THE U.S. FEDERAL HIGHWAY ADMINISTRATION WINTER MAINTENANCE DECISION SUPPORT SYSTEM (MDSS) PROJECT

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1. Introduction

Managing a winter maintenance program today is an increasingly complex endeavor. Just making sure that a plow blade is at the ready when the first flake falls is only a small part of the task. With tight budgets and the high expectation of the public for keeping roads clear of snow and ice, today's maintenance manager has to be able to handle multiple tasks or risk getting behind the onslaught of winter weather. Good information leads to effective practices, however all of the regulations concerning chemical applications, environmental impacts and multiple, often contradictory weather forecasts can lead to information overload.

The United States Department of Transportation (DOT), Federal Highway Administration (FHWA) recognized this potential problem in the late 1990's as part of its Road Weather Management (RWM) program. Generally speaking, there were plenty of weather forecasts, along with a few companies that issued road-specific forecasts, but there was a lack of linkage between the information available and the decisions made by winter maintenance managers. It was this weak link that became the genesis for the winter Maintenance Decision Support System (MDSS).

The MDSS has since matured into a functional prototype. During the winter of 2002-2003, the prototype was deployed at several maintenance garages in central Iowa for a field demonstration. This paper will document the implementation of the demonstration, a summary of lessons learned, and technology transfer activities. It will also describe plans for a longer, more comprehensive demonstration during the winter of 2003-2004.

2. Organizational Overview

The MDSS is a research project that is funded and administered by the FHWA RWM program. Five U.S. national laboratories in coordination with state DOTs, academia and the private sector have also been participating in the development and implementation of the project, including:

- U.S. Army Cold Regions Research and Engineering Laboratory (CRREL)
- National Center for Atmospheric Research (NCAR)
- Massachusetts Institute of Technology – Lincoln Laboratory (MIT/LL)
- National Oceanic and Atmospheric Administration (NOAA) Forecast Systems Laboratory (FSL)
- NOAA National Severe Storms Laboratory (NSSL)

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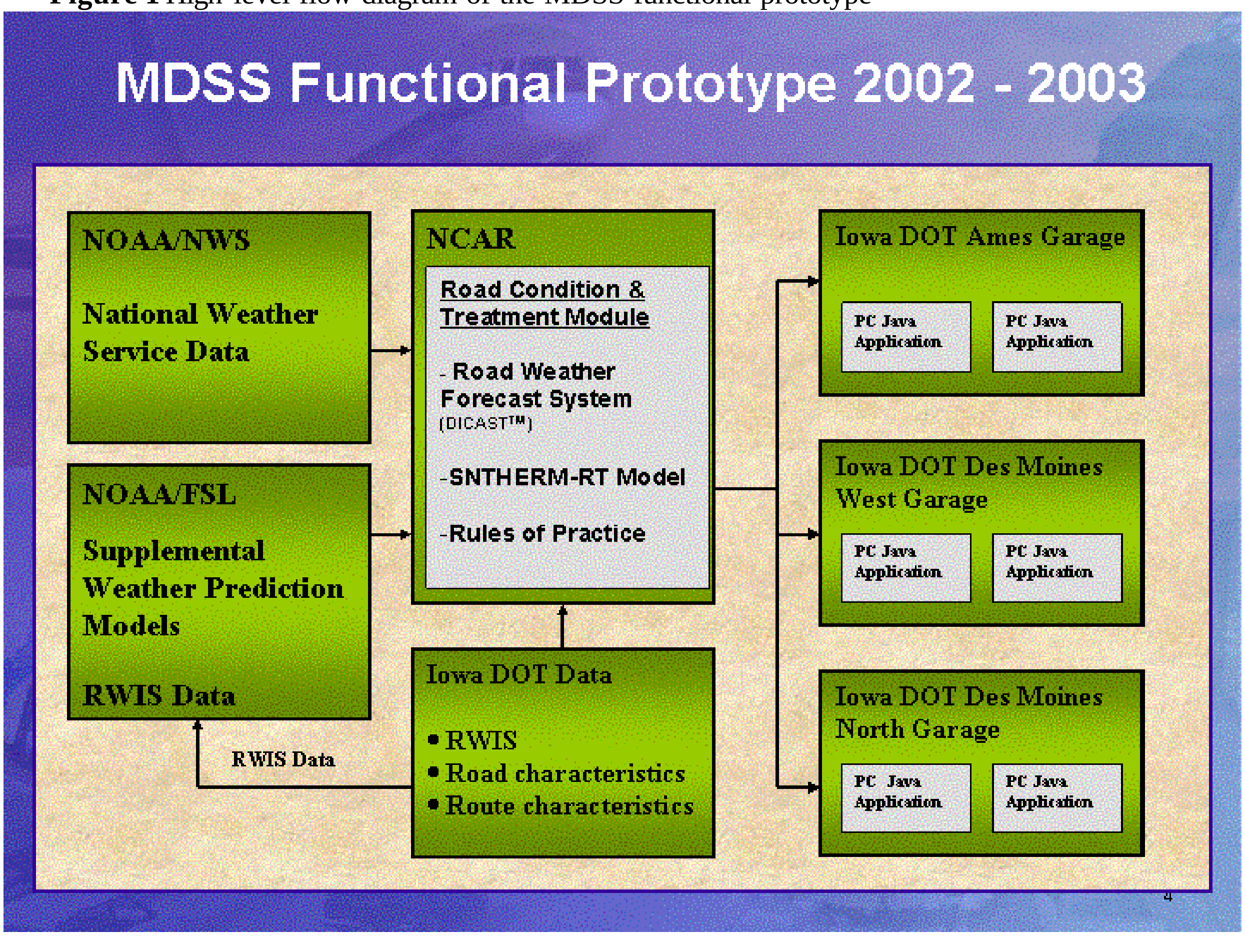
The MDSS project integrates state-of-the-art weather forecasting and data fusion techniques with computerized winter road maintenance rules-of-practice. The result is a set of guidance aimed at maintenance managers that provides a specific forecast of surface conditions and treatment recommendations customized for plow routes.

