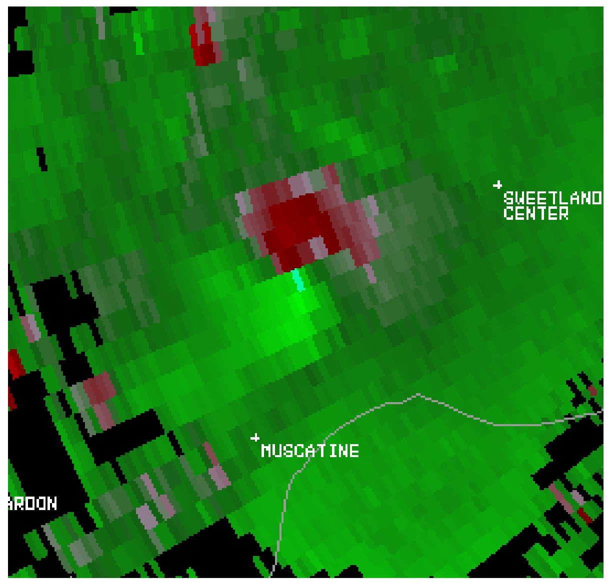

Figure 1. Muscatine, IA, F1 Tornado. High Resolution Base Velocity Image Displayed on AWIPS.

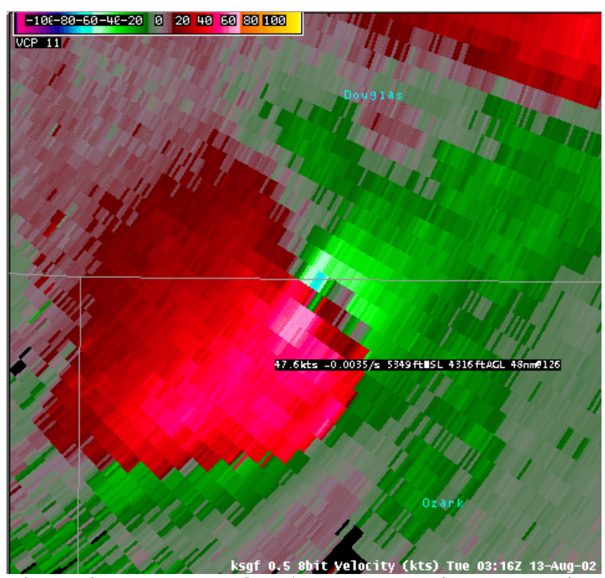

Figure 2. Wasola, MO, F1 Tornado. High Resolution Base Velocity Image Displayed on AWIPS

