10B.6 THE NEW WEATHER RADAR FOR AMERICA'S SPACE PROGRAM IN FLORIDA: AN OVERVIEW

William P. Roeder Todd M. McNamara Billie F. Boyd Francis J. Merceret*
45th Weather Squadron *National Aeronautics and Space Administration
Patrick AFB, FL Kennedy Space Center, FL

1. INTRODUCTION

The 45th Weather Squadron (45 WS) is the U.S. Air Force unit that provides weather support to America's space program at Cape Canaveral Air Force Station (CCAFS), NASA Kennedy Space Center (KSC), and Patrick AFB (PAFB). The weather requirements of the space program are very stringent (Harms et al., 1999). In addition, the weather in east central Florida is very complex. This is especially true of summer thunderstorms and associated hazards. Central Florida is 'Lightning Alley', the area of highest lightning activity in the U.S. (Huffines and Orville, 1999). The 45 WS uses a dense network of weather sensors to meet the operational requirements in this environment (Roeder et al., 2003).

One of the most important weather sensors to the 45 WS mission is the WSR-74C radar at PAFB (Roeder et al., 2005). This radar is near the end of its lifecycle and is being replaced by a new Radtec Titan Doppler Radar with 4.3 m antenna and 250 KW average transmitted power (TDR 43-250) manufactured by Radtec Engineering, Inc. (Radtec, 2005).

Five other papers related to this new radar are presented at this conference. These papers are listed in Table 1.

TABLE 1. Other papers at this conference related to the new TDR 43-250 radar.

Paper	Topic
P6.2	Scan Strategy Design (Roeder and Short, 2009)
P1.6*	Temperature Profile Adaptive Scan Strategy (Carey et al., 2009a)
P12.3*	Lightning Onset Prediction Using Dual-Polarization (Petersen et al., 2009a)
P1.11*	Lightning Onset Prediction Using Dual-Polarization (Deierling et al., 2009)
P10A.2*	Lightning Onset/Cessation Prediction and Electric Fields Detection Using Dual-Polarization (Carey et al., 2009b)

* Being developed jointly by the University of Alabama/ Huntsville and NASA Marshall Spaceflight Center, including use of the Advanced Radar for Meteorological and Operational Research (Petersen et al., 2009b)

2. Overview of the TDR 43-250

Seven aspects of the new radar are discussed in the following sections: 1) basic features, 2) siting, 3) scan strategy, 4) testing, 5) training, 6) on-going improvement initiatives, and 7) possible future improvement initiatives.

2.1 Basic Features

The new TDR 43-250 radar offers several advantages over the WSR-74C at Patrick AFB that it is replacing. Three major new features are Doppler capability, dual-polarization capability, and an off-center feed antenna. The Doppler capability has well known benefits for tornado detection, which is especially important in central Florida, which has the highest density of tornadoes in the U.S. Doppler capability also allows improved ground clutter filtering. The TDR 43-250 has excellent phase control of the transmitted radar pulses, which should provide excellent Doppler ground clutter filtering. The dual-polarization capability should provide many operational benefits, especially to improved lightning forecasting (Petersen et al., 2009a and Deierling et al., 2009). Lightning watches and warnings are some of the most important missions done by the 45 WS (Weems et al., 2001). The off-center feed antenna provides significantly weaker side lobes for reduced ground clutter. Other basic features of the TDR 43-250 and why they were selected are listed in Table 2.

The analysis and display software is the Integrated Radar Information System (IRIS) Version 8.12 from Vaisala, Inc., originally developed by Sigmet, Inc. One very useful new feature of this version is the ability to do continuous vertical cross-sections. The vertical cross-section product can update continuously as the analysis line is rotated through all angles, allowing the viewing of all possible vertical cross-sections through a weather feature in a very few seconds. This should significantly improve the analysis for severe weather by finding the optimum vertical cross-section. The SHEAR option is also installed to detect wind shear lines and downbursts. A selection of the IRIS radar products is listed in Table 3.

TABLE 2. Basic features of the new TDR 43-250. Green shading indicates an advantage of one radar over the other. The new TDR 43-250 radar has many benefits over the current WSR-74C at Patrick AFB.

