9.2 THE ROC/NSSL TECHNOLOGY TRANSFER MOU: A SUCCESS STORY IN RADAR APPLICATIONS TECHNOLOGY TRANSFER

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1. INTRODUCTION

The National Severe Storms Laboratory (NSSL) at its inception in 1964 began successful radar applications technology transfer for the WSR-57 radar system. Early NSSL work with 10 cm Doppler weather radar led to the Joint Doppler Operational Project (JDOP; 1976-1979) that had technology transfer components. JDOP success helped convince Federal government operational weather radar users (DOC/National Weather Service (NWS), DOT/Federal Aviation Agency, and DOD/Air Force) to begin a procurement program for a new generation of Doppler Weather radar, which was called NEXRAD. A Joint System Procurement Office (JSPO) was formed to oversee the program. To help continue and accelerate the technology transfer process for NEXRAD during the 1980's, JSPO placed its Interim Operational Test Facility (IOTF) in Norman, co-located with NSSL.

As deployment of the WSR-88D (1988, Doppler) approached, JSPO decided to establish the NEXRAD Operational Support Facility (OSF) in Norman, merging the IOTF into the new facility. The OSF (now Radar Operations Center (ROC)) realized the need for continuing support from NSSL researchers on issues of hardware and software development and enhancement, correct radar operation, interpretation of WSR-88D data, and assistance with training courses for radar maintainers and operators/forecasters. Thus was born the ROC (aka OSF)/NSSL Technology Transfer Memorandum of Understanding (MOU) (hereafter, Technology Transfer MOU). The MOU, which has continuously been in existence since 1987, has assured continuity in improvement of radar hardware, software, and applications. After the completion of deployment of all radars in the mid to late 1990's, the radar program began concentrating on WSR-88D enhancements with the formation of the NEXRAD Product Improvement (NPI) project. Improvements to the WSR-88D associated with hardware and processor software (but not applications software) were transferred to a newly developed NPI MOU, involving NSSL and other research groups. NPI MOU work is not a subject of this paper.

The Technology Transfer MOU has enjoyed great success over the nearly two decades of its existence. Many of the applications that are now a part of the current WSR-88D baseline were developed through the MOU process, including all of the severe weather algorithms. Management structure and oversight that allows the MOU to be successful will be briefly outlined in Section 2. Section 3 will highlight MOU contributions during the early years and deployment phase (1987-1996). In more recent years, some of the MOU emphasis has shifted to improvements in data quality and to applications enabled by open systems enhancements (Open Radar Products Generator (ORPG) and Open Radar Data Acquisition (ORDA)). Recent accomplishments of the MOU will be given in Section 4. Section 5 will list current MOU projects (FY06) and Section 6 will comment on possible near-future MOU priorities. Concluding remarks will be in Section 7.

2. MOU MANAGEMENT STRUCTURE AND OVERSIGHT

Although there have been a number of changes in MOU management personnel and ROC and NSSL management, MOU management and oversight has remained mostly constant over the MOU life. The Technology Transfer MOU between the ROC and NSSL (Agreement #205-02-007) is the responsibility of the ROC Director (currently Richard Vogt) and the NSSL Director (currently Dr. Jeff Kimpel). Within the ROC, the MOU is managed within the Applications Branch (current Chief is Lt. Col Randy George). At NSSL, the MOU is managed by the Warning Research and Development Division (current Chief is Dr. Dave Jorgensen). During the years of MOU life, the NSSL managing division has been known by other names: Forecast Applications Research Division, and Storm-Scale Research and Applications Division. Within the appropriate ROC and NSSL division there is an MOU Manager to oversee day-to-day MOU issues: Mark Fresch is currently ROC MOU Manager; Don Burgess is currently NSSL MOU Manager. The NSSL MOU Manager is also designated as the MOU Senior

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Scientist. A Principal Investigator (PI) for each MOU project is assigned by each organization.

In preparation for the next fiscal year, the MOU managers work with PIs to develop a list of potential projects for the coming year. The PIs collaborate on statements of work to describe the project, risks, resources, deliverables, and deliverable due dates. The deadline for the draft MOU is September 1, and the signing date for the final MOU (detail statement of work) is September 30 (the last day of the fiscal year).

The potential projects are prioritized based on input from the ROC management, NPI management, and tri-agency representatives and committees. For example, the NEXRAD Technical Advisory Committee (TAC) maintains a prioritized list of technical needs. The highest priority projects are included in the year's work plan.