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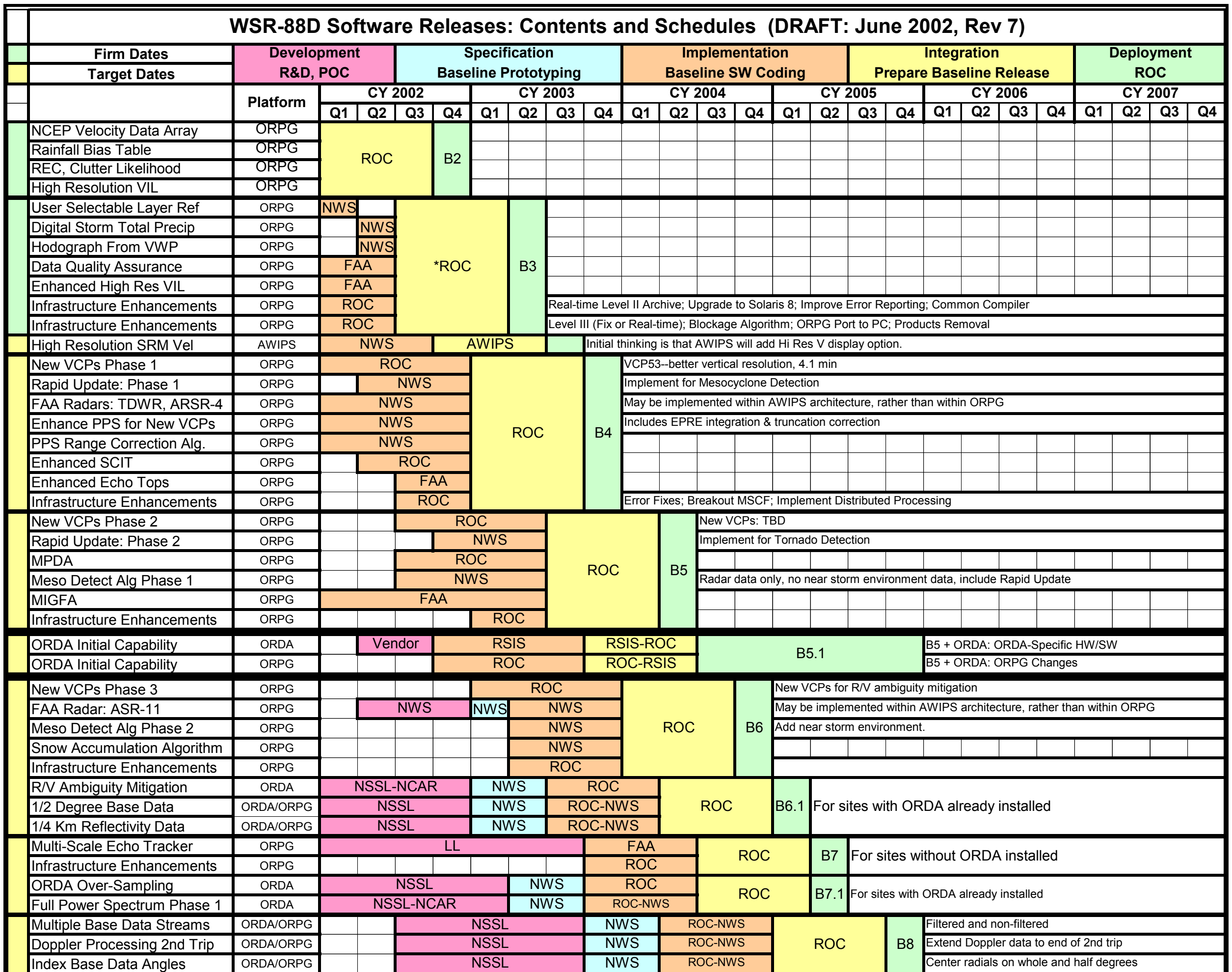

Figure 3. Current planning for NEXRAD functionality enhancements.

The next set of enhancements will be released in October 2002, and further sets are scheduled for release at 6-month intervals. The contents of the future releases are not finalized, but many specific enhancements have target release dates over the next several years (Figure 3).

2.2 *ORDA Status*

The ORDA project [14] consists of the procurement of commercial components to replace the existing RDA Status and Control (RDASC) components, the Signal Processing components, and the analog receiver. The ORDA will include a modern digital signal processor (DSP) and a digital receiver. The ORDA is scheduled to be deployed in 2004-2005. Figure 4 shows planned new components for ORDA and Dual Polarization.

2.3 *Dual Polarization Status*

The National Severe Storms Laboratory (NSSL) [4] is developing a prototype dual polarization capability for the NSSL WSR-88D (KOUN). Polarimetry data are being collected from KOUN, and a Joint Polarization Experiment (JPOLE) is underway. JPOLE will first validate the KOUN implementation for its engineering design, data accuracy and potential operational issues. In a second phase, JPOLE will conduct a field exercise to increase the scientific knowledge of applying polarimetric data to hydro-meteorological mission needs. If development and funding proceed satisfactorily, dual polarization could be