	TDR 43-250	WSR-74C	Reason For TDR 43-250 Selection
Wavelength	5.33 cm (C-band)	5.33 cm (C-band)	- Less attenuation than K-band - Better detection of lightning rain and clouds than S-band - Avoids duplication of S-band capability from WSR-88D at Melbourne, FL - Provides objective identification of chaff when combined with S-band WSR-88D (Roeder, 1995)
Power	250 KW	250 KW	- Match capability of WSR-74C at PAFB
Signal Generator (solid state, digital phase control)	Klystron	Magnetron	- More precise control of amplitude, frequency, and phase. The latter helps provide more precise Doppler velocity
Doppler Capability	Yes	No	- Tornado detection - Improved ground clutter filter
Dual-Polarization Capability (simultaneous horizontal and vertical transmission)	Yes	No	- Improved prediction of lightning onset likely - Improved prediction of lightning cessation possible - Improved detection of hail - Possible detection of electric fields aloft in some clouds
Beam Width	0.95°	1.05°	- Improved resolution
Antenna Size	4.30 m	3.5 m	- Part of TDR 43-250 design
Antenna Feed	Off Center	Center	- Reduced side lobes for less ground clutter
Volume Scan Rate	2.65 min	2.65 min	- Match capability of WSR-74C at PAFB
Height Above Ground	100 ft	60 ft	- Less ground clutter
Hydrophobic Radome	Yes	No	- Less attenuation during and just after heavy rain at the radar site
Analysis/Display Software	IRIS (8.12)	IRIS (7.31)	- Dual-polarization products - Continuously variable vertical cross-sections update in real-time

TABLE 3. Selected Products provided by the Integrated Radar Information System (IRIS), Version 8.12

Product	Description	Comments
CAPPI	Constant Altitude Plan Position Indicator	Horizontal cross section at user specified altitude(s)
MAX	Maximum reflectivity in all vertical columns	Equivalent to Composite Reflectivity
RAIN1	Rainfall accumulation over 1-hour	None
TOPS	Maximum altitude of user specified reflectivity threshold(s)	30 dBZ for Storm Top, 18 dBZ for Rain Top, and 0 dBZ for Cloud Top
TRACK	Storm track and forecast	None
VIL	Vertically Integrated Liquid	Units are mm, which are numerically equal to kg/m^2
VVP	Velocity Volume Processing	Equivalent to Velocity Azimuth Display
WARN	Warning and centroid product	None
WIND	Wind speed and direction	None
XSECT	Vertical cross-section	None
SHEAR	Wind shear and downburst detection	Requires Wind Shear option
SLINE	Shear line detection	Requires Wind Shear option
Z_{DR}	Differential Reflectivity	Requires dual-polarization option
ϕ_{DP}	Differential Phase	Requires dual-polarization option
K_{DP}	Specific Differential Phase	Requires dual-polarization option
ρ_{HV}	Correlation Coefficient	Requires dual-polarization option

2.2 Siting

The site of the new TDR 43-250 is 23 nmi to the southwest of most of the launch pads at CCAFS/KSC (Figure 1). Many factors influenced the selection of this site. This distance is optimal for the evaluation of Lightning Launch Commit Criteria (LCC), lightning prediction, and detecting low-level boundaries that dominate local thunderstorm formation in central Florida in summer. The Lightning LCC are the weather rules to avoid natural and triggered lightning strikes to in-flight rockets (Roeder and McNamara, 2006).

The current WSR-74C is located on top of Building-423 on PAFB. That building could not be used for the new TDR 43-250 since the radar's heavier weight would exceed the structural limits and since the larger radome would intrude into the flight safety cordon for PAFB. Other possible locations on PAFB would have excessive beam blockage.

An off-base location was already preferred for the new TDR 43-250 since siting the radar far enough away from the base would eliminate the requirement to be synchronized with the other C-band radars on PAFB to avoid interfering with the other radars and receiving interference itself from the other radars. This synchronization would have required a fixed Pulse Repetition Frequency of 160 Hz. This would produce a maximum unambiguous Doppler velocity of 4.2 kt, crippling the Doppler velocity applications, even with 2 or 3 times velocity unfolding. Such a low maximum unambiguous Doppler velocity would render the radar useless for tornado detection, downburst outflow speed detection, and even vertical velocity profiles under most conditions. It would also reduce the effectiveness of the Doppler ground clutter filter. A site to the southwest to northwest of CCAFS/KSC was desired to improve detection of the sea breeze front and Indian and Banana River breeze fronts that strongly influence local thunderstorm development in summer.