During the fiscal year as projects are being accomplished, progress is monitored by monthly time charging summaries, by frequent meetings of the MOU managers where progress and deliverable due dates are reviewed, and by quarterly meetings where ROC and NSSL directors and management staffs are given updates on progress and resource utilization. Many projects require design reviews where a steering committee of MOU managers, NSSL researchers, ROC Applications Branch personnel, and others meet at regular intervals to monitor progress, give advice on issues that arise, and help develop standards and objective measures for projects that contain performance or improvement elements. Certain improvements require planning and conducting field tests (often at NWS forecast offices) to verify performance scores and to get field forecaster input. In some previous years during and just after deployment of these improvements, User Group Meetings with operational forecasters were conducted. A Final MOU Meeting is conducted just after the end of each fiscal year and a final report is generated for all MOU activities for the previous year.

3. MOU CONTRIBUTIONS DURING THE EARLY YEARS (1987-1996)

The first baseline radar hardware, software, and concepts of use had been developed from early NSSL/JDOP/IOTF testing and integration and further development by the prime contractor. The baseline was defined during operational test and evaluation. During this process, a number of baseline applications limitations were documented and ideas for transfer of newly developed applications were generated. Also, at this time the TAC first developed their list of technical needs. These elements formed the projects on which MOU work began. A list of some of the important applications, year(s) of MOU work, and year of addition to the baseline is shown in Table 1.

Table 1. Early MOU Applications

Item	MOU Year(s)	Baseline Year
Velocity Dealiasing Algorithm (VDA)	1987-1991	1992
Hail Algorithm	1987-1991	1992
Tornadic Vortex Signature (TVS) Algorithm	1987-1991	1992
Storm Cell Identification and Tracking (SCIT) Algorithm	1990-1996	1996
Hail Detection Algorithm (HDA)	1990-1997	1996
Mesocyclone Detection Algorithm (MDA)	1992-2001	2003
Tornado Detection Algorithm (TDA)	1993-1999	1998
Revised VDA	1994-1996	1998
Multi-PRF Dealiasing Algorithm (MPDA; VCP121)	1994-2000	2004
Damaging Downburst Prediction & Detection Algorithm (DDPDA)	1994-2000	NA

As can be seen from Table 1, the process of applications development and transfer to the WSR-88D baseline is one that takes several years. Time and effort are necessary to change research concepts into operational algorithms: code the algorithms, test/score the algorithms on robust data sets, prepare training associated with the applications, and, finally field the application as part of software build, which itself includes several testing steps. At times, as much as a decade has been required to take an application from development to deployment. It should be noted that some of that interval for some applications has been associated with waiting for needed hardware/software upgrades or the NEXRAD tri-agency priority process used to define the software builds.

In one case, DDPDA listed in Table 1, algorithm testing revealed applicability constraints that limited the usefulness of the application to only pulse storms in low-shear environments. As such, there was a resulting recommendation to not include the algorithm into software used by all sites.

Besides algorithms, other important projects were included in the MOU's early years. Among those were:

1) Development of early WSR-88D training materials (with NWS Warning Decision Training Branch), including early versions of a Tornado Warning Guidance (TWG) document.
2) Development of the Radar Interface and Data Distribution System (RIDDS), an early form of

real-time distribution of high-resolution (aka Level II) WSR-88D data to support real-time use/testing.

3) Proof of concept testing of new algorithms, displays, and human factors improvements at NWS Offices, utilizing the NSSL Warning Decision Support System (WDSS).
4) Development of the WSR-88D Algorithm Testing and Display System (WATADS) for non-real-time testing of new algorithms/applications (including adaptable parameters) and construction of storm/event case studies.
5) Formation and meetings of a tri-agency WSR-88D User Group to get feedback on radar performance and consultation on new applications.
6) Development of a robust database of WSR-88D cases (Level II data and environmental and verification information) for many weather types from all parts of the country for use in future applications development and testing.

4. MOU CONTRIBUTIONS DURING LATER YEARS (1997-2005)

In more recent years, the MOU has evolved to support increased emphasis on data quality and the transition of NEXRAD to open systems concepts (ORPG and ORDA). Transition to ORPG in 2002 and the upcoming transition to ORDA (2006) are allowing the development of new and more elaborate scanning strategies (new VCPs and super resolution data), better data quality (SZ phase coding and staggered PRT to reduce range folding and velocity alaising), and introduction of new capabilities (polarization diversity and spectral processing). A list of some of the recent important applications, year(s) of MOU work, and year of addition to the baseline are shown in Table 2.

Table 2. Later MOU Applications

Item	MOU Year(s)	Baseline Year
New VCPs (VCP 12 and others)	1998-	2004-
MDA Rapid Update	1999-2002	2004-2006
TDA Rapid Update	1999-2003	2004
Dual-Polarization Moments and Algorithms	2002-	TBD
Filtered SCIT	2003-2004	2006
TDWR Algorithms	2003-	TBD
Radar Reflectivity Comparison Tool (RRCT; only to ROC)	2003-2005	2004
Rotation Tracks	2005-	TBD

As can be seen from Tables 1 and 2, there are fewer new applications/algorithms during the later MOU years. The primary reason is there has been emphasis on projects other than algorithm development (see next paragraph). Also, the Dual-Polarization upgrade for NEXRAD, although shown as only one line in Table 2, actually involves several efforts…multiple radar outputs and multiple algorithms. Note that the TDWR algorithms that are being developed are derivatives of the already developed WSR-88D algorithms and are to operate within the ORPG Supplemental Products Generator (SPG).