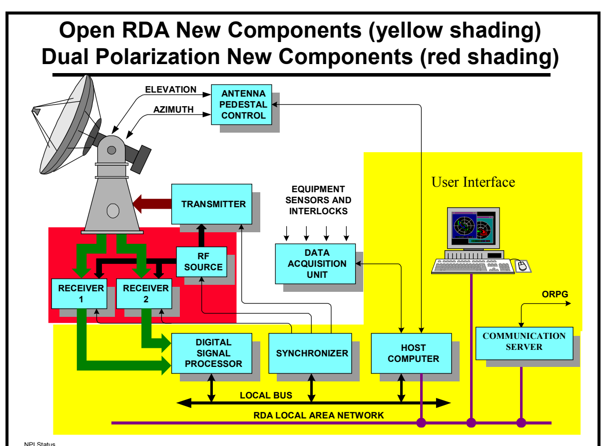

Figure 4. ORDA Conceptual Design

implemented on NEXRAD in the 2007-2008 period.

2.4 *FAA Radar Data*

The FAA operates four radar systems that include channels with capabilities for processing and distributing weather data. These systems are the Terminal Doppler Weather Radar (TDWR), the Airport Surveillance Radar (ASR) 9 and 11, and the Air Route Surveillance Radar (ARSR) 4 [10]. The NWS is planning to begin incorporating FAA data from selected sites in late 2003. Although these radars have different engineering characteristics (compared to each other as well as to the WSR-88D), the three agencies can potentially use FAA weather radar information to complement WSR-88D coverage for [9, 11]:

- Complementary coverage for closer or unobstructed views of particular storms,
- Coverage in case of NEXRAD outages,
- Multiple radar wind field calculations,
- AP and clutter mitigation.

3. SCIENTIFIC OPPORTUNITIES

3.1 *Early ORPG Enhancements*

The initial ORPG enhancements included full resolution reflectivity and velocity data array products, and a LAN-to-LAN connection to the NWS Advanced Weather Interactive Processing System (AWIPS) for high speed transmission of products to forecasters. Future enhancements will include:

- Clutter and anomalous propagation identification,
- High resolution Vertically Integrated Liquid water,
- User defined layers of maximum Composite Reflectivity,
- New Volume Coverage Patterns,
- Enhanced Mesocyclone Detection,
- Snow Accumulation,
- Multi-scale echo tracker and boundary detection.

3.2 *Early ORDA Enhancements*

When deployed, the DSP capability of the ORDA will immediately support the implementation of a number of enhancements that will provide better data for scientific algorithms. Some enhancements [13] have already been specified, and will be developed for early, follow on releases after initial ORDA deployment. These early enhancements will include:

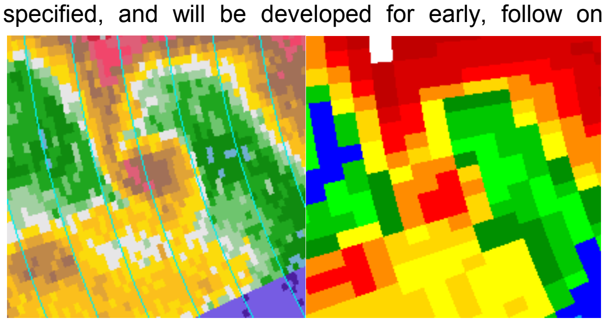

Figure 5. ORDA ½ ° by 1/4 km Reflectivity data versus current 1° by 1 km data for a May 3, 1999 tornado.

- Range - Velocity ambiguity mitigation,
- Radial sampling at ½ degree intervals,
- Reflectivity data at 1/4 km range resolution,
- Algorithm-specific application of SNR (Signal to Noise Ratio) thresholds,
- Doppler processing to end of 2nd trip.

Figure 5 shows the effect of implementing the ½ degree and 1/4 km techniques.

The expanded base data will be available in the ORPG to be utilized to improve current algorithms, and to support improved science.