A distance of 20-25 nmi to the launch pads at CCAFS/KSC was considered optimal for the evaluation of the Lightning Launch Commit Criteria (LCC), lightning prediction, and detecting low-level boundaries. Government sites were considered to save cost, but those sites were either too close or too far from CCAFS/KSC or had many antennas that would cause too much beam blockage.

Several private property sites underwent initial consideration for lease, evaluated on distance, orientation, and clear line of site to CCAFS/KSC. The top three candidates were evaluated in detail with the final site shown in Figure-1. This site is 23 nmi from most of the launch pads at CCAFS/KSC, which is in the optimal 20-25 nmi range. Another advantage is this location provides the only line of sight to CCAFS/KSC at that distance without major intervening building development. This will help reduce ground clutter. The direction from the radar site to CCAFS/KSC is close to perpendicular to the shorelines of the Atlantic Ocean, Indian River, and Banana River, which will improve detection of the sea breeze and river breeze fronts. The only large disadvantage of this site is that some thunderstorms will cross its cone of silence just before those storms approach CCAFS/KSC. The resultant apparent change in thunderstorm behavior complicates forecasting. This problem will be partly mitigated through use of higher beam angles in the scan strategy (highest angle is 28.3°). The problem will be completely mitigated if the desired overlay of data from the WSR-88D at Melbourne is implemented.

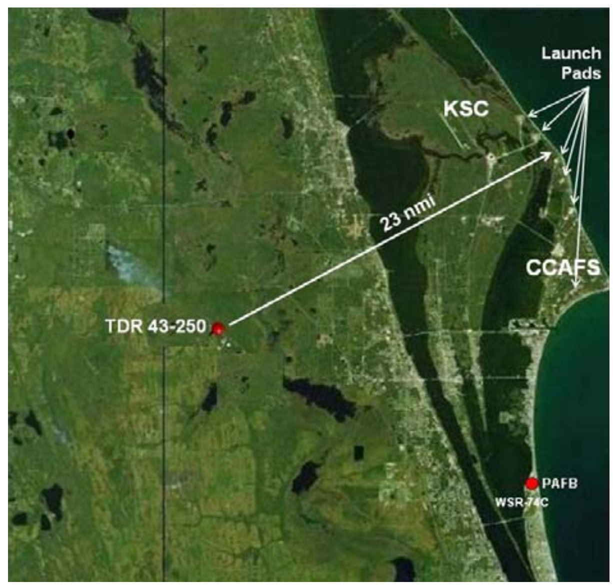

Figure 1. Location of the new TDR 43-250 radar relative to CCAFS/KSC and their launch pads.

2.3 Scan Strategy

A scan strategy optimized for the 45 WS mission was designed by Short (2008) of the Applied Meteorology Unit. The Applied Meteorology Unit provides technology transfer and technique development to improve weather support to America's space program (Bauman et al., 2004). The requirements for the scan strategy are discussed in Table 4. The beam angles selected are listed in Table 5 and shown graphically in Figure 2.

TABLE 4. 45 WS requirements for the TDR 43-250 radar scan strategy.

Requirement	Reason	Solution
Volume scan ≤ 3 min (< 2.5 min desired)	Rapidly changing thunderstorms in summer in Florida	13 beam angles (2.65 min volume scan)
Maximum beam gap ≤ 2,250 ft from mean +5°C -2σ to mean -20°C +2σ heights within 5 nmi of launch pads (< 1,500 ft desired)	Lightning Launch Commit Criteria (LLCC)* evaluation, especially 'Thick Cloud' rule (Roeder and McNamara, 2006)	See Table 5
Maximum beam gap ≤ 2,250 ft from mean +0°C -2σ to mean -20°C +2σ heights within 10 nmi of CCAFS/KSC (< 1,500 ft desired)	Lightning forecasting (Roeder and Pinder, 1996)	See Table 5
Outstanding coverage of planetary boundary layer (< 5,000 ft) within 25 nmi of the radar	1) Detect low-level boundaries that dominate thunderstorm formation in summer in Florida 2) Detect low-level vortices that may contribute to thunderstorm formation and more intense thunderstorms	See Table 5
Excellent coverage from 25,000 ft to 40,000 ft (up to 50,000 ft desired)	LLCC* evaluation, especially 'Attached/Detached Anvil' rules	See Table 5
Significantly reduce Cone of Silence	Proper tracking of thunderstorm behavior when they approach CCAFS/KSC form the southwest	See Table 5
Beam gaps independent of range at a given altitude is desired	Easier analysis of radar data	Not met—could not be done while also meeting the higher priority beam gap and volume scan time requirements
Good combination of 1) maximum unambiguous Doppler velocity and 2) maximum range	1) Severe weather warnings 2) Detect approaching weather with enough lead-time for warnings	Dual Pulse Repetition Frequency of 800/533 Hz for a Maximum Unambiguous Doppler Velocity/Max Range of 20.6 kt/152 nmi, respectively (originally was 1200/800 Hz for a Maximum Unambiguous Doppler Velocity/Max Range of 30.8 kt/101 nmi, but was changed to stop multi-trip echo 'spoking' interference (Donaldson et al., 2001)
Good pulse power	Mitigate attenuation	Pulse Width 2.0 μs
Good data quality	Proper analysis of weather	24 samples per pulse