The project has several goals:

1. Demonstrate to the state DOTs that new technologies are available to assist maintenance managers with maintaining safety and mobility on roadways and provide for more efficient use of chemicals, equipment and staff.
2. Show the private sector road weather providers that there is a market for these new technologies within the states. To aid this process, the FHWA will provide the core MDSS modules to any company in hopes that they will be integrated into their product lines.

Success, as defined by the FHWA, will be reached when private sector companies integrate MDSS components or similar functions into their products. It is anticipated that state DOTs will purchase these new services. In the end, the project will serve to raise the bar on standards for services provided by the private road weather forecasting industry.

Figure 1 High-level flow diagram of the MDSS functional prototype



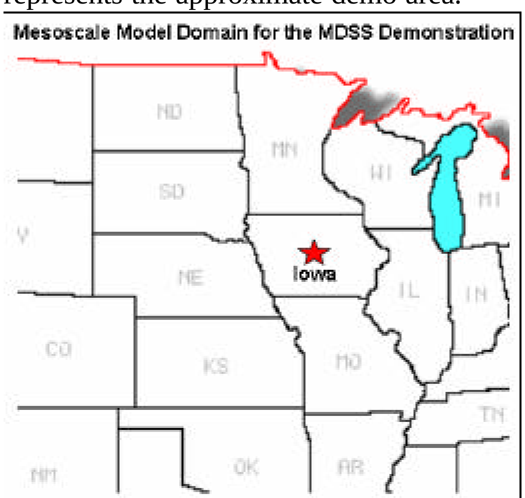
3. System Overview

Each national laboratory brings unique capabilities and expertise to the project. Much of the software used in the core MDSS modules has been reused from other projects and tied together via inter-process communications.

Figure 1 shows a high-level flow diagram for the MDSS functional prototype that was used in the winter 2002-2003 demonstration (Mahoney, 2003). The top box in the left column represents data received from the U.S. National Weather Service (NWS), National Centers for Environmental Prediction (NCEP). These data include surface observations, statistical guidance products, daily weather summaries and numerical weather prediction model output from both the Eta and GFS (Global Forecast System – formerly known as AVN) models.

Figure 2 shows the coverage area of the supplemental mesoscale numerical weather prediction models that were provided and run by FSL. These models were the MM5 (Mesoscale Model 5), the RAMS (Regional Atmospheric Modeling System) and the WRF (Weather and Research Forecasting model). The models had a grid spacing of 10 km and were run four times per day out to 24 hours.