3.3 *Dual Polarization Benefits*

Dual Polarization takes advantage of ways in which the transmitted wave's polarization affects the backscattering of hydrometeors. With a radar with polarization diversity, information related to both the

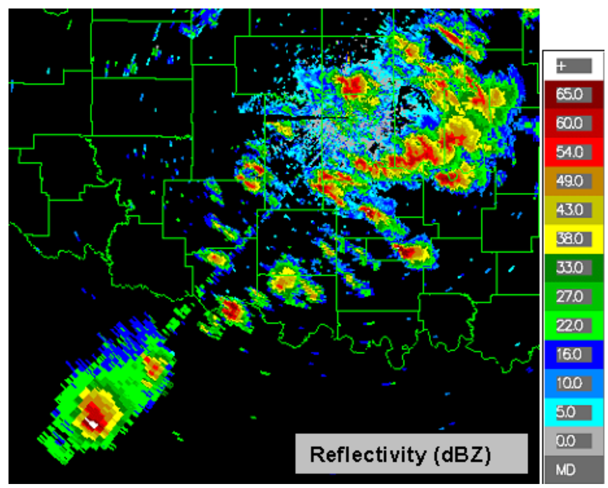

Figure 6. Reflectivity.

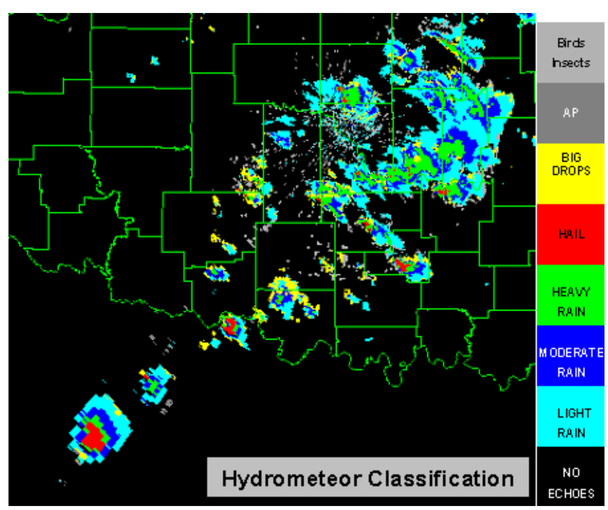

Figure 7. Corresponding Hydrometeor Classification.

horizontal and vertical dimensions of the observed scatterers can be derived. Polarimetry in the WSR-88D will:

- Improve quantitative precipitation estimation,
- Identify hail and possibly gauge hail size,
- Identify precipitation type in winter storms,
- Identify biological scatterers and wind measurement effects,
- Identify the presence of chaff and its effects on precipitation measurements,
- Identify areas of anomalous propagation (AP) and clutter, and
- Provide improved initial conditions to numerical models.

Figure 7 shows the improved description of precipitation types as compared to the legacy reflectivity image in Figure 6.

3.4 ***FAA Data Use***

FAA radar data will initially be used to generate base reflectivity and velocity image products similar to those produced for the WSR-88D. More sophisticated use of FAA data will involve multiple Doppler wind field analyses, merging the data with WSR-88D data to produce 'best' radar data mosaics, retrieval of vertical wind profiles, and more. The scientific algorithms needed for optimum use of FAA data remain to be developed, offering opportunities for innovative developers. Figure 8 shows the utility of using an FAA TDWR radar that is close to a severe tornadic event.

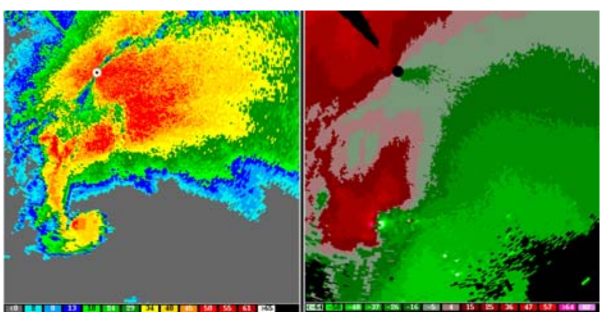

Figure 8. FAA TDWR data for May 3, 1999 tornado.