* LLCC are the weather rules to avoid natural and rocket triggered lightning to in-flight rockets

TABLE 5. Beam angles used in the new scan strategy for the TDR 43-250 radar for 45 WS. Beam angles are interleaved to reduce long-term wear on the radar and provide slightly faster volume scans. Color shading shows groups of related operational uses. Some beams are related to two groups.

<table>
<tr><th>Beam No.</th><th>Beam Order</th><th>Beam Angle</th><th>Main Operational Use</th></tr>
<tr><td>1*</td><td>1</td><td>0.2°</td><td>- Detect low-level boundaries to predict thunderstorm formation</td></tr>
<tr><td>2*</td><td>13</td><td>1.2°</td><td>- Detect low-level boundaries for thunderstorm formation prediction
- Detect low-level vortices that may contribute to thunderstorm formation and more intense thunderstorms</td></tr>
<tr><td>3*</td><td>2</td><td>2.2°</td><td>- Detect low-level vortices that may contribute to thunderstorm formation and more intense thunderstorms
- Detect low-level boundaries</td></tr>
<tr><td>4</td><td>12</td><td>4.0°</td><td rowspan="8">- Maximum beam gap ≤ 2,250 ft from mean +5°C -2σ to mean -20°C +2σ heights within 5 nmi of launch pads for evaluation of LLCC, especially ‘Thick Cloud’ rule
-- Annual mean heights of 0°C -2σ and -20°C +2σ are from the Range Reference Atmosphere (radiosonde climatology) for CCAFS (Range Reference Atmosphere, 2006)
- Maximum beam gap ≤ 2,250 ft from mean +0°C -2σ to mean -20°C +2σ heights within 10 nmi of CCAFS/KSC to predict formation of lightning
- Detect tops of convective clouds and anvil clouds within 10 nmi of launch pads for LLCC evaluation, especially the ‘Attached Anvil’, ‘Detached Anvil’, and ‘Lightning’ rules (based on mean height +2 σ of these cloud tops in east central Florida (Jun-Aug 2002-2007) (HQ AFWA/WEA, 2009))</td></tr>
<tr><td>5</td><td>3</td><td>5.7°</td></tr>
<tr><td>6</td><td>11</td><td>7.3°</td></tr>
<tr><td>7</td><td>4</td><td>8.9°</td></tr>
<tr><td>8</td><td>10</td><td>10.6°</td></tr>
<tr><td>9</td><td>5</td><td>12.5°</td></tr>
<tr><td>10</td><td>9</td><td>14.5°</td></tr>
<tr><td>11</td><td>6</td><td>17.6°</td></tr>
<tr><td>12</td><td>8</td><td>22.3°</td><td>- Detect tops of convective clouds and anvil clouds within 10 nmi of launch pads for LLCC evaluation</td></tr>
<tr><td>13</td><td>7</td><td>28.3°</td><td>- Reduce the Cone Of Silence over the radar to avoid false changes in reported behavior for weather approaching CCAFS/KSC from the southwest</td></tr>
</table>

* Angles 1-3 have half-power beam widths vertically adjacent to provide continuous coverage of the planetary boundary layer in the vicinity of CCAFS/KSC.