Figure 2 Model domain for the MDSS demonstration. Area under the red star represents the approximate demo area.



In order to provide diversity into the data fusion module, FSL used the NWS models to provide lateral boundary conditions to initialize each mesoscale model. Hence, four times per day, FSL would generate six model solutions for the forecast domain.

Differing from the NWS models, the mesoscale models used a new initialization routine to add realistic distributions of moisture and clouds to the model atmosphere. This method, called "hot-start" (McGinley, 2000), allows the mesoscale models to begin with a much better representation of clouds and precipitation. The benefit of the hot start process is a more accurate prediction, particularly in the first 6 hours of he forecast cycle.

Forecast output from the models, plus surface observations from state DOT road weather information systems (RWIS) were forwarded to NCAR's data fusion engine called the road weather forecast system (RWFS). The RWFS module uses a fuzzy logic ensembling scheme that has the ability to generate more accurate forecasts than any one individual model input (Mahoney, 2003).

Specialized algorithms such as the road temperature forecast module and the road condition and treatment (RCTM) module use the model outputs to generate temperature forecasts for the state and condition of the road surface as well as guidance for chemical concentration and dilution rates.

The final module in the system contains the rules-of-practice algorithms. The rules-of-practice are customized rules and techniques that are used at DOT maintenance garages for maintaining mobility during winter conditions. These rules tend to be different for each state and in many cases are different for each garage. Hence, this module has the ability to customize many of its inputs so that it can be portable between garages.

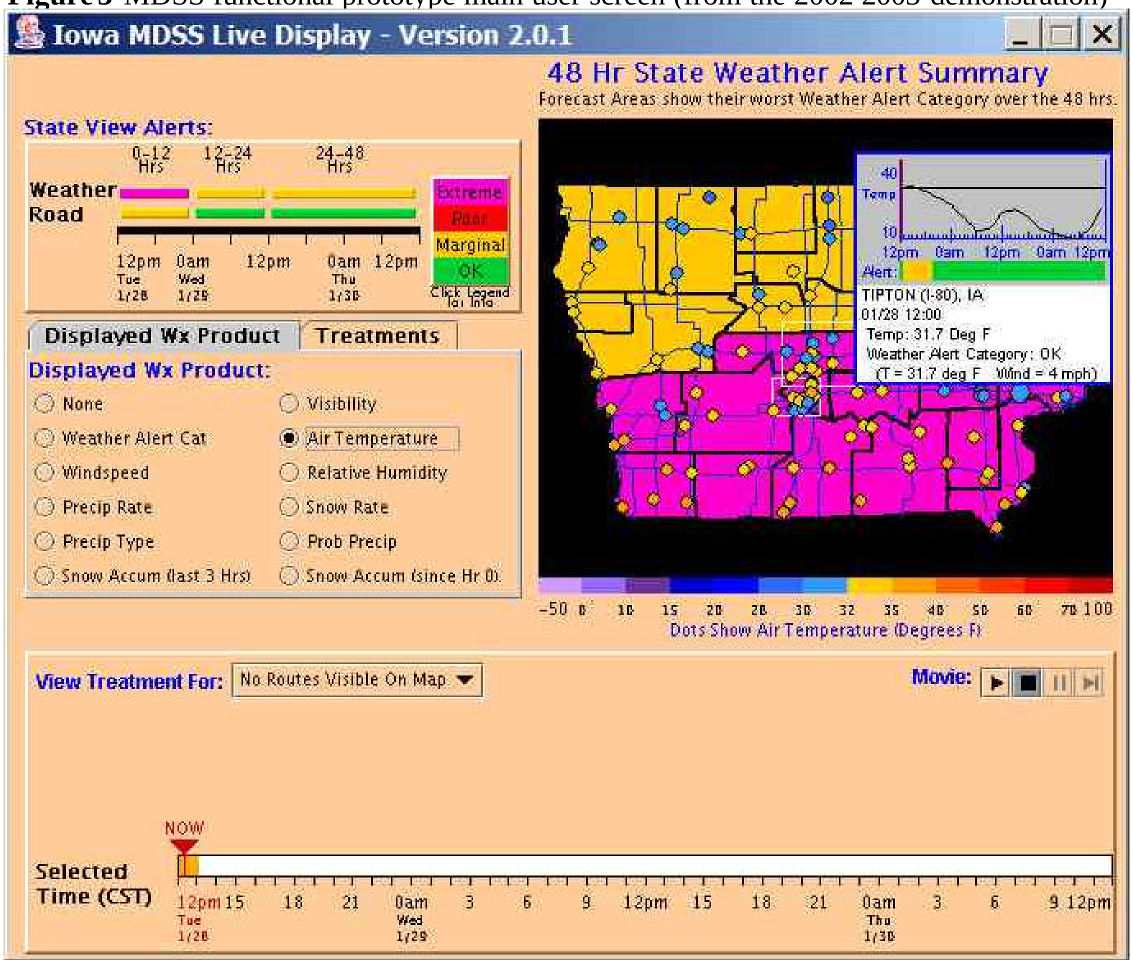
Output from the rules-of-practice module includes treatment recommenddations for the DOT garage supervisor. Some of the guidance information contains:

- Recommended treatment plan (plow only, chemical use, abrasives, etc).
- Recommended chemical amount
- Timing of initial and subsequent treatments

Figure 3 is an example from the MDSS prototype main display. The top left panel shows a summary table with color-coded bars showing forecast weather and road conditions for the next 48 hours. The panel at the left center provides access for displaying weather parameters or treatment routes. The bottom section controls the forecast time selection and animation. The main map (top right) can show either an entire state view or a zoomed-in route view (Figure 4).

Each dot on the main map represents an observation point. Forecasts are generated for these points and also for locations along each plow route using interpolation techniques. Moving a cursor over any point brings up a time series graph of the selected forecast parameter plus additional site specific details.

Figure 3 MDSS functional prototype main user screen (from the 2002-2003 demonstration)



The MDSS contains a "what-if" scenario treatment selector. This means that the operator is able to modify the recommended treatment times, chemical types or application rates, and see how the road condition predictions might change.

In Figure 5, a chemical concentration display shows the results of two scenarios following an initial application prior t this time period. The green trace shows the dilution rate of sodium chloride on the road surface if no additional treatments of chemicals are applied. In this case, given the forecast weather conditions, the chemical concentration on the road surface would fall to 10 percent or less within 24 hours. With a second application of sodium chloride (at a rate of 300 pounds per lane mile), the red trace indicates that the chemicalconcentration would stay about constant through the 48 hour forecast period.