Among the items developed in later years are:

1) Support for RIDDS and CRAFT
2) Continuing support for training, including later TWG versions
3) Recoding of algorithms for ORPG
4) Support for the Common Operational Development Environment (CODE)
5) Support for the System for Convective Analysis and Nowcasting (SCAN)
6) Proof of concept testing of new algorithms, displays and human factors improvements at NWS Offices, utilizing NSSL's WDSSII
7) Evaluation of super-resolution data
8) Evaluation of sensitivity of moments with dual polarization
9) Evaluation of data quality enhancements (REC, DQA, and others)
10) Continuation and enhancement of WSR-88D Case Database, now including experimental WSR-88D data (dual-polarization data, super-resolution data, and time series data) and TDWR data.
11) Use of Shared Mobile Atmospheric Research & Teaching Radars (SMARTRs) with WDSSII as potential temporary back-ups for failed WSR-88D radars.
12) Helping the ROC develop better automated VCP selection functions, including de-selection of precipitation mode.

5. CURRENT (2006) MOU PROJECTS

Per agency policy and MOU management practice, specifics of the FY06 MOU were developed during the last two months of FY05 (August, September). The current MOU contains the following projects:

1. Dual Polarization: Continuing technology transfer support…in coordination with the NPI Project. Three subtasks: Transfer of algorithms (2.1); Product development (2.2); and Independent Validation & Verification support (2.3).
2. Super Resolution: Compare different types of super-resolution data (different processing

window functions). Recommend the best processing options for Mesocyclone and TVS detection.
3. New VCPs: Recommend techniques that could improve the VCP Mode Selection Function.
4. Data Quality: Complete evaluation of performance of severe weather algorithms for various data quality techniques (REC, DQA, and NSSL routines) operating on ORDA data.
5. TDWR: Analyze and compare the performance of the WSR-88D Dealiasing Algorithm (optimized for TDWR) and NSSL's 2-D Multi-Pass Dealiasing Algorithm on TDWR data used in the SPG.
6. Database: Maintain and add to the existing database of WSR-88D case datasets, experimental WSR-88D datasets, and TDWR datasets.

6. POTENTIAL TOPICS FOR FUTURE MOU PROJECTS

Several of the current MOU projects are multi-year efforts and will probably continue for some time to come. Included in that category are Dual Polarization, Super Resolution, New VCPs, Data Quality, TDWR, and Database.

During each yearly MOU development cycle, potential topics for future projects are identified. Potential lists are maintained and some thought is given to how the project would be executed. In the event additional resources become available, NEXRAD priorities change, and/or a current project ends, the potential projects can easily be added to the MOU. At the current time, the potential project list includes:

1. Investigation of ORDA Velocity Dealiasing Algorithm failures. For FY06, the priority for this project was too low to be funded.
2. Improvements to the current VAD/VWP Algorithm. Failure analysis and suggested improvements were completed during the FY05 MOU. For FY06, the priority for this project was too low to be funded.
3. New VCPs with scanning angles below 0.5 degree elevation angle. These new VCPs would be used for testing at selected radars most of which are in higher terrain and would benefit from lower elevation angles to scan lower elevation regions. Beginning of the project awaits resolution of high-level NEXRAD policy issues.
4. Rotation Track quantitative performance evaluation. For FY06, the priority for this project was too low to be funded.

Knowledge of the full range of upcoming NPI Project enhancements suggests other areas of attractive topics for potential MOU work. Items such as use of better velocity data (SZ Phase Coding and Staggered PRT) and routine collection of time series data and advanced spectral processing (both moments and algorithms that operate on spectral shapes) create many new opportunities for continued technology transfer utilizing the MOU process. Farther into the future, current basic research initiatives such as Phased Array Radar and Boundary Layer Radar will likely become topics for technology transfer beyond the end of the current decade.

7. CONCLUSION

With this year's IIPS theme of documenting success stories in applications of atmospheric and hydrologic science, it is appropriate to submit this paper on the ROC/NSSL Technology Transfer MOU. The long list of early-year and later-year activities and products, over a nearly 20-year time period, supports the statement that the ROC/NSSL Technology Transfer MOU is a success story in technology transfer for the NEXRAD operational agencies and NOAA's research being conducted at NSSL. Important current MOU activities (those associated with Dual Polarization enhancement and others) continue the transfer of important and exciting research into better operational products and services. Attractive new areas of potential radar technology, both current NPI projects and basic research into phased array and boundary layer radars, suggest that, through the technology transfer process, new research will continue benefiting the American public for many years to come.

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