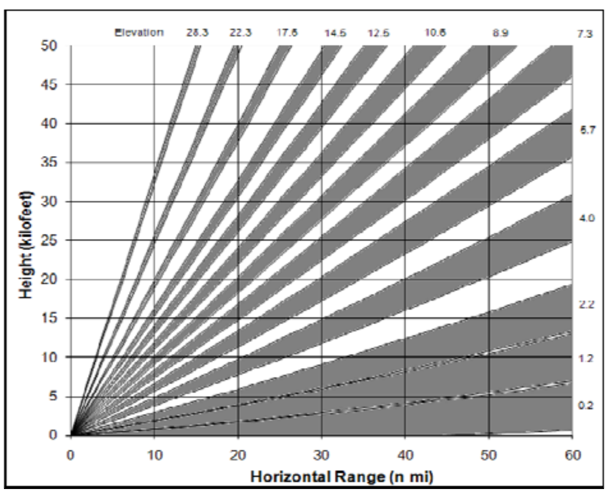

Figure 2. Vertical coverage vs. range in the scan strategy for the new TDR 43-250 radar optimized for the 45 WS mission. Most of the CCAFS/KSC launch pads are at 23 nmi. This scan strategy was designed by the Applied Meteorology Unit (Bauman at al., 2004).

A very low first beam angle (0.2°) was selected for the scan strategy. The reduced ground clutter expected from the off-center feed antenna, combined with the expected Doppler ground clutter filter from the excellent phase control, along with the very flat terrain in east central Florida and the unobstructed line of sight to CCAFS/KSC, all suggested this very low beam angle was feasible. The first three beam angles (0.2°, 1.2°, and 2.2°) are stacked with half-power beam widths vertically adjacent. Combined with the very low first beam angle, these first three beam angles should provide excellent detection of low-level boundaries, which are critical to forecasting local thunderstorm development in east Central Florida in summer.

The volume scan rate of 2.65 min, while not, meeting the desired volume scan rate of 2.5 min or less, meets the requirement of 3 min or less. This did not meet the desired volume scan rate of

2.5 min or less. The 45 WS decided another scan angle to improve the vertical resolution was more important than the faster volume scan.

The average vertical beam gap in the atmospheric electrification layer (0°C to -20°C) within 10 nmi of CCAFS/KSC is 1,302 ft, with a maximum beam gap of 2,250 ft. This meets the requirement and is 35% better than provided currently by the WSR-74C at PAFB. The beam gaps are measured between half power beam widths. The annual climatological bounds of the atmospheric electrification layer (± 2σ) were used to ensure this layer was covered the majority of the time throughout the year. The climatology was based on the archived observations of the CCAFS radiosonde Range Reference Atmosphere (2006).

Further details of this new scan strategy design are discussed at Roeder and Short (2009).

2.4 Testing

The new TDR 43-250 radar is undergoing extensive testing before being accepted for operational use. The system has already passed Factory Acceptance Test and Site Acceptance Test, which included calibrations with instrument controlled input and Sun calibration, in addition to other tests. It is now undergoing Developmental Test & Evaluation (DT&E) testing that includes eight test cases (Table 6). The first test case compares twelve reflectivity and Doppler products against the WSR-74C at PAFB and the WSR-88D at Melbourne, respectively. The reflectivity products will be tested by tracking a single weather feature for each product for 20-40 minutes with a volume-time average as the pass/fail criteria (Table 7). The Doppler velocity product will be tested on ten volume scans and based on a vector difference between the two winds for separate volume scans. The Doppler test is complicated by the VVP product being centered on the radar and since the TDR 43-250 and the WSR-88D are separated by 24 nmi. Testing will be done under as homogeneous winds as possible in the area to mitigate this problem. In addition, only 70% of the ten cases being analyzed must meet the criteria to pass this test. Unfortunately, no other dual-polarization radar is available in east central Florida to use for comparison of the dual-polarization products. The other seven test cases in DT&E verify other aspects of the new radar (Table 6). These tests were done in addition to the calibration of the new radar in the previous tests to increase confidence in the new radar and since many of the operational tools and techniques may be subtly tuned to the WSR-74C that has been is use by 45 WS for many years.

A separate Operational Test will use the difference in volume average of the reflectivity products from each volume scan in the DT&E test, i.e. without the time averaging done in DT&E. In addition, several months of parallel operations will be completed comparing the new TDR 43-250 radar to the WSR-74C at Patrick AFB and WSR-88D at Melbourne, FL. The goal is to find any problems not uncovered by the other tests.

TABLE 6. Test cases for Developmental Test & Evaluation (DT&E) testing for the new TDR 43-250 radar. Other tests have been and will be done.

Test Case	Purpose Of Test Case
1	Operational Acceptance Test (see Table 7)
2	IRIS Product Generation Test
3	Startup Test
4	Configuration and Control Test
5	Product Distribution Test
6	Data Archive and Playback Test
7	Health and Status Monitoring Test
8	Miscellaneous Test

TABLE 7. Radar products tested in Test Case-1 of DT&E for the new TDR 43-250 radar before acceptance for operational use.