Figure 4 Des Moines area MDSS routes and forecast points

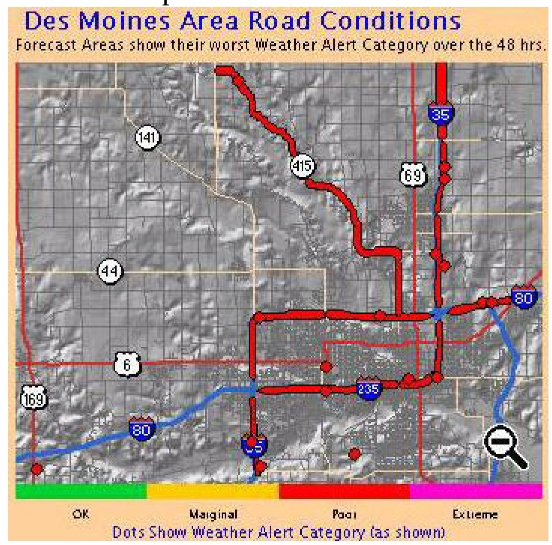
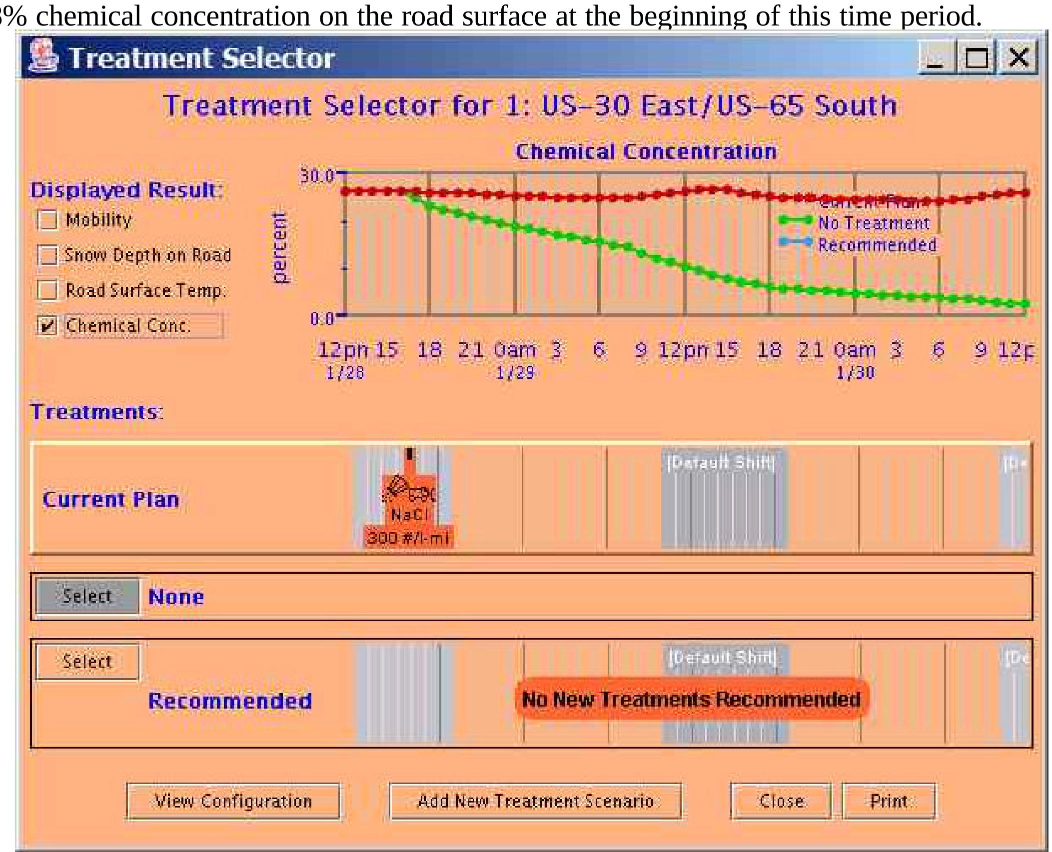


Figure 5 MDSS treatment selector screen. The red trace (top window) shows the predicted chemical concentration if the treatment application is followed. The green trace shows the chemical dilution rate if no chemicals were applied. Note that a prior application has left a 28% chemical concentration on the road surface at the beginning of this time period.



4. Field Demonstration 2003

During the summer of 2002, a half dozen states competed to win the opportunity to host the MDSS project. While there were several very good candidates, the Iowa Department of Transportation (IADOT) was selected. Determining factors included their progressive maintenance programs, the availability of high speed communications and computers at maintenance garages and a willingness of the DOT personnel to participate in training and verification activities. Iowa also was surrounded by a dense network of surface observations and did not have complex terrain.

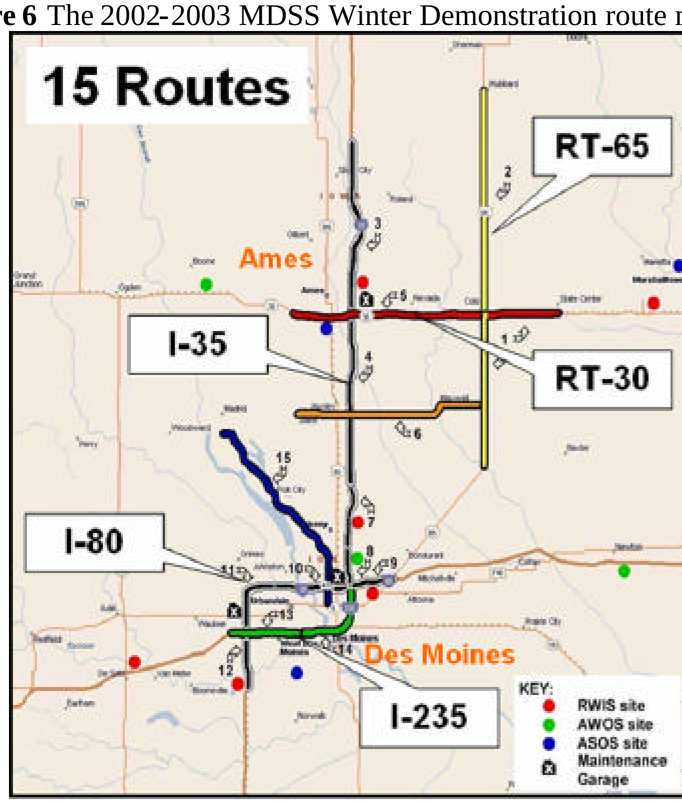
In all, 15 routes and three maintenance garages around Des Moines and Ames Iowa were selected to participate in the demonstration (Figure 6) (MDSS Evaluation Plan, 2003).