3.5 ***Weather Systems Synthesis***

With the implementation of ORPG and its high speed link to AWIPS, one of the original goals of the NPI program is within reach. To date, the ORPG algorithms have largely been radar data specific, with only minimal, user entered environment information utilized. Now, synergistic algorithms can be implemented that would combine the NEXRAD data with the full range of observational and model data available on AWIPS. Applications exploiting meso-scale and storm- scale models are now practical. It is envisioned that university and laboratory research community innovative development will provide major contributions to improving the operational benefits of the new infrastructure.

The NWS has recognized the importance of an integrated approach to operations and applications development. The SCAN (System for Convection Analysis and Nowcasting) project is bringing together developers from NWS, NSSL, National Center for Atmospheric Research and Lincoln Laboratory to work collaboratively to combine features from their individual research into a common AWIPS application to support the warning decision process. The SCAN application is designed to foster incorporation of additional elements from other development activities. A key point of SCAN is that it emphasizes synergistic processing and display, using all of the environmental information relevant to a given Weather Forecast Office's area of responsibility. The SCAN approach can serve as a template for similar integrated applications to address other forecast and warning missions.

3.6 ***Software Development Tools***

Supporting efforts such as SCAN, the Agencies are developing software tools to enable scattered development groups to not only collaborate more effectively, but also to enhance the compatibility of their applications with the operational WSR-88D. This project, termed CODE (Common Operations and Development Environment), is designed to provide an Application Programming Interface, underlying software modules, program layout and documentation support, and other tools that are compliant with the operational system [5, 6, 7, 8]. One expected benefit of CODE is that the integration of new science into operational systems will be eased, leading to a shorter time period between approval of an algorithm and its operational use. CODE is now the primary development tool for NWS and FAA programmers producing ORPG compliant implementations of new algorithms. Figure 9 portrays using CODE to go quickly from concept to operational capability.

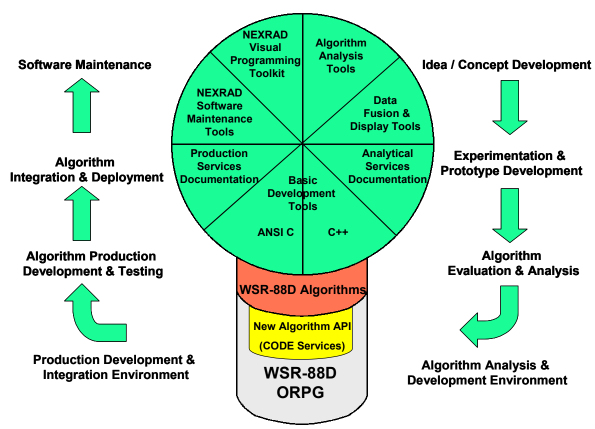

Figure 9. A conceptual view of CODE.

The NWS is working with UCAR/Unidata to offer CODE to the broader radar development community. The NWS plans to implement an electronic dissemination of base data in near real time. Unidata is currently collaborating with the University of Oklahoma to test such a capability with the Collaborative Radar Acquisition Field

Test (CRAFT) project [12]. Under CRAFT, data from a number of WSR-88D sites are being distributed over the Internet using the Unidata Local Data Manager (LDM) software. One of the features of CODE is the ability to incorporate an LDM interface and ingest data from any of the LDM WSR-88D sites for developing and testing algorithms.

4. SUMMARY

In summary, the NEXRAD infrastructure enhancements, dissemination of base data, and development of radar application development tools have combined to offer a heretofore unmatched environment for radar science development and operational implementation.

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