Radar Product	Pass/Fail Standard	Comparison Radar
XSECT	RMSD* ≤ 5 dBZ	WSR-74C
CAPPI (2 K)	RMSD ≤ 5 dBZ	WSR-74C
CAPPI (5 K)	RMSD ≤ 5 dBZ	WSR-74C
CAPPI (10 K)	RMSD ≤ 5 dBZ	WSR-74C
CAPPI (20 K)	RMSD ≤ 5 dBZ	WSR-74C
VIL	RMSD ≤ 14.3 mm	WSR-74C
MAX	RMSD ≤ 5 dBZ	WSR-74C
TOPS (0 dBZ)	RMSD ≤ 3.9 km	WSR-74C
TOPS (18 dBZ)	RMSD ≤ 3.9 km	WSR-74C
TOPS (30 dBZ)	RMSD ≤ 3.9 km	WSR-74C
RAIN1	RMSD ≤ 50 mm	WSR-74C
VVP	Vector difference ≤ ±12.0 kt for ≥ 70% of ten volume scans	WSR-88D

* RMSD is the Root Mean Square Difference of volume-time average between the TDR 43-250 and the comparison radar.

2.5 Training

Implementing the TDR 43-250 into operations offers a mix of easy and difficult training challenges. The IRIS analysis and display software (version 8.12) has a very similar look and feel as the current version (7.31) used with the WSR-74C at PAFB. As a result, training on the new products should be relatively easy, as was experienced when 45 WS upgraded to IRIS version 7.31 in 2003, after it was initially installed in 1997 (Boyd et al., 2003). The 45 WS already has experience using Doppler data from the WSR-88D at Melbourne, so no difficulties are expected using the new Doppler capability of the TDR 43-250 as compared to the non-Doppler WSR-74C. However, the dual-polarization products are entirely new to 45 WS. As a result, 45 WS has developed an in-house training program on dual-polarization radar and its products. In addition, training is one of the deliverables under the dual-polarization applications project being developed for 45 WS by the University of Alabama/Huntsville and the National Space Science and Technology Center at Marshall Spaceflight Center (Petersen et al., 2009a). Finally, 45 WS is collaborating with the NEXRAD Weather Decision Training Branch to share the training materials they are developing for the upgrade of the WSR-88D network to dual-polarization capability. In return, 45 WS offered a beta-test of those materials, and share the training materials developed by 45 WS and being developed being developed by the University of Alabama/Huntsville and NASA Marshall Spaceflight Center (Carey et al., 2009).

2.6 On-going Improvement Initiatives

The University of Alabama/Huntsville and NASA Marshall Spaceflight Center are jointly developing dual-polarization applications for 45 WS. This project includes developing a temperature adaptive scan strategy (Carey et al., 2009a); tools to predict the onset of lightning, the cessation of lightning, and convective winds; and training materials. The computer program that will provide the temperature adaptive scan strategy should reduce the number of beam angles in the static scan strategy (section 2.3) by 1-3 beam angles depending on conditions. This will allow faster volume scans and/or or more samples per pulse for better data quality. This adaptive scan strategy will also provide a user-selected option for a scan strategy for when deep convection is not expected. This ‘clear air’ scan strategy will emphasize beam angles to cover the lowest 10,000 ft of the atmosphere over and around CCAFS/KSC with many samples per pulse, slower rotation rate for longer volume scans, and other techniques to provide high quality data detecting low level boundaries. A severe weather option may also be added with a high maximum unambiguous Doppler velocity and shorter range and scan angles optimized to detect mesoscale cyclones and other tornado precursors, and other severe weather signatures. If this severe weather option is not added to the adaptive scan strategy, it will be considered as a possible future improvement initiative discussed in section 2.7

2.7 Possible Future Improvement Initiatives

There are several opportunities to make the TDR 43-250 more useful for the 45 WS mission. These opportunities are not yet funded.

Interpretation of the new dual-polarization products is very complex. The 45 WS wants to add the HydroClass option to the IRIS analysis and display software. The HydroClass option provides an automated identification of hydrometeors. This should significantly ease the use of the new dual-polarization products, especially for newly assigned forecasters.