The Des Moines West garage is located just to the west of I-80 and is responsible for portions of I-80 and I-235. The Des Moines North garage is located near the intersection of I-80, I-35 and I-235. This garage is responsible for the expressways through and north of downtown including secondary roads to the north of the city. The Ames garage is located about 40 miles north of Des Moines near the intersection of I-35 and U.S. 30. The Ames garage is responsible for longer, but less traveled routes through the rural areas of central Iowa.

The colored dots along the roadways represent automated surface observing stations that were either operated by the NWS, the state or the FAA. These stations served as ground truth for forecast initialization and verification.

The demonstration period began on Monday, 3 February 2003 and concluded on Monday, 7 April 2003. During that time, five light snow events (3 inches or less accumulation), three heavy snow events (accumulations of greater than 3 inches) and one mixed rain/snow/ice event occurred.

Figure 6 The 2002-2003 MDSS Winter Demonstration route map



4.1 Summary of Lessons Learned

The following list contains lessons learned or confirmed from the 2002-2003 MDSS field demonstration:

- The MDSS requires highly specfic forecasts of precipitation, which is pushing the limits of predictability.
- The rules-of-practice module needs additional development to handle a wider variety of weather and road condition scenarios and treatment responses.
- The availability and quality of observed real-time precipitation rate data are very poor for snow and ice.
- Light snow and intermittent events are critical to DOT operations and are particularly hard to predict.
- The road temperature prediction model needs more development to account for the impact of travel, chemicals, snow compaction, and blowing snow.
- Because weather will not soon be predicted perfectly at road scales, probabilistic products should be developed.
- Just varying the lateral bounds models (Eta, GFS) has little effect on adding dispersion to the ensemble.

5.0 Plans for Demo II – Winter 2004

The FHWA has funded a second field demonstration of the MDSS. It will take place in central Iowa from 29 December 2003 until 19 March 2004 (MDSS Evaluation Plan, 2003).

This second field demonstration will attempt to close gaps found from the first demonstration and to allow for one more full development cycle for the overall software package. The exercise will also generate an entire season's worth of verification data that can be presented to both public and private sector stakeholders for evaluation.

6.0 Technology Transfer

During the course of the MDSS project, the system technologies (software and documentation) have been made available publicly through software releases. Two software releases have been made thus far. Once the second field demonstration is complete, the laboratories will begin to compile new verification statistics and evaluation reports. The FHWA will also continue the process of outreach and technology transfer. In 2004, the focus will be on identifying organizations and public/private partnerships that can assist in the technology transfer process. It is hoped that components of the MDSS will be integrated into the product lines of private companies so that the technology can be used to raise the level of service for all state DOTs.

The sixth meeting of the MDSS stakeholder group will be held in July 2004 in Boulder, Colorado. At this meeting, the laboratories will be holding a workshop to provide a detailed engineering overview of the MDSS and exchange technical information with any company that is interested in exploring the MDSS technology.

In addition, CDs with all of the software and documentation associated with the winter 2004 demonstration (MDSS Release-3) will be distributed to interested parties during the fall of 2004 via the NCAR MDSS web site:

http://www.rap.ucar.edu/projects/rdwx_mdss/index.html

7.0 Summary

The FHWA has been funding and directing a team of national laboratories to create and refine a decision support system for the winter road maintenance community. A demonstration of the MDSS prototype was conducted in central Iowa during the winter of 2003. Reviews from this first demonstration were mixed. The system showed consistent improvement as the season progressed and a list of lessons learned has been presented. A second demonstration will be conducted during the winter of 2003-2004.

Evaluation of the second demonstration will be presented at a stakeholder meeting in July 2004. Technology transfer activities will include presentations at conferences, an engineering workshop and the establishment of public/private partnerships to assist in bringing core MDSS modules into the marketplace.

Current documentation, progress reports and contact information for prospective stakeholders can be found on the NCAR web site:

8.0 References

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