The 45 WS also wants to add the IRIS option to integrate data from other radars. Integrating data from the WSR-88D at Melbourne should eliminate the cone of silence of the TDR 43-250. This is important since some thunderstorms approach CCAFS/KSC from the southwest, potentially crossing part of the cone of silence just before affecting the primary area of concern. Integrating the WSR-88D Melbourne data should avoid the difficulty of interpreting changes in thunderstorm behavior as they cross the cone of silence.

The 45 WS may develop new scan strategies for specific missions. For example, one possibility is a long-range non-Doppler scan strategy for an infrequent special mission of 45 WS. If the severe weather scan strategy discussed in section 2.6 is not added to the temperature profile adaptive scan strategy program, it will be considered as a possible future improvement initiative.

Other improvement opportunities include upgrading the IRIS in the Applied Meteorology Unit to the ‘Analysis’ level to facilitate future tasks to develop applications for the TDR 43-250. Likewise, providing raw data from the TDR 43-250 to Marshall Spaceflight Center will facilitate their development of dual-polarization applications. The inference of strong vertical electric fields, or the actual value of those electric fields, may be added to this project to potentially assist in the evaluation of lightning Launch Commit Criteria (Carey et al., 2009b). This effort would likely require a new Airborne Field Mill experiment (Dye et al., 2007) to measure the electric fields aloft to calibrate any technique that is developed. In addition, 45 WS has been developing convective wind tools with Plymouth State University, funded by a New Hampshire Space Grant, and 45 WS may ask that development of dual-polarization convective wind tools be added to that project. The 45 WS would also like to install the IRIS Lightning option to overlay cloud-to-ground and intra-cloud lightning data over the radar data. The 45 WS has began to consider how to archive the data from the TDR 43-250 by an external organization with convenient access to facilitate operational research to develop and refine radar applications for the 45 WS mission, especially dual polarization applications. Finally, the 45 WS will continue monitoring improvements made available for the TDR 43-250 radar and the IRIS analysis and display software and make upgrades as deemed cost-effective.

3. Summary

The 45 WS is installing a new Radtec 43-250 weather radar to replace the aging WSR-74C at Patrick AFB. Some of the more important new features include Doppler and dual-polarization capability, and an off-center feed antenna. A scan strategy optimized for the 45 WS mission was developed by the Applied Meteorology Unit. The upgraded analysis and display software will display dual-polarization products and allow continuous vertical cross-sections. This new radar will provide significant new capability to 45 WS in support of America's space program in Florida.

4. Acknowledgements

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5. References

Bauman, W. H., W.P. Roeder, R. A. Lafosse, D. W. Sharp, F. J. Merceret, 2004: The Applied Meteorology Unit--Operational Contributions To Spaceport Canaveral, *11th Conference on Aviation, Range, and Aerospace Meteorology*, 4-8 Oct 04, 24 pp.

Boyd, B. F., J. W. Weems, W. P. Roeder, C. S. Pinder, and T. M. McNamara, 2003: Use Of Weather Radar to Support America's Space Program – Past, Present, And Future, *31st International Conference on Radar Meteorology*, 6-12 Aug 03, Paper 11B.7, 815-818

Carey, L. D., W. A. Petersen, W. Deierling, and W. P. Roeder, 2009a: The New Weather Radar For America's Space Program In Florida: A Temperature Profile Adaptive Scan Strategy, *34th Conference on Radar Meteorology*, 5-9 Oct 09, Paper P1.6

Carey, L. D., W. A. Petersen, and W. Deierling, 2009b: Radar Differential Phase Signatures Of Ice Orientation For The Prediction Of Lightning Initiation And Cessation, *34th Conference on Radar Meteorology*, 5-9 Oct 09, Paper P10A.2

Deierling, W., W. A. Petersen, L. Carey, and C. Kessinger, 2009: Assessing The Benefits Of Dual-Polarimetric Radar Information For Lightning Potential Nowcasting, *34th Conference on Radar Meteorology*, 5-9 Oct 09, Paper P1.11

Donaldson, N., C. Pierce, M. Sleigh, A. Seed, T. Saxen, 2001: Comparison Of Forecasts Of Widespread Precipitation During The Sydney 2000 Forecast Project, 30t h International Conference on Radar Meteorology, 18-24 Jul 01, Paper 8.11, 3 pp.

Dye, J.E., M.G. Bateman, H.J. Christian, E. Defer, C.A. Grainger, W.D. Hall, E.P. Krider, S.A. Lewis, D.M. Mach, F.J. Merceret, J.C. Willett and P.T. Willis, 2007: Electric Fields, Cloud Microphysics and Reflectivity in Anvils of Florida Thunderstorms, Journal of Geophysical Research, 112, D11215, doi:10.1029/2006JD007550

Harms, D. E., A. A. Guiffrida, B. F. Boyd, L. H. Gross, G. D. Strohm, R. M. Lucci, J. W. Weems, E. D. Priselac, K. Lammers, H. C. Herring and F. J. Merceret, 1999: The Many Lives Of A Meteorologist In Support Of Space Launch, *8th Conference On Aviation, Range, and Aerospace Meteorology,* 10-15 Jan 99, 5-9

HQ AFWA/WEA, 2009: Algorithm Description For The Cloud Depiction And Forecast System II, Headquarters Air Force Weather Agency, HQ AFWA/WEA, 106 Peacekeeper Drive, STE

2N3, Offutt AFB, NE 68113-4039, 8 May 2009, 416 pp.

Huffines, G. R., and R. E. Orville, 1999: Lightning ground flash density and thunderstorm duration in the continental United States: 1989-96. *Journal of Applied Meteorology*, **38,** 1013-1019

Petersen, W. A., L. D. Carey, W. Deierling, E. V. Johnson, and M. Bateman, 2009a: Developing Lightning Prediction Tools For The CCAFS Dual-Polarimetric Radar, *34th Conference on Radar Meteorology*, 5-9 Oct 09, Paper P12.3

Petersen, W. A., K. Knupp, L. D. Carey, D/ Phillips, W. Deirerling, and P. N. Gatling, 2009b: The UAH/NSSTC Advanced Radar For Meteorological And Operational research (ARMOR), *34th Conference on Radar Meteorology*, 5-9 Oct 09, Paper P8.5

Radtec, 2005: Technical Description TDR Series C-Band Doppler Radar TDR 43/250-43/75, product description from Radtec Corp., www.radar-sales.com, 25 pp.

Range Reference Atmosphere, 2006: Radiosonde climatology for Cape Canaveral Air Force Station Jan 1990-Jan 2002 (listed as Kennedy Space Center), EXCEL spreadsheet, *14th Weather Squadron*, 14 WS, 250 Patton Ave Rm 120, Asheville, NC 28801-5002, https://notus2.afccc.af.mil, 30 Aug 06

Roeder, W. P., and D. A. Short, 2009: The New Weather Radar For America's Space Program In Florida: Scan Strategy Design, *34th Conference on Radar Meteorology*, 5-9 Oct 09, Paper P6.2, 6 pp.

Roeder, W. P., and T. M. McNamara, 2006: A Survey Of The Lightning Launch Commit Criteria, *2nd Conference on Meteorological Applications of Lightning Data*, 29 Jan-2 Feb 06, 18 pp.

Roeder, W. P., T. M. McNamara, B. F. Boyd, J. W. Weems, and S. B. Cocks, 2005: Unique Uses of Weather Radar For Space Launch, *32nd Conference on Radar Meteorology*, 23-29 Oct 05, 13 pp.

Roeder, W. P., D. L. Hajek, F. C. Flinn, G. A. Maul, and M. E. Fitzpatrick, 2003: Meteorological And Oceanic Instrumentation At Spaceport Florida – Opportunities For Coastal Research, *5th Conference on Coastal Atmospheric and Oceanic Prediction and Processes*, 6-8 Aug 03, 132-137

Roeder, W. P., and C. S. Pinder, 1996: Lightning Forecasting Empirical Techniques For Central Florida In Support Of America's Space Program, *16th Conference on Weather Analysis and Forecasting*, 11-16 Jan 98, 475-477

Roeder, W. P., 1995: Operational Impacts and Identification of Chaff on Weather Radar, *27th Conference on Radar Meteorology*, 9-13 Oct 95, 373-375

Short, D. A., 2008: Radar Scan Strategies for the Patrick Air Force Base Weather Surveillance Radar, Model-74C Replacement, Applied Meteorology Unit Final Report, *NASA Contractor Report NASA/CR-2008-214745*, http://science.ksc.nasa.gov/amu/final-reports/radar-scan-strategies-radtec.pdf, Jun 08, 29 pp.

Weems, J. W., C. S. Pinder, W. P. Roeder, and B. F. Boyd, 2001: Lightning Watch And Warning Support to Spacelift Operations, 18th Conference on Weather Analysis and Forecasting, 30 Jul-2 Aug 01, 301-305